Driver assistance systems in an aging society - willingness to pay, acceptance and the influence of life events

Von der Fakultät für Ingenieurwissenschaften, Abteilung Maschinenbau und Verfahrenstechnik der Universität Duisburg-Essen zur Erlangung des akademischen Grades eines

Doktors der Wirtschaftswissenschaften

Dr. rer. pol.

genehmigte Dissertation

von

Timo Günthner

aus

Stuttgart

Tag der Disputation:	15.12.2021
1. Gutachter:	Prof. Dr. Heike Proff
2. Gutachter:	Prof. Dr. Andreas Wömpener

Abstract

Sales volumes in the automotive market are stagnating. Therefore, new market opportunities and sales potential must be developed that address the growing customer group of drivers 50+ with their increasing purchasing power. This customer group is likely to have a strong interest in maintaining mobility into old age due to their increasing individual physical limitations and their need for safety. The automotive market can ensure this demand for mobility by offering vehicles with individually equipped driver assistance systems at various levels of automation, offering increased safety on the roads specifically for the aforementioned 50+ customer group. However, the success of the driver assistance systems on the market remains below expectations.

This dissertation examines the willingness to pay of the 50+ age group using the Van-Westendorp-method and an empirical study. Motives and backgrounds for the manifestation of the willingness to pay remain unclear. Previous acceptance studies have so far not provided any clear results on technology acceptance in old age. Therefore, the acceptance of driver assistance systems in the 50+ age group is examined in more detail using an acceptance model derived from the literature, in which the influencing factors as critical success factors for the use of a technology are verified and analyzed with the help of a quantitative study. Not only the influencing factors such as "perceived usefulness", "perceived ease of use", "subjective norm", "trust in technology" and "personal innovativeness" are examined for the degree of acceptance of driver assistance systems, but also the influence of age and critical life events in the age group 50 years and older. Implications for research and practice are consequently derived from the results of the research studies.

Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1. Problem and research objective

The global passenger car sales figures clearly indicate that the global automotive market is stagnating (VDA, 2020). The automotive industry is therefore called upon to seek and generate new market opportunities and sales potential. Due to their relatively high purchasing power and an increasing share of the total population, older people (50+) represent an interesting customer group (Kohlbacher & Herstatt, 2011; Klimczuk, 2016). For example, the average new car buyer is over 50 years old (KBA, 2017) and has an average household net income of €4,376;00 per month (DAT, 2018). The market opportunities in the 50+ age group (Klimczuk, 2016) are demonstrated by the fact that they accounted for two-thirds (63.4%) of the 3.6 million new registrations in Germany in 2019 (Zentralverband Deutsches Kraftfahrzeuggewerbe, 2020).

At the same time, older people have never been more mobile (Schlag, 2013; Nobis et al., 2019) and account for 45 percent of driver's license holders (Kraftfahrt-Bundesamt, 2019). Increased life expectancy is a result of advanced health care systems, improved medications, expanded knowledge, and better financial status. In this context, demographic change represents a major challenge for the near future (European Commission, 2018; OECD, 2016; Peine et al., 2015). This also applies to Germany, where the over-50s already make up more than 40 percent of the total population (Statistisches Bundesamt, 2019a). For older generations, mobility means independence, social participation, physical activity, and increased quality of life (Burgard, 2005; Holley-Moore & Creighton, 2015; Musselwhite, 2018; Musselwhite & Haddad, 2018). Numerous studies show that limited mobility in older people leads to feelings of uselessness, dissatisfaction, and depression and reduces well-being (Haustein & Siren, 2014; Fonda et al., 2001; Shaheen & Niemeier, 2001). Therefore, by driving their own car, older people can maintain their independence, social participation, and activities (Limbourg, 1999), which in turn contributes to an improvement in their quality of life (Burghard, 2005; Engeln, 2001). However, appropriate technical assistance systems are needed to meet the physiological requirements of older road users and to increase traffic safety for all road users (Boot & Scialfa, 2016; Rudinger et al., 2013).

Older drivers are more likely than younger drivers to experience problems on the road, especially in complex traffic situations such as turning left with oncoming traffic or merging and changing lanes on high-speed highways (Chandraratna & Stamatiadis, 2003). Additionally, older road users show increased impairment due to visual changes such as fog, rain, or dusk (Gruber et al., 2013; McGwin Jr. et al., 2000). As a healthy person ages, a number of cognitive abilities are preserved, such as crystalline intelligence, i.e., semantic knowledge and age wisdom, but specific cognitive functions experience an age-associated decline in performance (Brand & Markowitsch, 2010; Markowitsch et al., 2005). With age, road users experience declines in perceptual ability (i.e., vision and hearing), cognitive reaction time (i.e., coordination of motor skills), cognitive memory and attention, and physical strength and dexterity (Kline et al., 1992; Shaheen & Niemeier, 2001;). These relate to memory abilities and the so-called executive functions such as the targeted suppression of action tendencies, cognitive flexibility, planning, working memory, and the selection of strategies, which in turn are associated with successful driving (Ashendorf & McCaffrey, 2008; Hodzik & Lemaire, 2011; Reuter-Lorenz & Sylvester, 2005; Uekermann et al., 2006).

Advanced driver assistance systems (ADAS), which are continuously being improved, can compensate for these deficits in older drivers (Karthaus et al., 2016; Wild, 2014). These systems aim to prolong the ability to drive, regardless of driver limitations. New technologies such as advanced driver assistance systems hold promise for compensating for these declining abilities of older drivers and ensuring safe mobility in later years (Eby & Molnar, 2012). Such driver assistance systems thus have the potential to increase driving comfort and road safety (Anderson et al., 2014; Duncan et al., 2015; Fagnant & Kockelman, 2015; Gruyer et al., 2017; Naujoks & Neukum, 2014). This improves safety by avoiding collisions and provides comfort for vehicle occupants (Gruyer et al., 2017; Naujoks & Neukum, 2014). Such driver assistance systems include partially automated systems, such as Active Brake Assist, (Adaptive) Cruise Control, Adaptive Front-lighting System, Adaptive High-Beam System, Blind Spot Detection, Driver Drowsiness Detection, Emergency Brake Assist, Intelligent Parking Assist System, Lane Detection System, Lane Departure Warning, Lane Keep Assist, Night View Assist, Parking Assist, Tire Pressure Monitoring and Traffic Sign Recognition (Winner et al., 2015). The EU regulation 2019/2144 "Regulation concerning type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users" (EU, 2019), which came into effect at the end of 2019, will apply to all passenger cars type-approved in the EU from 06.07.2022. It requires all newly registered passenger cars to be fitted with the following driver assistance systems as standard from 07.07.2024: Intelligent speed assistance; alcohol interlock installation facilitation; driver drowsiness and attention warning; advanced driver distraction warning; emergency stop signal; reversing detection and event data recorder. These important assistance systems are designed to ensure a sustained reduction in the number of accidents and road users killed in traffic accidents. They are seen as steps in the digital transformation to autonomous driving, i.e., up to Level 5 "no driver" and enabling Level 2 today, see Figure 1 (SAE, 2019).

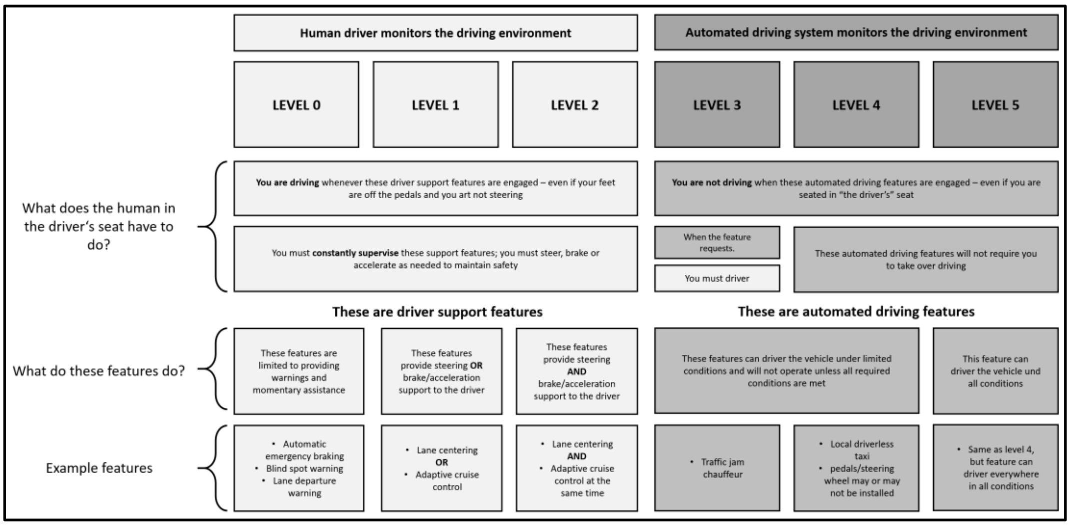

Figure 1: Levels of driving automation (SAE, 2019)

With increasing age, there is a decrease in reaction time among older drivers in particular (Shaheen & Niemeier, 2001). The study on traffic accidents of seniors in road traffic in Germany illustrates the most frequent misbehavior while driving a vehicle among seniors 65 years and older (Statistisches Bundesamt, 2019b). According to the statistics, the errors occur mainly in connection with right of way and priority in road traffic (17.7%), turning, reversing, entering a road and accelerating (17.0%), and distance errors (8.8%). Based on these statistics on accidents involving senior citizens in road traffic in Germany and the evaluation of a pretest on the needs of older drivers, the driver assistance systems Cross Traffic Alert, Park Distance Control and Lane Departure Warning are selected and investigated. All systems are to be placed within the scope of automation levels 1 and 2 (SAE, 2019).

Although there is a need to support older drivers, the success of many driver assistance systems is far from the expectations of car manufacturers (Winner & Schopper, 2015). Thus, driver assistance systems have not been able to be established in the market of older drivers with the expected success. Since an holistic view of this is lacking in the literature, **the first research question is whether drivers aged 50 years and older are willing to pay for driver assistance systems**.

Acceptance of technology is a critical success factor in implementing technology in the everyday lives of older people (Hu et al., 1999) and influences willingness to pay (Arndt, 2011). A commonly cited reason for not using technology is that acceptance of technology decreases with age. Studies in the field of acceptance research show both positive and negative effects of age on the acceptance of new technologies (Alexandrakis et al., 2020; Arning & Ziefle, 2007; Escobar-Rodriguez & Bartual-Sopena, 2013; Hauk et al., 2018; Jimoh et al., 2012; Martins et al., 2014; Morris et al., 2005; Morris & Venkatesh, 2000) and specifically on the acceptance of driver assistance systems (Braun et al., 2019; Larue et al., 2015; Roberts et al., 2012; Souders & Charness, 2016; Xu et al., 2010).

Different acceptance models have been developed to explain technology acceptance. The foundations of these are the Theory of Reasoned Action (TRA, Ajzen & Fishbein, 1980) and the Theory of Planned Behavior (TPB, Ajzen, 1991) and, related to these, the Technology Acceptance Model (TAM) by Davis et al. (1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh & Davis (2003). They posit that a person's behavioral intention directly influences their actual behavior. Davis et al. (1989) developed the Technology Acceptance Model (TAM), which, with its extensions and further developments, is the basis of numerous technology acceptance studies. The model is an adaptation and specialization of the Theory of Reasoned Action (TRA) to the specific requirements of information systems and technology (Ajzen & Fishbein, 1980). It examines the likelihood of individual user behavior in voluntary system use and attempts to establish consistent indicators for various research questions. The intention is to provide a general explanation of the factors of information system use that is at the same time as simple as possible (Legris et al., 2003; Ma & Liu, 2004). Based on these technology acceptance models, although there are many studies, a clear and unambiguous statement on technology acceptance in old age has been lacking (Hauk et al., 2018). Therefore, the **second research question is which factors influence the acceptance of driver assistance systems in the group of older drivers (50 years and older)**.

Evidence suggests that technology acceptance and use is not based solely on the perceived ease of use or perceived usefulness of the technology, but that social and cultural aspects of older users in particular can explain technology acceptance or rejection (Chen & Chan, 2014; Knowles & Hanson, 2018; Mitzner et al, 2016; Waycott et al, 2016;). The life course approach seeks to better understand acceptance behavior by implementing additional determinants and demographic factors into research models (Alemi et al., 2018; Lanzendorf, 2003; Herrenkind et al., 2019;). In this regard, critical life events play a role because they can lead to a change in daily routines and thus to a change in mobility behavior and increase the willingness to use driver assistance systems (Busch-Geertsema & Lanzendorf, 2017; Clark et al, 2016; Janke & Handy 2019; Lanzendorf, 2010; Oakil et al, 2011; Schäfer et al., 2012; Scheiner & Holz-Rau, 2013; van der Waerden et al, 2003; Zhang, 2017). Typically, these include age-related events such as studying, starting a career, starting a family, and ending a career, but also non-age-related events such as unemployment, life-threatening illnesses, or the death of a relative or partner (Elder, 1994; Müggenburg et al., 2015; Uteng et al., 2019). These events not only interrupt the everyday course of life, but also the natural ageing process and lead to age-induced effects that need to be further investigated. The implementation of life events in studies thus represents another approach to further investigate the acceptance of driver assistance systems and to explore them as influencing factors on technology in general and on the acceptance of driver assistance systems in particular (Ryu et al., 2009; Uteng et al., 2019). In order to increase the explanatory power of the previous research, the **third research question is what influence critical life events have on the acceptance of driver assistance systems**.

Three *research objectives* (RO) of this dissertation emerge from the research questions:

RO_1: Development of a method to measure the willingness to pay for driver assistance systems of road users aged 50 and older.

RO_2: Development of an acceptance model to identify the factors influencing the acceptance of driver assistance systems within different age groups.

RO_3: Development of an acceptance model to investigate the influence of life events on the factors influencing the acceptance of driver assistance systems in the 50+ age group.

The research objectives were investigated within the framework of a research project (age-appropriate driver assistance systems - AFLASY), in cooperation with Ford-Werke GmbH, HEAD acoustics GmbH and Allround Team GmbH from 01.04.2017 to 30.06.2020. The ALFASY project was funded by the European Regional Development Fund (ERDF) and aims to develop, build and empirically test an age-appropriate acoustic driver assistance system that is tailored to the needs of the steadily growing group of individual mobile older drivers and whose inclusion in the product portfolio also makes business sense for automotive manufacturers and suppliers.

The willingness to pay and the acceptance of advanced driver assistance systems were investigated in various work packages. To increase the explanatory power beyond the project, critical life events were also included in the study of acceptance as moderating variables in the course of the project. The results of the three studies were summarized in three articles.

1.2. Organization of the dissertation

To answer the research questions, three studies were necessary. In the first study, the willingness to pay for driver assistance systems of drivers aged 50 and older was to be determined (research objective 1). For this purpose, a widely used research method (van Westendorp, 1976) was extended to measure willingness to pay. This study shows that a correlation between willingness to pay and age cannot be confirmed across the board. However, the age groups 60-69 years and 70-90 years showed a significantly higher willingness to pay than the group 50-59 years for four of the five driver assistance systems (parking assistance, blind spot assistant, lane departure warning and tire pressure monitoring systems).

Consequently, further acceptance of such driver assistance systems among older drivers had to be investigated in a second study. Therefore, a structural equation model was developed as as extension of the technology acceptance model (Davis et al., 1989) to investigate the acceptance of driver assistance systems. It found that the acceptance as well as the influence of the perceived usefulness are similarly high for the old and the young. However, differences exist in the influence of trust in technology and the opinion of the environment. Both factors tend to be more important for younger people. For the older generations, the user friendliness of the systems tends to be essential. The study did not provide sufficient results to draw sustainable, reliable and valid conclusions. Therefore, selected critical life events (retirement, birth of a grandchild, serious illness and serious accident) are examined more closely in a third study. Because no direct influence of these events on the acceptance of driver assistance systems among older drivers can be shown on the basis of the study, the moderating effect of these events was examined. It is shown that critical life events have an influence on the acceptance of driver assistance systems, but to varying degrees.

The three studies are summarized in three articles:

Article 1: Günthner, T., Proff, H., Jovic, J. & Zeymer, L. (2021). Tapping into Market Opportunities in Aging Societies – the example of advanced drive assistance systems in the transition to autonomous driving. *Journal of Automotive Technology and Management*, *21*(1/2), 75-97. https://doi.org/10.1504/IJATM.2021.113352.

Article 2: Günthner, T. & Proff, H. (2021). On the way to autonomous driving: How age influences the acceptance of driver assistance systems. *Transportation Research Part F: Traffic Psychology and Behaviour*, 81, 586-607. https://doi.org/10.1016/j.trf.2021.07.006.

Article 3: Günthner, T. (n.d.). The Moderating Influence of Life Events on the Acceptance of Advanced Driver Assistance Systems in Aging Societies. *Computers in Human Behavior Reports*, peer review.

The three investigations form the core of the cumulative dissertation (chapters 4 to 6). Chapter 1 was used to parenthesize the three articles. This already explained the research problem and objective of the thesis. Furthermore, the parenthesis provides an overview of the theoretical background and the scientific methodology of the studies (chapters 2 and 3) and summarizes the results at the end of the thesis, discusses implications for future research and practice and offers future perspective (chapter 7). Figure 2 summarizes the organization of the study.

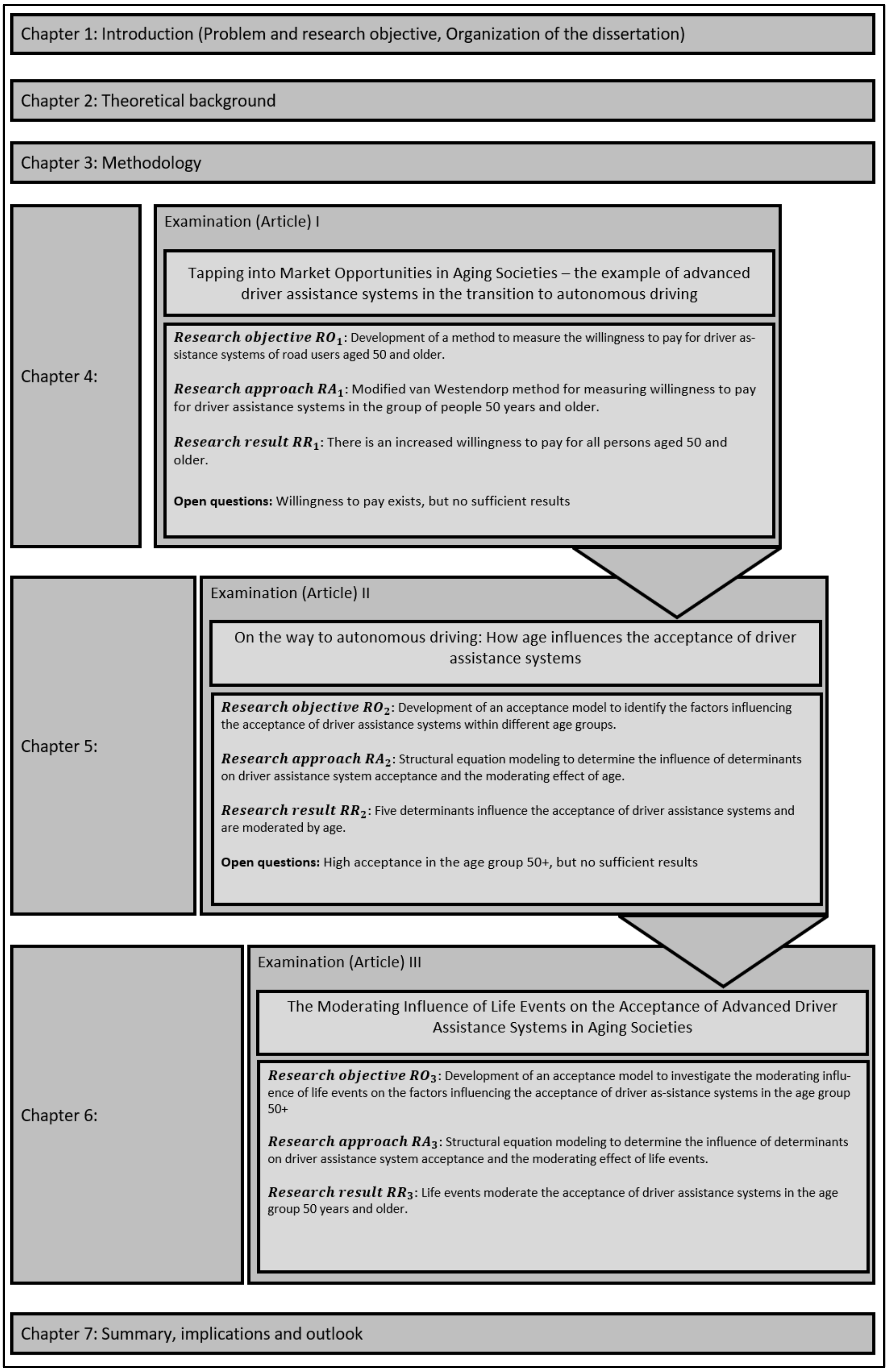

Figure 2: Organization of the dissertation (own design)

References

Ajzen, I. (1991): The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.

Ajzen, I. & Fishbein M. (1980). Understanding Attitudes and Predicting Social Behavior, Englewood Cliffs, Prentice-Hall.

Alemi, F., Circella, G., Handy, S. & Mokhtarian, P. (2018). What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services in California. *Travel Behaviour and* Society, *13*, 88‑104.

Alexandrakis, D., Chorianopoulos, K., & Tselios, N. (2020). Older Adults and Web 2.0 Storytelling Technologies: Probing the Technology Acceptance Model through an Age-related Perspective. *International Journal of Human–Computer Interaction*, 1–13.

Anderson, J.M., Nidhi, K., Stanley, K.D., Sorensen, P., Samaras, C. & Oluwatola, O.A. (2014). *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation.

Arndt, S. (2011). *Evaluierung der Akzeptanz von Fahrerassistenzsystemen: Modell zum Kaufverhalten von Endkunden*, Dissertation, Technische Universität Dresden, Wiesbaden, Gabler.

Arning, K., & Ziefle, M. (2007). Understanding age differences in PDA acceptance and performance. *Computers in Human Behavior*, *23*(6), 2904-2927.

Ashendorf, L. & McCaffrey, R. J. (2008). Exploring age-related decline on the Wisconsin Card Sorting Test. *Clinical Neuropsychologist. 22*, 262–272.

Boot, W. & Scialfa, C. (2016). The aging road user and technology to promote safe mobility for life, in Kwon, S. (Eds.), *Gerontechnology: Research, Practice, and Principles in the Field of Technology and Aging*, Springer, New York (inpress), 207-222.

Brand, M., Markowitsch, H.J. (2010). Aging and decision-making: A neurocognitive perspective. *Gerontology*, *56*(3), 319–324.

Braun, H., Gärtner, M., Trösterer, S., Akkermans, L. E., Seinen, M., Meschtscherjakov, A., & Tscheligi, M. (2019). Advanced driver assistance systems for aging drivers: Insights on 65+ drivers' acceptance of and intention to use ADAS. *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Utrecht, 123-133.

Busch-Geertsema, A. & Lanzendorf, M. (2017). From university to work life–Jumping behind the wheel? Explaining mode change of students making the transition to professional life. *Transportation Research Part A: Policy and Practice*. *106*, 181–196.

Burgard, E. (2005). *Fahrkompetenz im Alter - Die Aussagekraft diagnostischer Instrumente bei Senioren und neurologischen Patienten*. PhD thesis, Ludwig-Maximilian-Universität München, Munich, Germany.

Chen, K., & Chan, A. H. S. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics*, *57*(5), 635–652.

Chandraratna, S. & Stamatiadis, N. (2003). Problem driving maneuvers of elderly drivers. *Transportation Research Record*, *1843*(1), 89-95.

Clark, B., Chatterjee, K. & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice*. *89*, 89‑105.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models, *Journal of Management Science*, *35*(8), 982-1003.

Duncan, M., Charness, N., Chapin, T., Horner, M., Stevens, L., Richard, A., Souders, D. Crute, J., Riemondy, A. & Morgan, D. (2015). *Using Automated Vehicles, Enhanced mobility for aging populations using automated vehicles* (No. BDV30 977-11). Florida. Dept. of Transportation

Eby, D.W. & Molnar, L.J. (2012). *Has the Time Come for an Older Driver Vehicle?*. [online] https://www.aaafoundation.org/sites/default/files/SeniorsAndSelfRegulation Report.pdf (Accessed 02 April 2021).

Elder Jr, G. H. (1994). *Time, human agency, and social change: Perspectives on the life course*. Social psychology quarterly, pp. 4-15.

Engeln, A. (2001). *Aktivität und Mobilität im Alternsprozess*. Aachen: Shaker.

Escobar-Rodriguez, T., & Bartual-Sopena, L. (2013). The roles of users' personal characteristics and organisational support in the attitude towards using ERP systems in a Spanish public hospital. *Health Information Management Journal*, *42*(1), 18-28.

European Comission (2018). *The Silver Economy – Final report* [online]. https://op.europa.eu/en/publication-detail/-/publication/a9efa929-3ec7-11e8-b5fe-01aa75ed71a1 (Accessed 02 April 2021)

European Comission (2019). *REGULATION (EU) 2019/2144 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL* [online]. https://eur-lex.europa.eu/eli/reg/2019/2144/oj (Accessed 18 August 2021)

Fagnant, D.J. & Kockelman, K., (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transport. Res. A: Pol. Pract*., *77*, 167–181.

Fonda, S. J., Wallace, R. B. & Herzog, A. R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *The Journal of Gerontology Series B*, *56*(6), 343-351.

Gruber, N., Mosimann, U. P., Müri, R. M., & Nef, T. (2013). Vision and night driving abilities of elderly drivers. *Traffic injury prevention*, *14*(5), 477-485.

Gruyer, D., Magnier, V., Hamdi, K., Claussmann, L., Orfila, O., & Rakotonirainy, A. (2017). Perception, information processing and modeling: Critical stages for autonomous driving applications. *Annual Reviews in Control*, *44*, 323–341.

Hauk, N., Hüffmeier, J., & Krumm, S. (2018). Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Computers in Human Behavior*, *84*, 304–319.

Haustein, S. & Siren, A. (2014). Seniors' unmet mobility needs – how important is a driving license?. *Journal of Transport of Geography*, *41*, 45–52.

Herrenkind, B., Nastjuk, I., Brendel, A. B., Trang, S. & Kolbe, L. M. (2019). Young people’s travel behavior – Using the life-oriented approach to understand the acceptance of autonomous driving. *Transportation Research Part D: Transport and Environment*, *74*, 214-233.

Hodzik, S. & Lemaire, P. (2011). Inhibition and shifting capacities mediate adults’ age-related differences in strategy selection and repertoire. *Acta Psychologica*, *137*, 335–344.

Holley-Moore, G. & Creighton, H. (2015). *The future of transport in an ageing society*, London: UK: International Longevity Centre-UK.

Hu, P. J., Chau, P. Y., Liu Sheng, O. R. & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine. *Journal of Management Information System*, *16*(2), 91–112.

Janke, J. & Handy, S., 2019. How life course events trigger changes in bicycling attitudes and behavior: Insights into causality. *Travel Behaviour and Society*, *16*, 31–41.

Jimoh, L., Pate, M. A., Lin, L., & Schulman, K. A. (2012). A model for the adoption of ICT by health workers in Africa. *International Journal of Medical Informatics*, *81*(11), 773-781.

Karthaus, M., Falkenstein, M. & Toepper, M. (2016). Functional Changes and Driving Performance in Older Drivers: Assessment and Interventions. *Geriatrics*, *1*(2).

Klimczuk, A. (2016). Comparative analysis of national and regional models of the silver economy in the European Union. *International Journal of Ageing and Later Life*, *10(*2), 31-59.

Kline, D. W., Kline, T. J. B., Fozard, J. L., Kosnik, W., Schieber, F. & Sekuler, R. (1992). Vision, Aging, and Driving: The Problems of Older Drivers. *Journal of Gerontology*, *47*(1), 27–34.

Knowles, B. & Hanson, V. L. (2018). The Wisdom of Older Technology (Non-) Users. *Communications of the ACM*, *61*(3), 72–77.

Kohlbacher, F. & Herstatt, C. (2011). *The silver market phenomenon: Marketing and innovation in aging society*, 2nd ed., Springer, Berlin.

Kraftfahrt-Bundesamt (2017). *Fahrzeugzulassungen (FZ): Bestand an Kraftfahrzeugen und Kraftfahrzeuganhängern nach Haltern, Wirtschaftszweig 01.01.2017* [online]. https://www.kba.de/SharedDocs/Publikationen/DE/Statistik/Fahrzeuge/FZ/2017/fz23_2017_pdf.pdf?__blob=publicationFile&v=4 (Accessed 02 April 2021).

Kraftfahr-Bundesamt (2019). *Fahrerlaubnisbestand im Zentralen Fahrerlaubnisregister (ZFER) am 01.01.2019 – Basisdatenblatt* [online]. https://www.kba.de/DE/Statistik/Kraftfahrer/Fahrerlaubnisse/Fahrerlaubnisbestand/fahrerlaubnisbestand_node.html (Accessed 02 April 2021).

Lanzendorf, M. (2003). Mobility biographies. A new perspective for understanding travel behaviour. *Paper presented at the 10th International Conference on Travel Behaviour Research*, Lucerne, 10th–15th August.

Lanzendorf, M. (2010). Key events and their effect on mobility biographies: the case of childbirth. *International Journal of Sustainable Transportation*, *4*, 272–292.

Larue, G.S., Rakotonirainy, A., Haworth, N.L. & Darvell, M. (2015). Assessing driver acceptance of Intelligent Transport Systems in the context of railway level crossings. *Transport. Res. Part F: Traff. Psychol. Behav., 30*, 1–13.

Legris, P., Ingham, J. & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model, *Journal of Information & Management*, *40*(3), 191-204.

Ma, Q. & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing*, *16*(1), 59-73.

Markowitsch, H. J., Brand, M., & Reinkemeier, M. (2005). Neuropsychologische Aspekte des Alterns. In: S.-H. Filipp, U. M. Staudinger (Hrsg.): *Entwicklungspsychologie des mittleren und höheren Erwachsenenalters*. Göttingen: Hogrefe, S. 79-122.

Martins, C., Oliveira, T., & Popovič, A. (2014). Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management*, *34*(1), 1-13.

McGwin Jr, G., Chapman, V., & Owsley, C. (2000). Visual risk factors for driving difficulty among older drivers. *Accident Analysis & Prevention*, *32*(6), 735-744.

Mitzner, T. L., Rogers, W. A., Fisk, A. D., Boot, W. R., Charness, N., Czaja, S. J. & Sharit, J. (2016). Predicting older adults' perceptions about a computer system designed for seniors. *Universal Access in the Information Society*, *15*(2), 271–280.

Morris, M. G. & Venkatesh, V. (2000). Age differences in technology adoption decisions: Implications for a changing work force. *Personnel Psychology*, *53*(2), 375-403.

Morris, M. G., Venkatesh, V. & Ackerman, P. L. (2005). Gender and age differences in employee decisions about new technology: An extension to the theory of planned behavior. *IEEE Transactions on Engineering Management*, *52*(1), 69-84

Müggenburg, H., Busch-Geertsema, A. & Lanzendorf, M. (2015). Mobility biographies: A review of achievements and challenges of the mobility biographies approach and a framework for further research. *Journal of Transport Geography*, *46*, 151‑163.

Naujoks, F. & Neukum, A. (2014). Specificity and timing of advisory warnings based on cooperative perception. In: *Mensch & computer workshopband*, 229–238.

Nobis, C., Kuhnimhof, T., Follmer, R., & Bäumer, M. (2019). Mobilität in Deutschland – Zeitreihenbericht 2002 – 2008 – 2017. *Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur*, FE-Nr. 70.904/15.

Oakil, A., Ettema, D., Arentze, T., Timmermans, H., 2011. A longitudinal analysis of the dependence of the commute mode switching decision on mobility decisions and life cycle events. Transportdynamics: Proceedings of 16th International Conference of Hong Kong Society for Transportation Studies (HKSTS). Hong Kong Society for Transportation Studies, Hong Kong.

Organisation for Economic Co-operation and Development (2016). *Die OECD in Zahlen und Fakten 2015-2016: Wirtschaft, Umwelt, Gesellschaft.* OECD Publishing [online] http://www.oecd-ilibrary.org/docserver/download/3015045e.pdf?expires=1473688939&id=id&accname=guest&checksum=5F8DA3BED955294D4578D1B6AC7634C0 (Accessed 02 April 2021).

Peine, A., Faulkner, A., Jaeger, B. & Moors, E. (2015). Science, Technology and the 'Grand Challenge' of Ageing: Understanding the Socio-material Constitution of Later Life. *Technological Forecasting and Social Change*, *93*, 1–9.

Reuter-Lorenz, P. A. & Sylvester, C.-Y. (2005). The cognitive neuroscience of working memory and aging. In: R. Cabeza, L. Nyberg, D. Park (Hrsg.*), Cognitive Neuroscience of Aging*. Oxford: Oxford University Press.

Roberts, S.C., Ghazizadeh, M. & Lee, J.D. (2012). Warn me now or inform me later: drivers' acceptance of real-time and post-drive distraction mitigation systems. *Int. J. Hum. Comput. Stud.*, *70*(12), 967–979.

Rudinger, G. (2013). Ältere Verkehrsteilnehmer: Gefährdet oder gefährlich? Defizite, Kompensationsmechanismen und Präventionsmöglichkeiten. *Presentation in Congress Ältere Verkehrsteilnehmer: Gefährdet oder gefährlich?*. 18 April 2013, Wissenschaftszentrum Bonn, Germany.

Ryu, M.H., Kim, S. & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC services. *Computers in Human Behavior*, *25*, 619-632.

SAE International (2019). *SAE Standards News: J3016 automated-driving graphic update.* SAE Publisher [online] https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic (Accessed 16 August 2021).

Schäfer, M., Jaeger-Erben, M. & Bamberg, S. (2012). Life events as windows of opportunity for changing towards sustainable consumption patterns?. *Journal of Consumer Policy*, *35*(1), 65–84.

Scheiner, J. & Holz-Rau, C. (2013). A comprehensive study of life course, cohort, and period effects on changes in travel mode use. *Transportation Research Part A: Policy and Practice*, *47*, 167–181.

Schlag, B. (2013). Persönliche Veränderungen der Mobilität und der Leistungsfähigkeit im Alter. In: B. Schlag, K. J. Beckmann (Hrsg.): *Mobilität und demografische Entwicklung*, Köln: TÜV Media, S. 119-143. (= Schriftenreihe Mobilität und Alter der Eugen-Otto-Butz-Stiftung, Bd. 7).

Shaheen, S.A. & Niemeier, D.A. (2001). Integrating vehicle design and human factors: minimizing elderly driving constraints. *Transportation Research Part C: Emerging Technologies*, *9*(3), 155-174

Souders, D. J. & Charness, N. (2016). Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles. Human Aspects of IT for the Aged Population. *Healthy and Active Aging*, 428-440.

Statistisches Bundesamt (2019). *Bevölkerung Deutschlands bis 2060: Ergebnisse der 14. koordinierten Bevölkerungsvorausberechnung - Hauptvarianten 1 bis 9*. [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/bevoelkerung-deutschland-2060-5124202199014.pdf?__blob=publicationFile (Accessed 02 April 2021).

Statistisches Bundesamt (2019b): *Unfälle von Senioren im Straßenverkehr 2018.* [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/unfaelle-senioren-5462409187004.pdf?__blob=publicationFile (Accessed 23 December 2020).

Uekermann, J., Channon, S. & Daum, I. (2006). Humor processing, mentalizing, and executive function in normal aging. *Journal of International Neuropsychological Society*, *12*, 184–911.

Uteng, T. P., Julsrud, T.E. & George, C. (2019). The role of life events and context in type of car share uptake: Comparing users of peer-to-peer and cooperative programs in Oslo, Norway. *Transportation Research Part D, 71*, 186-206.

van der Waerden, P., Timmermans, H. & Borgers, A. (2003). The Influence of Key Events and Critical Incidents on Transport Mode Choice Switching Behaviour: A Descriptive Analysis. *10th International Conference on Travel Behaviour Research*, 1‑23.

Van Westendorp, P. H. (1976). NSS Price Sensitivity Meter (PSM) – A new approach to study consumer perception of prices. *Proceedings of the 29th ESOMAR Congress,* Venice, 139-167.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Verband der Automobilindustrie (2020). *Neuzulassungen.* [online] https://www.vda.de/de/services/zahlen-und-daten/jahreszahlen/neuzulassungen.html (Accessed 02 April 2021).

Waycott, J., Vetere, F., Pedell, S., Morgans, A., Ozanne, E. & Kulik, L. (2016). Not for me: Older adults choosing not to participate in a social isolation intervention. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems,* 745–757.

Wild, A. (2014). Zwischen Wunsch und Wirklichkeit: Fahrerassistenzsysteme für ältere Autofahrer. *Zeitschrift für die gesamte Wertschöpfungskette Automobil*, *17*(1), 58-63.

Winner, H. & Schopper, M. (2015). Adaptive Cruise Control, in Winner, H., Hakuli, S., Wolf, G. (Eds.) *Handbuch Fahrerassistenzsysteme - Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort*, Wiesbaden, Vieweg+Teubner, 851-891.

Winner, H., Hakuli, S. & Wolf, G. (2015). *Handbuch Fahrerassistenzsysteme - Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort*. 3. Aufl., Wiesbaden, Vieweg+Teubner.

Xu, C., Wang, W., Chen, J., Wang, W., Yang, C. & Li, Z. (2010). Analyzing travelers' intention to accept travel information. Transportation Research Record: Journal of the Transportation Research Board, *2156*(1), 93–100.

Zentralverband Deutsches Kraftfahrzeuggewerbe e. V. (2020). *Zahlen & Fakten 2019*. [online], https://www.kfzgewerbe.de/fileadmin/user_upload/Presse/Zahlen_Fakten/Zahlen___Fakten_2019.pdf (Accessed 02 April 2021)

Zhang, J., 2017. Life-oriented behavioral research for urban policy. Springer.

Chapter 2: Theoretical background

Researching age-induced effects with respect to the research questions requires a concept that empirically examines, analyzes, problematizes, and identifies dependencies among older drivers' acceptance, age, and life events as well as their willingness to pay. Regarding the research questions and objectives, the different theoretical foundations are briefly presented below.

Willingness to pay

In order to successfully place driver assistance systems in the market of older drivers, the willingness of this target group to pay for the use of driver assistance systems must be determined and represents a fundamental prerequisite for the adoption of these systems in the market. Household theory and explanations of intertemporal consumption are used to explain the market potential of driver assistance systems for older drivers (Breidert, 2005; Diller, 2008; Miller et al., 2011; Potoglou & Kanaroglou, 2007; Proff, 2019).

According to the household theory, a household, like an individual, can optimize current and future consumption based on income (Varian, 2014). Research demonstrates a hump-shaped ("hump-shaped") progression of the consumer spending curve over the life cycle (Fernández-Villaverde & Krueger, 2007; Yang, 2009). A distinction is made between baskets of goods and services, e.g., necessities, durables, and luxuries, which change with age. These assumptions are confirmed by the theory of intertemporal consumption (Blundell et al., 1994), which establishes a relationship between age and demand via baskets of goods (see Figure 3). The approach assumes that a household's consumption expenditures are directed in such a way that the marginal utility of income remains the same over the course of a lifetime. Young people therefore cover their basic needs first. As they grow older (middle age), once demand is saturated, fewer additional needs are satisfied. Future income growth, income risks and savings can then be more rationally assessed by this group of people based on their spending behavior (Miles, 1997). The remaining income gains can consequently be invested in various consumer goods. The baskets of goods to be derived from the intertemporal consumption behavior of households are divided into (Moschis, 2012): (1) young households (basic needs), (2) an average middle-aged family with younger children, and (3) retired households (goods of replacement needs, especially for the elderly).

Based on the approach, it can be assumed that a willingness to pay for advanced driver assistance systems exists among older drivers overall and among individual age groups. However, the level of willingness to pay at older ages remains unclear and requires further research.

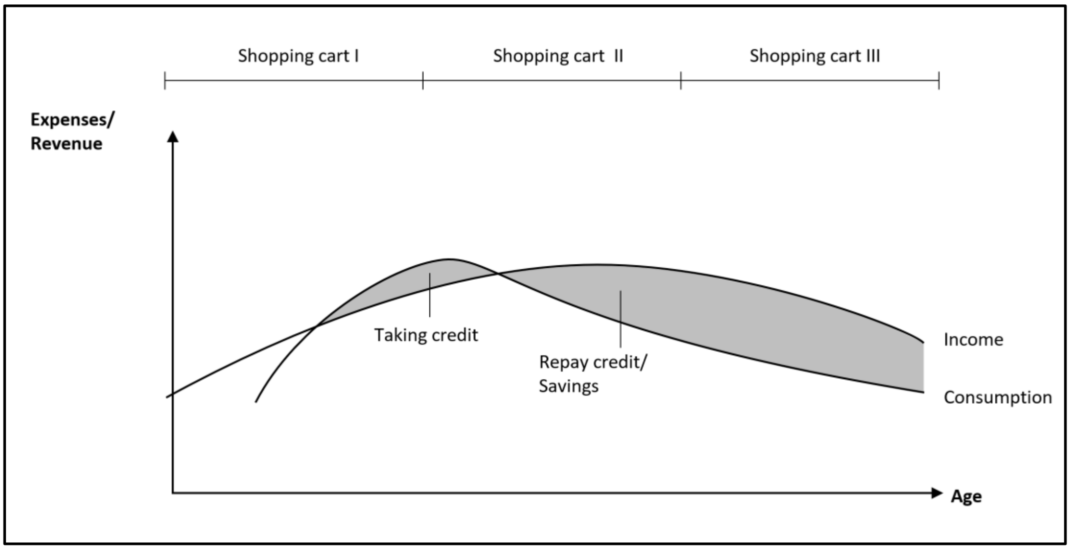

Figure 3: Theory of intertemporal consumption (Proff, 2019)

Acceptance

Acceptance models are used in the context of an empirical study to structure existing approaches and their influencing factors and mechanisms and to place them in an overall context (Schäfer & Keppler, 2013). They are both visually and verbally described models that describe the essential components and effect relationships of the constructs. They can be divided into structural and process models (Abelson & Levi, 1985).

In structural models, the focus is on analyzing the effect relationships between different determinants, related to a concrete research object (Kornmeier, 2009). Input models represent the simplest form of a structural model (Schäfer & Keppler, 2013). The core of the models is the representation of relevant constructs of acceptance. However, there is no consideration of effect sizes. Therefore, the results do not show an acceptance process. Input/output models have the same structure as input models, but in addition to independent variables of acceptance, they also have dependent variables, which allows for empirical model testing (Kornmeier, 2009). The output thus represents the outcome of an acceptance process. The feedback models show the feedback effect of the acceptance process on the influencing factors and thus assume a circularity of the process, whereby individual influencing factors are neglected. In this constellation, acceptance is considered to be a dynamic variable due to the constant testing of the model.

The best-known acceptance model is the Technology Acceptance Model (TAM) by Davis et al. (1989), which, with its extensions and further developments (see Figure 5), forms the basis of numerous technology acceptance studies (Gefen et al, 2003; Gefen & Straub 1997; van der Heijden, 2004; Zarmpou et al. 2012). The model is based on the Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB) (Figure 4 separates the two from each other) and is adapted to the specific requirements of information systems and technology (Ajzen & Fishbein, 1980; Ajzen, 1991). It examines the probability of individual user behavior when the system is used voluntarily.

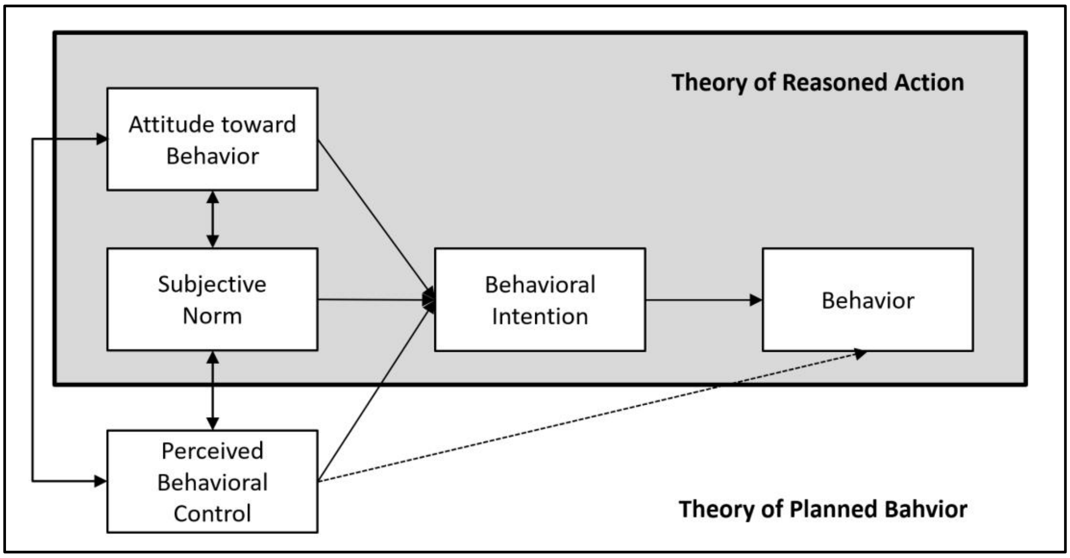

Figure 4: Theory of Reasoned Action and Theory of Planned Behavior (Ajzen & Fishbein, 1980; Ajzen, 1991)

Consistent with the Theory of Reasoned Action, the Technology Acceptance Model states that perceived usefulness and perceived ease of use have additional influence on attitudes toward use and intention to use (Davis et al., 1989). The easier the system is to use and higher the usefulness, the greater a user's willingness to use the system (Simon, 2001). The model is proven, solid, and the most influential model for studying information technology acceptance (Carr, 2008; King & He, 2006; Koivumäki et al., 2017; Schepers & Wetzels, 2007; Wu et al., 2011), Venkatesh and Davis (2000) further developed it into TAM 2.

Age has received little attention in previous acceptance studies (Venkatesh et al., 2003), although it has been included in several studies as an important external variable influencing behavioral intention and technology acceptance (Chung et al., 2010; Wang et al., 2003). The literature does not have clear results on technology acceptance in old age, but the meta-analysis by Hauk et al. (2018) indicates a rather negative influence of age on technology acceptance. Since no clear result or linear relationship can be derived from the studies across age, acceptance at older ages remains unclear and requires further research.

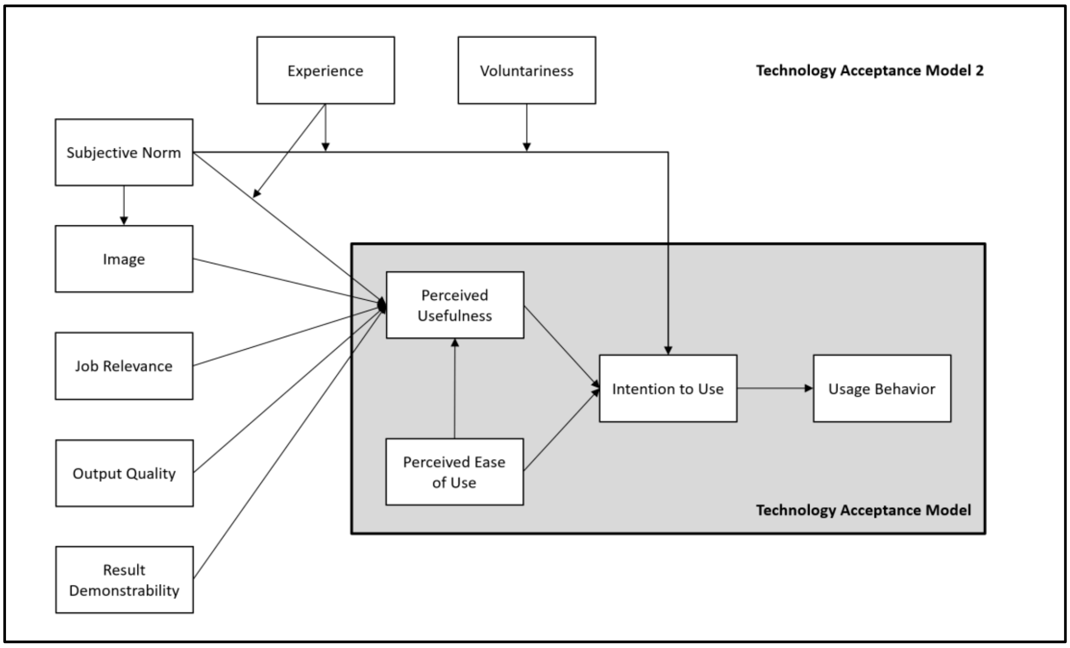

Figure 5: Technology Acceptance Model (Davis et al., 1989)

Life events over the life course

According to Ryu et al. (2009), life courses and life events influence acceptance and can thus change the (consumption) behavior of users or consumers and thus interrupt age-induced effects.

Life-cycle research can be used to derive a deeper understanding of consumer behavior based on lifespan (Harrison et al., 2011). This concept assumes that human life is characterized by passing through a specific sequence of stages (Arndt, 1979) and suggests that relationships exist between life stages, demographic, and behavioral characteristics of individuals (Blackwell, 1942). Initially, life-cycle research focused on families and examined the influence of different life stages on various factors, including consumption, but looks less at individual transitions such as education, careers, and retirement. In the 1970s, there was a stronger orientation toward the life course with a focus on these individual transitions (Elder, 1978; Hareven, 1978), which included changes in family structure as well as individual developments. The prevailing view is that life-cycle models must account for changes in the life course and the timing of life events and transitions. The life cycle concept, which has been expanded in subsequent decades, considers developments in modern society when it incorporates the increasing number of growing elderly populations (Hamermesh, 1984; Krisjanous, 2001), single-parent families (Hill, 1986; Sundeen, 1990), and gender issues (Gentry et al., 2003). Within empirical research, the life-cycle concept maps as a determinant of consumption of numerous product categories, including free-time behavior (Danko & Schaninger, 1990), vacation behavior (Lawson, 1991; Fodness, 1992), and health care behavior (Hong and Kim, 2000).

Recent research focuses its analysis on consumers (Bailey et al., 2010; Cornwell et al., 2008) and their specific roles in different social institutions (in the family, in the professional environment, in the neighborhood). These are represented in the life course perspective and are considered in different contexts (Macmillan & Copher, 2005). Here, research examines the consequences of specific transitions between different roles for the individual (Thomsen & Sorensen, 2006) or resulting patterns of dependency between individual household members (Cornwell et al., 2008). For consumer research, the life course perspective implies a focus on individual consumers and their life cycles, as well as the need to examine consumers' household structures, life courses, and consumption patterns over time (Bauer & Auer-Srnka, 2012). In this regard, according to Elder (1985), "the life course generally refers to the interweaving of age-graded trajectories, such as occupational careers and family trajectories, that are subject to changing conditions and future options, as well as short-term transitions ranging from leaving school to retirement" (Elder, 1994). Specifically, this research relates to the dynamics of individual life trajectories, changing social roles, and the stress induced by role transitions and their effects on consumer behavior. Various life course perspective concepts incorporate life events and transitions (Mathur et al., 2008; Schouten, 1991), which are defined as "events that produce changes in an individual's perceptions (of self, of the world) and in the organization of his or her roles, resources, and central relationships" (Hopkins et al., 2006). Transitions between life cycle stages are considered an important event that causes behavioral changes in lifestyle and consumption (Hopkins et al., 2006; Moschis, 2007; Wilkes, 1995). In research, life events can be divided into two categories: age-based and non-age-based life events, each of which causes a change in a person's life that can be short-term or longer-term and potentially threatening, e.g. illness, divorce, or death of a partner (see Figure 6).

Life events thus represent stressors of considerable weight in life event research (Lazarus, 1990). "The more this event changes the person's life and thus the higher the "readjustment effort" to the life situation changed by the event" (Filipp, 2007), the higher the stress of the individual to adjust in balance with the environment.

According to Hultsch & Cornelius (1995), life events can be characterized as a process that represents a condensation of an event sequence, or an adaptive effort to achieve equilibrium. Alternatively, the reason for experiencing a critical life event and its occurrence may be personal or environmental.

Measurement based on the degree of stress and controllability of life events with specific measurement instruments has proved difficult in research (Baumeister et al., 2001; Klumb & Baltes, 2004). Therefore, the single-event approach places a focus on specific life events and their effects in the life context of the research of life events (Filipp, 2007).

According to Elder's (1994) life course approach, life events are qualified as social events and roles that an individual fills over a period of time. In this context, life events as key elements are not predetermined (Elder, 1998). Consistent with Elder (1994), Mayer (2009) also sees life courses as entities shaped by the occurrence and absence of events.

Since the 21st century, the individual life events have also been considered in mobility research following the single event approach and have been referred to as key events, life course events, disruptive events, life-cycle events, or turning points (Beige & Axhausen, 2012; de Groot et al., 2011; Lanzendorf, 2010; Marsden &

Docherty, 2013; Schäfer et al., 2012; Scheiner, 2007; Sharmeen et al., 2014; van der Waerden et al., 2003).

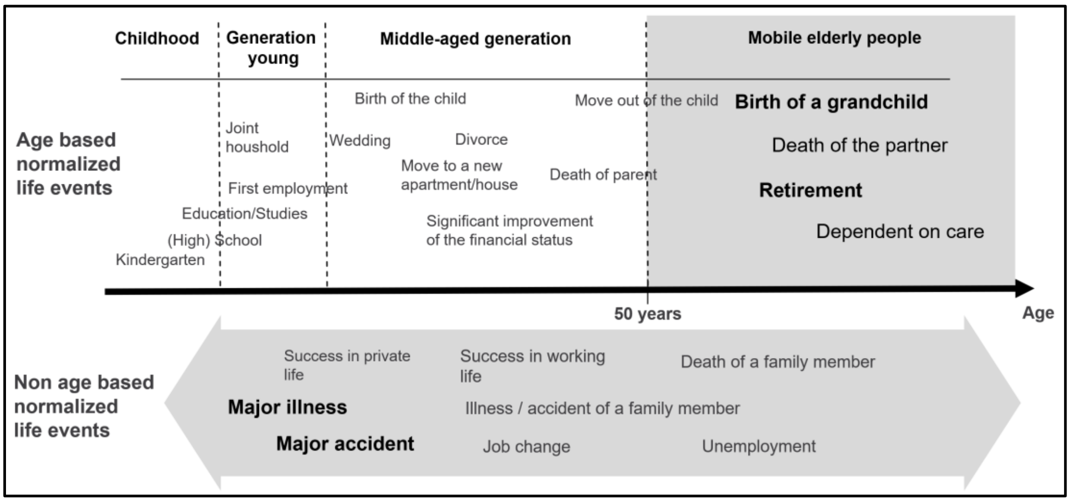

Figure 6: Critical life events (based on Filipp, 2007)

The single-event methodology is thus used as the approach in this thesis to analyze the influence of life events on the behavior of individuals.

Interaction of the explanations

Different theoretical approaches, all of which deal with consumer behavior, are presented.

- The aim of the theory of intertemporal consumption is to determine consumer behavior on the basis of shopping baskets. The theoretical bases of the willingness to pay (theory of the intertemporal consumption) only provide direct measurement values with absolute figures, from which no concrete behavior or their background, of special person and age groups, can be derived.
- The presented technology acceptance models measure the attitude of consumers towards the use of new technologies.
    - The explanation of acceptance in the form of acceptance models, with their different behavioral variables, on the other hand, represent indirectly measurable influencing variables of behavior, such as the intention to use. In addition, age as a moderating variable can influence the behavior of different groups of people both positively and negatively.

- Life Course Theory, on the other hand, is generally concerned with the behavior of consumers over the course of their lives, considering influencing factors such as critical life events.

These theoretical foundations represent explanatory approaches to completely different problems and research questions. However, research questions often cannot be answered from within a single discipline, so that a multidisciplinary view and analysis of partial views is necessary in order to unite, highlight and bring into relation different perspectives on an object of research (Kumar, 2014; Tobi & Kampen, 2018). Here, the approaches map direct and indirect measured values for their target areas of consumer behavior, usage behavior and behavioral change, which can be comparable with each other in relation to the group of consumers. Thus, the common object of investigation of all approaches in this dissertation is the measurement of consumer behavior.

With the help of the research objectives and the developed methods and models, the research questions can be analyzed based on the results. The results can be used as a foundation for deriving implications for research and practice from a scientific point of view.

References

Abelson, R.P. & Levi, A. (1985): Decision making and decision theory, in: G. Lindzey, E. Aronson (Hrsg.): *Handbook of Social Psychology*, New York, Random House, 231-309.

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process*, *50*, 179–211.

Ajzen, I. & Fishbein M. (1980). *Understanding Attitudes and Predicting Social Behavior*, Englewood Cliffs, Prentice-Hall.

Arndt, J. (1979). "Family life cycle as a determinant of size and composition of household expenditures", in Wilkie, W.L. (Ed.), *Advances in Consumer Research, Vol. 6, Association for Consumer Research*, Ann Arbor, MI, pp. 128-32.

Bailey, A.R., Shaw, G., Alexander, A. & Nell, D. (2010), Consumer behaviour and the life course: shopper reactions to self-service grocery shops and supermarkets in England c. 1947-75. *Environment and Planning A*, *42*(6), 1496-512.

Bauer, M. & Auer-Srnka, K.J. (2012), The life cycle concept in marketing research. *Journal of Historical Research in Marketing*, *4*(1), 68-96.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C. & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology*, *5*(4), 323–370.

Beige, S. & Axhausen, K.W. (2012). Interdependencies between turning points in life and long-term mobility decisions. *Transportation*, *39*(4), 857–872.

Blackwell, G.W. (1942). Correlates of the state of family development among farm families on relief. *Rural Sociology*, *7*(2), 161-74.

Blundell, R., Browning, M., & Meghir, C. (1994). Consumer demand and the life-cycle allocation of household expenditures. *The Review of Economic Studies*, *61*(1), 57-80.

Breidert, C. (2005). *Estimation of willingness-to-pay. Theory, measurement, and application*, Published PhD thesis, ePubWU Institutional, WU Vienna University of Economics and Business, Vienna, Austria.

Carr, M. (2008). Adoption and diffusion of Internet banking. In: V. Ravi (Hrsg.): *Advances in Banking Technology and Management*, New York, Hershey, 33-52.

Chung, J. E., Park, N., Wang, H., Fulk, J., & McLaughlin, M. (2010). Age differences in perceptions of online community participation among non-users: An extension of the Technology Acceptance Model. *Computers in Human Behavior*, *26*(6), 1674-1684.

Cornwell, T.B., Wamwara-Mbugua, L.W. and Nicovich, S.G. (2008), Dependence patterns in consumer behavior: exploration and refinement of a concept. *Journal of Consumer Behaviour*, *7*(1), 51-71.

Danko, W.D. & Schaninger, C.M. (1990a). Attitudinal and leisure activity differences across modernized household life cycle categories in Goldberg, M.E., Gorn, G. and Pollay, R.W. (Eds), *Advances in Consumer Research*, *17*, 886-94.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Journal of Management Science*, *35*(8), 982-1003.

De Groot, C.D., Mulder, C.H., Das, M. & Manting, D. (2011). Life events and the gap between intention to move and actual mobility. *Environ. Plan. A*, *43*(1), 48–66.

Diller, H. (2007). *Preispolitik*, 4th ed., Verlag Robert Kohlhammer, Stuttgart.

Elder, G.H. (1978). Approaches to social change and the family. *American Journal of Sociology*, *84*, 1-38.

Elder, G.H. (1985). *Life Course Dynamics: Trajectories and Transitions*. Cornell University Press,Ithaca, NY.

Elder, G. Jr (1994). Time, human agency, and social change: perspectives on the life course. *Social Psychology Quarterly*, *57*(1), 4-15.

Elder, G. H. (1998). *Children Of The Great Depression: 25th Anniversary Edition*. New York, NY: Westview Press.

Fernández-Villaverde, J., & Krueger, D. (2007). Consumption over the life cycle: Facts from consumer expenditure survey data. *The Review of Economics and Statistics*, *89*(3), 552-565.

Filipp, S.-H. (2007). Kritische Lebensereignisse. In J. Brandtstädter (Hrsg.), *Entwicklungspsychologie der Lebensspanne. Ein Lehrbuch* (S. 337–366). Stuttgart, Deutschland: Kohlhammer.

Fodness, D. (1992). The impact of family life cycle on the vacation decision-making process. *Journal of Travel Research*, *31*(2), 8-13.

Gefen, D., Karahanna, E. & Straub, D. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly*, *27*(1), 51–90.

Gefen, D. & Straub, D.W. (1997). Gender Differences in the Perception and Use of E-Mail: An Extention to the Technology Acceptance Model. *MIS Quarterly*, *21*(4), 389-400.

Gentry, J.W., Commuri, S. & Jun, S. (2003). Review of literature on gender in the family. *Academy of Marketing Science Review*, *1*, 1-20.

Hamermesh, D.S. (1984). Consumption during retirement: the missing link in the life cycle. *Review of Economics and Statistics*, *66*(1), 1-7.

Hareven, T.K. (1978). Cycles, courses and cohorts: reflections on theoretical and methodological approaches to the historical study of family development. *Journal of Social History*, *12*(1), 97-109.

Harrison, R.L.I., Veeck, A. & Gentry, J.W. (2011). A life course perspective of family meals via the life grid method. *Journal of Historical Research in Marketing*, *3*(2), 214-33.

Hauk, N., Hüffmeier, J., & Krumm, S. (2018). Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Computers in Human Behavior*, *84*, 304–319.

Hill, R. (1986). Life cycle stages for types of single parent families: of family development theory. *Family Relations*, *35*(1), 19-29.

Hong, G.S. & Kim, S.Y. (2000), Out-of-pocket health care expenditure patterns and financial burden across the life cycle stages. *Journal of Consumer Affairs, 34*(2), 291-313.

Hopkins, C.D., Roster, C.A. & Wood, C.M. (2006). Making the transition to retirement: appraisals, post-transition lifestyle, and changes in consumption patterns, *Journal of Consumer Marketing*, *23*(2), 87-99.

Hultsch, D., & Cornelius, S. (1995). Kritische Lebensereignisse und lebenslange Entwicklung: Methodologische Aspekte. In S.-H. Filipp (Hrsg.), *Kritische Lebensereignisse* (S. 72–91). Weinheim, Deutschland: Beltz.

King, W.R. & He, J. (2006). A meta-analysis of the technology acceptance model. *Inf. Manage.*, *43*, 740–755.

Koivumaki, T., Pekkarinen, S., Lappi, M., Vaisanen, J., Juntunen, J. & Pikkarainen, M. (2017). Consumer Adoption of Future MyData-Based Preventive eHealth Services: An Acceptance Model and Survey Study. *J med Internet Res*, *19*(12), 1-15

Kornmeier, K. (2009). *Determinanten der Endkundenakzeptanz mobilkommunikationsbasierter Zahlungssysteme – Eine theoretische und empirische Analyse.* Dissertation, Universität Duisburg-Essen.

Klumb, P. L., & Baltes, M. M. (2004). Adverse Life Events in Late Life: Their Manifestation and Kohli, M. (Hrsg.). (1978). *Soziologie des Lebenslaufs. Darmstadt*, Deutschland: Luchterhand.

Krisjanous, J. (2001). *The end of a few good years: redefining the household life cycle classification for the elderly in the 21st century*, in Chetty, S. and Collins, B. (Eds), ANZMAC, Auckland.

Kumar, R. (2014). *Research Methodology: A Step-by-Step Guide for Beginners*, 4th edn. Sage, Los Angeles.

Lanzendorf, M. (2010). Key events and their effect on mobility biographies: the case of childbirth. *International Journal of Sustainable Transportation*, *4*, 272–292.

Lawson, R.W. (1991). Patterns of tourist expenditure and types of vacation across the family life cycle. *Journal of Travel Research*, *29*(4), 12-18.

Lazarus, R. S. (1990). Stress und Stressbewältigung - ein Paradigma. In S.-H. Filipp (Hrsg.), *Kritische Lebensereignisse* (S. 198–232). München, Deutschland: Beltz.

Macmillan, R. & Copher, R. (2005). Families in the life course: interdependency of roles, role configurations, and pathways. *Journal of Marriage and Family*, *67*(4), 858-79.

Marsden, G. & Docherty, I. (2013). Insights on disruptions as opportunities for transport policy change. *Transport. Res. Part A: Policy Pract*, *51*, 46–55.

Mathur, A., Moschis, G. & Lee, E. (2008). A longitudinal study of the effects of life status changes on changes in consumer preferences. *Journal of the Academy of Marketing Science*, *36*(2), 234-46.

Mayer, K. U. (2009). New Directions in Life Course Research. *Annual Review of Sociology*, *35*(1), 413–433.

Miles, D. (1997). A household level study of the determinants of income and consumption. *The Economic Journal*, *107*(440), 1-25.

Miller, K.M., Hofstetter, R., Krohmer, H. & Zhang, Z.J. (2011). How should consumers' willingness to pay be measured? An empirical comparison of state-of-the-art approaches. *Journal of Marketing Research*, *48*(1), 172–184.

Moschis, G. (2007). Life course perspectives on consumer behavior. *Journal of the Academy of Marketing Science*, *35*(2), 295-307.

Moschis, G. P. (2012). Consumer behavior in later life: Current knowledge, issues, and new directions for research. *Psychology & Marketing*, *29*(2), 57-75.

Potoglou, D. & Kanaroglou, P.S. (2007). Household demand and willingness to pay for clean vehicles. *Transportation Research Part D: Transport and Environment*, *12*(4), 264-274.

Proff, H. (2019). *Multinationale Automobilunternehmen in Zeiten des Umbruchs: Herausforderungen - Geschäftsmodelle - Steuerung*. Wiesbaden: Springer.

Ryu, M.H., Kim, S. & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC services. *Computers in Human Behavior*, *25*, 619-632.

Schäfer, M. & Keppler, D. (2013). Modelle der technikorientierten Akzeptanzforschung - Überblick und Reflexion am Beispiel eines Forschungsprojekts zur Implementierung innovativer technischer Energieeffizienz-Maßnahmen. [online] https://www.tu-berlin.de/fileadmin/f27/PDFs/Discussion_Papers/Akzeptanzpaper__end.pdf (Accessed 13.07.2021).

Schäfer, M., Jaeger-Erben, M. & Bamberg, S. (2012). Life events as windows of opportunity for changing towards sustainable consumption patterns?. *Journal of Consumer Policy*, *35*(1), 65–84.

Scheiner, J., 2007. Mobility biographies: elements of a biographical theory of travel demand. *Erdkunde*, *61*, 161–173.

Schepers, J. & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects. *Journal of Information & Management*, *44*(1), 90-103.

Schouten, J. (1991). Selves in transition: symbolic consumption in personal rites of passage and identity reconstruction. *Journal of Consumer Research*, *17*(4), 412-25.

Sharmeen, F., Arentze, T. & Timmermans, H. (2014). An analysis of the dynamics of activity and travel needs in response to social network evolution and life-cycle events: a structural equation model. *Transport. Res. Part A: Policy Pract*, *59*, 159–171.

Simon, B. (2001). *E-Learning an Hochschulen. Gestaltungsräume und Erfolgsfaktoren von Wissensmedien*. Lohmar, Josef Eul.

Sundeen, R.A. (1990). Family life course status and volunteer behavior: implications for the single parent. *Sociological Perspectives*, *33*(4), 483-500.

Thomsen, T. & Sorensen, E. (2006). The first four-wheeled status symbol: pram consumption as a vehicle for the construction of motherhood identity. *Journal of Marketing Management*, *22*(9), 907-27.

Tobi, H. & Kampen, J.K. (2018). Research design: the methodology for interdisciplinary research framework. *Qual Quant*, *52*, 1209–1225.

van der Heijden, H., (2004). User Acceptance of Hedonic Information Systems. *MIS Quaterly*, *28*(4), 695-704.

van der Waerden, P., Timmermans, H. & Borgers, A. (2003). The Influence of Key Events and Critical Incidents on Transport Mode Choice Switching Behaviour: A Descriptive Analysis. *10th International Conference on Travel Behaviour Research*, 1‑23.

Varian, H. R. (2014). *Grundzüge der Mikroökonomik*. 8. Aufl., Oldenburg: München.

Venkatesh, V. & Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four longitudinal Field Studies. *Management Science*, *46*(2), 186-204.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Wang, Y. S., Wang, Y. M., Lin, H. H. & Tang, T. I. (2003). Determinants of user acceptance of internet banking: An empirical study. *International journal of service industry management*, *14*(5), 501-519.

Wu, K., Zhao, Y., Zhu, Q., Tan, X. & Zheng, H. (2011). A meta-analysis of the impact of trust on technology acceptance model: Investigation of moderating influence of subject and context type. *Int. J. Inf. Manage.*, *31*, 572–581.

Wilkes, R. (1995). Household life-cycle stages, transitions, and product expenditures. *Journal of Consumer Research*, *22*(1), 27-42.

Yang, F. (2009). Consumption over the life cycle: How different is housing. *Review of Economic Dynamics*, *12*(3), 423-443.

Zarmpou, T., Saprikis, V., Markos, A. & Vlachopoulou, M. (2012). Modeling users' acceptance of mobile services. *Electronic Commerce Research*, *12*(2), 225-248.

Chapter 3: Methodology

In order to be able to identify age-induced effects in willingness to pay and in the acceptance of for driver assistance systems, the needs and consumer behavior of the group of older drivers must be determined. Based on the three theoretical approaches, different methods are used to measure the objects of investigation: willingness to pay, acceptance and life events.

Since the willingness to pay is a directly measurable (Kloss & Kunter, 2016), absolute value, the Van Westendorp method is used for the measurement (van Westendorp, 1976).

The explanation of acceptance in the form of acceptance models with their different behavior-oriented variables, on the other hand, represents indirectly measurable influencing variables and requires a model to measure these values (Weiber & Mühlhaus, 2014). For this purpose, structural equation modeling (SEM) is used, which enables the interrelationships and the simultaneous investigation of several determinants in the form of a structural model and evaluates them with the help of structural equation analysis (Hair et al., 2017). The acceptance model makes general statements across all age groups, according to the sample collected. In order to be able to capture age-dependent behavior, groups of people of different ages must be used, examined and measured. This is done in the form of multi-group analysis within the framework of structural equation modeling (Hair et al., 2018).

Life events over the life course, as well as the previously mentioned determinants of acceptance and age, do not represent a direct influencing variable within the framework of structural equation modeling (Weiber & Mühlhaus, 2014). In order to be able to make more detailed statements about the groups of people 50+ among themselves, they must be included as moderating variables within the framework of the acceptance model (Chung et al., 2010; Rahman et al., 2019; Venkatesh et al., 2003) and their influence on the relationships must be measured by means of multi-group analysis (see Figure 7).

Therefore, the methodological approaches, the operationalization and the validation of the results with statistical tests are presented below.

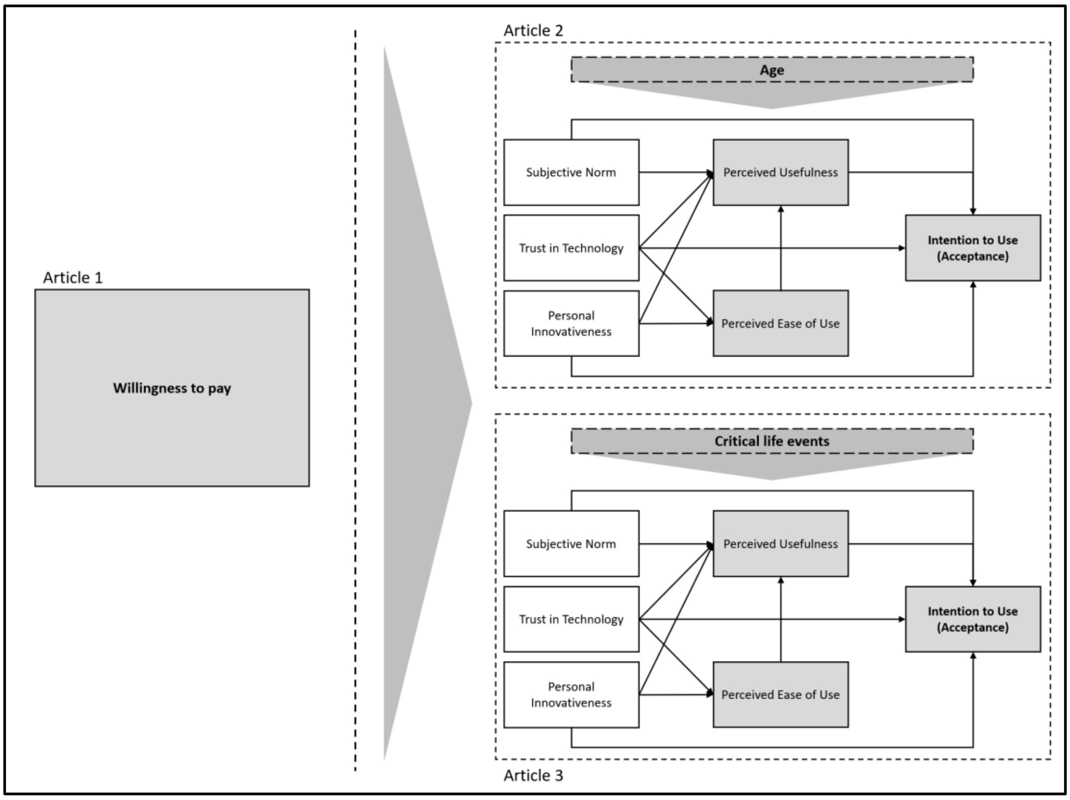

Figure 7: Research model (own design)

Willingness to pay

To determine the willingness to pay for a driver assistance system, the van Westendorp method is used and slightly modified (Kloss & Kunter 2016; van Westendorp 1976). Instead of an open-ended price question as in van Westendorp (1976), four given prices ("too expensive," "expensive," "cheap," "too cheap") are offered for evaluation and the expected price of the driver assistance system is determined by aggregating the responses to the four given prices (Proff et al., 2019). Prices for each driver assistance system were provided by an international car manufacturer in Germany, e.g., for Cross Traffic Alert higher than €870, €580 - €870, €290 - €580, and lower than €290. Based on the literature and using the input from the car manufacturer, in the evaluation, "too expensive" was recorded with a value of 4, "expensive" with 3, "cheap" with 2 and "too cheap" with 1 (Kloss & Kunter, 2016). The age of the older respondents was recorded, first the exact age and then the age group: 50 - 59, 60 - 69 and 70+.

Acceptance

In order to be able to empirically test the acceptance model for the selected driver assistance systems, the acceptance (intention to use), which can only be measured indirectly, and the effect relationships of the individual determinants are represented by means of a structural equation model. Structural equation modeling represents the process of formulating a hypothesis system that reflects the assessment of results obtained by means of structural equation analysis and the illustration of relationships between the theoretical preliminary considerations and the statistical model (Weiber & Mühlhaus, 2014). The relationships are estimated based on empirical data using structural equation analysis, presented in visual form in a path diagram for easier grasp of complex structures, and compared with the a priori assumed relationships (Kornmeier, 2009; Chin, 1998). Structural equation analysis is capable of considering multiple hypotheses simultaneously (Hair et al., 2017). In particular, latent variables that are not directly measurable (such as intention to use) can be measured in their expression using this method (Weiber & Mühlhaus, 2014) and age-induced effects can be visualized within different groups using a multi-group analysis (Hair et al., 2018).
To test the hypotheses, structural analysis is performed using Smart-PLS v.3.2.6, which is based on a variance analytic approach (Weiber & Mühlhaus, 2014). The estimation is performed using the Partial Least Square (PLS) method. The variable age and its influence with its different age groups is examined using multi-group analysis (Hair et al., 2018).

Since there are no global quality criteria in the literature for the variance analytical approach (PLS) for testing the reliability and validity of structural equation models, an individual assessment of the measurement and structural models is carried out using the following quality criteria mentioned in Table 1 according to Hair et al. (2018): Convergence validity, discriminant validity, indicator reliability, indicator significance Construct reliability for the measurement model and strength of the path coefficients, significance of the path coefficients and coefficient of determination for the structural model.

Table 1: Quality criteria for the measurement and structural model (own design)

Quality type	Criteria	Name	Value
Measurement model			
Convergence validity	Average variance extracted	AVE	> 0,5
Discriminant validity	Fornell-Larcker-Criterion	FLK	$\sqrt{\text{DEV}} \geq \lvert\text{KORR}\ \xi/\eta \text{ und } \xi/\eta\rvert$
Indicator reliability	Share of the variance of an indicator	λ	> 0,7
Indicator significance	T-Value	t-Value	> $\lvert \pm 1{,}96\rvert$
Construct reliability	How well the latent variable is measured by indicators	CR	> 0,6
Structural model			
Strength of the path coefficients	Factor loading	γ	> $\lvert \pm 0{,}1\rvert$
Significance of the path coefficients	T-Value	t-Wert	> $\lvert \pm 1{,}96\rvert$
Coefficient of determination	R^2-Value	R^2	> 0,3

Life events over the life course

In the acceptance model, life events are included as moderating variables and examined within the framework of structural equation modeling. Thus, they are only indirectly measurable factors that can influence acceptance (Hair et al., 2018). To measure the strength of the influence of life events on acceptance, structural equation analysis and multi-group analysis are again used. The methodological procedure corresponds to the previous analysis of acceptance.

Operationalization

The van Westendorp method is used to determine the willingness to pay for the selected driver assistance systems. The subjects are asked to name four prices on the basis of four questions, from which the optimum price and price sensitivity can be determined. The operationalization of the Van Westendorp method comprises the following four price queries (Van Westendorp, 1976):

1. At what price (in Euros) would the assistance system be too expensive for you, so that you would definitely not buy it?
2. At what price (in Euros) would the assistance system be expensive for you, but you might buy it anyway?

3. At what price (in Euros) would the assistance system be cheap for you, i.e. a good offer?
4. At what price (in Euros) would the assistance system be too cheap for you, so that you doubt the quality and do not buy it?

The acceptance of the driver assistance system is defined as the customers' intention to use such a system. It is measured with five independent variables (Personal Innovativeness, Subjective Norm, Trust in technology, Perceived Ease of Use, Perceived Usefulness) and one dependent variable (Intention to Use). All constructs are measured with items that already exist in the literature but are adapted to the background of the research (see Table 2). Acceptability questions were measured with a 7-point Likert scale ranging from "strongly disagree" to "strongly agree." Demographic data on driver assistance system experience and product knowledge were collected using a 7-point interval scale. All other demographic data (gender, age, net income, education, miles driven per day) were measured using nominal and ordinal scales. To check the comprehensibility and correctness of the items, a pretest was conducted with 50 randomly selected respondents aged 20-90 years.

Table 2: Operationalization of the constructs (own design)

Construct	Item		References
Intention to Use	ITU_01	I will use the advanced driver assistance system	Davis et al. (1989); Venkatesh et al. (2003);
	ITU_02	I can imagine having the advanced driver assistance system in my vehicle	
Subjective Norm	SN_01	People who are important to me would appreciate it if I used the advanced driver assistance system	Venkatesh & Davis (2000); Venkatesh et al. (2003)
	SN_02	People who influence my behavior would appreciate it if I used the advanced driver assistance system	
Perceived Ease of Use	PEOU_01	It would be easy for me to learn how to use the advanced driver assistance system	Davis et al. (1989); Venkatesh et al. (2003)
	PEOU_02	I do not see any major problems in operating the advanced driver assistance system	
Personal Innovativeness	PERIN_01	I am interested in new products	Lee (2019)
	PERIN_02	I like to experiment with new information technologies	
	PERIN_03	I regularly keep an eye out for new products	

	PERIN_04	I am usually the one who informs others about new products	
Perceived Usefulness	PU_01	I think the advanced driver assistant system is a good idea	Davis et al. (1989); Venkatesh & Davis (2000); Venkatesh et al. (2003)
	PU_02	I think the advanced driver assistant system is useful	
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	

The operationalization of the life events is identical to the query of the demographic data, which are measured on a nominal scale of 1 for "Yes, I experienced the event" or 2 for "No, I did not experience the event."

Validation of the results

To validate the results, differences in willingness to pay between the different age groups (50-59 years, 60-69 years, and 70 years and older) are performed using a two-sample t-test for unpaired samples at a significance level of $p \leq 0.05$ (highly significant) and $p \leq 0.10$ (slightly significant). All age groups are compared. Variance equality is determined at the same significance level ($p \leq 0.05$) using Levene's test (Levene, 1960). In case of variance heterogeneity, Welch's t-test is used to determine significant differences (Welch, 1944). The Pearson correlation coefficient shows the correlation between age and willingness to pay (Pearson, 1895).

To determine the influence of age and critical life events between pre-defined data groups such as age groups or critical life events, multi-group analysis is performed (Hair et al., 2018). The moderating influence of age and life events is thereby tested by significant differences in path coefficients. For this purpose, the PLS-MGA approach integrated in SmartPLS is used (Hair et al., 2018). This method uses a non-parametric significance test to test for significant group differences. 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% is considered a difference to be significant (Sarstedt et al., 2011; Henseler et al., 2009).

References

Chung, J. E., Park, N., Wang, H., Fulk, J., & McLaughlin, M. (2010). Age differences in perceptions of online community participation among non-users: An extension of the Technology Acceptance Model. Computers in Human Behavior, 26(6), 1674-1684.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Journal of Management Science*, *35*(8), 982-1003.

Gefen, D., Karahanna, E. & Straub, D. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly, 27*(1), 51–90.

Hair, J. F., Hult, G. T. M., Ringle, C. M. & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2 ed.). Thousand Oaks, CA: Sage.

Hair, J. F., Sarstedt, M., Ringle, C. M. & Gudergan, S. P. (2018). *Advanced Issues in Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Thousand Oaks, CA: Sage.

Henseler, J., Ringle, C. M. & Sinkovics, R. R. (2009). The Use of Partial Least Squares Path Modeling in International Marketing. *Advances in International Marketing*, *20*, 277-320.

Kloss, D., & Kunter, M. (2016). The van Westendorp price-sensitivity meter as a direct measure of willingness-to-pay. *European Journal of Management*, *16*(2), 45-54.

Kornmeier, K. (2009): Determinanten der Endkundenakzeptanz mobilkommunikationsbasierter Zahlungssysteme – Eine theoretische und empirische Analyse, Dissertation, Universität Duisburg-Essen.

Lee, M. S. (2019). Effects of personal innovativeness on mobile device adoption by older adults in South Korea: the moderation effect of mobile device use experience. *International Journal of Mobile Communications*, *17*(6), 682-702.

Levene, H. (1960). Robust Tests for Equality of Variances. In: I. Olkin, et al., Eds., *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*, Stanford University Press, Palo Alto, 1960, pp. 278-292.

Pearson, K. (1895). Notes on Regression and Inheritance in the Case of Two Parents. *Proceedings of the Royal Society of London*, *58*, 240-242.

Proff, H. (2019). Multinationale Automobilunternehmen in Zeiten des Umbruchs: Herausforderungen - Geschäftsmodelle - Steuerung. Wiesbaden: Springer.

Rahman, M. M., Deb, S., Strawderman, L., Burch, R. & Smith, B. (2019). How the older population perceives self-driving vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*, 242–257.

Sarstedt, M., Henseler, J. & Ringle, C. M. (2011). Multi-Group Analysis in Partial Least Squares (PLS) Path Modeling: Alternative Methods and Empirical Results. *Advances in International Marketing*, *22*, 195-218.

Van Westendorp, P. H. (1976). NSS Price Sensitivity Meter (PSM) – A new approach to study consumer perception of prices. *Proceedings of the 29th ESOMAR Congress,* Venice, 139-167.

Venkatesh, V. & Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four longitudinal Field Studies, *Management Science*,*46*(2), 186-204.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Weiber, R. & Mühlhaus, D. (2014). *Strukturgleichungsmodellierung. Eine anwendungsorientierte Einführung in die Kausalanalyse mit Hilfe von AMOS, SmartPLS und SPSS (2. ed.)*. Berlin, Heidelberg: Springer Gabler.

Welch, B.L., (1947). The Generalization of Student's Problem When Several Different Population Variances Are Involved. *Biometrika*, *34*(1-2), 28-35.

Chapter 4: Tapping into Market Opportunities in Aging Societies – the example of advanced driver assistance systems in the transition to autonomous driving

Timo Günthner[1], Heike Proff[1], Josip Jovic[1] and

Lukas Zeymer[1]

[1] Chair of General Business Administration & International Automotive Management, University of Duisburg-Essen, Duisburg, Germany

1. Introduction

Global car sales figures indicate that the automotive market as a whole is stagnating, especially in the Triad markets (VDA, 2020). This forces automotive companies to seek new market opportunities.

The so-called "silver market" offers such opportunities, however, they are often neglected (Kohlbacher & Herstatt, 2011; Matsuno & Kohlbacher, 2019). Since the populations of industrial nations are getting older (OECD, 2016), this market is growing. With 199 million people aged 50 and older in 2015, the “silver economy” represents 39% of the total EU population and is responsible for 40,6% of private consumption expenditure (European Commission, 2018). In 2025 a population of 42.9% is expected with a share of 44.3% of private consumption expenditure. Due to the purchasing power and an increasingly growth elderly represent an interesting customer group (Kohlbacher & Herstatt, 2011; Klimczuk, 2016). In Germany, older people (in this study people over the age of 50) currently account for more than 40% of the total population (Statistisches Bundesamt, 2018a), and their share of the total population will continue to rise steeply up to the year 2030 (Schlag, 2013). A particularly important silver market is the automotive market, because given the high costs of new cars and increasing income in old age (Statistisches Bundesamt, 2018b; OECD, 2019), the average new car buyer is over 50 years old (KBA, 2017) and has an average household net income of €4,376 per month (DAT, 2018). Market opportunities in the silver auto market become apparent by looking at the number of vehicle sales. In 2019 two-thirds (63.4%) of the 3.6 million new vehicle registrations in Germany have been in the age group of 50 years and older (Zentralverband Deutsches Kraftfahrzeuggewerbe, 2020) and almost all of them state that they feel significantly restricted in their mobility without a car. Almost 60 percent of senior citizens pay for their car in cash with an average vehicle price of €29,750 (DAT, 2018) which also indicates that older people generally have more money available.

At the same time, older people have never been so mobile as today (Schlag, 2013; Nobis et al., 2019) and they account for 45% of driving licence holders (KBA, 2019). For older generations, mobility provides and represents independence, social participation, physical activity and an increased quality of life (Burgard, 2005; Holley-Moore & Creighton, 2015; Musselwhite, 2018; Musselwhite & Haddad, 2018).

In the natural aging process, cognitive performance, especially in executive functions such as decision-making and problem-solving, tends to decline (Markowitsch et al., 2005; Brand & Markowitsch, 2010; Boot et al., 2014). The accomplishment of tasks in day-to-day traffic becomes more difficult for older road users not only with increasing traffic density, but due to these age-related physical and cognitive limitations, which represent a risk to safe driving (Engin et al., 2010; Dobbs & Schopflocher, 2010; Boot et al., 2014; Souders et al., 2017). The majority of trips taken by older people are for shopping, family visits, recreation, social engagements as well as medical related journeys (Duncan et al., 2015).

Therefore, suitable technical assistance that meets the physiological and economic requirements is needed in order to increase road safety for all road users (Rudinger et al., 2013; Boot & Scialfa, 2016).

Advanced driver assistance systems already exist to help elderly and other drivers (Wild, 2014; Karthaus et al., 2016), and they are being continuously improved. These systems aim to prolong the ability to drive, regardless of the limitations of the driver. However, although there is a need to support elderly drivers, the success of many driver assistance systems is far removed from car manufacturers' expectations (Winner & Schopper, 2015). That is surprising, because studies prove that people are willing to pay for technologies that improve their quality of life (Schulz et al., 2013; Souders et al., 2017).

Several studies have investigated age-related aspects of advanced driver assistance systems, i.e. user acceptance (Son et al., 2015), experience and the barriers to usage (Truebswetter & Bengler, 2013). However, so far, the only existing studies investigate the willingness to pay for some of these driver assistance systems in older age. Therefore, the aim of this study is to identify the willingness to pay for advanced driver assistance systems of people aged 50 and older.

The perfect mobility solution would be autonomous driving for older people. Since, however, this technology will not reach widespread adoption before 2030 and is assumed to be very expensive (Deloitte, 2019), this study only examines market opportunities for driver assistance systems as a transition technology.

Therefore, the article is structured as follows: in section 2, the literature on advanced driver assistance systems and on market opportunities in aging societies is reviewed to support the need for an empirical examination of assumptions made on the market opportunities of advanced driver assistance systems in aging societies (section 3). The willingness to pay for five selected driver assistance systems of 181 elderly German drivers is therefore examined in section 4. The article discusses the results (section 5) and finally concludes with implications, limitations and an outlook (Section 6).

2. Literature review

2.1. Advanced driver assistance systems in transition to autonomous driving

Driver assistance systems offer a means to enhance active and integrated safety (Bengler et al., 2014). These systems already exist to help elderly and other drivers (Wild, 2014; Karthaus et al., 2016) and they are being continuously improved, e.g. adaptive cruise control, adaptive light systems, attention assist, blind spot detection, cross traffic alert, cruise control, emergency brake assist, intersection assistant, lane departure warning, lane keeping assistance, night vision, parking assistance, park distance control, tyre-pressure monitoring system, traffic jam assistance, traffic sign recognition (Kukkala et al., 2018**)**.

Advanced driver assistance systems can be seen as an interim technology in the transition to autonomous driving (Reimer, 2014), i.e. to level 5 automation "no driver" (see Figure 1). Although these systems are currently only allocated to level 1 to 3 ("eyes off" after "feet off" and "hands off", see also Figure 1), forecasts predict that autonomous driving (level 5) will not hit the road and be widely adopted until 2030 (Deloitte, 2019). Even if, e.g., the CEO of Weymo, John Krafcik, in his speech at the opening of the International Motor Show (IAA) in September 2019 in Frankfurt, Germany, reported on experiments with autonomous driving on level 5, the risk of slow driver reactions on level 3 and 4 autonomous driving is still very high (Gold et al., 2013; Kyriakidis et al., 2019) and there are many unsolved problems (with data protection and other issues). For this reason, German and other manufacturers will concentrate on level 3 and 4 as a transition technology for the moment.

The ultimate goal of automated and cooperative traffic thus remains a vision of the future, but intermediate steps towards that aim can be realised by systems that mitigate or avoid collisions in selected driving situations (Bengler et al., 2014; Jiménez, 2018).

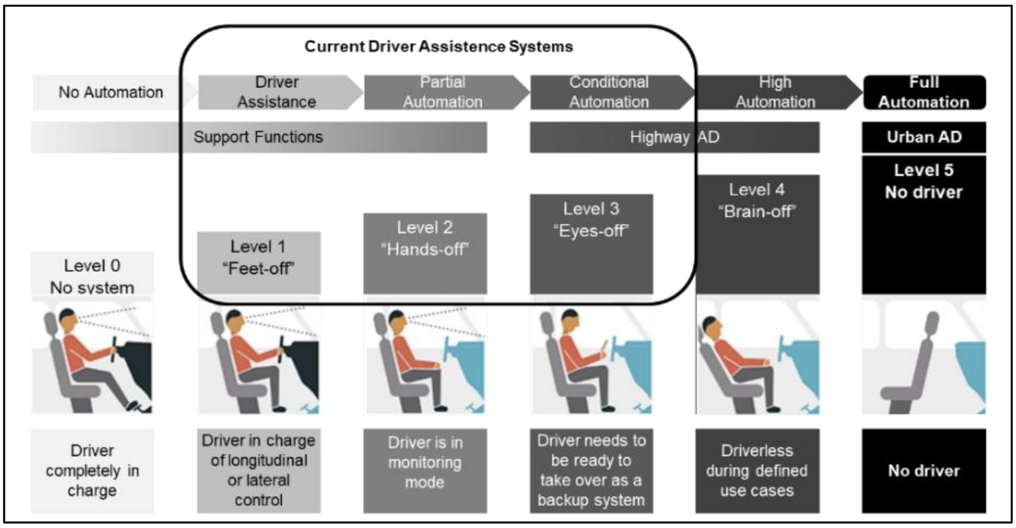

Figure 8: Levels of Automation (based SAE International, 2016)

Various studies show that if a person has doubts about a technology's safety or benefits, he or she will tend to avoid using it (Rudin-Brown & Parker, 2004; Reimer, 2014). Many drivers do not properly understand the operating characteristics of new systems and may consequently have even less trust in systems to intervene in critical situations (Abraham et al., 2017). Older drivers in particular do not understand the operation of in-vehicle technologies (Shaw et al., 2010; Zhan et al., 2013; Koppel et al., 2013; Eby et al., 2015).

Thus, researchers suggest that autonomous driving technology should be launched gradually to increase both safety and trust (König & Neumayr, 2017). In order to tap the full potential of driver assistance systems, increased emphasis should be placed on driver groups with "special needs", such as first-time and elderly drivers (Brookhuis et al., 2001; Bengler et al., 2014). We are therefore considering advanced driver assistance systems as the pre-stage to autonomous driving and as an introduction to future autonomous driving, especially for older drivers. In order to maximise these systems' contribution to overall traffic safety, however, increased market penetration is required (Lu, 2006; Noy et al., 2018).

2.2. Advanced driver assistance systems and their importance in aging societies

Driving a car covers a variety of tasks such as operating the vehicle, speed control, starting and stopping or reacting to different traffic conditions and is an informational activity. All decisions while driving are based on human information processing which consists of information perception (visual, haptic, acoustic), decision and response selection and execution of the decision (Wickens et al., 2006). Therefore, cognitive performance is essential but decreases with age (Brand & Markowitsch, 2010). Especially cognitive functions such as memory performance and executive functions, i.e. planning, categorization, monitoring processes and cognitive flexibility, decrease over time (Reuter-Lorenz & Sylvester, 2005; Uekermann et al., 2006; Ashendorf & McCaffrey, 2008; Hodzik & Lemaire, 2011). Besides an age-related decrease in cognitive performance, visual skills may also decrease beginning from age 40, which can significantly affect driving (Davidse, 2007). Due to limited mobility beginning at age 50 (turning to the right and left), fine motor skills and reduced muscle strength, motor performance decreases with increasing age as well (Fisk et al., 2009). Older people therefore tend to be insecure and overstrained, especially in time-critical and difficult traffic situations, which can lead to an increased error rate (Schlag, 2008). In the US, 39% of those aged 65 and older suffer with one or more disabilities in hearing, vision and cognitive abilities (Wan & Larsen, 2014) whilst 44% of aged over 65 Europeans report one or more disabilities. In a pre-test with n = 381 elderly persons (age 50 and older) 2017/18[1], we asked them to describe their age-related physical limitations. Most of the probands stated to have physical disabilities (28%) and limitations of sensory abilities (34%) like decreasing vision and information processing. As a result, it can be stated that age-related sensory, cognitive and motor deficits exist, which all affect driving (Shaheen & Niemeier, 2001). Already from the age of 40, there is a decrease in performance, which becomes increasingly severe around age 50.

Suitable driver assistance systems can help to compensate these deficits. In general, all of the above-mentioned driver assistance systems can help (older) drivers to compensate for their individual deficits (Schieber, 2006; Fisk et al., 2009). However, not all driver assistance systems can be studied in a driving simulator. Therefore, only market-ready, established and easy to implement driver assistance systems can be tested. In addition, the driver assistance systems examined should focus on compensating for the above-mentioned deficits and should be based on the wishes of older people. Furthermore, in the pre-test 2017/18, over 50% of the 381

[1] The pre-test is used to check the qualification of the test persons and was conducted from the beginning of the study in 2017 until the beginning of 2018.

older drivers tested want assistance with driving, especially in such tasks as driving on crossroads and in traffic, breaking, accelerating, maintaining speed, changing lanes and parking situations. For this reason, Cross Traffic Alert (CTA), Park Distance Control (PDC), Blind Spot Detection (BSD), Lane Departure Warning (LDW), and the Tyre-Pressure Monitoring System (TPMS) were selected and proofed.

2.3. Market opportunities in aging societies

Market opportunities in the attractive silver market (that includes 199 million people aged 50 and older in the European Union with 40,6% of private consumption expenditure) result from the behaviour of individual customers. A review of 128 studies on the behaviour of older consumers (Zniva & Weitzl, 2016) showed that different age-related factors (chronological, biological, psychological and social age as well as psychosocial characteristics) have an impact on consumer behaviour and are still being investigated in different fields of marketing research. Ryu et al. (2009) and Werner et al. (2011) found out that, in particular, psychological well-being (e.g. coping style, size of social network and role-related emotional health) as well as life course events (e.g. retirement, becoming a grandparent and loss of spouse) significantly influence older people's technology usage behavior.

Travel behaviour research in general considers a number of sociodemographic factors like age, living situation and environment, life stages, expectations about transportation (Beige & Axhausen, 2008; Sun et al., 2009; Chatterjee et al., 2013; Clark et al., 2016; Beige & Axhausen, 2017). Kroesen (2014) investigated the influence of several psychosocial characteristic in travel behaviour and found significant influence for age, the residential environment, moving house and changing jobs. For example, working adults who used public transport for non-work trips before retirement, tend to rely on an automobile for these same trips once they enter retirement (Reimer, 2014).

Mobility in old age is often regarded as a way of maintaining quality of life. Driving a car helps older people to keep their social structures and contacts, to feel independent and to improve their mental well-being (Edwards et al, 2009; Musselwhite et al., 2015). About 89% of all trips made by elderly are by automobile (Santos et al., 2011).

That means that the perceived quality of life declines as mobility becomes increasingly restricted (Owsley, 2002; Musselwhite & Haddad, 2010; Holley-Moore & Creighton, 2015; Musselwhite, 2018; Musselwhite & Haddad, 2018). According to Fonda et al. (2001), even changes in driving patterns, i.e. only being able to drive shorter distances or having to make intermediate stops, can have a deleterious effect on depressive symptoms in older people. Initiatives to assist older people should therefore focus on strategies that help them to retain or regain driving skills.

However, extending older people's ability to be mobile with driver assistance systems or, even more so, with autonomous driving has been neglected or barely considered in research, although some researchers highlight its potential to aid older people's personal mobility (Reimer, 2014; Musselwhite et al., 2015).

There are, however, studies that prove that driver assistance systems have a high acceptance and perceived value, especially if drivers have experience with such systems (Truebswetter & Bengler, 2013; Souders et al., 2017). There are also studies which show that older drivers in particular tend to have a higher level of acceptance (Oxley & Mitchell, 1995; Stevens, 2012; Son et al., 2015;) and a more positive attitude (Viborg, 1999) towards these driver assistance systems than younger drivers. However, older drivers are more worried about self-driving cars (König & Neumayr, 2017). Furthermore, older adults also tend to have less technological ability and understanding of features and studies have suggested older adults learn to use these systems differently, relying more on vehicle manuals, car-salesmen and less on trial-and-error (Shaw et al., 2010; Eby et al., 2015).

Even closer to actual buying behavior and thus market potential are studies on customer willingness to pay. This is because willingness to pay is indicated by "the highest purchase price that the customer will pay for goods or services" (Proff & Fojcik, 2014; based on Breidert, 2005; Potoglou & Kanaroglou, 2007; Diller, 2008; Miller et al., 2011). Schulz et al. (2013) and Souders et al. (2017) show that older people in particular have a greater willingness to pay for products that improve their quality of life.

Concerning the willingness to pay for driver assistance systems, results from the few existing studies differ: Blythe & Curtis (2004) state that there is only a low willingness to pay for driver assistance systems in general. A more recent study even shows a gap between the willingness to pay and the actual price for these systems (BCG, 2015).

In contrast to these results, Truebswetter (2015) examined the willingness to pay for driver assistance systems of persons over the age of 50 and found that older drivers had a greater willingness to pay for these systems, indicating market opportunities in the silver market. Furthermore, Souders et al. (2017) found, more specifically, that older adults valued blind spot detection about twice as much as younger adults. Therefore, a high willingness to pay and the existence of market opportunities can also be assumed for advanced driver assistance systems (Daziano et al., 2017; Bansal et al., 2016).

In summary, these studies show that although the importance of prolonging mobility to an older age is undisputed, there is a need for a heavier emphasis on research about older drivers and their willingness to pay for systems prolonging the ability to drive. In addition, Elder (1994) observed that age does not have a linear effect on needs (Glenn, 2003) and that therefore individual age groups of elderly people need to be considered. The lack of this perspective in the few previous studies underscores the need to examine the willingness to pay for advanced driver assistance systems of elderly drivers in aggregate and of individual age groups. There seems to be an interesting market opportunity in the silver market that would benefit from being analysed further.

3. Assumptions on market opportunities for driver assistance systems in aging societies

The above-mentioned importance of studies of older drivers' willingness to pay for safety-relevant solutions and the increasing physical limitations with age, which can be compensated for by the application of driver assistance systems, combined with the simultaneous research gap in this field emphasise the need for further quantitative research pursuing theory-based assumptions.

It can be stated that driver assistance systems can compensate certain deficits, meaning that there should be an increased willingness to pay for the addition of driver assistance systems and the solving of problems in road traffic through these. For instance, in case of limited mobility, a cross traffic alert, blind spot assistant or parking assistant makes it easier to handle driving tasks. Moreover, if visual and cognitive limitations are existent the lane departure warning or the tyre-pressure monitoring system will give the driver necessary information and support. Of course, there are a number of psychological and social factors that can further influence the willingness to pay negatively or positively.

Therefore, explanations of the differentiation of demand for mobility (the theory of the household and intertemporal consumption) can be used here (Proff, 2019).

According to the theory of the household, an individual or a household can optimise present and future consumption according to their income (Varian, 2014). However, it is unrealistic to assume that households have perfect information. Therefore, different shopping preferences will be distinguished for the procurement of a variety of goods and services, e.g. daily needs, consumer durables and luxury goods, that change over time and with age (see Figure 2).

Previous studies confirm that consumption expenditure is a bell curve over the life cycle (Fernández-Villaverde & Krueger, 2007; Yang, 2009). This means that expenditure starts low early in life, rises considerably around middle age and then falls in advanced age. Fernández-Villaverde & Krueger (2007) model life cycle profiles of total expenditure peaking typically in the age group of 40 to 50 years.

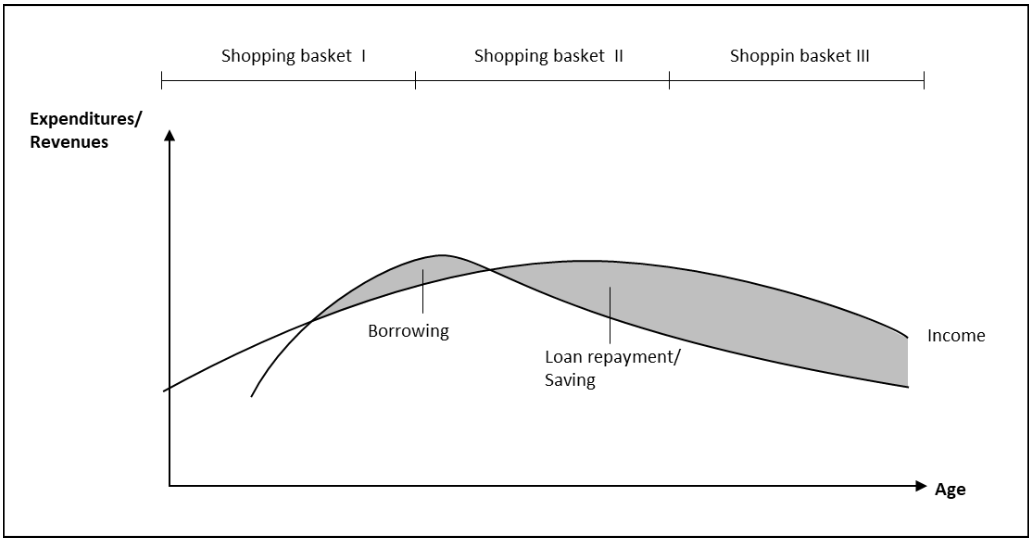

Figure 9: Demand for mobility depending on the age of the consumers (Proff, 2019)

These observations are confirmed by the theory of intertemporal consumption behaviour (Blundell et al., 1994), which explains the relationship between demand and age through purchasing preferences. It assumes that a household determines its consumption expenditure in such way that the marginal utility of income remains the same over the course of life (age). This means that e.g. young people first meet their basic needs, and in middle age, people meet additional and less rational needs when their demand is saturated. At that age, they can make a more realistic estimate of expected future income, income risks and saving propensity (Proff, 2019; with reference to Miles, 1997). Figure 9 shows that income and consumption curves are unevenly distributed over the life cycle. As a result, borrowing, loan repayment and savings are unevenly distributed over the life cycle.

Shopping baskets can be derived from the intertemporal consumption behaviour of households with different needs (Stobbe, 1984; Szmigin & Carrigan, 2001**;** Moschis, 2012; see also Figure 2):

- shopping basket I of young households (basic needs)
- shopping basket II of an average middle-aged family with younger children (basic and luxury needs, especially for middle-aged people)
- shopping basket III of pensioner households (goods for replacement purposes, especially for old people).

These population cohorts roughly correspond to the age distribution of the under-25s, the 25- to 65-year-olds and the over-65s – at least in Germany, where these relationships were investigated. However, this general trend demonstrates significant country-specific differences, because the options for mobility and the degrees of freedom of the demand for mobility both differ in individual countries (Proff, 2019). In addition, different age groups turned out to have different consumer behaviour highlighting older people with a special need for advanced driver assistance systems, i.e. in the group of people with basket III (65+). This applies even more to the larger group of elderly people over 50, younger members of which are often still working.

Furthermore, we expand Figure 9, because we assume that elderly people do not buy goods solely due to the need for replacement. Based on the literature in section 2.2, we also assume that:

- older people have a higher willingness to pay for products that improve their quality of life (Schulz et al., 2013) and
- in more concrete terms, willingness to pay for driver assistance systems will increase in more advanced age, as these systems are targeted at improving quality of life and compensate for physical limitations (Davidse, 2005; Fisk et al., 2009; Trübswetter, 2015; Souders et al., 2017).

Because Elder (1994) and Silver (1997), Moschis (2012) observed that age does not have a clear linear effect on needs (see also section 2.2), and thus individual age groups of elderly people above the age of 50 need to be considered, we can derive two hypotheses for the investigation as a whole:

H1: Willingness to pay for advanced driver assistance systems correlates with age.

H2: Willingness to pay for advanced driver assistance systems increases with the average age of different age groups.

4. Empirical study

4.1. Study approach

The hypotheses of increasing willingness to pay for advanced driver assistance systems with increasing age and with an increase in the average age of a specific group next have to be translated into an empirical approach. The correlation between age and willingness to pay for such systems is examined first, followed by a test of the significance of differences between age groups of elderly people. Furthermore, differences in gender, income, product knowledge and experience are tested.

Due to the fact that

- most new vehicles are bought by drivers aged 50 and older (Zentralverband Deutsches Kraftfahrzeuggewerbe, 2020).
- physical limitations become increasingly severe around age 50 (Wickens et al., 2006; Davidse, 2007; Fisk et al., 2009; Brand & Markowitsch, 2010; Hodzik & Lemaire, 2011; Wan & Larsen, 2014) and
- given the regulations on early retirement, this life event, which is important for the purchase of driver assistance systems, can occur from the age of 50 (OECD, 2019),

this study focuses on drivers over the age of 50 at a single point in time. An international car manufacturer, located in Germany, supported the planning of this investigation. Five advanced driver assistance systems in total were selected: Cross Traffic Alert (CTA), Park Distance Control (PDC), Blind Spot Detection (BSD), Lane Departure Warning (LDW), and the Tyre-Pressure Monitoring System

(TPMS). It was assumed that not every driver has experience of using driver assistance systems. Therefore, a two-stage study design was required.

First of all, the participants tested the five selected advanced driver assistance systems in a driving simulator to ensure that all participants had the same level of knowledge about the functionality of these systems. A static driving simulator of a close-to-production vehicle of the compact class was used. The simulator was located in a rectangular "cave" in which the simulated environment was projected on to the wall. In this arrangement, the driver's field of view outside the vehicle was 180°, so that the entire front of the vehicle was included. Furthermore, the side mirrors of the vehicle were replaced by screens, which also provided a mirrored visual representation of the vehicle environment. Additionally, a monitor was placed behind the vehicle's rear window, this monitor was used for both the rear view and for the reflection of the image in the interior mirror.

Next, they filled out a questionnaire about their willingness to pay for these tested advanced driver assistance systems. The relevant assistance system was described and its functionality depicted in the questionnaire.

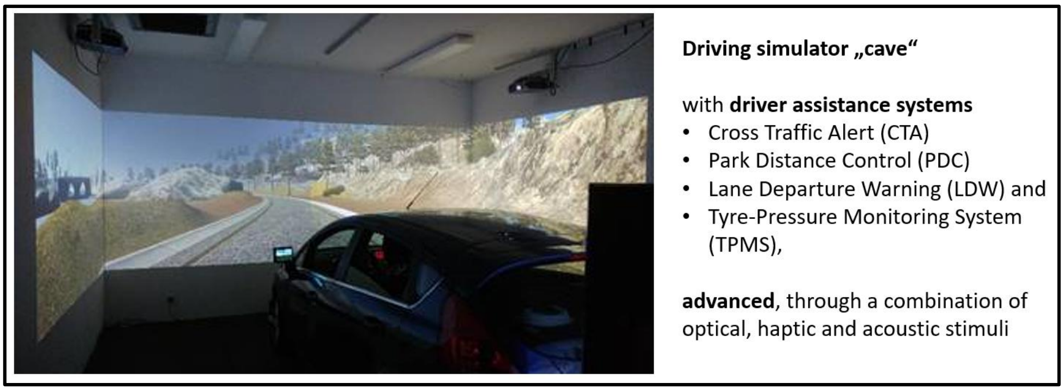

Figure 10: Driving simulator cave (own illustration)

4.2. Operationalisation of the variables

As stated above, willingness to pay is defined by the highest purchase price that customers will pay for goods or services (Potoglou & Kanaroglou, 2007; Miller et al., 2011; Proff & Fojcik, 2014; Proff et al., 2019). The price question is normally asked directly, i.e. not indirectly (e.g. by conjoint analyses, Balderjahn, 1994; Völckner, 2006; Schmidt & Bijmolt, 2020), with the help of individual partial values.

The van Westendorp method was selected to determine the willingness to pay for an advanced driver assistance system (van Westendorp 1976; Kloss & Kunter 2016), i.e. asking directly for pricing for each individual advanced driver assistance system. Even if directly asking for prices - especially with more expensive products and innovative offers which are new to the consumer - can lead to biased results in this method, it could not be assumed that prospective purchasers (test persons) had a clear idea of the price they would pay for the different driver assistance systems. They were not even able to name a price range between a minimum and a maximum, from which a fair ("average") price could be determined (Proff et al., 2019). This was due to the fact that some or all of the five identified driver assistance systems might be new to the customer. As "really new products" to them (Urban et al., 1996; Hoeffler, 2003) they will alter market structures and are based on new technologies on the path to autonomous driving (Urban et al., 1996). Therefore, they require customers to undergo a market-related and technological learning process (Leifer et al., 2001) to create new and unfamiliar knowledge structures (Moreau et al., 2001).

The van Westendorp method was therefore slightly altered: instead of asking for an open statement of prices which in the test subjects' opinion were "too expensive", "expensive", "cheap", "too cheap", they were asked to rate four different given prices as "too expensive", "expensive", "cheap" or "too cheap". The preferred price for a concrete advanced driver assistance system was then determined by aggregating the answers to the four given prices (Proff et al., 2019). The prices given for each driver assistance system were provided by an international automotive OEM in Germany, e.g. for the Cross Traffic Alert higher than €870, €580 - 870, €290-580 and lower than €290.

In the evaluation, "too expensive" was captured by value 4, "expensive" by 3, "cheap" by 2 and "too cheap" by 1. The elderly respondents' age was recorded, firstly the exact age and then the age group: 50 - 59, 60 - 69 and 70+.

In addition, control variables were collected: income (in euros), gender (male/female), product knowledge and experience (each on a 7-point Likert scale from 1 - very low to 7 - very high).

4.3. Sample

The study was conducted in the Rhine-Ruhr Area of Germany in 2018. Focusing on one specific country is of advantage as the comparability of customers is increased, since country-specific effects are eliminated (Miozzo & Yamin, 2012; Proff, 2019).

A total of 381 drivers above the age of 50 were recruited through newspaper advertisements and an incentive of 40 euros as compensation for participation in the survey. From September 2017 to January 2018[2], the respondents' psychological and physical fitness for experiments and driving in the driving simulator were tested by psychologists and physicians participating in the project. The remaining drivers were asked to sign a consent form and were invited again to attend the general survey. In the end, 181 elderly drivers participated.

5. Results and discussion

5.1. Descriptive statistics

Most of the surveyed elderly drivers were male (144, or 79.6%). Due to the higher interest of men in technology and although we tried very hard to attract more women for the study, e.g. with woman-specific adverting of the study, there were 37 (20.4 %) female participants. However, the average age was 65.4 years (standard deviation SD = 7.945). 49 of the respondents in the sample (27.1 %) were between 50 and 59 years old, 76 (42.0 %) between 60 and 69 and the remaining 56 (30.9 %) were 70 or older (more than half of them between 70 and 74), see Tab. 1.

The largest group had a net income between €2,001 and– 3,000 per month. The participants' knowledge and experience of driver assistance systems varied. On a Likert scale from 1 (none) to 7 (very high), the average evaluation (rating) of their own product knowledge was 3.26 and the evaluation of their experience was 3.44. The self-rating of product knowledge was highest in the 60 - 69 group (mean M= 3.4474; standard deviation SD = 1.5526) and lower in the 70+ (M= 3.1250; SD = 1.4655) and 50 - 59 years old (M= 3.1224; SD = 1.4525) age groups.

[2] The pre-test with 381 subjects serves as the basis for the main study. Of these 381 subjects, 181 over the age of 50 who participated in the main study remained at the end. This study has been conducted in the period from the end of 2017 until the beginning of 2018.

Table 3: Descriptive statistics

Control variables	Description	n (total 181)	Proportion of respondents (%)
Gender	Male	144	79.6
	Female	37	20.4
age group	50 – 59	49	27.1
	60 – 69	76	42
	70 +	56	30.9
Net income	500-	2	1.1
	€501 – 1,000	11	6.1
	€1,001 - 2,000	31	1.1
	€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
Product knowledge	1	33	18.2
	2	25	13.8
	3	31	17.1
	4	59	32.6
	5	22	12.2
	6	9	5.0
	7	2	1.1
Experience with driver assistance systems	1	32	17.7
	2	22	12.2
	3	34	18.8
	4	49	27.1
	5	21	11.6
	6	17	9.4
	7	6	3.3

5.2. Correlation between willingness to pay and age

The test of correlation between age and willingness to pay for the five selected advanced driver assistance systems showed a partial correlation between the two variables (see Table 2: Correlation table). It was significant for the (7.) Blind Spot Detection r(181) = .197, p < .001 and for the (9.) Tyre Pressure Monitoring System r(181) = .211, p < .001. However, there was no significant correlation between age and the willingness to pay for the other three advanced driver assistance systems (Cross Traffic Alert, Park Distance Control and Lane Departure Warning). There was no correlation with age even with the control variables (product knowledge, experience and net income). Therefore, hypothesis 1 could only be confirmed for two out of the five selected driver assistance systems (see Tab. 2).

Table 4: Correlation table

	1. Age	2. Exp. .	3. Prod. Knowl.	4. Net Income	5. WTP CTA	6. WTP PDC	7. WTP BSD	8. WTP LDW	9. WTP TPMS
1. Age	-								
2. Experience	.029	-							
3. Product Knowledge	.024	**.708****	-						
4. Net Income	-.058	**.241****	**.363****	-					
5. WTP for CTA	.084	.053	.009	.019	-				
6. WTP for PDC	.117	.043	.043	.070	**.652****	-			
7. WTP for BSD	**.197****	.131	.009	.123	**.666****	**.758****	-		
8. WTP for LDW	.122	.039	.033	.137	**.666****	**.655****	**.688****	-	
9. WTP for TPMS	**.211****	.056	.004	.063	**.507****	**.607****	**.579****	**.580****	-

* correlation is significant at the 0.01 level (2-tailed)

**** correlation is significant at the 0.05 level (2-tailed)**

WTP = Willingness to pay

CTA = Cross Traffic Alert

PDC = Park Distance Control

BSP = Blind Sport Detection

LDW = Lane Departure Warning

TPMS = Tire Pressure Monitoring System

These results are in line with Elder's observation (1994) that age does not have a clear linear effect on needs, and supports the need for a study of individual age groups among elderly people above the age of 50.

5.3. Age group differences in willingness to pay

To determine mean differences for the willingness to pay between the three age groups (50 - 59, 60 - 69 and 70+) a two-sample t-test for unpaired samples was used. Each age group was compared with each of the others. The level of significance was set at $p \leq 0.05$ (Park Distance Control only ≤ 0.10). Equality of variances was assessed by Levene’s test (with the p-value also set at $p \leq 0.05$. Where the assumption of equality of variances was dropped, Welch's t-test was used instead. Correlations between willingness to pay for driver assistance systems and age were determined by Pearson's correlation.

The results are summarised in Tables 3 to 7. At first glance, the mean values of the willingness to pay are higher for all five advanced driver assistance systems in the two older age groups (60 - 69 and 70 +) than in the younger one (50 - 59) and tend to indicate a higher willingness to pay in older age. However, closer examination is needed.

The advanced **Park Distance Control** showed significant differences (Table 3): willingness to pay on the scale from 1 (too cheap respectively < €335) to 4 (too expensive respectively > €1.005) in the 60 - 69 group was slightly (insignificantly) higher than in the 70+ group and in both these groups the willingness to pay was significantly higher than in the 50 - 59 age group.

Table 5: Willingness to pay for the advanced Park Distance Control (PDC) by age group

Group	N	Mean	SD	T	df	p	Hypothesis 2
50 - 59 60 - 69	49 76	1.76 2.00	.522 .653	-2.208	123	.029	Accept
50 - 59 70 - 90	49 56	1.76 1.96	.522 .687	-1.738	103	.085	Accept
60 - 69 70 - 90	76 56	2.00 1.96	.653 .687	.304	130	.762	Reject

For the advanced **Lane Departure Warning** (LDW), too (see Table 4), the age group 60 - 69 group had the highest value followed by the 70+ group and the 50 - 59 group (with a willingness to pay measured on a scale between < €335 and > €1005). The comparison of the groups again showed a significant difference between the 50 - 59 and 60 - 69 age groups and between the 50-59 and 70+ age groups see Table 4. In addition, there was a significant difference between men and women, with men having higher willingness to pay.

Table 6: Willingness to pay for the advanced Lane Departure Warning (LDW) by age group

Group	N	Mean	SD	T	df	P	Hypothesis 2
50 – 59	49	1.67	.658	-2.082	123	.039	Accept
60 – 69	76	1.93	.699				
50 – 59	49	1.67	.658	-1.713	103	.090	Accept
70 – 90	56	1.89	.652				
60 – 69	76	1.93	.699	.346	130	.730	Reject
70 – 90	56	1.89	.652				

The analysis of the advanced **Blind Spot Detection** produced similar results (Table 5). However, here the 70+ age group had the highest average willingness to pay (measured on the scale from <€290) to >€870) closely followed by the 60 - 69 age group. The 50 - 59 age group was least willing to pay, again with a highly significant difference to both the 60 - 69 group and the 70+ group.

Table 7: Willingness to pay for the advanced Blind Spot Detection (BSD) by age group

Group	n	Mean	SD	T	Df	P	Hypothesis 2
50 - 59	49	1.76	.630	-2.692	123	.008	Accept
60 - 69	76	2.09	.715				
50 - 59	49	1.76	.630	-2.681	103	.009	Accept
70 - 90	56	2.11	.705				
60 - 69	76	2.09	.715	-.120	130	.905	Reject
70 - 90	56	2.11	.705				

The **Tyre Pressure Monitoring** system also showed significant differences (Table 6): The highest willingness to pay here was also found in the 70 - 90 age group (here on the scale from <€250) to >€750) which was again higher than in the 60 - 69 group. In both groups, the willingness to pay was significantly higher than in the 50 - 59 group.

Table 8: Willingness to pay for the Tyre Pressure Monitoring System (TPMS) by age group

Group	n	Mean	SD	T	df	P	Hypothesis 2
50 - 59	49	1.61	.533	-2.698	123	.008	Accept
60 - 69	76	1.91	.636				
50 - 59	49	1.61	.533	-2.385	103	.019	Accept
70 - 90	56	1.93	.783				
60 - 69	76	1.91	.636	-.167	130	.867	Reject
70 - 90	56	1.93	.783				

For these four advanced driver assistance systems, hypothesis 2 could be confirmed. Only the advanced Cross-Traffic Alert showed no more than a slight tendency for older age groups to have a higher willingness to pay for the system, but no significance was found (see Table 7). For the cross-traffic alert, the 60 - 69 group of drivers showed the highest average willingness to pay (<€290) to >€870), followed by the 70 + group and the 50 - 59 group (see Table 7).

Table 9: Willingness to pay for the Cross-Traffic Alert (CTR) by age group

Group	n	Mean	SD	T	df	p	Hypothesis 2
50 – 59	49	1.98	.750	-.984	123	.327	Reject
60 – 69	76	2.12	.783				
50 – 59	49	1.98	.750	-.669	103	.505	Reject
70 – 90	56	2.07	.657				
60 – 69	76	2.12	.783	.365	130	.716	Reject
70 – 90	56	2.07	.657				

5.4. Discussion of results

The study examined the willingness of elderly drivers to pay for advanced driver assistance systems, as this field has so far been neglected in research. On the one hand, this investigation is of value because assistance systems represent a relevant step on the way to autonomous driving. On the other hand, older people account for a fairly large proportion of the driving population.

Due to their age-related physiological developments, they have the potential to need more support than younger groups. According to the hypotheses, they should therefore be more willing to pay for driver assistance systems than younger age groups.

Willingness to pay appeared likely to generally correlate with age (hypothesis H1), however, this could only be confirmed to a limited extent in the study (significant confirmation was found for only two of the advanced assistance systems, however, there was a perceptible trend for them all).

However, a closer look at the three age groups of elderly drivers (50 to 59, 60 to 69 and over 70 years) showed a significant higher willingness to pay in drivers aged 60 or over compared to 50-59-year-olds at least for four of the five systems (Park Distance Control, Blind Spot Detection, Lane Departure Warning, and Tyre Pressure Monitoring Systems). Though not significant, tendencies towards an increased willingness to pay could also be observed in the case of the fifth assistance system, the Cross-Traffic Alert. Therefore, hypothesis H2 was clearly confirmed for the assistance systems in question: there were significant differences (in one case a strong tendency) between the 50- to 59-year-old drivers and the over-60s, but no further distinction within the group of older drivers.

The results showed that there was no clear correlation between willingness to pay and age, even for safety-related products such as driver assistance systems. Instead, individual age groups needed to be compared. In future investigations, an examination should be made as to whether a non-linear, bell-shaped correlation curve might provide a better explanation, because drivers over 60 had a higher willingness to pay than drivers between the ages of 50 and 59, but the willingness to pay for some assistance systems decreases again in drivers over 70 years of age (Park Distance Control and Lane Distance Warning).

According to e.g. Elder (1994), Silver (1997), Moschis (2012), even more significant indications of market opportunities are possible if not only age groups, but also critical life events (Hutchison, 2018) such as retirement, the birth of a first grandchild and/or the death of a partner are taken into account.

6. Implications, limitations and outlook

The results show that age has an influence on the willingness to pay for driver assistance systems. Since age itself is undoubtedly not the only variable that influences willingness to pay and the promising "silver market” could be more effectively accessed, a closer analysis of the market and older people is needed. It is advisable to take a closer look at age groups in order to generate even further growth, especially within the group of older people.

In future studies, a closer examination should be made of whether there is a peak in willingness to pay, and if so where it lies. Finding this peak is crucial in the search for new market opportunities for advanced driver assistance systems. Furthermore, critical life events could have a considerable influence on people's willingness to pay. This research direction can help transform market potentials into market growth.

However, the study's limitations are not solely due to a lack of detailed consideration of a peak in willingness to pay for advanced driver assistance systems, possibly showing a bell-shaped correlation with age and critical life events. There is also a lack of information about the reasons behind older drivers' increased willingness to pay. Such reasons should therefore also be examined in a next stage by identifying the critical life events and other psycho-social variables of older drivers. Furthermore, the study does not explain why the trend towards higher willingness to pay in the elderly is not significant for all systems. Therefore, an even wider range of driver assistance systems should be considered in further studies on this topic. Another drawback is the local limitation of the residence of the sample. Since all the test persons come from one small area in western Germany, regional and national influences may affect the overall results. Also, the investigated sample has more men than women probably owing to the interest of men in technology. Although, there was only one significant gender difference detected, the lower share of woman could have an influence on the result which slightly limits the representativeness of the sample.

Looking at the future autonomous driving market, it is important to note that the worldwide market launch and market substitution will take at least another 10 to 15 years. Therefore, developing the stagnating markets of the Triad countries more effectively and taking advantage of market opportunities in the “silver market” is a promising route to pursue.

REFERENCES

Abraham, H., McAnulty, H., Mehler, B. & Reimer, B. (2017). Case Study of Today's Automotive Dealerships - Introduction and Delivery of Advanced Driver Assistance Systems. *Transportation Research Record, Journal of the Transportation Research Board*, *2660*(1), 7–14.

Ashendorf, L. & McCaffrey, R. J. (2008). Exploring age-related decline on the Wisconsin Card Sorting Test. *Clinical Neuropsychologist. 22*, 262–272.

Balderjahn, I. (1994). Der Einsatz der Conjoint-Analyse zur Bestimmung von Preisresponsefunktionen. *ZFP – Journal of Research and Management*, *16*(1), 12-20.

Bansal, P., Kockelman, K. M. & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1-14.

Beige, S. & Axhausen, K.W. (2008). Long-term and mid-term mobility decisions during the life course. *Paper Presented at the 87th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2008.

Beige, S. & Axhausen, K.W. (2017). The dynamics of commuting over the life course: Swiss experiences. *Transp. Res. Part A Policy Pract*, *104*, 179–194.

Bengler, K., Dietmayer, K., Färber, B., Maurer, M., Stiller, C. & Winner, H. (2014). Three Decades of Driver Assistance Systems - Review and Future Perspectives. *IEEE Intelligent transportation systems magazine*, *6*(4), 6-22.

Blundell, R., Browning, M. & Meghir, C. (1994). Consumer demand and the life-cycle allocation of household expenditures. *The Review of Economic Studies*, *61*(1), 57-80.

Blythe, P. T. & Curtis, A. M. (2004). Advanced driver assistance systems: Gimmick or reality. Conference Proceedings at the *11th World Congress on Intelligent Transport Systems and Services.* 18-24 October 2004. Nagoya, Japan.

Boot, W. & Scialfa, C. (2016). The aging road user and technology to promote safe mobility for life, in Kwon, S. (Eds.), *Gerontechnology: Research, Practice, and Principles in the Field of Technology and Aging*, Springer, New York (inpress), 207-222.

Boot, W., Stothart, C. & Charness, N. (2014). Improving the Safety of Aging Road Users: A Mini-Review. *Gerontology*, *60*(1), 90-96.

Boston Consulting Group (BCG) and The Motor & Equipment Manufacturers Association (MEMA) (Eds.), (2015). *A Roadmap to Safer Driving through Advanced Driver Assistance Systems*. Washington DC.

Brand, M. & Markowitsch, H.J. (2010). Aging and decision-making: a neurocognitive perspective. *Gerontology*, *56*(3), 319-324.

Breidert, C. (2005). *Estimation of willingness-to-pay. Theory, measurement, and application*, Published PhD thesis, ePubWU Institutional, WU Vienna University of Economics and Business, Vienna, Austria.

Brookhuis, K. A., de Waard, D. & Janssen, W. H. (2001). Behavioural impacts of Advanced Driver Assistance Systems - An overview. *European Journal of Transport and Infrastructure Research*, *1*(3), 245-253.

Burgard, E. (2005). *Fahrkompetenz im Alter - Die Aussagekraft diagnostischer Instrumente bei Senioren und neurologischen Patienten*. PhD thesis, Ludwig-Maximilian-Universität München, Munich, Germany.

Chatterjee, K., Sherwin, H. & Jain, J. (2013). Triggers for changes in cycling: the role of life events and modifications to the external environment. *J. Transp. Geogr.*, *30*, 183–193

Clark, B., Chatterjee, K. & Melia, S. (2016). Changes to commute mode: the role of life events, spatial context and environmental attitude. *Transp. Res. Part A Policy Pract*, *89*, 89–105

Davidse, R. (2007). *Assisting the older driver. Intersection design and in-car devices to improve the safety of the older driver*. Leidschendam, NL: SWOV-Dissertatiereeks.

Daziano, R. A., Sarrias, M. & Leard, B. (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *78*, 150-164.

Deloitte (2019). *Autonomous Driving: Hype or Reality? Moonshot Project with Quantum Leap from Hardware to Software & AI Focus.* [online] https://www2.deloitte.com/content/dam/Deloitte/be/Documents/Deloitte_Autonomous-Driving.pdf (Accessed 31 October 2019).

Deutsche Automobil Treuhand (2018). *DAT Report 2018*. [online]. https://files.vogel.de/vogelonline/vogelonline/issues/kfz/sonst/2018/8803.pdf (Accessed 11 May 2020).

Diller, H. (2007). *Preispolitik*, 4th ed., Verlag Robert Kohlhammer, Stuttgart.

Dobbs, B.M. & Schopflocher, D. (2010). The introduction of a new screening tool for the identification of cognitively impaired medically at-risk drivers: The SIMARD A modification of the DemTect. *Journal of Primary Care and Community Health*, *1*(2), 119-127.

Duncan, M., Charness, N., Chapin, T., Horner, M., Stevens, L., Richard, A., Souders, D. Crute, J., Riemondy, A. & Morgan, D. (2015). *Using Automated Vehicles, Enhanced mobility for aging populations using automated vehicles* (No. BDV30 977-11). Florida. Dept. of Transportation

Eby, D. W., Molnar, L. J., Zhang, L., St Louis, R. M., Zanier, N. & Kostyniuk, L. P. (2015) *Keeping older adults driving safely: A research synthesis of advanced in-vehicle technologies*, AAA Foundation for Traffic Safety, Washington DC.

Edwards, J. D., Perkins, M., Ross, L.A. & Reynolds, S. L. (2009). Driving status and three-year mortality among community-dwelling older adults. *The Journals of Gerontology: Series A*, *64*(2), 300–305.

Elder Jr, G. H. (1994). Time, human agency, and social change: Perspectives on the life course. *Social Psychology Quarterly*, *57*(1), 4-15.

Engin, T., Kocherscheid, K., Feldmann, M. & Rudinger, G. (2010). *Entwicklung und Evaluation eines Screening-Tests zur Erfassung der Fahrkompetenz älterer Kraftfahrer (SCREEMO),* Bremerhaven: Berichte der Bundesanstalt für Straßenwesen (Bast) Mensch und Sicherheit, Vol. M 210.

European Comission (2018). *The Silver Economy – Final report* [online]. https://op.europa.eu/en/publication-detail/-/publication/a9efa929-3ec7-11e8-b5fe-01aa75ed71a1 (Accessed 11 May 2020)

Fernández-Villaverde, J. & Krueger, D. (2007). Consumption over the life cycle: Facts from consumer expenditure survey data. *The Review of Economics and Statistics*, *89*(3), 552-565.

Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J. & Sharit, J. (2009). *Designing for older adults: principles and creative human factors approaches*, 2. Auflage, Boca Raton: CRC Press.

Fonda, S. J., Wallace, R. B. & Herzog, A. R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *The Journal of Gerontology Series B*, *56*(6), 343-351.

Glenn, N. D. (2003). Distinguishing age, period, and cohort effects, in Mortimer, J. T. and Shanahan, M. J., *Handbook of the life course*, Springer, Boston, 465-476.

Gold, C., Damböck, D., Lorenz, L. & Bengler, K. (2013). "Take over!" How long does it take to get the driver back into the loop?. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *57*(1), 1938-1942.

Hodzik, S. & Lemaire, P. (2011). Inhibition and shifting capacities mediate adults' age-related differences in strategy selection and repertoire. *Acta Psychologica*, *137*, 335–344.

Hoeffler, S. (2003). Measuring preferences for really new products. *Journal of Marketing Research*, *40*(4), 406–420.

Holley-Moore, G. & Creighton, H. (2015). *The future of transport in an ageing society*, London: UK: International Longevity Centre-UK.

Hutchison, E. D. (2018). *Dimensions of human behavior: The changing life course*, 6th ed., Sage Publications, Los Angeles.

Jiménez, F. (2018). Driver Assistance Systems and Safety Systems, in Jiménez, F. (Eds.), *Intelligent Vehicles. Enabling Technologies and Future Developments*, Butterworth-Heinemann, Oxford, 209-226.

Karthaus, M., Falkenstein, M. & Toepper, M. (2016). Functional Changes and Driving Performance in Older Drivers: Assessment and Interventions. *Geriatrics*, *1*(2).

Kloss, D. & Kunter, M. (2016). The Van Westendorp Price-Sensitivity Meter As A Direct Measure of Willingness-To-Pay. *European Journal of Management*, *16*(2), 45–54.

Kohlbacher, F. & Herstatt, C. (2011). *The silver market phenomenon: Marketing and innovation in aging society*, 2nd ed., Springer, Berlin.

Koppel, S., Clark, B., Hoareau, E., Charlton, J. L. & Newstead, S. V. (2013). How important is vehicle safety for older consumers in the vehicle purchase process?. *Traffic Injury Prevention*, *14*, 592-601.

König, M. & Neumayr, L. (2017). Users' resistance towards radical innovations: The case of the self-driving car. *Transportation Research Part F*, *44*, 42-52.

Klimczuk, A. (2016). Comparative analysis of national and regional models of the silver economy in the European Union. *International Journal of Ageing and Later Life*, *10*(2), 31-59.

Kraftfahrt-Bundesamt (2017). *Fahrzeugzulassungen (FZ): Bestand an Kraftfahrzeugen und Kraftfahrzeuganhängern nach Haltern, Wirtschaftszweig 01.01.2017* [online]. https://www.kba.de/SharedDocs/Publikationen/DE/Statistik/Fahrzeuge/FZ/2017/fz23_2017_pdf.pdf?__blob=publicationFile&v=4 (Accessed 11 May 2020).

Kraftfahr-Bundesamt (2019). *Fahrerlaubnisbestand im Zentralen Fahrerlaubnisregister (ZFER) am 01.01.2019 – Basisdatenblatt* [online]. https://www.kba.de/DE/Statistik/Kraftfahrer/Fahrerlaubnisse/Fahrerlaubnisbestand/fahrerlaubnisbestand_node.html (Accessed 5 November 2019).

Kroesen, M. (2014). Modeling the behavioral determinants of travel behavior: An application of latent transition analysis. *Transportation Research Part A: Policy and Practice, 65,* 56–67.

Kukkala, V. K., Tunnell, J., Pasricha, S. & Bradley, T. (2018). Advanced driver-assistance systems: a path toward autonomous vehicles. *IEEE Consumer Electronics Magazine*, *7*(5), 18-25.

Kyriakidis, M., de Winter, J. C. F., Stanton, N., Bellet, T., van Arem, B., Brookhuis, K., Martens, M. H., Bengler, K., Andersson, J., Merat, N., Reed, N., Flament, M., Hagenzieker, M. & Happee, R. (2019). A Human Factors Perspective on Automated Driving. *Theoretical Issues in Ergonomics Science*, *20*(3), 223-249.

Leifer, R., Corarelli O'Conner, D. & Rice, M. (2001). Implementing radical innovations in mature firms: The role of hubs. *Academy of Management Executive*, *15(*3), 102–113.

Lu, M. (2006). Modelling the effects of road traffic safety measures. *Accident Analysis and Prevention*, *38*(3), 507-517.

Markowitsch, H. J., Brand, M. & Reinkemeier, M. (2005). Neuropsychologische Aspekte des Alterns, in Filipp, S. H. and Staudinger, U. M. (Eds.), Enzyklopädie der Psychologie: Themenbereich C/V/6, Entwicklungspsychologie des mittleren und höheren Erwachsenenalters, Hogrefe, Göttingen, 79-122.

Matsuno, K. & Kohlbacher, F. (2019). Proactive marketing response to population aging: The roles of capabilities and commitment of firms. *Journal of Business Research, 113*, 93-104.

Miles, D. (1997). A household level study of the determinants of income and consumption. *The Economic Journal*, *107*(440), 1–25.

Miller, K.M., Hofstetter, R., Krohmer, H. & Zhang, Z.J. (2011). How should consumers' willingness to pay be measured? An empirical comparison of state-of-the-art approaches. *Journal of Marketing Research*, *48*(1), 172–184.

Miozzo, M. & Yamin, M. (2012). Institutional and sectoral determinants of headquarters-subsidiary relationships: A study of UK service multinationals in China, Korea, Brazil and Argentina. *Long Range Planning*, *45*(1), 16–40.

Moreau, C. P., Lehmann, D. R. & Markman, A. B. (2001). Entrenched knowledge structures and consumer response to new products. *Journal of marketing research*, *38*(1), 14-29.

Moschis, G. P. (2012). Consumer behavior in later life: Current knowledge, issues, and new directions for research. *Psychology & Marketing*, *29*(2), 57-75.

Musselwhite, C., Holland, C. & Walker, I. (2015). The role of transport and mobility in the health of older people. *Journal of Transport & Health*, *2*(1), 1–4.

Musselwhite, C. (2018). Mobility in later life and wellbeing, in Friman, M. et al. (Eds), Quality of Life and Daily Travel, Springer, Cham, 235-251.

Musselwhite, C. & Haddad, H. (2010). Mobility, accessibility and quality of later life. *Quality in Ageing and Older Adults, 11*(1), 25-37.

Musselwhite, C. & Haddad, H. (2018). Older people's travel and mobility needs: a reflection of a hierarchical model 10 years on. *Quality in Ageing and Older Adults*, *19*(2), 87-105.

Nobis, C., Kuhnimhof, T., Follmer, R. & Bäumer, M. (2019). *Mobilität in Deutschland – Zeitreihenbericht 2002 – 2008 – 2017*, Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur, FE-Nr. 70.904/15.

Noy, I. Y., Shinar, D. & Horrey, W. J. (2018). Automated driving: Safety blind spots. *Safety science*, *102*, 68-78.

Organisation for Economic Co-operation and Development (2016). *Die OECD in Zahlen und Fakten 2015-2016: Wirtschaft, Umwelt, Gesellschaft.* OECD Publishing [online] http://www.oecd-ilibrary.org/docserver/download/3015045e.pdf?expires=1473688939&id=id&accname=guest&checksum=5F8DA3BED955294D4578D1B6AC7634C0 (Accessed 31 October 2019).

Organisation for Economic Co-operation and Development (2019). *Pensions at a Glance 2019: OECD and G20 Indicators*. OECD Publishing, Paris, [online] http://www.oecd-ilibrary.org/docserver/download/3015045e.pdf?expires=1473688939&id=id&accname=guest&checksum=5F8DA3BED955294D4578D1B6AC7634C0 (Accessed 19 May 2020).

Owsley, C. (2002). Driving Mobility, Older Adults, and Quality of Life. *Gerontechnology*, *1*(4), 220 – 230.

Oxley, P. R. & Mitchell, C. G. B. (1995). Final report on elderly and disabled drivers information telematics (Project EDDIT). *Commission of the European Communities DG XIII, R & D Programme Telematics Systems in the Area of Transport* (DRIVE II), Brussels, Belgium.

Potoglou, D. & Kanaroglou, P.S. (2007). Household demand and willingness to pay for clean vehicles. *Transportation Research Part D: Transport and Environment*, *12*(4), 264-274.

Proff, H. (2019). *Multinationale Automobilunternehmen in Zeiten des Umbruchs*. 1st ed., Springer Gabler, Wiesbaden.

Proff, H. & Fojcik, T.M. (2014). Accelerating Market Diffusion of Battery Electric Vehicles through alternative mobility concepts. *International Journal of Automotive Technology and Management, 14*(3), 347-368.

Proff, H., Szybisty, G. & Fojcik, T.M. (2019). From electric cars to energy-efficient houses – the automotive retail sector at the crossroads. *International Journal of Automotive Technology and Management*, *19(*1/2), 55-73.

Reimer, B. (2014). Driver Assistance Systems and the Transition to Automated Vehicles: A Path to Increase Older Adult Safety and Mobility?. *Public Policy & Aging Report*, *24,* 27-31.

Reuter-Lorenz, P. A. & Sylvester, C.-Y. (2005). The cognitive neuroscience of working memory and aging. In: R. Cabeza, L. Nyberg, D. Park (Hrsg.*), Cognitive Neuroscience of Aging*. Oxford: Oxford University Press.

Rudin-Brown, C. M. & Parker, H. A. (2004). Behavioural adaptation to adaptive cruise control (ACC): Implications for preventive strategies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *7*(2), 59–76.

Rudinger, G. (2013). Ältere Verkehrsteilnehmer: Gefährdet oder gefährlich? Defizite, Kompensationsmechanismen und Präventionsmöglichkeiten. *Presentation in Congress Ältere Verkehrsteilnehmer: Gefährdet oder gefährlich?*. 18 April 2013, Wissenschaftszentrum Bonn, Germany.

Ryu, M. H., Kim, S. & Lee, E. (2009). Understanding the Factors Affecting Online Elderly User's Participation in Video UCC Services. *Computers in Human Behavior*, *25*(3), 619–632.

Santos, A., McGuckin, N., Nakamoto, H.Y., Gray, D. & Liss, S. (2011). Summary of Travel Trends: 2009 National Household Transportation Survey (No. FHWA-PLLl-022). *United States Department of Transportation*, Washington, DC.

SAE International (2016). *SAE J3016™: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*. SAE Publisher, [online] https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles (Accessed 5 November 2019).

Schieber, F. (2006). Vision and aging. In Birren, J. E., Schaie, K. W. (Eds.), *Handbook of the Psychology of Aging*, 129-161. Amsterdam: Academic Press.

Schmidt, J. & Bijmolt, T. H. (2020). Accurately measuring willingness to pay for consumer goods: A meta-analysis of the hypothetical bias. *Journal of the Academy of Marketing Science*, *48*(3), 499-518.

Schlag, B. (2008). Älter werden und Auto fahren. *Report Psychologie, 33*(2), 72-84.

Schlag, B. (2013). Persönliche Veränderungen der Mobilität und der Leistungsfähigkeit im Alter, in Schlag, B. and Beckmann, K. J. (Eds.) *Mobilität und demografische Entwicklung,* Schriftenreihe Mobilität und Alter der Eugen-Otto- Butz-Stiftung, Köln, 119-143.

Schulz, R., Beach, S. R., Matthews, J. T., Courtney, K., Dabbs, A. D., Mecca, L. P. & Sankey, S. S. (2013). Willingness to Pay for Quality of Life Technologies to Enhance Independent Functioning Among Baby Boomers and the Elderly Adults. *The Gerontologist*, 54(3), 363–374.

Shaheen, S.A. & Niemeier, D.A. (2001). Integrating vehicle design and human factors: minimizing elderly driving constraints. *Transportation Research Part C: Emerging Technologies*, *9*(3), 155-174

Shaw, L., Polgar, J. M., Vrkljan, B. & Jacobson, J. (2010). Seniors' perceptions of vehicle safety risks and needs. *The American Journal of Occupational Therapy*, 64, 215-224.

Silvers, C. (1997). Smashing old stereotypes of 50-plus America. *Journal of Consumer Marketing, 14*(4), 303-309.

Son, J., Park, M. & Park, B. B. (2015). The effect of age, gender and roadway environment on the acceptance and effectiveness of Advanced Driver Assistance Systems. *Transportation Research Part F: Traffic Psychology and Behaviour, 31*, 12-24.

Souders, D. J., Best, R. & Charness, J. (2017). Valuation of Active Blind Spot Detection Systems by Younger and Older Adults. *Accidental Analysis and Prevention, 106*, 505-514.

Statistisches Bundesamt (2018a). *GENSIS-Online Datenbank- Abruf des Bevölkerungsstandes Alter, Stichtage am 31.12.2018.* Statistisches Bundesamt [online] https://www genesis.destatis.de/genesis/online/data?operation=abruftabelleBearbeiten&levelindex=1&levelid=1572947350519&auswahloperation=abruftabelleAuspraegungAuswaehlen&auswahlverzeichnis=ordnungsstruktur&auswahlziel=werteabruf&selectionname=12411-0005&auswahltext=&werteabruf=Werteabruf (Accessed 5 November 2019).

Statistisches Bundesamt (2018b). *Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen Einkommen, Einnahmen und Ausgaben privater Haushalte*. Statistisches Bundesamt [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Einkommen-Konsum-Lebensbedingungen/Einkommen-Einnahmen-Ausgaben/Publikationen/Downloads-Einkommen/einnahmen-ausgaben-privater-haushalte-2150100177004.pdf;jsessionid=4E321899EC94353724C1AC36BC714E67.internet8721?__blob=publicationFile (Accessed 14 May 2020).

Stevens, S. (2012). The Relationship between Driver Acceptance and System Effectiveness in Car-Based Collision Warning Systems: Evidence of an Overreliance Effect in Older Drivers?. *SAE Int. J. Passeng. Cars - Electron. Electr. Syst*., *5*(1), 114-124.

Stobbe, A. (1998). *Volkswirtschaftliches Rechnungswesen*., 9th ed., Springer, Berlin.

Sun, Y., Waygood, E.O.D., Fukui, K. & Kitamura, R. (2009). Built environment or household life-cycle stages: which explains sustainable travel more? Case of Kyoto–Osaka–Kobe, Japan, built area. *Transp. Res. Rec, 2135*, 123–129.

Szmigin, I. & Carrigan, M. (2001). Learning to love the older consumer. *Journal of Consumer Behaviour: An International Research Review*, *1*(1), 22-34.

Truebswetter, N. & Bengler, K. (2013). Why Should I Use ADAS? Advanced Driver Assistance Systems and the Elderly: Knowledge, Experience and Usage Barriers. *Proceedings of the Seventh International Driving Symposium on Human Factors in Driver Assessment*, Training and Vehicle Design, 17-20 June 2013, Public Policy Center, University of Iowa, Iowa City, USA, 495-501.

Truebswetter, N. (2015). *Akzeptanzkriterien und Nutzungsbarrieren älterer Autofahrer im Umgang mit Fahrerassistenzsystemen*. Published PhD thesis, Technische Universität München, Munich, Germany.

Uekermann, J., Channon, S. & Daum, I. (2006). Humor processing, mentalizing, and executive function in normal aging. *Journal of International Neuropsychological Society*, *12*, 184–911.

Urban, G.L., Weinberg, B. & Hauser, J.R. (1996). Premarket forecasting of really new products. *Journal of Marketing*, 60(1), 47–60.

Van Westendorp, P. H. (1976). NSS Price Sensitivity Meter (PSM) – A new approach to study consumer perception of prices. *Proceedings of the 29th ESOMAR Congress*, 5-9 September 1976, Venice, Italy, 139-167.

Varian, H.R. (2014). *Grundzüge der Mikroökonomik*, 8th ed., Oldenbourg, München.

Verband der Automobilindustrie (2015). *Automatisierung - Von Fahrerassistenzsystemen zum automatisierten Fahren* [online], https://www.vda.de/dam/vda/publications/2015/automatisierung.pdf (Accessed 14 November 2019).

Verband der Automobilindustrie (2020). *Neuzulassungen.* [online] https://www.vda.de/de/services/zahlen-und-daten/jahreszahlen/neuzulassungen.html (Accessed 20 May 2020).

Viborg, N. (1999). Older and younger driver's attitudes toward in-car ITS a questionnaire survey. Bulletin, *181*.

Völckner, F. (2006). Methoden zur Messung individueller Zahlungsbereitschaften: ein Überblick zum State of the Art. *Journal für Betriebswirtschaft*, *56*(1), 33-60.

Wan, H. & Larsen, L. (2014). *Older Americans With a Disability: 2008−2012*. [online] https://www. census.gov/content/dam/Census/library/publications/2 014/acs/acs-29.pdf.

Werner, J. M., Carlson, M., Jordan-Marsh, M. & Clark, F. (2011). Predictors of Computer Use in Community-Dwelling, Ethnically Diverse Older Adults. *Human Factors*, *53*(5), 431–447.

Wickens, C. D. & Carswell, C. M. (2006). Information processing. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (3rd ed.). Hoboken, NJ: John Wiley & Sons

Wild, A. (2014). Zwischen Wunsch und Wirklichkeit: Fahrerassistenzsysteme für ältere Autofahrer. *Zeitschrift für die gesamte Wertschöpfungskette Automobil*, *17*(1), 58-63.

Winner, H. & Schopper, M. (2015). Adaptive Cruise Control, in Winner, H., Hakuli, S., Wolf, G. (Eds.) *Handbuch Fahrerassistenzsysteme - Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort*, Wiesbaden, Vieweg+Teubner, 851-891.

Yang, F. (2009). Consumption over the life cycle: How different is housing. *Review of Economic Dynamics*, *12*(3),423-443.

Zentralverband Deutsches Kraftfahrzeuggewerbe e. V. (2020). *Zahlen & Fakten 2019*. [online], https://www.kfzgewerbe.de/fileadmin/user_upload/Presse/Zahlen_Fakten/Zahlen___Fakten_2019.pdf (Accessed 29 April 2020)

Zhan, J., Porter, M. M., Polgar, J. & Vrkljan, B. (2013). Older drivers' opinions of criteria that inform the cars they buy: A focus group study. *Accident Analysis & Prevention, 61*, 281-287.

Zniva, R. & Weitzl, W. (2016). It's not how old you are but how you are old: A review on aging and consumer behavior. Management Review Quarterly, 66(4), 267-297.

Chapter 5: On the way to autonomous driving: How age influences the acceptance of driver assistance systems

Timo Günthner [a] and Heike Proff [a]

[a] Chair of General Business Administration & International Automotive Management, University of Duisburg-Essen, Duisburg, Germany

1. Introduction

In industrialized nations, the elderly population is continuously growing in size and influence and demographic change will become more visible in the future (Brunsbach, 2018; Schlag, 2008a). Increased life expectancy is a consequence of advanced healthcare systems, improved medicines, enhanced knowledge and better financial status. The demographic change is considered to be a major challenge for near future (European Commission, 2018; OECD, 2016; Peine et al., 2015), e.g. in the EU there were, in 2015, 199 million people aged 50 and older. This also applies to Germany, where people over 50 years of age already make up more than 40 percent of the total population (Statistisches Bundesamt, 2019a).

The “silver economy” also represents 39% of the total EU population and is responsible for 40,6% of private consumption expenditure (European Comission, 2018). In 2025, the proportion of older people is expected to be 42.9% and the elderly will have a share of 44.3% in private consumer spending. Due to their purchasing power the increase in the elderly population represents an interesting customer group (Klimczuk, 2016; Kohlbacher & Herstatt, 2011).

Simultaneously, older people have never been as mobile as today (Allgemeiner Deutscher Automobil-Club, 2018; Schlag, 2013). In Germany a total of 39 million people holds a driving license, 51 percent of whom are 50 years and older (Kraftfahrt-Bundesamt, 2018). The number of older people with a driver's license is expected to increase even further (Musselwhite & Haddad, 2018; Shergold et al., 2015), because it is agreed that individual mobility remains the most important part of mobility behaviour and symbolizes independence and well-being, especially for older people (Adler & Rottunda, 2006; Dickerson et al., 2007; Molnar & Eby, 2009). Therefore, losing the ability to drive represents an enormous loss of individual freedom and social participation (Waller, 1991). Numerous studies reveal that limited mobility leads to a feeling of uselessness, dissatisfaction as well as depression and reduces well-being in the elderly (Fonda et al., 2001; Haustein & Siren, 2014; Shaheen & Niemeier, 2001). Therefore, with driving their own car, older people are able to maintain their independence, social participation and activities (Limbourg, 1999), which in turn helps to improve their quality of life (Burghard, 2005; Engeln, 2001).

Due to their driving experience, older drivers can rely on compensatory strategies that help them drive more carefully and with more foresight despite physical limitations (Isabelle & Simon, 2020). With a lower number and type of trips (no daily travel to work) and a lower driving distance per ride, the senior group is disproportionately involved in accidents, accounting for 13.4% of all accident involvement compared to their share of the population, making them one of the safest groups of road users (Statistisches Bundesamt, 2019b). Despite the low involvement in accidents, the elderly group represents one of the highest risk driver populations for accidents resulting in serious injuries and fatalities (Koppel et al., 2011), requiring this group to receive special attention. Because with age comes a decline in perceptual ability (i.e., vision and hearing), cognitive reaction time (i.e., coordination of motor skills), cognitive memory and attention, and physical strength and dexterity (Kline et al., 1992; Shaheen & Niemeier, 2001). Simultaneously, older drivers may not recognize the decline in certain capabilities (Molnar et al., 2013; Sivak & Schoettle, 2011). As a result, complex traffic situations become a risk factor and may cause greater difficulty for older drivers. Perceiving all relevant information for decision making becomes increasingly difficult with complexity, leading to problems in everyday situations that require complex interaction with other road users, such as at intersections, crossing, merging, or changing lanes in heavy traffic. (Clarke, Ward, Bartle & Truman, 2010; Dukic & Broberg, 2012; Koppel et al., 2011). In contrast to older drivers, the lack of driving experience is a particular risk factor for younger drivers (McDonald et al., 2013). This becomes apparent in incorrect road use (such as cutting turns, speeding up or pulling out when being passed), not maintaining safety distances or speeding inappropriately. In addition, it is hazard perception and susceptibility to distraction while driving that present the greatest risks of accidents among young drivers (Crundall, 2016; Alberti et al., 2014; Borowsky & Oron-Gilad, 2013). They tend to scan the road more closely than experienced drivers, making them less effective at anticipating, recognizing, or reacting to hazards, especially when the hazards are not clearly visible.

The first development and implementation of assistance systems in vehicles has made it possible to ensure ever greater safety over the years. These first very simple systems, such as anti-lock braking system (ABS) or electronic stability control (ESC), which use proprioceptive sensors to measure the internal status of vehicles, enable vehicle dynamics to be controlled with the aim of following the driver's desired direction as closely as possible (Bengler et al., 2014). The second important step in increasing safety is the implementation of more intelligent systems such as lane departure warning (LDW) and adaptive cruise control (ACC). With the help of exteroceptive sensors (lidar, radar, video sensors, ultrasonic), the systems collect information about the road ahead and the presence and driving status of other road users or their position. Together with the first preliminary stages of artificial intelligence like knowledge-based systems, natural language processing or machine learning, such driver assistance systems have the potential to increase driving comfort and road safety by supporting the driver with information or react in a more intelligent manner to driving situations (Anderson et al., 2014; Duncan et al., 2015; Fagnant & Kockelman, 2015). Therefore, more intelligent advanced driver assistance systems (ADAS) like LDW and ACC hold promise in compensating for the declining capacities of older drivers to extend safe mobility in later years (Eby & Molnar, 2012). This improves safety by avoiding collisions and provides comfort to the vehicle’s occupants (Gruyer et al., 2017; Naujoks & Neukum, 2014). More recently, these ADAS have appeared as the most important and critical step to converge towards fully automated vehicles (Gruyer et al., 2017). In the future, the final step in maximizing safety will be automated driving, which uses a network of sensors, systems and artificial intelligence to ensure door-to-door mobility autonomously, without human intervention.

Although advanced driver assistance systems are therefore necessary, their application is lagging behind and only a minority of drivers enjoy the benefits of the systems. A study by Reagan et al. (2018) reveals that the driver assistance systems are switched off in 49% of the cars. Low usage rates of assistance systems not only reveal a poor market penetration but also limit the potential benefits for drivers, especially older drivers (Trübswetter, & Bengler, 2013; Viktorova & Sucha, 2018). The reasons why drivers do not use driver assistance systems are multilayered. One of the reasons is certainly the lack of information and knowledge about these systems. Trübswetter & Bengler (2013) reveal in their study that only 66% have heard of a distance control system and only about half know about the existence of systems such as lane departure warning or blind spot assistance. This information comes mainly from acquaintances, the media and car dealers, and less than 20% have had their own experience with driver assistance systems. Another reason also seems to be a lack of awareness with regard to the functional limits of the systems. Due to limitations in technology (such as sensors or cameras) and software (lack of learning and development of artificial intelligence in the interaction of the individual systems), driver assistance systems do not yet work in certain driving situations (Sullivan et al., 2016; Larsson, 2012). For example, the adaptive cruise control system has difficulty recognizing motorcycles or bicycles, which can lead to failures and malfunctions of the system. Although these limitations are known and stated in the user manual, many users, especially older drivers, are not aware of them, leading to irritation and refusal of the systems. The evaluation of the effectiveness of a system depends to a large extent on the feedback provided by the system (Ghazizadeh & Lee, 2014). Therefore, the different types of information delivery (visual, acoustic, haptic) can be mentioned as a reason for rejection.

A frequently mentioned reason for not using technology is often that with increasing age the acceptance of technology is lower. However, different studies in the field of acceptance research show both, positive and negative effects on acceptance (Alexandrakis et al., 2020; Arning & Ziefle, 2007; Escobar-Rodriguez & Bartual-Sopena, 2013; Hauk et al., 2018; Jimoh et al., 2012; Martins et al., 2014; Morris et al., 2005; Morris & Venkatesh, 2000). Also studies specifically on the acceptance of driver assistance systems do not show a clear result (Braun et al., 2019; Larue et al., 2015; Roberts et al., 2012; Souders & Charness, 2016; Xu et al., 2010). Most of these studies have in common that they refer to simple driver assistance systems that are not enhanced by artificial intelligence or machine learning, e.g. ABS, ESC, GPS navigation or road assistance. We believe that advanced driver assistance systems, which increasingly make use of artificial intelligence, will be experienced more positively by older people and can therefore also increase the adoption of automated driving. Therefore, the aim of this paper is to gain an insight into older drivers' acceptance of advanced driver assistance systems, as the technology of driver assistance systems is the basis of autonomous driving and how to facilitate the breakthrough of autonomous driving.

In order to examine the influence of age on the acceptance of driver assistance systems, it was necessary to develop a research model. Based on the literature, suitable models for this research are the Technology Acceptance Model (TAM) (Davis et al., 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). Both the TAM and its extensions and the UTAUT can be used as a basis for the research model to examine the influence of age on the acceptance of driver assistance systems. However, since conventional acceptance research, especially in the field of driver assistance systems, uses the TAM for its examinations (Chen & Chen, 2011; Ghazizadeh et al., 2012; Larue et al., 2015; Park & Kim, 2014; Souders & Charness, 2016) and as we want to continue this research and allow comparisons, we use the technology acceptance model as a basis for our research model. Therefore, we have developed and extended a research model in this article based on the TAM to examine the acceptance of driver assistance systems of 181 elderly drivers and a comparison group of 46 younger drivers. As a result, we developed a questionnaire to test the assumed causal relationships and the moderating effect of age with a multi-group analysis. Because many of the older drivers in particular are not familiar with the driver assistance systems, they first had to be familiarized with it. Therefore, they were allowed to experience the assistance systems in a driving simulator and were asked after driving in the simulator. With the help of the results, the acceptance of older people, and the influence of age will be discussed. This will on the one hand help to get a better understanding of the acceptance of advanced driver assistance systems and on the other will give an important basic understanding regarding autonomous driving in an aging society.

The article is organized as follows: In Section 2 we begin with a literature review on technology acceptance, technology acceptance in old age and the relevance of advanced driver assistance system for extending mobility in old age. The theoretical framework and the research hypotheses are presented in Section 3. In Section 4 the research methodology is described before the results and discussions are shown in section 5. The paper ends with a conclusion and a discussion on future work needed in Section 6.

2. Literature Review

2.1. Technology Acceptance Model

Davis et al. (1989) developed the Technology Acceptance Model (TAM), which with its extensions and further developments is 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; Koivumäki et al., 2006; Koufaris, 2002; Li & Huang, 2009; van der Heijden, 2004; Zarmpou et al. 2012; Zhang et al., 2020). The model is an adaptation and specialisation of the

Theory of Reasoned Action (TRA) to the specific requirements of information systems and technology (Ajzen & Fishbein, 1980). It examines the probability of individual user behaviour in the case of voluntary system use and attempts to establish uniform indicators for various research questions. The intention is to provide a general and, at the same time, as simple as possible explanation of the factors of use of information systems (Legris et al., 2003; Ma & Liu, 2004).

The Technology Acceptance Model states in accordance with the Theory of Reasoned Action that the perceived usefulness and the perceived ease of use are two constructs that have additional influence on the attitude towards use, and respectively the intention to use (Davis et al., 1989). Perceived usefulness is the subjectively assessed probability of the user that the information system used will help him to improve his performance. Perceived ease of use describes a person's assumption of how easy it is for them to use a system (Davis, 1989; Dillon & Morris, 1996). The higher the benefit and the easier the system is to use, the greater the willingness of the person to use the system (Simon, 2001). Since increased ease of use reduces the user's effort, the perceived ease of use also directly affects the perceived usefulness. In the empirical validation of the model, Davis (1989) states that the influence of the perceived usefulness on the intention to use is much stronger than the indirect influence of the perceived ease of use (Davis et al., 1989). In summary, based on the intention to use, the TAM tries to explain why individuals accept and use technology.

The model is proofed, solid and the most influential model for examining the acceptance of information technology (Carr, 2008; King & He, 2006; Koivumäki et al., 2017; Schepers & Wetzels, 2007; Wu et al., 2011). Thus, many research studies criticise that the technology acceptance model with its two central constructs is not meaningful enough to provide a complete and comprehensive description of the acceptance of an information system (Königstorfer & Gröppel-Klein, 2007). To overcome this criticism, the model is extended by additional external variables and constructs (Wu & Wang, 2005), linked to other models and research approaches. Together Venkatesh and Davis (2000) further developed the TAM to TAM 2 (see Figure 11). Over time, the construct of the attitude toward using has been replaced by the intention to use, as this is equivalent to the intention to use a system (Schwarz & Chin, 2007; Wu & Wu, 2005).

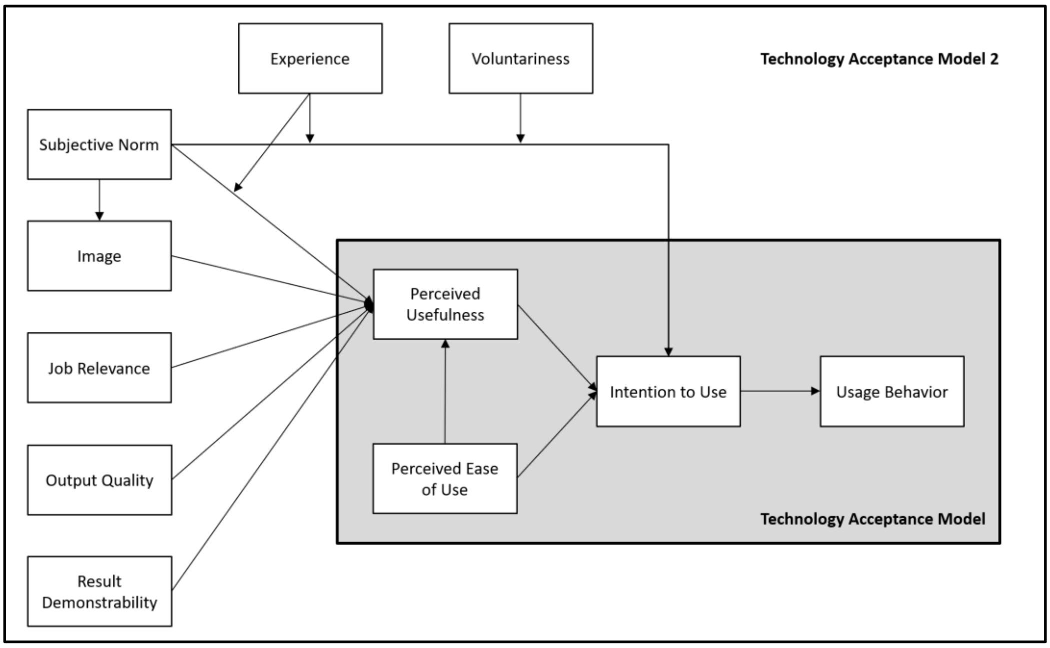

Figure 11: Technology Acceptance Model

2.2. Technology Acceptance Model in old age

In the beginning of technology acceptance research, age has received only little attention in previous studies (Venkatesh et al., 2003). Although age is seen as an important external variable influencing behavioural intention and acceptance of technology in some studies (Chung et al., 2010; Wang et al., 2003), there are several studies arguing that age is less important (Agarwal & Prasad, 1999; Davis et al. 1989). However, recent studies show that there are age-related differences in the acceptance and use of technologies (Arning & Ziefle, 2007; Morris & Venkatesh, 2000; Morris et al., 2005). Although most older people have a positive attitude towards 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).

In the literature there are no clear results concerning technology acceptance in old age. Several studies show that age has a positive influence on the acceptance of technology (Jimoh et al., 2012; Martins et al., 2014), while other studies postulate a negative or not significant influence (Alexandrakis et al., 2020; Escobar-Rodriguez & Bartual-Sopena, 2013; Porter & Donthu, 2006; Shin, 2009). The meta-analysis of Hauk et al. (2018) reveals a rather negative influence of age on the acceptance of technology. In the recent past, the TAM has also been applied in acceptance research in the context of driver assistance systems and autonomous driving (Chen & Chen, 2011; Ghazizadeh et al., 2012; Kervick et al., 2015; Larue et al., 2015; Park & Kim, 2014; Rahman et al., 2019; Roberts et al., 2012; Rodel et al., 2014; Xu et al., 2010). Souders & Charness (2016) investigate the adoption of driver assistance systems and autonomous driving among older adults (55 and older) and show that the intention to use a driver assistance system increases with age. Braun et al. (2019) can show that driver assistance systems experience a high level of acceptance in the age group 65 and older. However, since the studies cannot provide a clear result or a linear relationship over age, the acceptance in older age remains unclear.

2.3. Relevance of advanced driver assistance systems for extending mobility in old age

Driving a vehicle consists of information acquisition, processing, decision making and executing the decision (Wickens et al., 2006). All information is received by the human sensory organs and is based on visual, haptic and acoustic perception. However, physical and cognitive abilities of an individual such as loss of vision, memory, knowledge, strength and balance decrease more and more with increasing age. From age 40 onwards, visual abilities decrease and sensory abilities decrease around 60 years of age (Meyer, 2004). Both decreasing abilities can have a negative influence on driving (Davidse, 2006). Cognitive abilities and performance, such as memory and executive functions, become increasingly weaker with age (Ashendorf & McCaffrey, 2008; Brand & Markowitsch, 2010; Hodzik & Lemaire, 2011). Most people notice limited mobility (e.g. turning the body), limited fine motor skills and low muscle power from the age of 50 (Fisk et al., 2009). For this reason, older people have particular problems in time-critical traffic situations (Schlag, 2008b) and almost half of all Europeans over the age of 65 admit having problems with physical limitations (Wan & Larsen, 2014). Based on these facts, it can be assumed that physical performance declines more and more from the age of 50.

The process of declining abilities is a gradual process and takes place over a long period of time. This gives older drivers the opportunity to develop compensatory strategies with the help of their experience, e.g. an adapted driving style with the maintenance of a greater safety distance to compensate for declining reflexes (Isabelle & Simon, 2020). Reimer et al. (2013), for example, found that older drivers are less likely to change lanes and drive in the left lane. Furthermore, data from Charlton et al. (2013) show that older drivers self-regulate during more demanding driving tasks by performing fewer secondary tasks while driving (talking, operating multimedia functions). Despite the driving experience and compensatory strategies of older drivers, the physical limitations can only be partially compensated.

However, driver assistance systems can help drivers drive smoothly even with physical limitations (Fisk et al., 2009; Schieber, 2006). Some studies have tested the effects of driver assistance systems on safety while driving in a simulator. The different types of driver assistance systems used in these studies include forward collision warning system (Lubbe, 2017), lane change warning system (van der Heiden et al., 2019), dangerous situation warning system (Bella & Silvestri, 2017; Naujoks & Neukum, 2014), intersection warning system (Werneke & Vollrath, 2013) and stop warning system (Kazazi et al., 2015). The studies show that the use of the systems led to a reduction of collision rates, fast lane change, reduction of speed, improvement of braking responses and reduction of the number of collisions. Although these systems can help elderly drivers to remain mobile for longer and increase safety, their success remains far below expectations (Reagan et al., 2018; Viktorova & Sucha, 2018). There is, however, a lack of information about the reasons behind older drivers' adoption of advanced driver assistance systems.

3. Theoretical framework and research hypotheses

Although the literature shows that technology acceptance tends to be lower for older people, we assume with Souders & Charness (2016) and Braun et al. (2019) a generally positive influence of the acceptance due to the need for driver assistance systems in old age. Therefore, we have extended the basic technology acceptance model (Davis et al., 1989; Venkatesh & Davis, 2000) by the variable's trust and personal innovativeness to increase the degree of explanation.

3.1. TAM

Since the technology acceptance model forms the basis of the research model we use the intention to use as the main dependent construct (Venkatesh et al., 2003) and examine the acceptance from the end-user's point of view. Also, because driver assistance systems are spreading only slowly and not everyone has come into contact with them. The intention to use thus represents a dependent variable instead of actual use (Schwarz & Chin, 2007; Wu & Wu, 2005) and is defined as the "the degree to which a person intends to use an advanced driver assistance system" (Davis et al., 1989; Venkatesh & Davis, 2000). Along with the TAM, we therefore hypothesize the following:

$\mathbf{H_{1.1}}$: The greater the perceived usefulness, the greater the intention to use ADAS.

$\mathbf{H_{2.1}}$: The greater the perceived ease of use, the greater the intention to use ADAS.

$\mathbf{H_{3.1}}$: The greater the perceived ease of use, the greater the perceived usefulness of ADAS

$\mathbf{H_{4.1}}$: The greater the subjective norm, the greater the intention to use ADAS.

$\mathbf{H_{5.1}}$: The greater the subjective norm, the greater the perceived usefulness of ADAS.

3.2. Trust in Technology

Trust is not included as a determinant in the basic model of the technology acceptance model. The determinant is a multi-dimensional construct that can consist of different components or types of trust in technology and the risk that it involves, and strongly influences acceptance (Lee & Moray, 1992; Lee & See, 2004; Molnar et al., 2018; Parasuraman & Riley, 1997; Verberne et al., 2012). Mayer et al. (1995) define trust as the willingness to put oneself in a vulnerable position with a technology, combined with a positive expectation of a result or positive future behaviour. The user therefore decides to trust the system with the idea of having a positive experience with the technology - in this context in the form of the use of driver assistance systems. People appreciate dangers and associate a higher risk, especially with new and unknown systems (Bekiaris & Stevens, 2005). The variable with its different dimensions represents the fears of people in the context of the use of information systems with regard to them (Jacoby & Kaplan, 1972). Especially in the case of technologies that automate actions for humans, trust represents an enormous acceptance criterion (Choi & Ji, 2015; Gefen et al., 2003; Kaur & Rampersad, 2018; Lee & See, 2004; Parasuraman et al., 2008; Pavlou, 2003; Tussyadiah et al., 2017) Similar to an interpersonal relationship, humans also trust a machine or technology when using it (Lankton et al. 2014; Tussyadiah et al., 2017; Wang & Benbasat, 2005). The use of driver assistance systems during a journey, a user must have confidence in the system and relies not only on his existing and learned abilities, but also partly on the driver assistance systems. It has been shown that a user develops trust in a technology only through performance conviction (Johnson, 2007; Johnson et al., 2008; Schlosser et al., 2006). Therefore, the basis for trust is the performance and reliability that a system offers (Beller et al., 2013; Molnar et al., 2018). Trust in the technology is not only associated with a simple benefit for the user, but it also influences the perceived ease of use and directly the intention to use the system. We therefore derive the following hypotheses:

$\mathbf{H_{6.1}}$: The greater the trust in ADAS, the greater intention to use ADAS.

$\mathbf{H_{7.1}}$: The greater the trust in ADAS, the greater the perceived usefulness.

$\mathbf{H_{8.1}}$: The greater the trust in ADAS, the greater the perceived ease of use.

3.3. Personal innovativeness

The personal innovativeness is also not included as a determinant in the basic model. However, Rogers (2003) notes that the adoption of technologies is not based on the characteristics of innovation, but is influenced by the personal characteristics of the user. According to Rogers, new technologies and the information about them can be found within a social system, spread within it and are thus perceived by potential users. As a result, potential users develop an attitude towards the technology and consequently this forms the basis for an adoption decision.

The literature defines the personal innovativeness differently. It can be seen as a personality trait that indicates to what extent a person adopts and accepts a new technology (Midgley & Dowling, 1978). Furthermore, it is seen as a tendency to buy new products at an earlier stage of the market than the rest of the consumers (Foxall et al., 1998). Agarwal & Prasad (1998) define personal innovativeness as the enthusiasm of an individual to try a new technology and the willingness to accept a new innovation earlier than others. They also demonstrated that users with a higher degree of innovation have a more positive attitude towards technology. Further studies on the personal degree of innovation within acceptance research in various application areas of information systems (online shopping, virtual learning, blogging, wireless mobile services, mobile device adoption) show that the personal degree of innovation has a significant influence on perceived usefulness, perceived ease of use and intention to use (Bigné-Alcañiz et al., 2008; Lee, 2019; Lu et al. 2008; Van Raaji & Schepers, 2008; Wang et al., 2010). Consequently, in order to accept new technologies, potential users should have a high degree of personal innovation. Therefore, the following hypotheses are made:

$\mathbf{H}_{9.1}$: The greater the personal innovativeness, the greater the intention to use ADAS.

$\mathbf{H}_{10.1}$: The greater the personal innovativeness, the greater the perceived usefulness.

$\mathbf{H}_{11.1}$: The greater the personal innovativeness, the greater the perceived ease of use.

3.4. Moderation Effect of Age

It can also be assumed that the perceived usefulness is higher for older people than for younger people. Because of physical limitations (Fisk et al., 2009; Hodzik & Lemaire, 2011; Wan & Larsen, 2014), older people tend to be more restricted in their ability to drive a vehicle and driver assistance systems can help to compensate for this and therefore the following hypothesis can be derived:

$\mathbf{H}_{1.2}$: For older individuals the perceived usefulness has a greater influence on the intention to use ADAS than for younger individuals.

Although older people are generally open to technology, they are less interested in all kinds of technology, even if new technologies were available to them and could be used, they would still not use them (Ryu et al., 2009; Mitzner et al., 2010). This lack of experience with new technologies inevitably makes it harder for older people to operate the systems than for younger ones. This is why a particularly simple use of technology is important for older people and should lead to driver assistance systems being viewed more positively. The following hypothesis can be derived:

$\mathbf{H}_{2.2}$: For older individuals the perceived ease of use has a higher influence on the intention to use of ADAS than for younger individuals.

$\mathbf{H}_{3.2}$: For older individuals the perceived ease of use has a higher influence on the perceived usefulness of ADAS than for younger individuals.

Meta analyses already confirm that older people are less influenced by the environment than younger people (Schepers & Wetzels, 2007; Zhang et al., 2012), which means that the subjective norm for older people has less influence on their acceptance. The following hypothesis can be derived:

$\mathbf{H_{4.2}}$: For older individuals the subjective norm has a lower influence on the intention to use ADAS than for younger individuals.

$\mathbf{H_{5.2}}$: For older individuals the subjective norm has a lower influence on the perceived usefulness of ADAS than for younger individuals.

Trust can only be built through interaction and since older people interact less with new technology and have less experience with new technologies, they may have little experience and trust in driver assistance systems. Guo et al. (2016) have also shown that trust in technology is lower among older people than among younger ones. Trust in driver assistance systems therefore plays a major role, especially for older people, as they generally have less interaction with new technologies and therefore trust in technology is not a prerequisite for this group. We therefore derive the following hypothesis:

$\mathbf{H_{6.2}}$: For older individuals trust has a higher influence on the intention to use ADAS than for younger individuals.

$\mathbf{H_{7.2}}$: For older individuals trust has a higher influence on the perceived usefulness of ADAS than for younger individuals.

$\mathbf{H_{8.2}}$: For older individuals trust has a higher influence on perceived ease of use of ADAS than for younger individuals.

In addition, Lee (2019) was able to show that age plays a major role in the degree of personal innovativeness, because the older the test persons were and the higher the value, the greater was the influence. However, the problem is that older people have little experience with technology, they have less interest in technology and therefore personal innovativeness has less impact on the acceptance of older people. The following hypothesis can be derived:

$\mathbf{H_{9.2}}$: For older individuals the personal innovativeness has a lower influence on the intention to use ADAS than for younger individuals.

$\mathbf{H_{10.2}}$: For older individuals the personal innovativeness has a lower influence on the perceived usefulness of ADAS than for younger individuals.

$\mathbf{H_{11.2}}$: For older individuals the personal innovativeness has a lower influence on the perceived ease of use of ADAS than for younger individuals.

Figure 12 shows the final acceptance model with its hypotheses that will be empirically examined in sections 4 and 5.

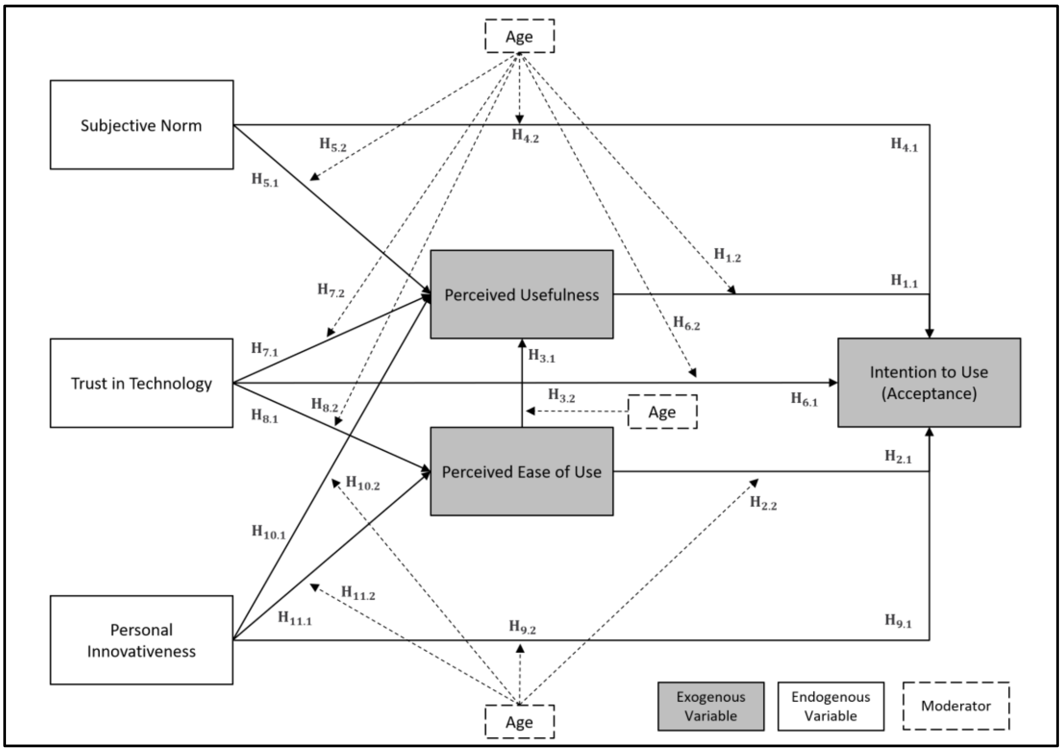

Figure 12: Acceptance model

4. Research Methodology

4.1. Measurement & operationalization of constructs

The acceptance of the driver assistance system is defined as the customers' intention to use such a system. It is measured with five independent variables (Personal Innovativeness, Subjective Norm, Trust, Perceived Ease of Use, Perceived Usefulness) and one dependent variable (Intention to Use). Since acceptance is being examined from the end-user's point of view, acceptance is determined by the intention to use and is therefore a dependent variable instead of actual use (Schwarz & Chin, 2007; Venkatesh et al., 2003; see Figure 12). All of the constructions are measured with items already existing in the literature, but which have been modified to fit the background of the research. These six variables are measured in the questionnaire with a total of 14 items. The questions on acceptance were measured with a 7-stage

Likert-scale ranging from "completely disagree" to "fully agree". Demographic data on experience with driver assistance systems and product knowledge were measured using a 7-level interval scale. All other demographic facts (gender, age, net income, education, driven km per day) were measured using nominal and ordinal scales. The dependent and independent constructs and their operationalisation are shown in the appendix (Appendix 1, Table 18). In order to check the comprehensibility and correctness of the 14 items, a pretest of the questions was carried out using the example of distance control cruise control and sent to 50 randomly selected respondents aged 20-90 years as well as to participating chairs from other disciplines. Since the survey took place in Germany, all questions have been translated into the German language and only with grammatical adjustments. The questions on the points related exclusively to technical questions about the driver assistance system, upon which we adjusted the technical descriptions of the driver assistance systems (see Appendix 2, Figure 14).

4.2. Data collection

In order to investigate the acceptance of driver assistance systems and the influence of age, a sample that is as large as possible is required. In addition, all test persons should know and have experienced the advanced driver assistance systems. For this reason, a preliminary examination was carried out before the main investigation in which the probands were tested for their eligibility in a driving simulator (see Figure 13).

Figure 13: Static driving simulator

Due to the partial high age of the test persons, it was necessary to query previous illnesses in order to exclude persons with critical illnesses such as epilepsy, dementia and Parkinson's from the tests. In the preliminary examination, reactions in the driving simulator were also tested, as empirical studies in the driving simulator had to reckon with the so-called "simulator sickness", which can lead to headaches, loss of orientation, dizziness or nausea and thus to a discontinuation of the tests because the test persons are artificially tempted to move although they are actually not moving. Studies show that older people are more frequently affected by "simulator disease" than younger people (Brooks et al., 2010; Roenker et al., 2003; Schweig et al., 2018).

To allow for the largest possible random sample, a total of 381 older test persons were recruited for the study. For this purpose and on the basis of the research model, an online questionnaire was developed using LimeSurvey. All data was generated in a period from August 2017 to September 2019[3] in the west of Germany. All test persons were invited and medically checked. Afterwards they were driving for about 45 minutes in the driving simulator and afterwards they filled out the online questionnaire. After checking for suitability[4], a total of 227 drivers from 20 to 90 years old with completed questionnaires remained. 74,6% of the participants are male and 23,4% are female. The average age of the sample is 58 years with 20,3% of participants in the age group 20-49, 21,6% of participants in the age group 50-59, 33,5% of the participants in the age group 60-69 and 24,6% in the age group of 70-90-years of age. The educational background varied as follows among the participants: no graduation (0,4%), secondary education (17,1%), qualification for university (63%), college of higher education (30,0%), university level (37,9%) and doctorate (0,9%). Also, the monthly net income differs with less than 500€ (4,8%), between 500€ and 1.000 (10,6%), between 1.001€ and 2.000 (18,1%), between 2.001€ and 3.000 (34,4%), between 3.001€ and 4.000 (14,5%), between 4.001€ and 5.000 (5,3%), between 5.001€ and 6.000 (0,9%) and more than 6.000€ (4,4%). Most participants drive about 21 to 50 km per day (35,7%), followed by 6 to 20 km (30,0%), 51 to 100 km (21,6%), less than 5 km (6,2%), 101 to 150 km (3,5%) and

[3] The pre-test with 381 subjects serves as the basis for the main study. From these 381 subjects, 181 over the age of 50 who participated in the main study remained at the end. In addition, 46 subjects under the age of 50 were interviewed and included in the study as a comparison group. All studies have been conducted in the period from the beginning of 2017 until the end of 2019.

[4] The subjects were tested for their fitness for the study on the basis of several medical tests and a test drive in the simulator.

more than 150 km per day (0,4%). The complete table of the descriptive statistics are shown in Table 10.

Table 10: Descriptive statistics

Control variables	Description	n (total 227)	Proportion of respondents	Average
Gender	male	173	74,6	/
	female	54	23,4	
age group	20-49	46	20,3	58
	50 - 59	49	21,6	
	60 - 69	76	33,5	
	70 - 90	56	24,6	
Net income	500-	11	4,8	/
	501 - 1.000€	24	10,6	
	1.001 - 2.000 €	41	18,1	
	2.001 - 3.000 €	78	34,4	
	3.001 - 4.000 €	33	14,5	
	4.001 - 5.000 €	12	5,3	
	5.001 - 6.000 €	2	0,9	
	6.001+ €	10	4,4	
	No information	16	7,0	
Education	No graduation	1	0,4	/
	certificate of secondary education	11	4,8	
	general certificate of secondary education	28	12,3	
	general qualification for university entrance	63	27,7	
	college of higher education	30	13,2	
	university level	86	37,9	
	doctorate	2	0,9	
	No information	6	2,6	

Driven km per day	< 5 km	14	6,2	/
	6 - 20 km	68	30,0	
	21 - 50 km	81	35,7	
	51 - 100 km	49	21,6	
	101 - 150 km	8	3,5	
	> 150 km	1	0,4	
	No information	6	2,6	
years of owning driver's license				38,1
Product knowledge				3,32
Experience				3,44

4.3. Choice of the driver assistance systems to be tested

For an analysis of the acceptance of advanced driver assistance systems and to empirically measure the effects of the design, a selection of age-appropriate driver assistance systems must be made in advance. Therefore, the study on traffic accidents of senior citizens in road traffic in Germany is considered (Statistisches Bundesamt, 2019b). According to the statistic, the most frequent misbehaviour in driving a vehicle occurs among senior citizens (65 years and older) in connection with right of way and priority in road traffic (17.7%), turning, turning around, reversing, entering a street and accelerating (17.0%) and distance errors (8.8%). Based on the results of the statistics on accidents involving senior citizens in road traffic in Germany, Cross-Traffic Alert, Park Distance Control and Lane Departure Warning were finally selected and implemented in the driving simulator.

5. Results and Discussion

In order to identify and to get a scientific understanding of the acceptance of advanced driver assistance systems among older people, an empirical model is necessary, as the literature has so far not provided any clear results. Due to the complexity of the model and to verify the influence of the different determinants on the intention to use, structural equation modeling (SEM) is applied. Because of the minimum sample size with at least 30 and fewer requirements for the model (Nitzl, 2010), we therefore use the PLS-SEM approach (Hair et al., 2017). Thus, we used SmartPLS

3.2.8 for PLS-based estimations which allows individual settings and with the application of the PLS estimation procedure and the Bootstrap Resampling. For the calculation of the model using PLS-algorithm, the path weighting scheme is selected, with a maximum iteration number of 1000 and a stop criterion of 10-7. Significance of the paths of the structural model is checked with the Bootstrap Resampling method. Therefore, subsamples are set to 1000 for the number of parameters estimates. For all other estimates we use SPSS Statistics 23. Because of the SEM approach, we will first verify the measurement model and then the structural model (Weiber & Mühlhaus, 2014).

5.1. Measurement Model Assessment

First, we need to validate the fit of the model and test the empirical data. Based on the catalogue of questions by Jarvis et al. (2003), this research operationalised reflective measurement models. In addition, measurement models are subject to errors, since indicators only represent individual aspects of the construct, which results in a loss of information during operationalisation. Therefore, a test of the quality of the construct measurement is necessary as part of the structural equation analysis (Trommsdorff, 2004). The quality assessment of the measurement model is first conducted on the basis of validity using the criteria content validity, convergent validity and discriminant validity and then on the basis of reliability using the criteria indicator reliability, indicator significance and construct reliability (Hair et al., 2017).

To guarantee the validity of the content, we use existing scales and items that fit the research model, and the questionnaire has also been checked by other experts. Convergence validity is tested by average variance extracted (AVE). It describes whether a construct is correctly reproduced by means of measurement by several indicators. The criterion is met if the average declared 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).

Using the average explained variance, the criterion of discriminant validity was examined. According to the Fornell-Larcker criterion, the root of the variance explained by the average must always be greater than or equal to the correlation of the construct with another construct ($\sqrt{DEV} \geq |KORR\ \xi/\eta$ und $\xi/\eta\ |$) and we therefore also checked for cross-loadings (Chin, 1998; Fornell & Larcker, 1981).

The indicator reliability (IR) indicates the share of the variance of an indicator in the corresponding total variance of the indicator and considers the factor charges. The factor charge can have 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 in a minimum value of 0.7 of the factors loading (Hair et al., 2017).

Next, we consider indicator significance, which reflects the degree of significance between the indicator and the latent variable. It is measured using the T-value and should have a value greater than |±1.96| (Weiber & Mühlhaus, 2014). Due to the lack of a normal distribution assumption, the T-values are determined using the "Bootstrap Resampling Method".

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

Table 11: Composite 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	0,974	0,950	**0,974**					
Personal Innovativeness	0,925	0,755	0,293	**0,869**				
Subjective Norm	0,957	0,918	0,507	0,208	**0,958**			
Trust	0,952	0,908	0,620	0,338	0,558	**0,953**		
Perceived Usefulness	0,975	0,952	0,804	0,334	0,490	0,665	**0,976**	
Perceived Ease of Use	0,881	0,787	0,558	0,240	0,326	0,450	0,591	**0,887**

Park Distance Control								
Acceptance	0,976	0,953	**0,976**					
Personal Innovativeness	0,925	0,755	0,393	**0,869**				
Subjective Norm	0,973	0,947	0,507	0,176	**0,973**			
Trust	0,961	0,924	0,566	0,285	0,474	**0,961**		
Perceived Usefulness	0,978	0,956	0,832	0,351	0,447	0,607	**0,978**	
Perceived Ease of Use	0,925	0,860	0,529	0,250	0,302	0,420	0,632	**0,927**
Lane Departure Warning								
Acceptance	0,981	0,962	**0,981**					
Personal Innovativeness	0,925	0,756	0,294	**0,870**				
Subjective Norm	0,987	0,973	0,575	0,219	**0,987**			
Trust	0,975	0,952	0,503	0,223	0,542	**0,976**		
Perceived Usefulness	0,98	0,96	0,808	0,315	0,573	0,553	**0,980**	
Perceived Ease of Use	0,930	0,869	0,475	0,236	0,280	0,410	0,504	**0,932**

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

The testing of the research models all three of the advanced driver assistance systems (Cross-Traffic-Alert, Park Distance Control and Lane Departure Warning) and indicate that the model fit is acceptable and reliable, thus enabling conclusions based on the data. The composite reliability of all designs is significantly higher than the required value of 0.6 and the average variance extracted is constantly above 0.5 as well. With a minimum of 0.809 and a maximum of 0.986, all factor loadings of the items are far above the required 0.7 and therefore meet the requirements of the indicator reliability (see Appendix 3, Table 19; Appendix 4, Table 20; Appendix 5, Table 21). In addition, the discriminant validity can also be confirmed with the Fornell-Larcker criterion; with every AVE higher than the shared variance with all other constructs (see Table 11).

5.2. Structural Model Assessment

After a valid and reliable estimate of reflective measurement models has been made, the quality of the structural model is checked. First of all, criteria are used to assess the path coefficients, such as the strength of action and significance of the path coefficients. Then the significance is checked by means of coefficient of determination (R2).

The analysis of the strength and significance of the path coefficients is based on regression analysis. The path coefficients can have values from minus one to one. Values near minus one and one describe a strong influence on the latent variable, whereas values near zero describe a weak influence. If the values are greater than 0.1, they are considered significant (Chin, 1998). The significance of the effect relationships is checked here, just as with the quality of the measurement models using the Bootstrap Resampling method, using the T-values and a significance is confirmed if the T-value is at least | ± 1.96|.

The coefficient of determination (R2) indicates the share of the variance of the exogenous variables affecting the endogenous variables. The value can be between 0 and 1, whereby values of 0.19-0.36 reflect a weak explanatory content, values of 0.37-0.66 an average and values of 0.67-1 a substantial explanatory content (Chin, 1998). The literature therefore requires a value of the coefficient of determination of at least 0.3.

Table 12: Structural model

Hypothesis	Path	CTA	PDC	LDW
H1.1	PU -> ITU	0,618***	0,706***	0,657***
H2.1	PEOU -> ITU	0,112**	-0,006	0,088*
H3.1	PEOU -> PU	0,343***	0,420***	0,288***
H4.1	SN -> ITU	0,115**	0,158***	0,163***
H5.1	SN -> PU	0,133**	0,143*	0,346***
H6.1	TIT -> ITU	0,093	0,035	0,009
H7.1	TIT -> PU	0,407***	0,326***	0,220***
H8.1	TIT -> PEOU	0,417***	0,380***	0,376***
H9.1	PERIN -> ITU	0,004	0,109***	0,031
H10.1	PERIN -> PU	0,087*	0,128***	0,122***
H11.1	PERIN -> PEOU	0,099*	0,142**	0,152***

Dependent variable	R-squared		
Intention to Use	0,68	0,73	0,68
Perceived Usefulness	0,57	0,57	0,50
Perceived Ease of Use	0,21	0,20	0,19

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

Using the PLS approach and calculation results show that most of the time all criteria are met. For the Cross-Traffic-Alert, 9 of the 11 hypotheses can be confirmed and the R values also show a good model fit with and R2 = 0.68 for Intention to Use. In addition, 9 of the 11 hypotheses for the Park Distance Control can be confirmed and also the R value with 0.73 of the Intention to Use is higher, which means a good model fit. Finally, the R value of the Intention to Use of the Lane Departure Warning is 0.82 and 9 out of 11 hypotheses can be confirmed.

Overall, the basic structure of the TAM (Davis et al., 1989) can therefore be largely confirmed. For all three models a significant effect of perceived usefulness on intention to use and perceived ease of use on perceived usefulness can be confirmed. However, in only two cases the influence of the perceived ease of use on the intention to use could be found. Furthermore, the influence of the subjective norm on the intention to use and on the perceived usefulness can be confirmed and is thus consistent with TAM2 (Venkatesh & Davis, 2000). The influence of trust in technology on the perceived usefulness and the perceived ease of use can be confirmed. However, the influence of trust in technology on the intention to use cannot be confirmed. Moreover, the influence of the personal innovativeness can be partially confirmed. The results show that there is a significant influence of personal innovativeness on the perceived ease of use. Nevertheless, the influence of personal innovativeness on perceived usefulness can only be confirmed in all three models and the influence of personal innovativeness on intention to use only in one of the three models (see Table 12 for the results). All three models can therefore be confirmed for the most part and allow further conclusions.

5.3. Influence of age on the acceptance of advanced driver assistance systems

Predefined data groups (Young: 20-49-year-old; Old: 50-90-year-old; Old1: 50-59-year-old; Group Old2b: 60-69-year-old; Group 2c: 70-90-year-old) can be used to test significant differences in their group-specific parameter estimates (e.g. external weights, external loads and path coefficients). In order to investigate the influence of age and due to differences in the path coefficients, we conducted a multi-group analysis (MGA). We therefore used the PLS-MGA approach, which is integrated in SmartPLS (Hair et al., 2018). This method uses a non-parametric significance test to test for significant group differences, with a p-value smaller than 0,10/0,05/0,01 or larger than 0,90/0,95/0,99 for a 10%/5%/1% probability of error (Henseler et al., 2009; Sarstedt et al., 2011).

5.3.1. Difference between younger and older generations

Table 13: Results of the group analysis for the groups 20-49 and 50-90

	CTA			PDC			LDW		
	50 - 90	20 - 49	50-90 – 20-49	50 - 90	20 - 49	50-90 – 20-49	50 - 90	20 - 49	50-90 – 20-49
PU -> ITU (H1.2)	0,613***	0,632***	-0,018	0,688***	0,760***	-0,072	0,683***	0,606***	0,077
PEOU-> ITU (H2.2)	0,097*	0,182	-0,085	0,017	-0,056	0,073	0,035	0,265***	**-0,229***
PEOU -> PU (H3.2)	0,351***	0,375***	-0,024	0,459***	0,160	**0,299***	0,332***	0,059	**0,273***
SN -> ITU (H4.2)	0,109**	0,114	-0,004	0,158***	0,128	0,03	0,166***	0,230	-0,064
SN -> PU (H5.2)	0,113*	0,206*	-0,094	0,111*	0,297***	**-0,186***	0,327***	0,357***	-0,030
TIT -> ITU (H6.2)	0,121*	-0,017	0,137	0,042	-0,013	0,055	0,035	-0,137	0,172
TIT -> PU (H7.2)	0,417***	0,334***	0,083	0,325***	0,407***	-0,082	0,191***	0,397***	-0,206
TIT -> PEOU (H8.2)	0,476***	0,158	**0,317***	0,391***	0,383***	0,008	0,372***	0,421***	-0,049
PERIN -> ITU (H9.2)	0,007	-0,002	0,008	0,107**	0,141	-0,034	0,016	0,078	-0,062
PERIN -> PU (H10.2)	0,048	0,281**	**-0,233***	0,120**	0,163	-0,044	0,120**	0,142	-0,022
PERIN -> PEOU (H11.2)	0,108	0,075	0,033	0,124*	0,266*	-0,142	0,159**	0,122	0,038

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

Analyzing the model for the Cross-Traffic-Alert, two significant differences can be identified between the younger and older group. The influences of personal innovativeness on perceived usefulness is significantly higher for younger participants and trust in technology on perceived ease of use is significantly higher for older participants. Also, the results of the Park Distance Control reveal two significant differences between subjective norm and perceived usefulness and is higher for the younger group whereas the influence of perceived ease of use on perceived usefulness is higher for the older age group. Moreover, there are two significant differences in the third driver assistance system. The influence of perceived ease of use on intention to use is higher for the younger people and the influence of perceived ease of use on perceived usefulness is higher for older test persons (see Table 13).

5.3.2. Differences in older generations

The comparison of the older generations among themselves shows clear differences in the acceptance depending on age and the examined assistance system. Significant differences exist between the groups of 50 to 59-year-old and 60 to 69 for five cause-effect relationships (see Table 14). For the Cross-Traffic-Alert, trust has a higher impact on the perceived usefulness for the 60-69-year-old and perceived ease of use has a higher influence on perceived usefulness for the group of 50-59-year-old. Looking at the Park Distance Control we can observe two significant differences. The influence of the subjective norm on the intention to use is higher for the younger group (50-59), but the influence of the perceived usefulness on the intention to use is higher for the older group (60-69). The last difference for the Lane Departure Warning is the effect of trust on the perceived usefulness and is again higher for the older group (60-69).

Table 14: Results of the group analysis for the groups 50-59 and 60-69

	CTA			PDC			LDW		
	50 - 59	60 - 69	50-59 – 60-69	50 - 59	60 - 69	50-59 – 60-69	50 - 59	60 - 69	50-59 – 60-69
PU -> ITU (H1.2)	0,717***	0,739***	-0,022	0,605***	0,873***	**-0,268***	0,732***	0,615***	0,117
PEOU-> ITU (H2.2)	-0,029	0,104	-0,132	-0,035	-0,010	-0,026	-0,001	0,052	-0,053
PEOU -> PU (H3.2)	0,753***	0,238**	**0,515*****	0,469**	0,393***	0,076	0,436***	0,332***	0,104
SN -> ITU (H4.2)	0,115	0,058	0,057	0,228***	0,126**	0,102	0,088	0,250***	-0,162
SN -> PU (H5.2)	0,125	0,144	-0,019	0,243**	0,005	**0,237***	0,406***	0,174*	0,232
TIT -> ITU (H6.2)	0,064	0,073	-0,009	0,132	-0,057	0,189	0,049	0,065	-0,016
TIT -> PU (H7.2)	0,049	0,542***	**-0,493*****	0,281**	0,356***	-0,076	-0,061	0,306***	**-0,367****
TIT -> PEOU (H8.2)	0,469***	0,403***	0,065	0,407***	0,297**	0,111	0,413***	0,210*	0,203
PERIN -> ITU (H9.2)	0,105	-0,032	0,138	0,112	0,060	0,052	0,039	-0,006	0,045
PERIN -> PU (H10.2)	-0,009	0,058	-0,068	0,036	0,206**	-0,170	0,063	0,160*	-0,097
PERIN -> PEOU (H11.2)	0,245**	0,153	0,092	0,224*	0,132	0,092	0,283**	0,219**	0,064

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

The multi-group analysis for the 50 to 59-year-olds compared with the oldest group of the 70 -90-year-olds shows three significant differences only for the Cross-Traffic-Alert (see Table 15). The significant paths are identical with the comparison of the 50-59-year-olds and the 60-69-year-olds. The influence of trust on perceived usefulness is significantly higher for the 70-90-year-olds and the influence of perceived ease of use on perceived usefulness is significantly higher for the 50 - 59-year-olds.

Table 15: Results of the group analysis for the groups 50-59 and 70-90

	CTA			PDC			LDW		
	50 - 59	70 - 90	50-59 – 70-90	50 - 59	70 - 90	50-59 – 70-90	50 - 59	70 - 90	50-59 – 70-90
PU -> ITU (H1.2)	0,717***	0,513***	0,204	0,605***	0,521***	0,084	0,732***	0,745***	-0,013
PEOU-> ITU (H2.2)	-0,029	0,103	-0,131	-0,035	0,207	-0,242	-0,001*	0,048	-0,048
PEOU -> PU (H3.2)	0,753***	0,161	**0,591*****	0,469***	0,537***	-0,068	0,436***	0,238*	0,198
SN -> ITU (H4.2)	0,115	0,085	0,029	0,228***	0,143	0,085	0,088	0,120	-0,033
SN -> PU (H5.2)	0,125	0,005	0,120	0,243**	0,147	0,096	0,406***	0,527***	-0,122
TIT -> ITU (H6.2)	0,064	0,258	-0,193	0,132	0,085	0,047	0,049	0,021	0,028
TIT -> PU (H7.2)	0,049	0,616***	**-0,567*****	0,281**	0,262**	0,019	-0,061	0,169	-0,230
TIT -> PEOU (H8.2)	0,469***	0,590***	-0,121	0,407***	0,495***	-0,087	0,413***	0,478***	-0,065
PERIN -> ITU (H9.2)	0,105	-0,128	0,234	0,112	-0,009	0,120	0,039	-0,024	0,063
PERIN -> PU (H10.2)	-0,009	0,039	-0,048	0,036	0,101	-0,065	0,063	0,045	0,018
PERIN -> PEOU (H11.2)	0,245**	-0,053	**0,298***	0,224**	0,019	0,205	0,283**	-0,025	0,308

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

The final analysis of the acceptance differences of the groups 60 - 69 years and 70 - 90 years indicates a significant difference for the Park Distance Control and two significant differences for the Lane Departure Warning (see Table 16). The first significant difference for the PDC is the perceived usefulness on the intention to use and is significantly higher for the group of 60-69-year-old. Next differences for the LDW are a higher influence of the subjective norm on the perceived usefulness as well as the influence of trust on the perceived ease of use and is both times higher for the 70 - 90-year-old group.

Table 16: Results of the group analysis for the groups 60-69 and 70-90

	CTA			PDC			LDW		
	60 - 69	70 - 90	60-69 – 70-90	60 - 69	70 - 90	60-69 – 70-90	60 - 69	70 - 90	60-69 – 70-90
PU -> ITU (H1.2)	0,739***	0,513***	0,226	0,873***	0,521***	**0,352***	0,615***	0,745***	-0,130
PEOU-> ITU (H2.2)	0,104	0,103	0,001	-0,010	0,207	-0,216	0,052	0,048	0,005
PEOU -> PU (H3.2)	0,238*	0,161	0,077	0,393***	0,537***	-0,144	0,332***	0,238*	0,094
SN -> ITU (H4.2)	0,058	0,085	-0,028	0,126**	0,143	-0,017	0,250***	0,120	0,130
SN -> PU (H5.2)	0,144*	0,005	0,139	0,005	0,147	-0,142	0,174*	0,527***	**-0,353****
TIT -> ITU (H6.2)	0,073	0,258	-0,185	-0,057	0,085	-0,142	0,065	0,021	0,044
TIT -> PU (H7.2)	0,542***	0,616***	-0,074	0,356***	0,262**	0,094	0,306***	0,169	0,137
TIT -> PEOU (H8.2)	0,403***	0,590***	-0,187	0,297**	0,495***	-0,198	0,210*	0,478***	**-0,268***
PERIN -> ITU (H9.2)	-0,032	-0,128	0,096	0,060	-0,009	0,068	-0,006	-0,024	0,018
PERIN -> PU (H10.2)	0,058	0,039	0,020	0,206**	0,101	0,105	0,160	0,045	0,115
PERIN -> PEOU (H11.2)	0,153	-0,053	0,205	0,132	0,019	0,113	0,219**	-0,025	0,244

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

5.4. Influence of income on the acceptance of advanced driver assistance systems

Since cost, as a major factor in determining technology acceptance, has often been overlooked or not considered in previous TAM-related studies (Mallenius, Rossi & Tuunainen, 2007), the sample's collected income is used to divide the sample into two groups (Lower income: net income lower than 3.001 €; higher income: net income higher than 3.000 €). Using the multi-group analysis (Hair et al., 2018), the sample is tested for significant group differences to address possible criticism regarding the cost factors.

Table 17: Results of the group analysis for the groups low income and high income

	CTA			PDC			LDW		
	Low income	High income	Low – High	Lower income	Higher income	Low – High	Lower income	Higher income	Low – High
PU -> ITU	0,583***	0,692***	-0,109	0,705***	0,727***	-0,023	0,583***	0,701***	-0,118
PEOU-> ITU	0,122	0,089	0,032	-0,001	-0,119	0,117	0,116***	0,026	0,090
PEOU -> PU	0,397***	0,359***	0,038	0,489***	0,381***	0,108	0,251***	0,425***	-0,174
SN -> ITU	0,138	0,053	0,085	0,177***	0,120	0,057	0,272***	-0,015	0,287***
SN -> PU	0,172*	0,144***	0,027	0,186***	0,025	0,162	0,358***	0,179	0,179
TIT -> ITU	0,120	0,064	0,056	0,006	0,159	-0,153	-0,071	0,156	-0,228
TIT -> PU	0,388***	0,359***	0,029	0,242***	0,380***	-0,138	0,227***	0,207*	0,020
TIT -> PEOU	0,344***	0,456***	-0,112	0,419***	0,363***	0,056	0,444***	0,217*	0,227
PERIN -> ITU	0,050	-0,060	0,110	0,118***	-0,055	0,172	0,090*	-0,146***	0,235***
PERIN -> PU	0,038	0,129***	-0,091	0,145***	0,091	0,054	0,143***	0,056	0,087
PERIN -> PEOU	0,000	0,173***	-0,174	0,097	0,195	-0,098	0,091	0,272**	-0,181

Note. *** $p < .01$; ** $p < .05$; * $p < 0.10$. 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.

Individual analysis of the two groups low-income and high-income reveals two significant differences only for the Lane Departure Warning (see Table 17). The influence of subjective norm and personal innovativeness on the intention to use is both times higher for the low-income group.

5.5. Discussion of the results

The analysis of the acceptance model shows that most relationships have a significant effect on the intention to use advanced driver assistance systems. In the following, the different driver assistance systems will be considered and then discussed in a comprehensive manner.

5.5.1. Technology Acceptance in any age

According to the technology acceptance models of Davis et al. (1989) and Venkatesh & Davis (2000), the majority of the causal connections can be confirmed in this research. In addition, the other constructs can also be confirmed according to the literature, although with minor deviations (Choi & Ji, 2015; Lee, 2019; Tussyadiah et al., 2017; Wang et al., 2010).

By far the most important effect for test persons is the influence of the perceived usefulness on the intention to use driver assistance systems (Davis et al., 1989; Fagan et al., 2008). The effect is equally high and important for old and young. Both groups are thus aware of the usefulness of the systems which they were able to test in this study. Thereby all three driver assistance systems have a similar weighting. The older drivers also benefit greatly from the assistance systems, as they can compensate for their increasing physical deficits. For the market, this result means that the customer group of older drivers in particular can be persuaded to use advanced driver assistance systems by means of a suitable and user-focused value proposition. By establishing the systems as standard in future vehicles, the demand for vehicles with driver assistance systems could also be awakened among younger drivers at an early stage due to the high benefits across all age groups. The use of technology as a matter of course is already standard in younger age groups.

In contrast to the existing literature (Gefen et al., 2003), the influence of ease of use on intention to use can only be partially confirmed in this study, and the influence is of similar importance for older and younger users. Ease of use is particularly important for the perceived usefulness of the assistance systems in the overall view (McCloskey, 2006), it is significantly more important for older people than for younger people and thus indirectly influences the acceptance. For the implementation of driver assistance systems in vehicles, this requires the usability of the human-machine interface to be designed in a particularly simple and straightforward way. This makes it much easier for drivers to absorb information - especially for older groups of people, information can be processed efficiently and decisions to act can be made quickly (Davis et al., 1989; van der Heijden, 2004). At the same time, a simple operation of driver assistance systems leads to driver assistance systems being required and established in vehicles.

The influence of the subjective norm on general acceptance tends to be important for both age groups. The influence on perceived usefulness is even more important for younger than for older persons (Zhang et al., 2012). Moreover, the test persons illustrate that the opinion of others and thus the opinion of society has a direct influence on the intention to use driver assistance systems (Bhattacherjee & Sanford, 2006; Neufeld et al., 2007). And at the same time, a positive view of society also increases the perceived usefulness. Hence, the success of driver assistance systems is not only a matter for the automobile manufacturers but also for the politics and culture of the countries. Political support and the demand for new technologies are therefore essential in order to achieve a broad diffusion and further development of the technology towards autonomous driving. There is no need for differentiation when addressing customer groups.

Furthermore, it was found that users trust in the technology has a major influence on the perceived usefulness and perceived ease of use of driver assistance systems (Choi & Ji, 2015; Tussyadiah et al., 2017). Trust was found to be similarly important for all user groups in the analysis in terms of usefulness and ease of use, but tended to be slightly higher among younger users. Trust in technology (just like in interpersonal relationships) can only be established through positive experiences and feedback with the systems. It is therefore essential to implement the systems in vehicles in order to give all kind of drivers the opportunity to experience these systems and have positive experiences with them. This concerns both manufacturers and the public sector, for example with systems in public transport. Especially in rental cars and car sharing vehicles, driver assistance systems are to be offered as standard in order to get to know and to value the advantages of usage of the technologies.

The proposed influence of personal innovativeness on intention to use, perceived usefulness and perceived ease of use can only be confirmed partially and to a limited extent. However, personal innovativeness has an influence on the acceptance of driver assistance systems (Lee, 2019; Wang et al., 2010) and for this reason more opportunities must be created for people in society to get in contact with new, promising technology in order to be able to recognise the usefulness for oneself. Finally, the influence of the personal innovativeness on the perceived usefulness and ease of use is slightly significant overall, but tends to be more important for the older demographic.

A moderating influence of income can be confirmed from the data only to a small extent in two cases (influence of subjective norm and personal innovativeness on intention to use) and is higher for people with low income. The data therefore show that acceptance is not higher for older people with higher incomes than for younger people with lower incomes. Although older people generally have a higher income and are more likely to be able to finance the purchase of driver assistance systems (Günthner et al. 2021), younger people with lower incomes are also interested in driver assistance systems and would like to use them. Regardless of income, as traffic safety increases, the advantages of intelligent systems exceed their potential costs.

In summary and as a recommendation, all drivers must be granted the opportunity to experience new technologies. In particular the usefulness, ease of use and trust in driver assistance systems must be addressed for the customers. This can be achieved through marketing campaigns, public events and legal requirements, such as the mandatory integration of systems in vehicles of all kinds and should already be included in the standard configuration. Driver assistance systems that are easy to operate, easy to understand and promise an individually designed value proposition will be accepted.

5.5.2. Technology Acceptance in older age

Age as moderating effect can have an influence on the acceptance of driver assistance systems (Braun et al., 2019; Souders & Charness, 2016), but still requires further investigation. The general comparison of the older persons (50-90 years) with the younger ones (20-49 years), supports the made assumptions, thus age has a positive effect on acceptance. In further consideration, the age groups (50-59), (60-69) and (70-90) are examined more closely and compared with each other.

Across groups, the influences of trust and personal innovativeness on intention to use are not significant and are therefore negligible, as is the influence of personal innovativeness on perceived usefulness. Highest influence of perceived usefulness on acceptance is for the group of 60-69 followed by the group of 50-59-year-old and 70-90-year-old, which partly confirms that the perceived usefulness is more important for older people than for younger ones. The gap is likely to be due to the fact that the oldest group have been driving for many years and are used to driving without technical support. One reason for this could be that the 50-69-year-olds, in contrast to the 70-90-year-olds, are likely to still be in working life and therefore use their vehicles for both business and private purposes. In addition, the fact that 60-69-year-olds see a greater benefit in driver assistance systems could be due to the fact that they suffer from physical deficits more frequently than younger drivers, which are compensated for by the use of assistance systems and convey a pleasant, safe driving experience. Therefore, the oldest ones in particular must be specially addressed so that they can recognise the benefits of driver assistance systems for themselves to engage with them and use them. This can be, for example, with special courses offered for older people such as driver training or dealer-led familiarisation courses. Although the influence of perceived ease of use on intention to use was partially confirmed in this study, no differences were found in the older age groups. Therefore, driver assistance systems must be easy to operate at all times for all target groups of an older age. Moreover, ease of use has a positive effect on the perceived usefulness in the individual age groups. Consequently, the usefulness increases significantly due to easy usability.

For the age group (50-59), the influences of ease of use on perceived usefulness, subjective norm on perceived usefulness, and personal innovativeness on ease of use are most important when comparing the three age groups to each other. Most important for the 60-69 age group, however, are the influences of perceived usefulness on intention to use and trust on perceived usefulness. For the 70-90 age group, the influence of trust on the ease of use is the most important factor. For all age groups, the influence of ease of use on the perceived usefulness, the subjective norm on the intention to use (except for the 70-90 year olds) and the trust on perceived usefulness and ease of use remain important.

The trust of 70-90-year-olds in the simple operation and the usefulness of driver assistance systems needs to be strengthened in order to win over this age group as users in the long term. For them, the age-related question is whether they should give up participating in road traffic for safety reasons or whether they can continue to participate in road traffic by using driver assistance systems. As a well-funded customer group, they are economically able to afford the costs of purchasing assistive technology. The market could therefore easily satisfy the needs of this age group with a suitable value proposition and take economic advantage of the demographic shift towards an increasingly older and more mobile population with increased demand for mobility.

The youngest group values a simple operation of using driver assistance systems in daily use. For this reason, this group should be persuaded by a simple human-machine interface, as a result of which trust can also be further increased. This age group is influenced by the opinions of third parties and should therefore be addressed more strongly via social norms, for example through increased driving safety and a reduction in traffic accidents through the assistance systems.

For the 60-69 age group, the perceived usefulness as well as the trust in driver assistance systems is essential, which could, additionally, increase the usefulness of the system for this group. The primary goal for the success of driver assistance systems in the market among this age group must be to further develop and increase trust levels, so that the daily use of driver assistance systems and thus the acceptance of driver assistance systems becomes the norm. Further technological advances, such as autonomous driving, would subsequently be so obvious to this age group that they would probably accept them without hesitation.

In conclusion, driver assistance systems must be easy to operate, clearly understandable and helpful to the individual. This will either improve driving comfort, compensate for the physical deficits of older drivers, and/or increase safety in traffic. With the above combination as a value proposition, driver assistance systems and future autonomous driving can be ideally placed in the market, as the elderly at the same time have the necessary financial means to be able to provide themselves with systems that are useful to them. The benefits of driver assistance systems are thus becoming more and more internalized.

6. Conclusion and future work

On the road to autonomous driving, there are still many challenges to be solved, both technical or political. Driver assistance systems offer the opportunity to simplify the process and create broad acceptance in society toward autonomous driving.

In line with the technology acceptance model (Davis et al., 1989), we developed a research model to investigate the acceptance of driver assistance systems specifically among older people. We demonstrated that not only the known constructs of the TAM influence acceptance, but also trust in technology (Lee & See, 2004; Molnar et al., 2018) and personal innovativeness (Lee, 2019; Wang et al., 2010), whereby age moderates influence on acceptance (Alexandrakis et al., 2020; Martins et al., 2014). In comparison to many other studies that have focused on more simple assistance systems (Larue et al., 2015; Roberts et al., 2012; Xu et al., 2010), the results show that the driver assistance systems examined in this study, which can learn through artificial intelligence, receive broad acceptance, especially among older drivers. After all, these systems are experienced more positively by older people and can thus also increase the acceptance of automated driving. Artificial intelligence will make assistance systems more and more human in their information output and decision making about risk, making it easier for the human driver to accept the information as well as the decisions made by the systems leading to more informed decisions. With the help of these increasingly learning and intelligent systems, an even broader acceptance of driver assistance through automation can be achieved in the future. This can greatly simplify the adoption of autonomous driving once it is available to the general population, as the systems in autonomous vehicles are based on the fundamentals of driver assistance systems. The experience of intelligent driver assistance systems is therefore of great importance and for the reduction of prejudices against autonomous driving.

In the long term, the behaviour of target groups will change, so technology companies will have to deal with even more acceptance factors in the future in order to optimally address assistance systems and not develop the technology in isolation of, or far from their customers. Especially car manufacturers that present the simplest and yet most pragmatic solutions of driver assistance systems, not only for the elderly, will prevail in the market. In a supporting role, politics is needed to gain understanding among the broad mass of car drivers in order to enable the best possible platform for technical progress.

The following limitations should be considered when interpreting the results. The sample of the study refers only to the western part of Germany. Further research should try to cover a broader sample such as including different countries to identify geographical differences. In our study, subjects had the opportunity to learn about driver assistance systems in order to have the same baseline. Presumably, the majority of subjects enrolled in the study were interested in technology. Therefore, the task in the future will be to recruit people with little or no technical experience for further studies. Furthermore, it is recommended to examine and compare all age groups in society to better understand individual acceptance. It would be beneficial to study age in general and to differentiate between cognitive and chronological age in different ways (Yang & Shih, 2020). Another limitation can be seen in the acceptance model itself. Although the model is based on the technology acceptance model and is extended by relevant constructs on the basis of the literature, there may be further influencing factors that can affect the acceptance of driver assistance systems. This study should provide a starting point for further studies in this area, but should consider using other models such as the UTAUT in order to approach the topic from a different point of view. Moreover, future studies should focus on further influences such as psychological aspects or the life course of individuals (with their life events and their influence on behaviour) to complete the acceptance criteria (Elder 1994; Lanzendorf, 2003; van der Waerden et al., 2003). Another limiting factor is the choice of driver assistance systems. The study shows a tendency to evaluate safety-related systems differently from systems that serve comfort (Davidse, 2006). It would therefore be of great interest to extend and investigate the research to different assistance systems as well. The systems studied are only partially intelligent, which is why future research must focus more on self-learning driver assistance systems in combination with artificial intelligence, which are then able to perform a far-reaching risk assessment of the driver in real time or drive a vehicle autonomously, considering the entire traffic infrastructure including individual traffic risks based on traffic situations.

APPENDIX

Appendix 1

Table 18: Operationalization of the constructs

Construct	Item		References
Intention to Use	ITU_01	I will use the advanced driver assistance system	Davis et al. (1989); Davis et al. (1992); Venkatesh (2000); Venkatesh et al. (2003); Fishbein & Ajzen (2010)
	ITU_02	I can imagine having the advanced driver assistance system in my vehicle	
Subjective Norm	SN_01	People who are important to me would appreciate it if I used the advanced driver assistance system	Ajzen & Fishbein (1975); Taylor & Todd (1995); Venkatesh & Davis (2000); Venkatesh et al. (2003)
	SN_02	People who influence my behaviour would appreciate it if I used the advanced driver assistance system	
Perceived Ease of Use	PEOU_01	It would be easy for me to learn how to use the advanced driver assistance system	Davis (1989); Davis et al. (1992); Venkatesh et al. (2003)
	PEOU_02	I do not see any major problems in operating the advanced driver assistance system	
Personal Innovativeness	PERIN_01	I am interested in new products	Lee (2019); Königstorfer (2008); Rogers (2003); Parasuraman (2000)
	PERIN_02	I like to experiment with new information technologies	
	PERIN_03	I regularly keep an eye out for new products	
	PERIN_04	I am usually the one who informs others about new products	
Perceived Usefulness	PU_01	I think the advanced driver assistant system is a good idea	Ajzen & Fishbein (1975); Ajzen (1991); Davis (1989); Taylor & Todd (1995b); Venkatesh & Davis (2000); Venkatesh et al. (2003)
	PU_02	I think the advanced driver assistant system is useful	
Trust in Technology	TIT_01	The advanced driver assistance system is technically reliable	Gefen et al. (2003); Pavlou (2003); Saeed et al. (2003); Gefen (2004); McKnight et al. (2011)
	TIT_02	I can trust the advanced driver assistance systems	

Appendix 2

Item	Strongly agree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
I will use the **Adaptive Cruise Control**	o	o	o	o	o	o	o
I can imagine having the **Adaptive Cruise Control** in my vehicle	o	o	o	o	o	o	o
People who are important to me would appreciate it if I used the **Adaptive Cruise Control**	o	o	o	o	o	o	o
People who influence my behaviour would appreciate it if I used the **Adaptive Cruise Control**	o	o	o	o	o	o	o
It would be easy for me to learn how to use the **Adaptive Cruise Control**	o	o	o	o	o	o	o
I do not see any major problems in operating the **Adaptive Cruise Control**	o	o	o	o	o	o	o
I am interested in new products	o	o	o	o	o	o	o
I like to experiment with new information technologies	o	o	o	o	o	o	o
I regularly keep an eye out for new products	o	o	o	o	o	o	o
I am usually the one who informs others about new products	o	o	o	o	o	o	o
I think the **Adaptive Cruise Control** is a good idea	o	o	o	o	o	o	o
I think the **Adaptive Cruise Control** is useful	o	o	o	o	o	o	o
The **Adaptive Cruise Control** is technically reliable	o	o	o	o	o	o	o
I can trust the **Adaptive Cruise Control**	o	o	o	o	o	o	o

Figure 14: Pretest questionnaire

Appendix 3

Table 19: Cross-Traffic-Alert - Cross-Loadings

	ITU	PERIN	SN	TIT	PU	PEOU
ITU_01	**0,975**	0,284	0,491	0,629	0,790	0,570
ITU_02	**0,974**	0,287	0,498	0,579	0,777	0,517
TIT_01	0,578	0,342	0,533	**0,951**	0,617	0,430
TIT_02	0,603	0,303	0,530	**0,954**	0,650	0,429
SN_01	0,539	0,203	**0,968**	0,546	0,515	0,316
SN_02	0,421	0,194	**0,948**	0,522	0,414	0,308
PERIN_01	0,280	**0,896**	0,172	0,278	0,319	0,243
PERIN_02	0,290	**0,899**	0,194	0,307	0,332	0,235
PERIN_03	0,225	**0,867**	0,202	0,311	0,246	0,181
PERIN_04	0,206	**0,809**	0,154	0,285	0,246	0,155
PEOU_01	0,540	0,227	0,324	0,417	0,555	**0,904**
PEOU_02	0,444	0,197	0,250	0,381	0,490	**0,870**
PU_01	0,773	0,353	0,457	0,654	**0,976**	0,602
PU_02	0,796	0,299	0,500	0,644	**0,976**	0,551

Appendix 4

Table 20: Park Distance Control - Cross-Loadings

	ITU	PERIN	SN	TIT	PU	PEOU
PERIN_01	0,374	**0,895**	0,174	0,233	0,331	0,267
PERIN_02	0,377	**0,899**	0,179	0,229	0,347	0,253
PERIN_03	0,310	**0,870**	0,152	0,282	0,285	0,193
PERIN_04	0,288	**0,809**	0,09	0,263	0,239	0,127
ITU_01	**0,976**	0,354	0,489	0,56	0,816	0,526
ITU_02	**0,976**	0,413	0,501	0,546	0,808	0,508
TIT_01	0,579	0,292	0,461	**0,967**	0,619	0,438
TIT_02	0,505	0,254	0,449	**0,956**	0,543	0,365
SN_01	0,509	0,176	**0,975**	0,465	0,455	0,304
SN_02	0,477	0,167	**0,971**	0,456	0,413	0,283
PEOU_01	0,523	0,246	0,271	0,413	0,619	**0,937**
PEOU_02	0,455	0,216	0,290	0,363	0,550	**0,918**
PU_01	0,791	0,319	0,417	0,583	**0,977**	0,646
PU_02	0,835	0,367	0,456	0,604	**0,978**	0,591

Appendix 5

Table 21: Lane Departure Warning - Cross-Loadings

	ITU	PERIN	SN	TIT	PU	PEOU
TIT_02	0,476	0,219	0,548	**0,975**	0,539	0,386
TIT_01	0,505	0,217	0,510	**0,977**	0,541	0,413
SN_01	0,589	0,210	**0,987**	0,547	0,568	0,274
SN_02	0,545	0,221	**0,986**	0,521	0,563	0,278
PEOU_01	0,462	0,214	0,271	0,408	0,471	**0,936**
PEOU_02	0,422	0,226	0,250	0,354	0,469	**0,928**
PU_01	0,771	0,305	0,555	0,550	**0,979**	0,507
PU_02	0,813	0,313	0,568	0,534	**0,980**	0,481
PERIN_01	0,250	**0,885**	0,187	0,186	0,276	0,244
PERIN_02	0,278	**0,891**	0,212	0,233	0,313	0,230
PERIN_03	0,257	**0,880**	0,189	0,208	0,277	0,178
PERIN_04	0,232	**0,821**	0,168	0,140	0,219	0,158
ITU_01	**0,982**	0,271	0,559	0,503	0,808	0,480
ITU_02	**0,980**	0,306	0,570	0,483	0,778	0,451

REFERENCES

Adler, G. & Rottunda, S. (2006). Older adults' perspectives on driving cessation. *Journal of Aging Studies*, *20*, 227–235.

Agarwal, R., & Prasad, J. (1998). A conceptual and operational definition of personal innovativeness in the domain of information technology. *Information Systems Research*, *9*, 204–215.

Agarwal R. & Prasad J. A. (1999). Are individual differences germane to the acceptance of new information technologies?. *Decision Sciences*, *30*(2), 361-391.

Agarwal, R. (2000). Individual acceptance of information technology. In: R.W. Zmud (Hrsg.): *Framing the Domains of IT-Management*, Cincinnati, Pinnaflex, pp. 85-104.

Ajzen, I. & Fishbein M. (1980). Understanding Attitudes and Predicting Social Behavior, Englewood Cliffs, Prentice-Hall.

Alberti, C. F., Shahar, A., & Crundall, D. (2014). Are experienced drivers more likely than novice drivers to benefit from driving simulations with a wide field of view? *Transportation Research Part F: Traffic Psychology and Behaviour*, *27*, 124–132.

Alexandrakis, D., Chorianopoulos, K., & Tselios, N. (2020). Older Adults and Web 2.0 Storytelling Technologies: Probing the Technology Acceptance Model through an Age-related Perspective. *International Journal of Human–Computer Interaction*, 1–13.

Allgemeiner Deutscher Automobil-Club (2018). *Ältere Kraftfahrer. Besser als ihr Ruf.* [online] https://www.adac.de/-/media/pdf/dko/senioren-am-steuer_adac-position.pdf?la=de-de&hash=52EC32DE812E85BA9C7B1E2A31E3A76E (Accessed 22 December 2020)

Anderson, J.M., Nidhi, K., Stanley, K.D., Sorensen, P., Samaras, C. & Oluwatola, O.A. (2014). *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation.

Arning, K., & Ziefle, M. (2007). Understanding age differences in PDA acceptance and performance. *Computers in Human Behavior*, *23*(6), 2904-2927.

Ashendorf, L., & McCaffrey, R. J. (2008). Exploring age-related decline on the Wisconsin Card Sorting Test. *Clinical Neuropsychologist*, *22*, 262–272.

Bagozzi, R.P. & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, *16*(1), 74-94.

Bekiaris, E., & Stevens, A. (2005). Common risk assessment methodology for advanced driver assistance systems. *Transport Reviews*, *25*(3), 283–292.

Bella, F., & Silvestri, M. (2017). Effects of directional auditory and visual warnings at intersections on reaction times and speed reduction times. *Transportation Research Part F: Traffic Psychology and Behaviour*, *51*, 88–102.

Beller, J., Heesen, M., & Vollrath, M. (2013). Improving the driver–automation interaction: An approach using automation uncertainty. *Human factors*, *55*(6), 1130-1141.

Bengler, K., Dietmayer, K., Farber, B., Maurer, M., Stiller, C., & Winner, H. (2014). Three Decades of Driver Assistance Systems: Review and Future Perspectives. *IEEE Intelligent Transportation Systems Magazine, 6*(4), 6–22.

Bhattacherjee, A. & Sanford, C. (2006). Influence Process for Information Technology Acceptance: An Elaboration Likelihood Model, *MIS Quartertly, 30*(4), 805-825.

Bigné-Alcañiz, E., Ruiz-Mafé, C., Aldás-Manzano, J., & Sanz-Blas, S. (2008). Influence of online shopping information dependency and innovativeness on internet shopping adoption. *Online Inf. Rev., 32*, 648-667.

Borowsky, A., & Oron-Gilad, T. (2013). Exploring the effects of driving experience on hazard awareness and risk perception via real-time hazard identification, hazard classification, and rating tasks. *Accident Analysis and Prevention, 59*, 548–565.

Brand, M. & Markowitsch, H.J. (2010): Aging and decision-making: a neurocognitive perspective. *Gerontology, 56*, 319-324.

Braun, H., Gärtner, M., Trösterer, S., Akkermans, L. E., Seinen, M., Meschtscherjakov, A., & Tscheligi, M. (2019). Advanced driver assistance systems for aging drivers: Insights on 65+ drivers' acceptance of and intention to use ADAS. *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Utrecht, 123-133.

Brooks, J. O., Goodenough, R. R., Crisler, M. C., Klein, N. D., Alley, R. L., Koon, B. L., Logan, W. C., Ogle, J., Tyrrell, R. A. & Wills, R. F. (2010). Simulator sickness during driving simulation studies. *Accident Analysis & Prevention, 42*(3), 788-796.

Brunsbach S. (2018). Demographischer Wandel – Megatrend des 21. Jahrhunderts. Politische Parteien in Zeiten des demographischen Wandels. *Empirische Studien zur Parteienforschung*. Springer VS, Wiesbaden.

Burghard, E. (2005). *Fahrkompetenz im Alter - Die Aussagekraft diagnostischer Instrumente bei Senioren und neurologischen Patienten*. Dissertation, Ludwig-Maximilian-Universität München.

Carr, M. (2008). Adoption and diffusion of Internet banking. In: V. Ravi (Hrsg.): *Advances in Banking Technology and Management*, New York, Hershey, pp. 33-52.

Charlton, J. L., Catchlove, M., Scully, M., Koppel, S., & Newstead, S. (2013). Older driver distraction: A naturalistic study of behaviour at intersections. *Accident Analysis & Prevention*. *58*, 271–278.

Chen, C.-F. & Chen, P.-C., (2011). Applying the TAM to travelers' usage intentions of GPS devices. *Expert Syst. Appl., 38*(5), 6217–6221.

Chin, W.W. (1998). The Partial Least Squares Approach to Structural Equation Modeling, In: G.A. Marcoulides (Hrsg.): *Modern Methods for Business Research*, Mahwah, Lawrence Erlbaum, 295-336.

Choi, J. K., & Ji, Y. G. (2015). Investigating the importance of trust in adopting an autonomous vehicle. *International Journal of Human-Computer Interaction, 31*, 692–702.

Chung, J. E., Park, N., Wang, H., Fulk, J., & McLaughlin, M. (2010). Age differences in perceptions of online community participation among non-users: An extension of the Technology Acceptance Model. *Computers in Human Behavior*, *26*(6), 1674-1684.

Clarke, D. D., Ward, P., Bartle, C., & Truman, W. (2010). Older drivers' road traffic crashes in the UK. *Accident Analysis & Prevention*, *42*(4), 1018–1024.

Crundall, D. (2016). Hazard prediction discriminates between novice and experienced drivers. *Accident Analysis and Prevention*, *86*, 47–58.

Davidse, R. (2006). Older drivers and ADAS. *IATSS Research*, *30*(1), 6–20.

Davis, F.D. (1989): Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, *MIS Quarterly*, *13*(3), 319- 340.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models, *Journal of Management Science*, *35*(8), 982-1003.

Dickerson A. E., Molnar L.J. & Eby D.W. (2004). Transportation and aging: a research agenda for advancing safe mobility. *Gerontology*, *47*(5), 578-590.

Dillon, A. & Morris, M.G. (1996). User acceptance of information technology: Theories and models, *Annual Review of Information Science and Technology*, *31*(1), 3-32.

Dukic, T., & Broberg, T. (2012). Older drivers' visual search behaviour at intersections. *Transportation Research Part F: Traffic Psychology and Behaviour*, *15*(4), 462–470.

Duncan, M., Charness, N., Chapin, T., Horner, M., Stevens, L., Richard, A., Souders, D., Crute, J., Riemondy, A. & Morgan, D. (2015). *Enhanced mobility for aging populations using automated vehicles*. [online]: http://www.dot.state.fl.us/researchcenter/Completed_Proj/Summary_PL/FDOT-BDV30-977-11-rpt.pdf (Accessed 23 December 2020)

Eby, D.W. & Molnar, L.J. (2012). *Has the Time Come for an Older Driver Vehicle?*. [online] https://www.aaafoundation.org/sites/default/files/SeniorsAndSelfRegulation Report.pdf (Accessed 23 December 2020).

Engeln, A. (2001). *Aktivität und Mobilität im Alternsprozess*. Aachen: Shaker.

Elder Jr, G. H. (1994). *Time, human agency, and social change: Perspectives on the life course*. Social psychology quarterly, pp. 4-15.

Escobar-Rodriguez, T., & Bartual-Sopena, L. (2013). The roles of users' personal characteristics and organisational support in the attitude towards using ERP systems in a Spanish public hospital. *Health Information Management Journal*, *42*(1), 18-28.

European Commission (2018). Silver Economy Study: How to stimulate the economy by hundreds of millions of Euros per year. [online] http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=50754 (Accessed 23 December 2020)

Fagan, M. H., Neill, S. & Wooldridge, B.R. (2008). Exploring the Intention to Use Computers: an Empirical Investigation of the Role of Intrinsic Motivation, Extrinsic Motivation and Perceived Ease of Use, *Journal of Computer Information Systems*, *48*(3), 31-37.

Fagnant, D.J. & Kockelman, K., (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transport. Res. A: Pol. Pract.*, *77*, 167–181.

Fishbein, M. & Ajzen, I. (2010). *Predicting and changing behavior. The reasoned action approach*. New York: Psychology Press.

Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J. & Sharit, J. (2009). *Designing for older adults: principles and creative human factors approaches*, 2. Auflage, Boca Raton: CRC Press.

Fonda, S.J., Wallace, R.B. & Herzog, A.R. (2001). Changes in driving patterns and worsening depressive symptoms among older adults. *Journal of Gerontology: Social Sciences*, *56*(6), 343–351.

Fornell, C. & Larcker, D.F. (1981). Evaluation structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 39–50.

Foxall, G., Goldsmith, R. E. & Brown, S. (1998). *Consumer psychology for marketing* (2nd ed). International Thomson Business Press, London; Boston

Gefen, D., Karahanna, E. & Straub, D. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly, 27*(1), 51–90.

Gefen, D. & Straub, D.W. (1997). Gender Differences in the Perception and Use of E-Mail: An Extention to the Technology Acceptance Model. *MIS Quarterly, 21*(4), 389-400.

Ghazizadeh, M., Peng, Y., Lee, J.D. & Boyle, L.N. (2012). Augmenting the Technology Acceptance Model with Trust: Commercial Drivers' Attitudes towards Monitoring and Feedback. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*(1), 2286–2290.

Ghazizadeh, M.; Lee, J. D. (2014). Modeling Driver Acceptance: From Feedback to Monitoring and Mentoring Systems. In Regan, M. A.; Horberry, T.; Stevens, A. (Eds.), *Driver Acceptance of new Technology: theory, measurement and optimization*, Ashgate Publishing, UK, 51–70.

Gruyer, D., Magnier, V., Hamdi, K., Claussmann, L., Orfila, O., & Rakotonirainy, A. (2017). Perception, information processing and modeling: Critical stages for autonomous driving applications. *Annual Reviews in Control*, *44,* 323–341.

Günthner, T., Proff, H., Jovic, J. & Zeymer, L. (2021). Tapping into Market Opportunities in Aging Societies – the example of advanced drive assistance systems in the transition to autonomous driving. *Journal of Automotive Technology and Management*, *21*(2).

Guo, X., Zhang, X., & Sun, Y. (2016). The privacy–personalization paradox in mHealth services acceptance of different age groups. *Electronic Commerce Research and Applications, 16,* 55–65.

Hair, J. F., Hult, G. T. M., Ringle, C. M. & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2 ed.). Thousand Oaks, CA: Sage.

Hair, J. F., Sarstedt, M., Ringle, C. M. & Gudergan, S. P. (2018). *Advanced Issues in Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Thousand Oaks, CA: Sage.

Hauk, N., Hüffmeier, J., & Krumm, S. (2018). Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Computers in Human Behavior*, *84*, 304–319.

Haustein, S. & Siren, A. (2014). Seniors' unmet mobility needs – how important is a driving licence?. *Journal of Transport of Geography, 41*, 45–52.

Henseler, J., Ringle, C. M. & Sinkovics, R. R. (2009). The Use of Partial Least Squares Path Modeling in International Marketing. *Advances in International Marketing, 20*, 277-320.

Herrenkind, B., Nastjuk, I., Brendel, A. B., Trang, S. & Kolbe, L. M. (2019). Young people's travel behavior – Using the life-oriented approach to understand the acceptance of autonomous driving. *Transportation Research Part D: Transport and Environment*, *74*, 214-233.

Hodzik, S., & Lemaire, P. (2011). Inhibition and shifting capacities mediate adults' age-related differences in strategy selection and repertoire. *Acta Psychologica*, *137*, 335–344.

Im, I., Kim, Y. & Han, H-J. (2007). The effects of perceived risk and technology type on users' acceptance of technologies. *Journal of Information & Management*, *45*(1), 1-9.

Isabelle, M.-P., & Simon, M. (2020). Comparison between elderly and young drivers' performances on a driving simulator and self-assessment of their driving attitudes and mastery. *Accident Analysis & Prevention*, *135*, 105317.

Jacoby, J. & Kaplan, L.B. (1972). The Components of Perceived Risk, *Proceedings of the Third Annual Conference of the Association for Consumer Research*, eds. M. Venkatesan, Chicago, IL : Association for Consumer Research, Pages: 382-393.

Jarvis, C.B., Mackenzie, S.B., Podsakoff, P.M., Mick, D.G. & Bearden, W.O. (2003). A critical review of construct indicators and measurement model misspecification in marketing and consumer research. *Journal of Consumer Research*, *30*(2), 199-218.

Jimoh, L., Pate, M. A., Lin, L., & Schulman, K. A. (2012). A model for the adoption of ICT by health workers in Africa. *International Journal of Medical Informatics*, *81*(11), 773-781.

Johnson, D. S. (2007). Achieving customer value from electronic channels through identity commitment, calculative commitment, and trust in technology. *Journal of Interactive Marketing*, *21*, 2–22.

Johnson, D. S., Bardhi, F., & Dunn, D. T. (2008). Understanding how technology paradoxes affect customer satisfaction with self-service technology: The role of performance ambiguity and trust in technology. *Psychology and Marketing*, *25*(5), 416-443.

Kaur, K. & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management*, *48*, 87-96.

Kazazi, J., Winkler, S., & Vollrath, M. (2015). Accident prevention through visual warnings: How to design warnings in head-up display for older and younger drivers. *IEEE 18th international conference on intelligent transportation systems*, 1028–1034).

Kervick, A.A., Hogan, M.J., O'Hora, D. & Sarma, K.M. (2015). Testing a structural model of young driver willingness to uptake Smartphone Driver Support Systems. *Acci. Anal. Preven*, *83*, 171–181.

King, W.R. & He, J. (2006). A meta-analysis of the technology acceptance model. *Inf. Manage.*, *43*, 740–755.

Klimczuk, A. (2016). Comparative analysis of national and regional models of the silver economy in the European Union. *International Journal of Ageing and Later Life*, *10*(2), 31-59.

Kline, D. W., Kline, T. J. B., Fozard, J. L., Kosnik, W., Schieber, F. & Sekuler, R. (1992). Vision, Aging, and Driving: The Problems of Older Drivers. *Journal of Gerontology*, *47*(1), 27–34.

Kohlbacher, F. & Herstatt, C. (2011): *The silver market phenomenon: Marketing and innovation in aging society*. Springer: Berlin, Heidelberg.

Koivumäki, T., Ristola, A. & Kesti, M. (2006): Predicting consumer acceptance in mobile services: Empirical evidence from an experimental end user environment. *International Journal of Mobile Communications, 4*(4), 418-435.

Koivumaki, T., Pekkarinen, S., Lappi, M., Vaisanen, J., Juntunen, J. & Pikkarainen, M. (2017). Consumer adoption of future mydata-based preventive ehealth services: An acceptance model and survey study. *J. Med. Internet Res.*, *19*, 1–15.

Koppel, S., Bohensky, M., Langford, J., & Taranto, D. (2011). Older Drivers, Crashes and Injuries. *Traffic Injury Prevention*, *12*(5), 459–467.

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior, *Information Systems Research*, *13*(2), 205-223.

Königstorfer, J. & Gröppel-Klein, A. (2007). Experiences of failure and anger when using the mobile and wired Internet: The interference of acceptance- and resistance-driving factors, *Marketing Journal of Research and Management*, *27*(1), 34-47.

Kraftfahrt-Bundesamt (2018). Bestand an allgemeinen Fahrerlaubnissen im ZFER am 1. Januar 2018 nach Geschlecht, Lebensalter und Fahrerlaubnisklassen. [online] https://www.kba.de/DE/Statistik/Kraftfahrer/Fahrerlaubnisse/Fahrerlaubnisbestand/2018/2018_fe_b_geschlecht_alter_fahrerlaubniskl.html?nn=2218648 (Accessed 23 December 2020)

Lankton, N., McKnight, D.H. & Thatcher, J.B. (2014). Incorporating trust-in-technology into Expectation Disconfirmation Theory. *Journal of Strategic Information Systems*, *23*, 128-145.

Lanzendorf, M. (2003). Mobility biographies. A new perspective for understanding travel behaviour. *Paper presented at the 10th International Conference on Travel Behaviour Research*, Lucerne, 10th–15th August.

Larsson, A. F. L. 2012. Driver usage and understanding of adaptive cruise control *Applied Ergonomics.43*, 501-506.

Larue, G.S., Rakotonirainy, A., Haworth, N.L. & Darvell, M. (2015). Assessing driver acceptance of Intelligent Transport Systems in the context of railway level crossings. *Transport. Res. Part F: Traff. Psychol. Behav., 30*, 1–13.

Lee, J. D. & Moray, N. (1992). Trust, control strategies, and allocation of function in human machine systems. *Ergonomics*, *22*, 671–691.

Lee, J. D. & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors*, *46*, 50–80.

Lee, M. S. (2019). Effects of personal innovativeness on mobile device adoption by older adults in South Korea: the moderation effect of mobile device use experience. *International Journal of Mobile Communications*, *17*(6), 682-702.

Legris, P., Ingham, J. & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model, *Journal of Information & Management*, *40*(3), 191-204.

Li, Y.-H. & Huang, J.-W. (2009). Applying Theory of Perceived Risk and Technology Acceptance Model in the Online Shopping Channel, *World Academy of Science, Engineering & Technology*, *53*(1), 919-925.

Limbourg, M. (1999). *Mobilität im Alter: Probleme und Perspektiven*. Vortrag bei der Fachtagung des Innenministeriums NRW „Seniorinnen und Senioren als Kriminalitäts- und Verkehrsunfallopfer. [online] http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-685/Seniorinfo.pdf (Accessed 20 December 2020)

Lu, J., Liu, C., Yu, C.S. & Wang, K. (2008). Determinants of accepting wireless mobile data services in China. *Information & Management*, *45*(1), 52–64.

Lubbe, N. (2017). Brake reactions of distracted drivers to pedestrian Forward Collision Warning systems. *Journal of Safety Research*, *61*, 23–32.

Ma, Q. & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing*, *16*(1), 59-73.

Mallenius, S., Rossi, M. and Tuunainen, V.K. (2007) Factors Affecting the Adoption and Use of Mobile Devices and Services by Elderly People - Results from a Pilot Study. *Proceedings of 6th Annual Global Mobility Roundtable*.

Martins, C., Oliveira, T., & Popovič, A. (2014). Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management*, *34*(1), 1-13.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *23*, 473–490.

McCloskey, D. W. (2006). The Importance of Ease of Use, Usefulness, and Trust to Online Consumers: An Examination of the Technology Acceptance Model with Older Customers. *Journal of Organizational and End User Computing*, *18*(3), 47-65.

McDonald, C. C., Seacrist, T. S., Lee, Y.-C., Loeb, H., Kandadai, V., & Winston, F. K. (2013). Headway time and crashes among novice teens and experienced adult drivers in a simulated lead truck braking scenario. *Proceedings of the Ellipsis International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design*, 439–445. [online] http://www.ncbi.nlm.nih.gov/pubmed/25197724 (Accessed 06 June 2021)

Meyer, J. (2004). *Personal Vehicle Transportation in Technology for Adaptive Aging*, edited by Richard Pew and Susan Van Hemel, The National Academies Press, Washington DC, 253–281.

Midgley, D. F. & Dowling, G. R. (1978). Innovativeness: the concept and its measurement. *Journal of Consumer Research*, *4*, 229–242.

Mitzner, T. L., Boron, J. B., Fausset, C. B., Adams, A. E., Charness, N., Czaja, S. J., Dijkstra, K., Fisk, A. D., Rogers, W. A. & Sharit, J. (2010). Older adults talk technology: Technology usage and attitudes. *Computers in Human Behavior, 26*(6), 1710-1721.

Molnar, L.J. & Eby, D.W. (2009). Getting around: meeting the boomers' mobility needs. In: Houston, R. (Ed.): *Boomer Bust?` Economic and Political Issues of the Graying Society*, Praeger Publishing, Westport, CT, Vol. 2.

Molnar, L.J., Eby, D.W., Charlton, J.L., Langford, J., Koppel, S., Marshall, S. & Man-Son-Hing, M. (2013). Driving avoidance by older adults: Is it always self-regulation?. *Accident Analysis and Prevention*, *57*, 96–104.

Molnar, L. J., Ryan, L. H., Pradhan, A. K., Eby, D. W. St. Louis, R. M. & Zakrajsek, J. S. (2018). Understanding trust and acceptance of automated vehicles: An exploratory simulator study of transfer of control between automated and manual driving. *Transportation Research Part F*, *58*, 319-328.

Morris, M. G. & Venkatesh, V. (2000). Age differences in technology adoption decisions: Implications for a changing work force. *Personnel Psychology*, *53*(2), 375-403.

Morris, M. G., Venkatesh, V. & Ackerman, P. L. (2005). Gender and age differences in employee decisions about new technology: An extension to the theory of planned behavior. *IEEE Transactions on Engineering Management*, *52*(1), 69-84

Musselwhite, C. & Haddad, H., (2018). Older people's travel and mobility needs: a reflection of a hierarchical model 10 years on. *Quality in Ageing and Older Adults*, *19*(2).

Naujoks, F. & Neukum, A. (2014). Specificity and timing of advisory warnings based on cooperative perception. In: *Mensch & computer workshopband*, 229–238.

Neufeld, D.J., Dong, L. & Higgins, C. (2007). Charismatic Leadership and User Acceptance of Information Technology, *European Journal of Information Systems*, *16*(4), 494-510.

Nitzl, C. (2010): Eine anwenderorientierte Einführung in die Partial Least Square (PLS)-Methode. In: Hansmann, K.-W. (Hrsg.): *Industrielles Management*, Arbeitspapier Nr. 21, Universität Hamburg.

OECD (2016). *OECD Science, Technology and Innovation Outlook*. [online] https://www.oecd.org/fr/sti/oecd-science-technology-and-innovation-outlook-25186167.htm (Accessed 23 December 2020).

Parasuraman, R. & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *39*(2), 230-253.

Parasuraman, R., Sheridan, T. B. & Wickens, C. D. (2008). Situation awareness, mental workload, and trust in automation: Viable, empirically supported cognitive engineering constructs. *Journal of Cognitive Engineering and Decision Making*, *2*(2), 140–60.

Park, E. & Kim, K.J. (2014). Driver acceptance of car navigation systems: integration of locational accuracy, processing speed, and service and display quality with technology acceptance model. *Perso. Ubiquitous Comput.*, *18*(3), 503–513.

Pavlou, P.A. (2003). Consumer acceptance of electronic commerce – integrating trust and risk with the technology acceptance model, *International Journal of Electronic Commerce*, *7*(3), 69-103.

Peine, A., Faulkner, A., Jaeger, B. & Moors, E. (2015). Science, Technology and the ‘Grand Challenge’ of Ageing: Understanding the Socio-material Constitution of Later Life. *Technological Forecasting and Social Change*, *93*, 1–9.

Porter, C. E. & Donthu, N. (2006). Using the technology acceptance model to explain how attitudes determine Internet usage: The role of perceived access barriers and demographics. *Journal of Business Research, 59*(9), 999-1007.

Rahman, M. M., Deb, S., Strawderman, L., Burch, R. & Smith, B. (2019). How the older population perceives self-driving vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour, 65*, 242–257.

Reagan, I.J., Cicchino, J.B., Kerfoot, L.B. & Weast, R.A. (2018). Crash avoidance and driver assistance technologies – are they used?. *Transp. Res. Part F Traffic Psychol. Behav.*, *52*, 176–190

Reimer, B., Donmez, B., Lavallière, M., Mehler, B., Coughlin, J. F. & Teasdale, N. (2013). Impact of age and cognitive demand on lane choice and changing under actual highway conditions. *Accident Analysis & Prevention*. *52*, 125–132.

Roberts, S.C., Ghazizadeh, M. & Lee, J.D. (2012). Warn me now or inform me later: drivers' acceptance of real-time and post-drive distraction mitigation systems. *Int. J. Hum. Comput. Stud.*, *70*(12), 967–979.

Rodel, C., Stadler, S., Meschtscherjakov, A. & Tscheligi, M. (2014). Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. *Paper Presented at the Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. Seattle, WA, USA.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G. & Edwards, J. D. (2003). Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors*, *45*(2), 218-233.

Rogers, E.M. (2003): *Diffusion of innovations*, 5. Aufl., New York, Free Press.

Ryu, M.H., Kim, S. & Lee, E. (2009). Understanding the factors affecting online elderly user’s participation in video UCC services. *Computers in Human Behavior, 25*, 619-632.

Sarstedt, M., Henseler, J. & Ringle, C. M. (2011). Multi-Group Analysis in Partial Least Squares (PLS) Path Modeling: Alternative Methods and Empirical Results. *Advances in International Marketing, 22*, 195-218.

Schepers, J. & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects, *Journal of Information & Management*, *44*(1), 90-103.

Schieber, F. (2006). Vision and aging. In Birren, J. E., Schaie, K. W. (Eds.), *Handbook of the Psychology of Aging*, 129-161. Amsterdam: Academic Press.

Schlag, B. (2008a): Älter werden und Auto fahren, *Report Psychologie*, *33*(2), 72-84.

Schlag, B. (2008b). Wie sicher sind die Älteren im Straßenverkehr?. In: B. Schlag (Hrsg.): *Leistungsfähigkeit und Mobilität im Alter*, Schriftenreihe Mobilität und Alter der Eugen-Otto-Butz-Stiftung, Bd. 3, Köln, TÜV Media, 19-36.

Schlag, B. (2013). Persönliche Veränderungen der Mobilität und der Leistungsfähigkeit im Alter. In: B. Schlag, K. J. Beckmann (Hrsg.): *Mobilität und demografische Entwicklung*, Schriftenreihe Mobilität und Alter der Eugen-Otto-Butz-Stiftung, Bd. 7, Köln, TÜV Media, S. 119-143.

Schlosser, A. E., White, T. B. & Lloyd, S. M. (2006). Converting Web site visitors into buyers: How Web site investment increases consumer trusting beliefs and online purchase intentions. *Journal of Marketing*, *70*, 133–148.

Schwarz, A. & Chin, W. (2007). Looking Forward: Toward an Understanding of the Nature and Definition of IT Acceptance, *Journal of the Association for Information Systems*, *8*(4), 230-243.

Schweig, S., Liebherr, M., Schramm, D., Brand, M. & Maas, N. (2018). The Impact of Psychological and Demographic Parameters on Simulator Sickness. *Proceedings of Simultech 2018*, 91-97.

Shaheen, S.A. & Niemeier, D.A. (2001). Integrating vehicle design and human factors: minimizing elderly driving constraints. *Transportation Research Part C*, *9*, 155–174.

Shergold, I., Lyons, G. & Hubers, C. (2015). *Future mobility in an ageing society – Where are we heading?. Journal of Transport and Health*, *2*, 86–94.

Shin, D. H. (2009). Understanding user acceptance of DMB in South Korea using the modified technology acceptance model. *International Journal of Human–Computer Interaction*, *25*(3), 173-198.

Simon, B. (2001). *E-Learning an Hochschulen. Gestaltungsräume und Erfolgsfaktoren von Wissensmedien*. Lohmar, Josef Eul.

Sivak, M. & Schoettle, B. (2011). Recent changes in the age composition of, U.S. drivers: implications for the extent, safety and environmental consequences of personal transportation. *Traffic Injury Prevention*, *12*(6), 588–592.

Souders, D. J. & Charness, N. (2016). Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles. Human Aspects of IT for the Aged Population. *Healthy and Active Aging*, 428-440.

Statistisches Bundesamt (2019a). *Bevölkerung Deutschlands bis 2060: Ergebnisse der 14. koordinierten Bevölkerungsvorausberechnung - Hauptvarianten 1 bis 9*. [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/bevoelkerung-deutschland-2060-5124202199014.pdf?__blob=publicationFile (Accessed 23 December 2020).

Statistisches Bundesamt (2019b): *Unfälle von Senioren im Straßenverkehr 2018.* [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/unfaelle-senioren-5462409187004.pdf?__blob=publicationFile (Accessed 23 December 2020).

Steele, R., Lo, Aa, Secombe, C. & Wong, Y.K. (2009). Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare. *International Journal of Medical Informatics, 78*(12);788-801.

Sullivan, J. M.; Flannagan, M. J.; Pradhan, A. K.; Bao, S. 2016. Literature Review of Behavioral Adaptation to Advanced Driver Assistance Systems. March 2016. *AAA Foundation for Traffic Safety*, Washington, DC.

Taylor, S. & Todd, P.A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research*, *6*(2), 145-176.

Trommsdorff, V. (2004): Nutzen und Einstellung. Über ein Konstrukt der Theorie des Konsumentenverhaltens. In: A. Gröppel-Klein (Hrsg.): *Konsumentenverhaltensforschung im 21. Jahrhundert*, Wiesbaden, Gabler, 479-500.

Trübswetter, N. & Bengler, K. (2013). Why should I use ADAS? Advanced driver assistance systems and the elderly: knowledge, experience and usage barriers. *Proceedings of 7th International Driving Symposium on Human Factors in Driver Assessment*, Training and Vehicle Design, University of Iowa, Bolton Landing, New York, USA, 495–501.

Tussyadiah, I., Zach, F.J. & Wang, J. (2017). Attitudes Toward Autonomous on Demand Mobility System: The Case of Self-Driving Taxi. *Information and Communication Technologies in Tourism, 17,* 24-26 Jan 2017, Rome, Italy.

van der Heiden, R. M., Janssen, C. P., Donker, S. F. & Merkx, C. L. (2019). Visual in-car warnings: How fast do drivers respond?. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*, 748-759.

van der Heijden, H., (2004). User Acceptance of Hedonic Information Systems. *MIS Quaterly*, *28*(4), 695-704.

van der Waerden, P., Timmermans, H. & Borgers, A. (2003). The Influence of Key Events and Critical Incidents on Transport Mode Choice Switching Behaviour: A Descriptive Analysis. *10th International Conference on Travel Behaviour Research*, 1–23.

Van Raaij, E.M. & Schepers, J.J.L. (2008). The acceptance and use of a virtual learning environment in China. *Computers & Education*, *50*(3), 838–852.

Venkatesh, V. & Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four longitudinal Field Studies, *Management Science*,*46*(2), 186-204.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Verberne, F.M.F.F., Ham, J. & Midden, C.J.H.H. (2012). Trust in smart systems: Sharing driving goals and giving information to increase trustworthiness and acceptability of smart systems in cars. *Human Factors*, *54*, 799–810.

Viktorova, L. & Sucha, M. (2018). Drivers' acceptance of advanced driver assistance systems – what to consider?. *Int. J. Traffic Transp. Eng.*, *8*, 320–333

Waller, P.F. (1991). The older driver. *Human Factors, 33*(5), 499-505.

Wan, H. & Larsen, L. (2014). *Older Americans With a Disability: 2008−2012*. [online] https://www. census.gov/content/dam/Census/library/publications/2 014/acs/acs-29.pdf (Accessed 22 December 2020).

Wang, Y. S., Wang, Y. M., Lin, H. H. & Tang, T. I. (2003). Determinants of user acceptance of internet banking: An empirical study. *International journal of service industry management*, *14*(5), 501-519.

Wang, Q.H. (2008). The effects of interface design about mobile phones on older adults' usage. *Proceedings of the 4th International Conference on Wireless Communications, Networking and Mobile Computing*; Dalian: WiCOM 2008, 1-4.

Wang, W. & Benbasat, I. (2005). Trust in and Adoption of Online Recommendation Agents. *Journal of the Association for Information Systems, 6*(3). 72-101.

Wang, C.Y., Chou, S.T. & Chang, H.C. (2010). Exploring an individual's intention to use blogs: the roles of social, motivational and individual factors. *Pacific Asia Conference on Information Systems*, PACIS 2010, Taipei, Taiwan, 1656–1663.

Weiber, R. & Mühlhaus, D. (2014). *Strukturgleichungsmodellierung. Eine anwendungsorientierte Einführung in die Kausalanalyse mit Hilfe von AMOS, SmartPLS und SPSS (2. ed.)*. Berlin, Heidelberg: Springer Gabler.

Werneke, J. & Vollrath, M. (2013). How to present collision warnings at intersections? A comparison of different approaches. *Accident Analysis & Prevention, 52,* 91–99.

Wickens, C. D. & Carswell, C. M. (2006). Information processing. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (3rd ed.). Hoboken, NJ: John Wiley & Sons.

Wu, J.-H. & Wang, S.-C. (2005). What drives mobile commerce? An empirical evaluation of the revised technology acceptance model. *Journal of Information & Management*, *42*(5), 719-729.

Wu, I.-L. & Wu, K.-W. (2005). A hybrid technology acceptance approach for exploring e-CRM adoption in organizations. *Behaviour & Information Technology, 24*(4), 303-316.

Wu, K., Zhao, Y., Zhu, Q., Tan, X. & Zheng, H. (2011). A meta-analysis of the impact of trust on technology acceptance model: Investigation of moderating influence of subject and context type. *Int. J. Inf. Manage.*, *31*, 572–581.

Xu, C., Wang, W., Chen, J., Wang, W., Yang, C. & Li, Z. (2010). Analyzing travelers' intention to accept travel information. Transportation Research Record: Journal of the Transportation Research Board, *2156*(1), 93–100.

Yang, K.-C. & Shih, P.-H. (2020). Cognitive age in technology acceptance: at what age are people ready to adopt and continuously use fashionable products?. *Telematics and Informatics, 51,* 101400.

Yao, D.F., Qiu, Y.F., Du, Z.X., Ma, J.Q. & Huang, H. (2009). A survey of technology accessibility problems faced by older users in China. *Proceedings of the 2009 International Cross-Disciplinary Conference on Web Accessibility W4A*. New York: ACM, 2009,16-25.

Zarmpou, T., Saprikis, V., Markos, A. & Vlachopoulou, M. (2012). Modeling users' acceptance of mobile services. *Electronic Commerce Research*, *12*(2), 225-248.

Zhang, L., Zhu, J. & Liu, Q. (2012). A meta-analysis of mobile commerce adoption and the moderating effect of culture. *Computers in Human Behavior*, *28*(5), 1902–1911.

Zhang, T., Tao, D., Qu, X., Zhang, X., Zeng, J., Zhu, H. & Zhu, H. (2020). Automated vehicle acceptance in China: Social influence and initial trust are key determinants. Transportation Research Part C: Emerging Technologies, 112, 220–233.

Chapter 6: The Moderating Influence of Life Events on the Acceptance of Advanced Driver Assistance Systems in Aging Societies

Timo Günthner[1]

[1] Chair of General Business Administration & International Automotive Management, University of Duisburg-Essen, Duisburg, Germany

1. Introduction

In modern societies, the use of technologies will continuously increase in size and influence. A major challenge will be to integrate ongoing digitalization and technical progress into the everyday lives of all people as part of demographic change (European Commission, 2018; OECD, 2016; Peine et al., 2015). In this context, the acceptance of technology is a critical success factor in the implementation of technology in everyday life (Hu et al., 1999). Recent research results show that younger generations have a fundamental affinity for technology, enjoy using it and have a positive attitude toward new technology (Steele et al., 2009; Wang, 2008). 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).

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 (Molnar & Eby, 2009; Dickerson et al., 2007; Adler & Rottunda, 2006). 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 (Musselwhite & Haddad, 2018; Musselwhite, 2018; Musselwhite et al., 2015; Eby & Molnar, 2012; Edwards et al., 2009). 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 are many studies on this topic in research, but a clear and unambiguous statement on technology acceptance in old age is missing so far (Hauk et al., 2018). There is evidence that acceptance and use of technology is not only based on the ease of use or usefulness of the technology, but that in particular social and cultural aspects of elderly users can explain the acceptance or rejection of technologies

(Knowles & Hanson, 2018; Waycott et al., 2016; Mitzner et al., 2016; Chen & Chan, 2014).

Emerged from travel behavior research, the life-oriented approach seeks to provide a better understanding by implementing additional determinants and demographic factors into research models (Herrenkind et al., 2019; Alemi et al., 2018; 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 in particular is still largely unexplored. To address these gaps, we developed and extended a research model based on the Technology Acceptance Model. Based on the life course approach, we consider life events as external social factors that can have a moderating influence on the variables influencing acceptance. As a result, a questionnaire was developed to test the hypothesized causal relationships and moderating effect with a multi-group analysis. 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 of older people. This leads to a better understanding of the acceptance of technology in general and more specifically driver assistance systems, which provide an important basic understanding of mobility in an aging society.

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 methodology before Section 4 provides the results of the study. Section 5 deals with the discussion of the results and concludes with implications and limitation.

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 (Herrenkind et al., 2019; Zarmpou et al. 2012; Li & Huang, 2009; Im et al., 2007; Koivumäkiet al., 2006; Bhattacherjee & Sanford, 2006; van der Heijden, 2004; Gefen et al., 2003; Koufaris, 2002; Agarwal, 2000; Gefen & Straub 1997). 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 (Ma & Liu, 2004; Legris et al., 2003). TAM, in line with, 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 TAM 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; Steele et al., 2009; Ryu et al., 2009; Yao et al., 2009; Wang, 2008). 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 (Martins et al., 2014; Jimoh et al., 2012), while others postulate a negative or non-significant influence (Alexandrakis et al., 2020; Escobar-Rodriguez & Bartual-Sopena, 2013; Shin, 2009; Porter & Donthu, 2006). The meta-analysis by Hauk et al. (2018) sums up a rather negative influence of age on technology acceptance. More recently, the TAM has also been applied in acceptance research in the context of driver assistance systems (Kervick et al., 2015; Larue et al., 2015; Park & Kim, 2014; Rodel et al., 2014; Roberts et al., 2012; Ghazizadeh et al., 2012; Chen & Chen, 2011; Xu et al., 2010;). Souders & 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 driver assistance systems are highly adopted in the 65 and older age group.

The TAM is proven, robust, and the most influential model for investigating the acceptance of information technology (Koivumäki et al., 2017; Wu et al., 2011; Carr, 2008; Schepers & Wetzels, 2007; King & He, 2006). Therefore, we hypothesize the following:

$\mathbf{H_1}$: The greater the perceived usefulness, the greater the intention to use ADAS.

$\mathbf{H_2}$: The greater the perceived ease of use, the greater the intention to use ADAS.

$\mathbf{H_3}$: The greater the perceived ease of use, the greater the perceived usefulness of ADAS

$\mathbf{H_4}$: The greater the subjective norm, the greater the intention to use ADAS.

$\mathbf{H_5}$: 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, we add additional external variables and constructs to the model and extend it (Wu & Wang, 2005). We extend the model with 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 willingness to accept a new innovation earlier than others (Agarwal & Prasad, 1998).

Therefore, the following additional hypotheses arise:

$\mathbf{H_6}$: The greater the trust in ADAS, the greater intention to use ADAS.

$\mathbf{H_7}$: The greater the trust in ADAS, the greater the perceived usefulness.

$\mathbf{H_8}$: The greater the trust in ADAS, the greater the perceived ease of use.

$\mathbf{H_9}$: The greater the personal innovativeness, the greater the intention to use ADAS.

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

$\mathbf{H_{11}}$: 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 (Ryu et al., 2009; Elder, 1994). The beginning of life event research was initiated by the work of Lindemann (1944) in the 1940s, used in many areas of psychology (Montada, 2008; Jonas & Lebherz, 2005; Horlacher, 2000; Filipp, 1995), 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). Although the understanding of life events varies in the literature (Montada 2008; Filipp, 1995), 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).

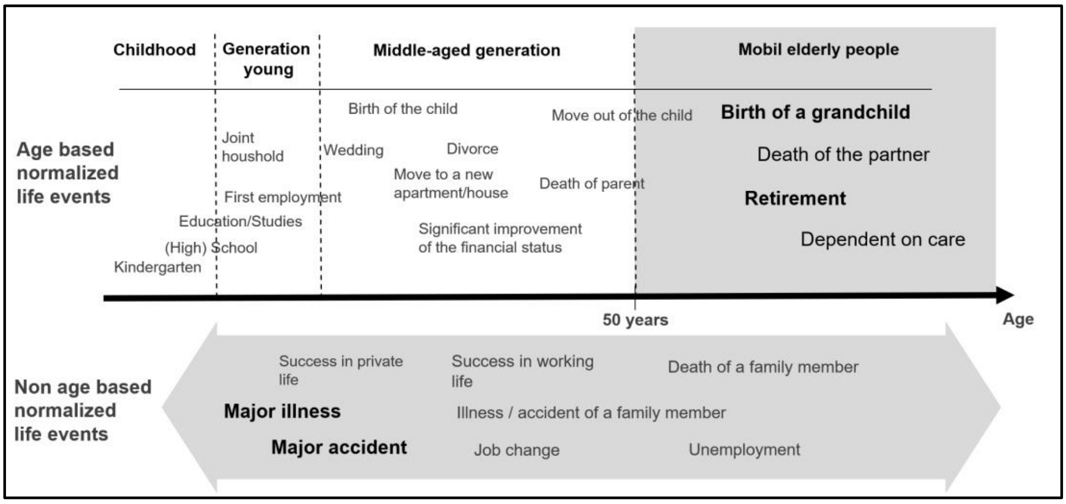

Figure 15: Life Events (based on Filipp, 2007)

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 lifetime 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 personal life that will trigger a process of reconsidering current behaviour” (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 occure unexpectedly (e.g. involvement in an accident). Despite different definitions of events in the literature which can influence and change behavior (Marsden & Docherty, 2013; Klöckner, 2005; van der Waerden et al., 2003), "key event" is the most common term within mobility biography research (Lanzendorf, 2010; Scheiner, 2007; van der Waerden et al., 2003; Lanzendorf, 2003). Other terms include "life (course) event" (Schäfer et al., 2012; De Groot et al., 2011; Klöckner, 2005), "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 (Herrenkind et al., 2019; Uteng et al., 2019; Wang et al., 2018; Clark et al., 2016; Schoenduwe et al., 2015; Müggenburg et al., 2015; Chatterjee & Scheiner, 2015; Scheiner, 2014; Scheiner & Holz-Rau, 2013; Beige & Axhausen 2012; Beige & Axhausen, 2008; Lanzendorf, 2003). Lanzendorf (2003) can examine how a new place of residence (and other changes in personal life) affect travel behavior. In addition, Beige & 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 & 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 partner, death of 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, we assume 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 (Figure 15) are used to investigate the influence of life events on acceptance and their influencing factors.

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.

$\mathbf{H_{12}}$: 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 conditions and thus in mobility behavior (Clark et al., 2014; Beige & Axhausen, 2012; 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.

$\mathbf{H_{13}}$: 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.

$\mathbf{H_{14}}$: 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.

$\mathbf{H_{15}}$: The life event "Major accident" moderates the influences that determine the intention to use ADAS.

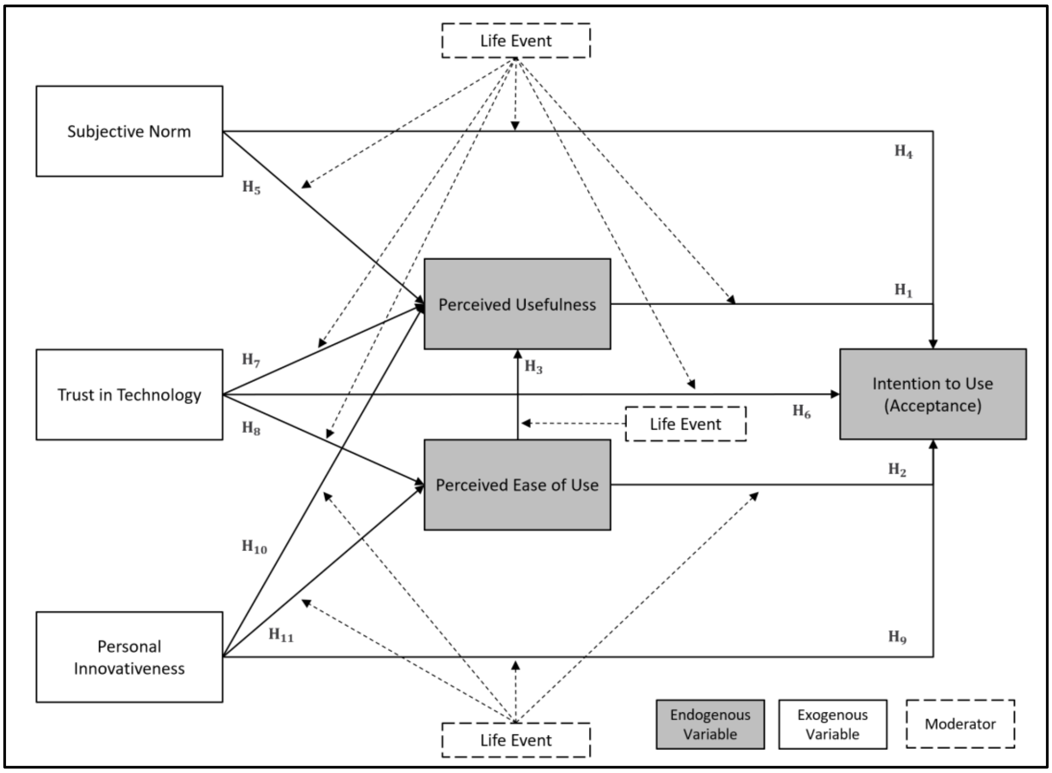

Figure 16: Acceptance model

3. Research Methodology

The moderating influence of life events on the acceptance of driver assistance systems 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 persons - generations over 50 years of age - and their suitability[5], a preliminary test was conducted in a driving simulator.

5 The subjects were tested for their fitness for the study on the basis of several medical tests and a test drive in the 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 (Schweig et al., 2018; Brooks et al., 2010; Roenker et al., 2003). 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 object of investigation, acceptance of driver assistance systems. The dependent variable acceptance (intention to use) was measured according to the TAM 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 28).

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 were generated in a period from August 2017 to September 2019[6] in the old federal states. All subjects were

[6] The pre-test with 381 subjects serves as the basis for the main study. From these 381 subjects, 181 over the age of 50 who participated in the main study remained at the end. All studies have been conducted in the period from the beginning of 2017 until the end of 2019.

invited and medically examined. They then drove in the driving simulator for approximately 45 minutes 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 22).

Table 22: 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

We use the PLS-SEM approach (Hair et al., 2017) due to the minimum sample size of N = 30 (Nitzl, 2010). For the PLS-based estimations, we use SmartPLS 3.2.8, 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, we use SPSS Statistics 23. 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, we will first test the measurement model and then the structural model (Weiber & Mühlhaus, 2014).

4.1. Measurement Model Assessment

In this study, reflective measurement models were operationalized based on the question cataolg 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 ($\sqrt{\mathrm{DEV}} \geq |\mathrm{KORR}\ \xi/\eta\ \mathrm{und}\ \xi/\eta\ |$) (Fornell & Lacrcker, 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 |±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).

Table 23: 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	0,953	**0,976**					
Personal Innovativeness	0,932	0,774	0,291	**0,880**				
Subjective Norm	0,955	0,914	0,519	0,223	**0,956**			
Trust	0,954	0,913	0,652	0,344	0,576	**0,956**		
Perceived Usefulness	0,975	0,951	0,812	0,312	0,493	0,679	**0,975**	
Perceived Ease of Use	0,873	0,774	0,581	0,271	0,369	0,513	0,619	**0,880**
Park Distance Control								
Acceptance	0,980	0,961	**0,980**					
Personal Innovativeness	0,932	0,774	0,399	**0,880**				
Subjective Norm	0,976	0,952	0,509	0,194	**0,976**			
Trust	0,958	0,919	0,580	0,310	0,482	**0,959**		
Perceived Usefulness	0,98	0,96	0,833	0,354	0,442	0,612	**0,980**	
Perceived Ease of Use	0,939	0,885	0,570	0,244	0,330	0,429	0,664	**0,941**
Lane Departure Warning								
Acceptance	0,981	0,963	**0,981**					
Personal Innovativeness	0,932	0,775	0,283	**0,880**				
Subjective Norm	0,987	0,975	0,574	0,222	**0,987**			
Trust	0,978	0,957	0,491	0,218	0,509	**0,978**		
Perceived Usefulness	0,979	0,958	0,816	0,314	0,552	0,518	**0,979**	
Perceived Ease of Use	0,921	0,854	0,471	0,240	0,305	0,407	0,538	**0,924**

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

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 29, Appendix 3: Table 20, Appendix 4: Table 21). 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 11).

4.2. Structural Model Assessment

Now the goodness 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 12). 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 Figure 17).

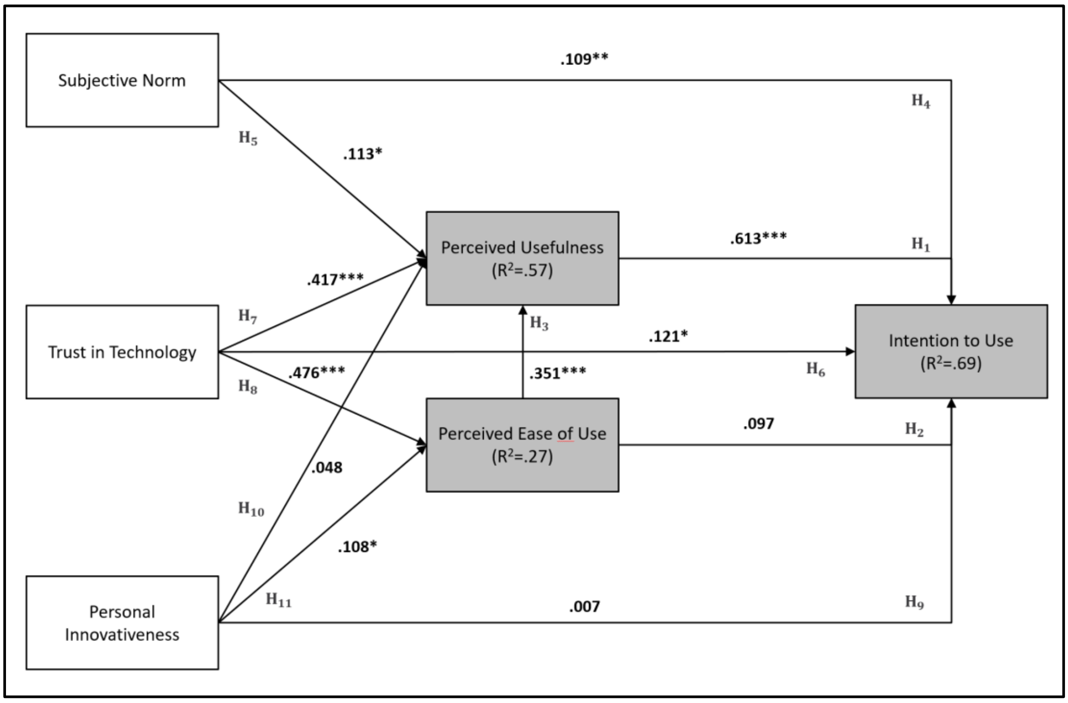

Figure 17: Structural model results - CTA

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 Figure 18).

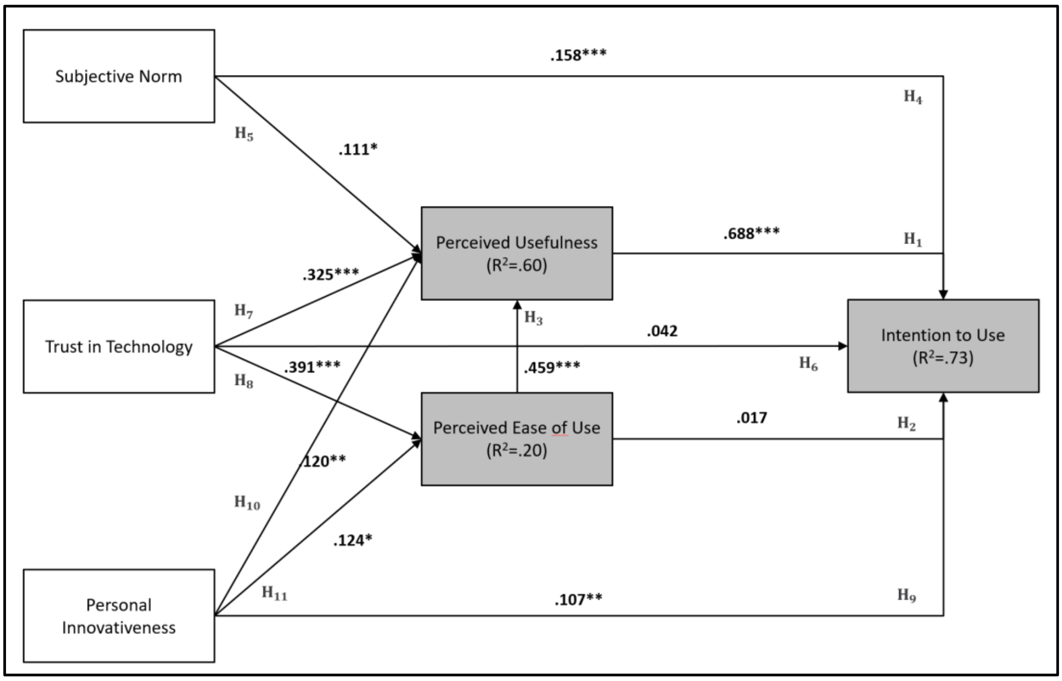

Figure 18: Structural model results – PDC

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 Figure 19).

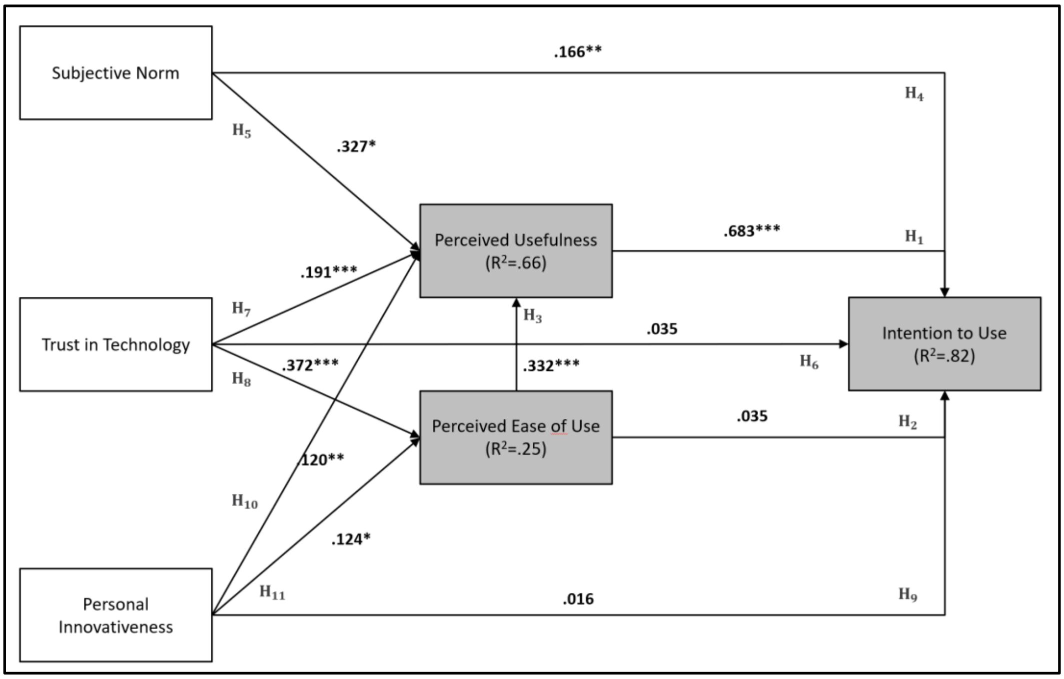

Figure 19: Structural model results - LDW

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 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, we performed a multigroup analysis. The moderating influence of life events is thereby tested by significant differences in path coefficients. For this purpose, we used the PLS-MGA approach integrated in SmartPLS (Hair et al., 2018). 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 (Sarstedt et al., 2011; Henseler et al., 2009).

4.3.1. Major illness

Table 24: 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

Note. *** p < .01; ** p < .05; * p < 0.10. 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.

Experiencing an illness leads to five significant differences in the cross-traffic alert. The influence between personal innovativeness and intention to use, subjective norm and intention to use, and 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 24).

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

Table 25: Results of the group analysis - Birth of a grandchild

	CTA			PDC			LDW		
	Grandchild	No grand-child	Grandchild - No grandchild	Grandchild	No grand-child	Grandchild - No grandchild	Grandchild	No grand-child	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 < 0.10. 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.

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 grandchild's and the influence of subjective norm on perceived usefulness is higher for probands with a grandchild (see Table 25).

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

Table 26: Results of the group analysis - Retirement

	CTA			PDC			LDW		
	retired	Not re-tired	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. *** $p < .01$; ** $p < .05$; * $p < 0.10$. 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.

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 26).

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

Table 27: 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 < 0.10. 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.

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 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 27).

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.

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.

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 (Lee, 2019; Tussyadiah et al., 2017; Choi & Ji, 2015; Wang et al., 2010)

The influence of perceived usefulness on the intention to use is by far the most important effect for the generation 50 and older among the determinants studied. Therefore, it is important to communicate the usefulness of driver assistance systems for future mobility. The high influence of perceived ease of use on perceived usefulness shows that users appreciate systems being easy to use and expect the system to work without any effort. Furthermore, the probands illustrate that the opinion of others, and thus the opinion of society, has a direct influence on the intention to use driver assistance systems. In this context, a positive opinion of society also increases perceived usefulness. The success of driver assistance systems is thus a reflection of the culture, 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, user 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.

Therefore, it is important to give older people the opportunity to experience, use and have positive feedback on these systems. This applies both to what is offered by manufacturers and to what is offered by the public sector, e.g., in the context of public transportation systems. 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 usefulness, ease of use, and confidence 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 effect on acceptance of driver assistance systems, but require more detailed 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, trust in 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 usefulness 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 offered assistance systems that minimize the risk of accidents and ensure a higher level of safety.

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. We observed 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 (Venkatesh et al, 2003; Venkatesh & Davis, 2000; Davis et al, 1989). This study has shown that life events are highly significant in terms of acceptance and can explain human behavior. Accordingly, it is essential to include life events as moderators or determinants within studies to investigate human behavior regarding the use of new technologies (acceptance).

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 courses and the evolving, differentiated needs of the subjects. The effect size of the respective determinants on the intention to use suggests the following practical implications to promote the acceptance of driver assistance systems and to prevent their rejection.

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, and 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.

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. Therefore, those who want to place assistance systems on the market should align their strategies with the self-interest of the respective participant groups in their marketing campaigns. 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 use 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 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 et al., 2020).

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 Germany 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 mainly people interested in technology registered for the study and are thus already very familiar with technology. In future studies, it should be considered to acquire test persons 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, which in our view can significantly influence 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.

APPENDIX

Appendix 1

Table 28: Operationalization of the constructs

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

Appendix 2

Table 29: 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 30: 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 31: 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 32: 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
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. *** $p < .01$; ** $p < .05$; * $p < 0.10$. 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.

REFERENCES

Adler, G. & Rottunda, S. (2006). Older adults’ perspectives on driving cessation. *Journal of Aging Studies*, *20*, 227–235.

Agarwal, R., & Prasad, J. (1998). A conceptual and operational definition of personal innovativeness in the domain of information technology. *Information Systems Research*, *9*, 204–215.

Agarwal, R. (2000). Individual acceptance of information technology. In: R.W. Zmud (Hrsg.): *Framing the Domains of IT-Management*, Cincinnati, Pinnaflex, pp. 85-104.

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process*, *50*, 179–211.

Ajzen, I. & Fishbein M. (1980). Understanding Attitudes and Predicting Social Behavior, Englewood Cliffs, Prentice-Hall.

Alexandrakis, D., Chorianopoulos, K., & Tselios, N. (2020). Older Adults and Web 2.0 Storytelling Technologies: Probing the Technology Acceptance Model through an Age-related Perspective. *International Journal of Human–Computer Interaction*, 1–13.

Alemi, F., Circella, G., Handy, S. & Mokhtarian, P. (2018). What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services in California. *Travel Behaviour and* Society, *13*, 88–104.

Allgemeiner Deutscher Automobil-Club (2018). *Ältere Kraftfahrer. Besser als ihr Ruf.* [online] https://www.adac.de/-/media/pdf/dko/senioren-am-steuer_adac-position.pdf?la=de-de&hash=52EC32DE812E85BA9C7B1E2A31E3A76E (Accessed 22 December 2020)

Arning, K., & Ziefle, M. (2007). Understanding age differences in PDA acceptance and performance. *Computers in Human Behavior*, *23*(6), 2904-2927.

Bagozzi, R.P. & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, *16*(1), 74-94.

Beige, S. & Axhausen, K.W. (2008). Long-term and mid-term mobility decisions during the life course: experiences with a retrospective survey. *IATSS Res*, *32*(2), 16–33.

Beige, S. & Axhausen, K.W. (2012). Interdependencies between turning points in life and long-term mobility decisions. *Transportation*, *39*(4), 857–872.

Bhattacherjee, A. & Sanford, C. (2006). Influence Process for Information Technology Acceptance: An Elaboration Likelihood Model, *MIS Quartertly*, *30*(4), 805-825.

Braun, H., Gärtner, M., Trösterer, S., Akkermans, L. E., Seinen, M., Meschtscherjakov, A., & Tscheligi, M. (2019). Advanced driver assistance systems for aging drivers: Insights on 65+ drivers' acceptance of and intention to use ADAS. *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Utrecht, 123-133.

Brooks, J. O., Goodenough, R. R., Crisler, M. C., Klein, N. D., Alley, R. L., Koon, B. L., Logan, W. C., Ogle, J., Tyrrell, R. A. & Wills, R. F. (2010). Simulator sickness during driving simulation studies. *Accident Analysis & Prevention*, *42*(3), 788-796.

Busch-Geertsema, A. & Lanzendorf, M. (2017). From university to work life–Jumping behind the wheel? Explaining mode change of students making the transition to professional life. *Transportation Research Part A: Policy and Practice*. *106*, 181–196.

Carr, M. (2008). Adoption and diffusion of Internet banking. In: V. Ravi (Hrsg.): *Advances in Banking Technology and Management*, New York, Hershey, pp. 33-52.

Chatterjee, K. & Scheiner, J. (2015). Understanding changing travel behaviour over the life course: Contributions from biographical research. *14th International Conference on Travel Behaviour Research*, pp. 19–23.

Chen, C.-F. & Chen, P.-C., (2011). Applying the TAM to travelers' usage intentions of GPS devices. *Expert Syst. Appl*., *38*(5), 6217–6221.

Chen, K., & Chan, A. H. S. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics*, *57*(5), 635–652.

Chin, W.W. (1998). The Partial Least Squares Approach to Structural Equation Modeling, In: G.A. Marcoulides (Hrsg.): *Modern Methods for Business Research*, Mahwah, Lawrence Erlbaum, 295-336.

Choi, J. K., & Ji, Y. G. (2015). Investigating the importance of trust in adopting an autonomous vehicle. *International Journal of Human-Computer Interaction*, *31*, 692–702.

Clark, B., Chatterjee, K. & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice*. *89*, 89–105.

Davis, F.D. (1989): Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, *MIS Quarterly*, *13*(3), 319- 340.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models, *Journal of Management Science*, *35*(8), 982-1003.

De Groot, C.D., Mulder, C.H., Das, M., Manting, D. (2011). Life events and the gap between intention to move and actual mobility. *Environ. Plan. A*, *43*(1), 48–66.

Dickerson A. E., Molnar L.J. & Eby D.W. (2007). Transportation and aging: a research agenda for advancing safe mobility. *Gerontology*, *47*(5), 578-590.

Dykstra, P.A. & van Wissen, L.J.G. (1999). Introduction: the life course approach as an interdisciplinary framework for population studies. *Population Issues: An Interdisciplinary Focus*, 1–22.

Eby, D.W. & Molnar, L.J. (2012). *Has the Time Come for an Older Driver Vehicle?*. [online] https://www.aaafoundation.org/sites/default/files/SeniorsAndSelfRegulation Report.pdf (Accessed 23 December 2020).

Edwards, J.D., Perkins, M., Ross, L.A. & Reynolds, S.L. (2009). Driving status and three-year mortality among community-dwelling older adults. *The Journals of Gerontology: Series A*, *64*(2), 300–305.

Elder Jr, G. H. (1994). *Time, human agency, and social change: Perspectives on the life course*. Social psychology quarterly, pp. 4-15.

Escobar-Rodriguez, T., & Bartual-Sopena, L. (2013). The roles of users' personal characteristics and organisational support in the attitude towards using ERP systems in a Spanish public hospital. *Health Information Management Journal, 42*(1), 18-28.

European Commission (2018). Silver Economy Study: How to stimulate the economy by hundreds of millions of Euros per year. [online] http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=50754 (Accessed 23 December 2020)

Filipp, S.-H. (Hrsg.). (1995). Kritische Lebensereignisse. Weinheim, Deutschland: Beltz.

Filipp, S.-H. (2007). Kritische Lebensereignisse. In J. Brandtstädter (Hrsg.), Entwicklungspsychologie der Lebensspanne. Ein Lehrbuch (S. 337–366). Stuttgart, Deutschland: Kohlhammer.

Fishbein, M. & Ajzen, I. (2010). *Predicting and changing behavior. The reasoned action approach*. New York: Psychology Press.

Fornell, C. & Larcker, D.F. (1981). Evaluation structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 39–50.

Gefen, D., Karahanna, E. & Straub, D. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly*, *27*(1), 51–90.

Gefen, D. & Straub, D.W. (1997). Gender Differences in the Perception and Use of E-Mail: An Extention to the Technology Acceptance Model. *MIS Quarterly*, *21*(4), 389-400.

Ghazizadeh, M., Peng, Y., Lee, J.D. & Boyle, L.N. (2012). Augmenting the Technology Acceptance Model with Trust: Commercial Drivers' Attitudes towards Monitoring and Feedback. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*(1), 2286–2290.

Gruyer, D., Magnier, V., Hamdi, K., Claussmann, L., Orfila, O., & Rakotonirainy, A. (2017). Perception, information processing and modeling: Critical stages for autonomous driving applications. *Annual Reviews in Control*, *44,* 323–341.

Günthner, T., Proff, H., Jovic, J. & Zeymer, L. (2021). Tapping into Market Opportunities in Aging Societies – the example of advanced drive assistance systems in the transition to autonomous driving. *Journal of Automotive Technology and Management*, *21*(1/2), 75-98.

Hair, J. F., Hult, G. T. M., Ringle, C. M. & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2 ed.). Thousand Oaks, CA: Sage.

Hair, J. F., Sarstedt, M., Ringle, C. M. & Gudergan, S. P. (2018). *Advanced Issues in Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Thousand Oaks, CA: Sage.

Hauk, N., Hüffmeier, J., & Krumm, S. (2018). Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Computers in Human Behavior*, *84*, 304–319.

Henseler, J., Ringle, C. M. & Sinkovics, R. R. (2009). The Use of Partial Least Squares Path Modeling in International Marketing. *Advances in International Marketing*, *20*, 277-320.

Herrenkind, B., Nastjuk, I., Brendel, A. B., Trang, S. & Kolbe, L. M. (2019). Young people's travel behavior – Using the life-oriented approach to understand the acceptance of autonomous driving. *Transportation Research Part D: Transport and Environment*, *74*, 214-233.

Hu, P. J., Chau, P. Y., Liu Sheng, O. R. & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine. *Journal of Management Information System*, *16*(2), 91–112.

Im, I., Kim, Y. & Han, H-J. (2007). The effects of perceived risk and technology type on users' acceptance of technologies. *Journal of Information & Management*, *45*(1), 1-9.

Jarvis, C.B., Mackenzie, S.B., Podsakoff, P.M., Mick, D.G. & Bearden, W.O. (2003). A critical review of construct indicators and measurement model misspecification in marketing and consumer research. *Journal of Consumer Research*, *30*(2), 199-218.

Jimoh, L., Pate, M. A., Lin, L., & Schulman, K. A. (2012). A model for the adoption of ICT by health workers in Africa. *International Journal of Medical Informatics*, *81*(11), 773-781.

Jonas, K., & Lebherz, C. (2005). Angewandte Sozialpsychologie. In K. Jonas, W. Stroebe, & M. Hewstone (Hrsg.), Sozialpsychologie - Eine Einführung. (S. 533–584). Heidelberg, Deutschland: Springer.

Kervick, A.A., Hogan, M.J., O'Hora, D. & Sarma, K.M. (2015). Testing a structural model of young driver willingness to uptake Smartphone Driver Support Systems. *Acci. Anal. Preven*, *83*, 171–181.

King, W.R. & He, J. (2006). A meta-analysis of the technology acceptance model. *Inf. Manage.*, *43*, 740–755.

Klöckner, C.A. (2005). Können wichtige Lebensereignisse die gewohnheitsmäßige Nutzung von Verkehrsmitteln verändern? – eine retrospektive Analyse. *Umweltpsychologie*, *9*, 28–45.

Knowles, B. & Hanson, V. L. (2018). The Wisdom of Older Technology (Non-) Users. *Communications of the ACM*, *61*(3), 72–77.

Koivumäki, T., Ristola, A. & Kesti, M. (2006): Predicting consumer acceptance in mobile services: Empirical evidence from an experimental end user environment. *International Journal of Mobile Communications*, *4*(4), 418-435.

Koivumaki, T., Pekkarinen, S., Lappi, M., Vaisanen, J., Juntunen, J. & Pikkarainen, M. (2017). Consumer adoption of future mydata-based preventive ehealth services: An acceptance model and survey study. *J. Med. Internet Res.*, *19*, 1–15.

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior, *Information Systems Research*, *13*(2), 205-223.

Königstorfer, J. & Gröppel-Klein, A. (2007). Experiences of failure and anger when using the mobile and wired Internet: The interference of acceptance- and resistance-driving factors, *Marketing Journal of Research and Management*, *27*(1), 34-47.

Lanzendorf, M. (2003). Mobility biographies. A new perspective for understanding travel behaviour. *Paper presented at the 10th International Conference on Travel Behaviour Research*, Lucerne, 10th–15th August.

Lanzendorf, M. (2010). Key events and their effect on mobility biographies: the case of childbirth. *International Journal of Sustainable Transportation*, *4*, 272–292.

Larue, G.S., Rakotonirainy, A., Haworth, N.L. & Darvell, M. (2015). Assessing driver acceptance of Intelligent Transport Systems in the context of railway level crossings. *Transport. Res. Part F: Traff. Psychol. Behav.*, *30*, 1–13.

Lazarus, R. S. (1990). Stress und Stressbewältigung - ein Paradigma. In S.-H. Filipp (Hrsg.), Kritische Lebensereignisse (S. 198–232). München, Deutschland: Beltz.

Lee, M. S. (2019). Effects of personal innovativeness on mobile device adoption by older adults in South Korea: the moderation effect of mobile device use experience. *International Journal of Mobile Communications*, *17*(6), 682-702.

Legris, P., Ingham, J. & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model, *Journal of Information & Management*, *40*(3), 191-204.

Li, Y.-H. & Huang, J.-W. (2009). Applying Theory of Perceived Risk and Technology Acceptance Model in the Online Shopping Channel, *World Academy of Science, Engineering & Technology*, *53*(1), 919-925.

Lindemann, E. (1944). Symptomatology and management of acute grief. *The American Journal of Psychiatry*, *101*, 141–148.

Ma, Q. & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing*, *16*(1), 59-73.

Martins, C., Oliveira, T., & Popovič, A. (2014). Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management*, *34*(1), 1-13.

Marsden, G. & Docherty, I. (2013). Insights on disruptions as opportunities for transport policy change. *Transport. Res. Part A: Policy Pract*, *51*, 46–55.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *23*, 473–490.

Mitzner, T. L., Boron, J. B., Fausset, C. B., Adams, A. E., Charness, N., Czaja, S. J., Dijkstra, K., Fisk, A. D., Rogers, W. A. & Sharit, J. (2010). Older adults talk technology: Technology usage and attitudes. *Computers in Human Behavior*, *26*(6), 1710-1721.

Molnar, L.J. & Eby, D.W. (2009). Getting around: meeting the boomers' mobility needs. In: Houston, R. (Ed.): *Boomer Bust?` Economic and Political Issues of the Graying Society*, Praeger Publishing, Westport, CT, Vol. 2.

Montada, L. (2008). Grundlagen der Entwicklungspsychologie. Fragen, Konzepte, Perspektiven. In R. Oerter, & L. Montada (Hrsg.), Entwicklungspsychologie (S. 3–48). Weinheim, Deutschland: Beltz.

Morris, M. G., Venkatesh, V. & Ackerman, P. L. (2005). Gender and age differences in employee decisions about new technology: An extension to the theory of planned behavior. *IEEE Transactions on Engineering Management*, *52*(1), 69-84

Müggenburg, H., Busch-Geertsema, A. & Lanzendorf, M. (2015). Mobility biographies: A review of achievements and challenges of the mobility biographies approach and a framework for further research. *Journal of Transport Geography*, *46*, 151–163.

Mulder, C.H. & Wagner, M. (1993). Migration and marriage in the life course: a method for studying synchronized events. *Eur. J. Popul.*, *9*, 55–76.

Musselwhite, C. & Haddad, H., (2018). Older people’s travel and mobility needs: a reflection of a hierarchical model 10 years on. *Quality in Ageing and Older Adults*, *19*(2).

Musselwhite, C. (2018). Mobility in later life and wellbeing. *Quality of Life and Daily Travel*, 235-251.

Musselwhite, C., Holland, C., & Walker, I. (2015): The role of transport and mobility in the health of older people. *Journal of Transport & Health*, *2*(1), 1–4.

Naujoks, F. & Neukum, A. (2014). Specificity and timing of advisory warnings based on cooperative perception. In: *Mensch & computer workshopband*, 229–238.

Nitzl, C. (2010): Eine anwenderorientierte Einführung in die Partial Least Square (PLS)-Methode. In: Hansmann, K.-W. (Hrsg.): *Industrielles Management*, Arbeitspapier Nr. 21, Universität Hamburg.

OECD (2016). *OECD Science, Technology and Innovation Outlook*. [online] https://www.oecd.org/fr/sti/oecd-science-technology-and-innovation-outlook-25186167.htm (Accessed 23 December 2020).

Park, E. & Kim, K.J. (2014). Driver acceptance of car navigation systems: integration of locational accuracy, processing speed, and service and display quality with technology acceptance model. *Perso. Ubiquitous Comput.*, *18*(3), 503–513.

Pavlou, P.A. (2003). Consumer acceptance of electronic commerce – integrating trust and risk with the technology acceptance model, *International Journal of Electronic Commerce*, *7*(3), 69-103.

Peine, A., Faulkner, A., Jaeger, B. & Moors, E. (2015). Science, Technology and the ‘Grand Challenge’ of Ageing: Understanding the Socio-material Constitution of Later Life. *Technological Forecasting and Social Change*, *93*, 1–9.

Porter, C. E. & Donthu, N. (2006). Using the technology acceptance model to explain how attitudes determine Internet usage: The role of perceived access barriers and demographics. *Journal of Business Research*, *59*(9), 999-1007.

Roberts, S.C., Ghazizadeh, M. & Lee, J.D. (2012). Warn me now or inform me later: drivers' acceptance of real-time and post-drive distraction mitigation systems. *Int. J. Hum. Comput. Stud.*, *70*(12), 967–979.

Rodel, C., Stadler, S., Meschtscherjakov, A. & Tscheligi, M. (2014). Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. *Paper Presented at the Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. Seattle, WA, USA.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G. & Edwards, J. D. (2003). Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors*, *45*(2), 218-233.

Rogers, E.M. (2003): *Diffusion of innovations*, 5. Aufl., New York, Free Press.

Ryu, M.H., Kim, S. & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC services. *Computers in Human Behavior*, *25*, 619-632.

SAE International (2016). Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. [online] https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles (Accessed 25 March 2021).

Sarstedt, M., Henseler, J. & Ringle, C. M. (2011). Multi-Group Analysis in Partial Least Squares (PLS) Path Modeling: Alternative Methods and Empirical Results. *Advances in International Marketing*, *22*, 195-218.

Schäfer, M., Jaeger-Erben, M. & Bamberg, S. (2012). Life events as windows of opportunity for changing towards sustainable consumption patterns?. *Journal of Consumer Policy*, *35*(1), 65–84.

Scheiner, J., 2007. Mobility biographies: elements of a biographical theory of travel demand. *Erdkunde*, *61*, 161–173.

Scheiner, J. (2014). The gendered complexity of daily life: Effects of life-course events on changes in activity entropy and tour complexity over time. *Travel Behav. Soc*, *1*, 91–105.

Scheiner, J. & Holz-Rau, C. (2013). A comprehensive study of life course, cohort, and period effects on changes in travel mode use. *Transportation Research Part A: Policy and Practice*, *47*, 167–181.

Schepers, J. & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects, *Journal of Information & Management*, *44*(1), 90-103.

Schoenduwe, R., Mueller, M.G., Peters, A. & Lanzendorf, M. (2015). Analysing mobility biographies with the life course calendar: a retrospective survey methodology for longitudinal data collection. *J. Transp. Geogr*, *42*, 98–109.

Schweig, S., Liebherr, M., Schramm, D., Brand, M. & Maas, N. (2018). The Impact of Psychological and Demographic Parameters on Simulator Sickness. *Proceedings of Simultech 2018*, 91-97.

Selye, H., 1984. The Stress of Life. McGraw-Hill, New York u.a..

Sharmeen, F., Arentze, T. & Timmermans, H. (2014). An analysis of the dynamics of activity and travel needs in response to social network evolution and life-cycle events: a structural equation model. *Transport. Res. Part A: Policy Pract, 59*, 159–171.

Shin, D. H. (2009). Understanding user acceptance of DMB in South Korea using the modified technology acceptance model. *International Journal of Human–Computer Interaction*, *25*(3), 173-198.

Simon, B. (2001). *E-Learning an Hochschulen. Gestaltungsräume und Erfolgsfaktoren von Wissensmedien*. Lohmar, Josef Eul.

Souders, D. J. & Charness, N. (2016). Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles. Human Aspects of IT for the Aged Population. *Healthy and Active Aging*, 428-440.

Statistisches Bundesamt (2019): *Unfälle von Senioren im Straßenverkehr 2018.* [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/unfaelle-senioren-5462409187004.pdf?__blob=publicationFile (Accessed 23 December 2020).

Steele, R., Lo, Aa, Secombe, C. & Wong, Y.K. (2009). Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare. *International Journal of Medical Informatics, 78*(12), 788-801.

Taylor, S. & Todd, P.A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research, 6*(2), 145-176.

Trommsdorff, V. (2004): Nutzen und Einstellung. Über ein Konstrukt der Theorie des Konsumentenverhaltens. In: A. Gröppel-Klein (Hrsg.): *Konsumentenverhaltensforschung im 21. Jahrhundert*, Wiesbaden, Gabler, 479-500.

Tussyadiah, I., Zach, F.J. & Wang, J. (2017). Attitudes Toward Autonomous on Demand Mobility System: The Case of Self-Driving Taxi. *Information and Communication Technologies in Tourism, 17*, 24-26 Jan 2017, Rome, Italy.

Uteng, T. P., Julsrud, T.E. & George, C. (2019). The role of life events and context in type of car share uptake: Comparing users of peer-to-peer and cooperative programs in Oslo, Norway. *Transportation Research Part D, 71*, 186-206.

van der Heijden, H., (2004). User Acceptance of Hedonic Information Systems. *MIS Quaterly*, *28*(4), 695-704.

van der Waerden, P., Timmermans, H. & Borgers, A. (2003). The Influence of Key Events and Critical Incidents on Transport Mode Choice Switching Behaviour: A Descriptive Analysis. *10th International Conference on Travel Behaviour Research*, 1–23.

Venkatesh, V. & Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four longitudinal Field Studies, *Management Science*,*46*(2), 186-204.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Wang, B., Rasouli, S., Timmermans, H. & Shao, C. (2018). Relationships between consecutive long-term and mid-term mobility decisions over the life course: a Bayesian network approach. *Transp. Res. Rec, 2672*, 159–170.

Wang, Q.H. (2008). The effects of interface design about mobile phones on older adults' usage. *Proceedings of the 4th International Conference on Wireless Communications, Networking and Mobile Computing*.

Wang, C.Y., Chou, S.T. & Chang, H.C. (2010). Exploring an individual's intention to use blogs: the roles of social, motivational and individual factors. *Pacific Asia Conference on Information Systems*, PACIS 2010, Taipei, Taiwan, 1656–1663.

Waycott, J., Vetere, F., Pedell, S., Morgans, A., Ozanne, E. & Kulik, L. (2016). Not for me: Older adults choosing not to participate in a social isolation intervention. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 745–757.

Weiber, R. & Mühlhaus, D. (2014). *Strukturgleichungsmodellierung. Eine anwendungsorientierte Einführung in die Kausalanalyse mit Hilfe von AMOS, SmartPLS und SPSS (2. ed.)*. Berlin, Heidelberg: Springer Gabler.

Wu, J.-H. & Wang, S.-C. (2005). What drives mobile commerce? An empirical evaluation of the revised technology acceptance model. *Journal of Information & Management*, *42*(5), 719-729.

Wu, K., Zhao, Y., Zhu, Q., Tan, X. & Zheng, H. (2011). A meta-analysis of the impact of trust on technology acceptance model: Investigation of moderating influence of subject and context type. *Int. J. Inf. Manage.*, *31*, 572–581.

Xu, C., Wang, W., Chen, J., Wang, W., Yang, C. & Li, Z. (2010). Analyzing travelers' intention to accept travel information. Transportation Research Record: Journal of the Transportation Research Board, *2156*(1), 93–100.

Yao, D.F., Qiu, Y.F., Du, Z.X., Ma, J.Q. & Huang, H. (2009). A survey of technology accessibility problems faced by older users in China. *Proceedings of the 2009 International Cross-Disciplinary Conference on Web Accessibility W4A*. New York: ACM, 2009,16-25.

Zarmpou, T., Saprikis, V., Markos, A. & Vlachopoulou, M. (2012). Modeling users' acceptance of mobile services. *Electronic Commerce Research*, *12*(2), 225-248.

Chapter 7: Summary, implications and outlook

7.1. Summary of the results

As stated in the introduction to this dissertation (Chapter 1), driver assistance systems can generate new market opportunities and sales potential for the automotive market, especially in the increasingly large customer group of older drivers with steadily growing purchasing power (DAT, 2018; Statistisches Bundesamt, 2019; Zentralverband Deutsches Kraftfahrzeuggewerbe, 2020). Therefore, there should be strong market opportunities for the introduction of advanced driver assistance systems in the international automotive market. This expectation is supported by increasing mobility, especially the increased mobility behavior of older road users in the 50+ age group. This age group has increasing problems moving safely in road traffic due to physical limitations. Driver assistance systems can compensate for this. Nevertheless, the success of assistance systems on the market falls far short of expectations.

There is a research gap regarding this market situation, because studies and scientific results of the willingness to pay of elderly persons for driver assistance systems are missing. As a result, research objective RO_1 aims to determine the willingness to pay for driver assistance systems in the 50+ age group.

Existing literature on measuring technology acceptance is guided by the approved acceptance models (Agarwal, 2000; Bhattacherjee & Sanford, 2006; Gefen et al., 2003; Gefen & Straub 1997; Herrenkind et al., 2019b; Im et al., 2007; Koivumäki et al., 2006; Koufaris, 2002; Li & Huang, 2009; van der Heijden, 2004; Zarmpou et al. 2012; Zhang et al., 2020), such as the TAM (Davis et al., 1989) or the UTAUT (Venkatesh et al., 2003). In terms of acceptance of driver assistance systems, few quantitative studies exist (Chen & Chen, 2011; Ghazizadeh et al., 2012; Kervick et al., 2015; Larue et al., 2015; Park & Kim, 2014; Rahman et al., 2019; Roberts et al., 2012; Rodel et al., 2014; Xu et al., 2010). However, purchasing behavior is influenced, among other factors, by acceptance toward the technology offered. Yet, the influencing factors as critical success factors to use a technology are unclear. These can be determined and analyzed by different models. Since no clear statement on technology acceptance in old age can be made in this context in the literature, research objective RO_2 sets out to determine the factors influencing the acceptance of driver assistance systems within different age groups.

Although the results do not allow any clear conclusions to be drawn about acceptance, they do show that there must be other factors influencing acceptance. The implementation of cultural and sociological aspects such as critical life events should further increase the explanatory power of acceptance. Moderating variables, such as inclusion of the group of older persons and life courses with their different life events, are hardly investigated in technology acceptance models (Braun et al., 2019; Souders & Charness, 2016); related to life courses, studies are not available at all. This results in research objective RO_3 with the development of an acceptance model to capture the moderating influences of life events on the factors influencing acceptance in the 50+ age group.

The stated research objectives of this dissertation are examined with the help of the theoretical approaches presented in chapter 2, after the theoretical foundations of willingness to pay (theory of intertemporal consumption), technology acceptance models and critical life events have been comprehensively presented

On the basis of these theoretical foundations, for the determination of the results of research objectives 1 to 3, the "Van Westendorp method" is used to investigate willingness to pay (van Westendorp, 1976). To measure the influence of age and critical life events on acceptance, two acceptance models are developed using structural equation modeling and tested for differences using multi-group analysis. To validate the results, t-tests with pre-specified error probabilities are used (see chapter 3).

The analysis of willingness to pay shows that a correlation between willingness to pay and age cannot be confirmed across the board (see Chapter 4). A closer look at the age groups reveals a significantly higher willingness to pay for four of the five systems (regarded parking assist, blind spot assist, lane departure warning and tire pressure monitoring systems) for the 60-69 and 70-90 age groups than for the 50-59 age group. Trends toward increased willingness to pay among the elderly were also observed for the fifth assistance system, cross-traffic assist, although not significantly. The established research objective RO_1 was achieved by the determined willingness to pay.

In order to obtain a reliable theoretical approach for measuring the acceptance of driver assistance systems, Chapter 5 identifies factors from the models already known in the literature that have an influence on the intention to use and develops an extended acceptance model from this. Due to its influencing factors, extensions and moderators, this model is able to generate valid results on the acceptance of three selected driver assistance systems (Cross Traffic Assist, Parking Assist and Lane Departure Warning) in the age groups presented. Using a quantitative survey and the analytical methodology of structural equation modeling (Hair et al., 2017; Weiber & Mühlhaus, 2014), results are obtained and the acceptance model is validated. With the exception of three influences that can be neglected in the overall analysis, all determinants and influences of the acceptance model are confirmed. After the evaluation, it can be seen that the influencing variables "perceived usefulness", "perceived ease of use" and "trust in technology" are significant in determining the level of acceptance. The higher the influence of these determinants, the greater the acceptance. As a result, the more useful and simpler a driver assistance system is to use and the more one trusts the system, the more willing drivers are to use a system. For the generations question, it remains to be determined after the evaluation that the benefit for old and young is equally high, but trust in technology and the opinion of the environment tends to be more important for younger people. On the other hand, the user-friendliness of the systems is more essential for the older generations. The established research objective RO_2 is achieved with the help of the acceptance model developed and with the inclusion of age as a moderator.

While chapter 5 examines the acceptance, influencing factors and age of different generations (20-90 years), chapter 6 deals with another behavioral approach of critical life events (Beige & Axhausen, 2012; de Groot et al., 2011; Elder, 1994; Lanzendorf, 2010; Marsden & Docherty, 2013; Ryu et al., 2009; Schäfer et al., 2012; Scheiner, 2007; Sharmeen et al., 2014; van der Waerden et al., 2003) and exclusively with the group of people 50 years and older in order to further increase the explanatory power of the original model. Therefore, in this chapter, the validity of this statement is analyzed on the basis of four selected life events (serious illness, birth of a child, retirement, and serious traffic accident) by means of a quantitative examination. The relationships of all determinants of the developed acceptance model are examined, considering the moderation of life events. The result states that the mentioned events have influence on the acceptance of driver assistance systems. For persons who have experienced the life event "serious illness", this is concretized in the fact that the benefit of and trust in a driver assistance system are particularly important. On the other hand, the "birth of a child" influences the behavior of this group of people in that trust and the opinion of the environment have a significant value in the intention to use a driver assistance system. The experience of "retirement" or a "serious traffic accident" increases the importance of trust in technology, especially in driver assistance systems. For the group of "retirees" the benefit and the simplicity of use are important at the same time. The latter influence is less important for the "accident victims" group. The personal environment also plays a lesser role for this group of users. Thus, critical life events also contain an explanatory contribution, as influencing factors on the acceptance of driver assistance systems in the 50+ age group. The established research objective RO_3 is achieved with the help of the developed acceptance model and with the inclusion of the critical life events as moderators.

7.2. Implications for research and practice

Based on the findings of this dissertation on the willingness to pay for driver assistance systems (research objective RO_1) and on the examined influencing factors of the acceptance of driver assistance systems in the group of people 50+ (research objective RO_2) and the critical life events (research objective RO_3), implications for research and for practice can be derived.

7.2.1. Implications for research

Based on research objective RO_1, the willingness to pay for driver assistance systems for the group 50+ is determined from the theoretical foundations and the results are validated with the help of quantitative data. The results of this study show that older drivers are willing to pay for driver assistance systems and are thus in line with previous research findings.

The study by Arndt (2011), which examines the parking assistant and the rain sensor among other assistance systems, establishes a willingness to pay for these assistance systems. Parallels to the present study (chapter 4) exist insofar as a price range of 200-500€ is determined for the parking assistant, which almost coincides with the results of this study. In both Arndt (2011) and the present study, the price range was based on the prices actually existing on the market, which the survey participants may already have known. Blythe & Curtis (2004) also note a willingness to pay for driver assistance systems, although they classify this as rather low. For the assistance systems studied, parking assist, lane departure warning, cruise control, etc., a willingness to pay with a price range of up to $500 was determined by Blythe

& Curtis (2004) despite the rather low willingness to pay. As a result, this study also corresponds to the price range of the present study. For the other assistance systems examined in this study, a similar price range is found for the respective driver assistance system.

In comparison to the previous studies (Arndt, 2011; Blythe & Curtis, 2004), this study focuses on older drivers (age group 50+) as the research object and their willingness to pay. Comparable studies are not yet available, since research has so far regularly examined only the willingness to pay for driver assistance systems in general. The work thus represents a first tendency for the special groups of people 50+, which must be examined more closely and differentiated by further investigations. For example, the price range or a specific absolute willingness to pay could be examined in more detail, and specific age limits could be determined from which the willingness to pay increases or decreases. The results of this work can therefore be used as a basis for future research and show a first tendency. A consistent verification of the assumption that willingness to pay for driver assistance systems increases with age is urgently needed for valid confirmation of the said assumption. In order to better reflect the reasons for the willingness to pay, further research approaches need to be generated at this point and verified by studies using conjoint analyses. As an example, the high income in old age could be causal for the willingness to pay, which could not be confirmed in this study. The causes of the further result of the study, that the willingness to pay of drivers does not increase with increasing experience and product knowledge, would have to be examined in more detail.

As a result of the research objective RO_2, the determinants of perceived usefulness, perceived ease of use, subjective norm, personal innovativeness, and trust can be confirmed as key factors influencing the acceptance of driver assistance systems (Braun et al., 2019; Chen & Chen, 2011; Ghazizadeh et al, 2012; Kervick et al, 2015; Larue et al, 2015; Park & Kim, 2014; Rahman et al, 2019; Roberts et al, 2012; Rodel et al, 2014; Souders & Charness, 2016; Xu et al, 2010). Following the constructs of the various technology acceptance models related in the literature, the determinants have been taken from the literature and reviewed to determine technology acceptance. Therefore, the results gained with this dissertation (Chapter 5) basically match the results of the research due to the congruence of the research method (Chen & Chen, 2011; Ghazizadeh et al., 2012; Kervick et al., 2015; Larue et al., 2015; Park & Kim, 2014; Rahman et al., 2019; Roberts et al., 2012; Rodel et al., 2014; Xu et al., 2010). This is because the influencing factors mentioned in the literature also have a significant impact on acceptance. However, gradual differences arise when considering the influence of the determinants on the acceptance of driver assistance systems, because the individual determinants can have a different significance for the respective user depending on the object of investigation.

The result of this work also agrees with the view represented in the literature that human acceptance behavior in the group of people 50+ is characterized and influenced by the determinants mentioned above (e.g. Braun et al., 2019). In contrast to Hauk et al. (2018), this work determines a generally high acceptance for driver assistance systems and thereby diverges considerably from the results of the research.

As a contribution to future research, these findings imply a closer look at the degree of individual influence of each determinant for drivers. In this context, the individual usefulness of the technology to the driver is determined using perceived usefulness (Braun et al., 2019; Park & Kim, 2014; Rahman et al., 2019). To get a more detailed understanding of the perceived usefulness, the background of the perceived usefulness, or the way it is used, for the individual user needs to be determined. This will allow a more detailed result on the causes of the usefulness to be presented.

The simplest possible handling of the technology can also lead to an increase in usefulness, because the perceived ease of use has a high impact as an influencing factor, especially among older drivers (Chen & Chan, 2011; Roberts et al., 2012). Therefore, the perceived ease of use must be further classified by asking and analyzing the user's individual assessment of when a use is easy for them through studies.

Social norms and values influence the acceptance of driver assistance systems as part of the subjective norm and should be addressed in future research to investigate the causes of driver opinion formation (Chen & Chan, 2011; Kervick et al., 2015; Larue et al., 2015; Rahman et al., 2019).

In addition to perceived usefulness, the determinant of trust in technology has significant influence on the acceptance of driver assistance systems according to both the findings in the literature and this dissertation (Braun et al., 2019; Ghazizadeh et al., 2012; Rahman et al., 2019; Xu et al., 2010). For researchers, this finding implies a need for further research on when and how much interaction with technology is necessary for users to feel and manifest "trust in technology” (Beller et al., 2013; Choi & Ji, 2015; Gefen et al., 2003; Johnson et al., 2008; Kaur & Rampersad, 2018; Lee & See, 2004; Molnar et al., 2018; Parasuraman et al., 2008; Pavlou, 2003; Tussyadiah et al., 2017).

A direct influence of the personal innovativeness on acceptance is not confirmed in the study. Nevertheless, it is shown that acceptance depends on individual tendency and interest in and with technology via the determinants of perceived usefulness and perceived ease of use (Chen & Chen, 2011; Herrenkind et al.; 2019a; Lee, 2019; Wang et al., 2010). Research needs to focus - to gain a better understanding of driver assistance system users - on the influencing factors that determine a user's personal level of innovation (genetics, education, environment, and society) in order to better capture the personality structure of users (see also Bigné-Alcañiz et al., 2008; Lee, 2019; Lu et al. 2008; Van Raaji & Schepers, 2008; Wang et al., 2010).

In general, the investigation of factors influencing acceptance requires further research related to the age of drivers (Braun et al., 2019; Chen & Chan, 2011). This is because, although the present study confirms a high acceptance of driver assistance systems among the age group 50+, it contradicts the findings of the meta-analysis by Hauk et. Al (2018), which postulates a rather negative influence of age on technology acceptance for the older group. The study provides insight into the degree of relationships of individual determinants in age. Future research needs to take a closer look at these relationships in the context of age, in which acceptance models are extended to include new determinants adapted to the topic (Rahman et al., 2019). In this way, the explanatory power can be further increased and a unified understanding of technology acceptance in old age can be formed. Only in this way can age-induced effects be made quantitatively and qualitatively measurable and identified, so that reliable and valid results can be derived from this diversity of data.

The results of the study show for research objective RO_3 that the selected life events significantly influence the degree of impact of individual determinants on acceptance (chapter 6). Comparable studies do not yet exist, so a comparison with the existing literature is not possible. However, Herrenkind et al. (2019b) state a correlation that the life course theory has an influence on acceptance as a determinant within the framework of a technology acceptance model. Surprising in this context is the result that experiencing life events decreases the acceptance of driver assistance systems in the age group 50+. This result is in line with the findings of Ryu et al. (2009). The present work thus generates a basic understanding of critical life events as a moderating variable in the context of technology acceptance models and thereby opens up broad areas of investigation of the effect of life events on technology acceptance. The shown result that acceptance decreases with the occurrence of life events is in contrast to the earlier mentioned result that acceptance is generally high and increases in old age without the life events. This interaction between acceptance, age, and life events requires further research with additional research questions on the specific age boundaries in order to compare and evaluate the recent studies. In order to generate further scientific knowledge, the study groups need to be validated with a larger and more diverse sample.

7.2.2. Implications for practice

In times of digitalization, companies can achieve a lasting competitive advantage through a market offering tailored to the customer and thus a value proposition adapted to the user, and thereby hold their position in an increasingly dynamic automotive market (SAE, 2020). Based on the results of this study, it can be stated that the proportion of older drivers will continue to increase in the future and represent a relevant buyer group for the market. The automotive market should therefore pay special attention to the needs and limitations of older drivers when designing and equipping new vehicles.

Older drivers are willing to pay for technical comfort and to improve their road safety with the relevant driver assistance systems. However, they are not prepared to pay more than around €600 for an assistance system (see also Arndt, 2011; Blythe & Curtis, 2004; SAE, 2020). Manufacturers must therefore take these financial circumstances into account when pricing future new vehicles. The recommendation to automotive manufacturers and suppliers is to plan business models for individual driver assistance systems as comprehensively and as early as possible, with the involvement of older drivers (SAE, 2020). It makes sense to offer driver assistance systems bundled in equipment packages and to include these packages in the basic equipment of new vehicles at no extra charge or to install them and activate them if required at a charge.

With the EU Type Approval Regulation (EU, 2019), policymakers have created a legal framework for the mandatory use of advanced and safety-relevant driver assistance systems in road traffic. This trend should be further accelerated by further political steps in order to thereby increase road safety and reduce the fatality rate in road traffic accidents. At the same time, today's dominant automotive manufacturers should proactively shape this progress in order to avoid undesirable developments and create optimal operations for implementing autonomous driving on the market. Therefore, now is the right time in combination with a suitable business model to transform individual mobility towards autonomous driving (Bengler, 2014). This will noticeably change the market and open up other possible use cases such as autonomous driving. This will result in further data-based business models. The data obtained by intelligent vehicles can be further commercialized to insurance companies and advertisers (Martens & Müller-Langer, 2018).

Driver assistance systems are generally suitable for providing older drivers with driving comfort and safety as well as compensating for physical limitations. Users are generally more cautious, skeptical, and rational about new technology as they age because of their basic understanding and being deterred and concerned about their safety and physical integrity (Liang et al., 2020). The needs of this target group must be the focus of automotive manufacturers and policymakers when implementing strategies to promote the diffusion of driver assistance systems.

The marketing strategies of the automotive industry should focus on drivers' trust in driver assistance systems, as trust accounts for a very high level of perceived usefulness and intention to use (Herrenkind et al., 2019b). This further increases perceived usefulness for older drivers in particular (Trübswetter & Bengler, 2013). To promote trust, marketing should focus on user ownership, e.g., optimizing road safety, economic and climate resources. To counteract the existing skepticism of older users, driver assistance systems must be offered technically and, in their human-machine communication in such a way that their use supports and relieves the driver, but does not disempower him (Bengler et al., 2014; Davidse, 2007; Park & Kim, 2014; Young et al., 2016;). This is because the development of driver assistance systems has not always been user-oriented up to now and is therefore partly responsible for the low acceptance and success on the market (Beiker & Burgelman, 2020; Maurer, 2012; SAE, 2021). In order for assistance systems to be successful on the market, the development of new simple user interfaces should accompany the increasing number of assistance systems (Bengler et al., 2014).

One way to promote the integration of driver assistance systems into new vehicles and make them accessible to the target group is to equip new vehicles, rental vehicles and loaner cars with selected, safety-relevant driver assistance systems as standard equipment. This would give (older) drivers the opportunity to experience the benefits of the new systems and learn to appreciate the features. In addition, manufacturers could provide trainers to help older drivers use the systems for the first time or video tutorials to facilitate and ensure the use of these systems by older drivers (Trübswetter, 2015). Product designers could actively use the influence of subjective norms to encourage the purchase of intelligent driver assistance systems in a social atmosphere characterized by diversity of opinion regarding driver assistance systems (Sohn & Kwon, 2019). In addition, manufacturers should suggest and communicate only benefits of driver assistance systems to users through targeted advertising, regarding road safety and comfort, and related marketing communications (Kervick et al., 2015). This is because consumers may be resistant to innovations due to negative feelings such as fear, uncertainty, and doubt (Ram, 1987).

With the help of this approach, customers can at the same time be bound to the manufacturer offering the product in such a way that they associate it inseparably with their product and the company's brand and ultimately equate it with safety and comfort (Sohn & Kwon, 2019). In this way, manufacturers can create an individual value proposition and brand identity that can bring industry dominance.

For the public sector, the results of this work imply that perceived usefulness is the greatest predictor of acceptance and that assistance systems must be made mandatory in public transit to allow passengers to experience the comfort and safety of these systems in a tangible way (Herrenkind et al., 2019b).

With regard to the constantly increasing age of the population, for the generation 50+, human behavior is the primary key to the acceptance of driver assistance systems and thus a crucial factor for the successful placement of the systems on the market (Braun et al., 2019). All participant groups in the study, including those with critical life events, indicated they would benefit from a driver assistance system because they expected it to improve their road safety. This confidence in the technology together with road safety represents to a large extent the perceived usefulness. For car manufacturers, this means that their (marketing) strategy should be geared precisely to the self-interests of the respective groups of people, e.g., the ease of use of the systems for retirees, while the opinion of other people is of high value for the group with grandchildren.

When looking at the life events, it can be seen that these regularly accumulate with increasing age and the acceptance of driver assistance systems decreases with an increasing number of critical life events (Ryu et al., 2009). This result is surprising in relation to the fact that ultimately, participants' own need for safety is the primary motivation for the usefulness and for the use of driver assistance systems (Liang et al., 2020). Therefore, automotive manufacturers and policymakers should place special importance on safety aspects and user-friendliness when developing, implementing, and marketing driver assistance systems to individuals with life events (Herrenkind et al., 2019b) in order to further increase the attractiveness of the systems. For the group of people whose life events have led to physical limitations (illness, accident), assistance systems must be promoted in such a way that it is accepted by consumers as a pre-stage of autonomous driving and understood as compensation for independent driving up to old age. The other two groups of life events (grandchildren and retirement) can be persuaded in particular by maximizing their safety thinking as a value proposition of the assistance systems.

The goal of all efforts by the market participants involved (manufacturers, politics, society) must be to lead mobility users toward autonomous driving not only from a climatic perspective (Herrenkind et al., 2019b), but also due to economic factors in order to secure and strengthen the technological competitive advantage of the German automotive industry nationally and internationally.

7.3. Limitation and outlook

The samples in this paper refer to the western part of Germany. Further research should therefore attempt to create a more comprehensive sample for the Federal Republic of Germany or cross-border in Europe and/or worldwide and to include geographical (Herrenkind et al., 2019a), ethnic and cultural differences in the studies on acceptance and willingness to pay for assistance systems (Park & Kim, 2014). Based on the results of the studies, it can be assumed that subjects who were more interested in technology and who were already very familiar with technology were recruited for the study (Rahman et al., 2019). Future studies should therefore acquire subjects who are not familiar with technology in order to assess the handling and usability of and with assistance systems of these groups of people in more detail (Park & Kim, 2014). In addition, the sample size for conducting multigroup analysis is sometimes below the required minimum size of N=30 (Roberts et al., 2012; Souders et al., 2017). To provide even more valid results, future studies will need to significantly increase the sample size (Liang et al., 2020).

In the future, willingness to pay should be researched more intensively by means of studies, for example for individual age groups (older and younger people) or occupational groups, and supplemented by variables influencing willingness to pay as well as motives. As such variables, it remains to be investigated, for example, whether the manufacturer's brand or product design can have an influence on the willingness to pay for driver assistance systems. Further studies could shed more light on whether there is a connection between willingness to pay and acceptance, and if so, what that connection is (Arndt, 2011). This could also include determining specific age limits at which willingness to pay increases or decreases. Based on the results of the study, there remains room for further research into the conditions under which there would be a greater willingness to pay for driver assistance systems. This would require identifying both the groups of people and other features of the driver assistance systems that result in a willingness to pay above €600.

The extension of the acceptance models to include additional determinants must be addressed and prioritized in future studies, as there are certainly other influencing variables besides age and the selected critical life events that have not yet been identified within this and other studies, such as other aspects of life course research (Herrenkind et al., 2019a). In addition, it is of great interest to extend the study to other assistance systems to make characteristic differences of driver assistance systems visible. Other acceptance models, such as the UTAUT, can also be used in future studies due to the different determinants to either validate the results of this study or to obtain differentiated results as a basis for further research (Herrenkind et al., 2019b).

Furthermore, it is recommended to conduct research in all age groups of society in order to filter out, understand, and compare individual differences in acceptance (Chen & Chen, 2011). Future research should not only examine age in general, but should differentiate between cognitive and chronological age on the acceptance of driver assistance systems to better categorize the statements from the group of people (Yang & Shih, 2020). The results show that there is a basic acceptance towards technological progress and automation. For the development of society, it remains to be examined in which other areas of life, such as consumer goods for daily use, automation is accepted in order to generate more quality of life through technological progress. For this reason, further interdisciplinary research should be conducted to determine the social impact of full automation and to examine the way in which it can be introduced into various areas of life and its impact on people's needs.

This dissertation finds that the four selected life events can significantly influence acceptance. It is possible that other life events may also moderate acceptance. Future research should therefore address life events that occur in adolescence or adulthood and explore them further (Müggenburg et al., 2015), because it can be assumed that such age-independent life events can also influence acceptance. Future studies should examine a longer life stage and its modification by specific life events on a person-specific basis in order to determine and analyze the degree of acceptance before and after the respective life events, if applicable (Clark et al., 2016).

The results show that all age groups accept the use of technology, including autonomous driving. This leaves room for automotive manufacturers and policymakers to focus on autonomous driving as a central issue of new mobility concepts in the future (Bengler et al., 2014). Here, the question of whether automobiles will continue to be purchased by private and public users or whether they will be replaced by mobility-as-a-service offerings will play a role. This is because the question arises for every user as to whether the acquisition of an autonomously driving vehicle makes sense and is financially advantageous, considering that vehicles generally have a standing time of 23 hours a day during which they are unused (Umweltbundesamt, 2020). In this case, consumers have to compare costs and benefits against Mobility-as-a-Service offers. This means that automakers and policymakers are called upon to develop attractive business models in the future that can meet the needs of users, such as cost/usefulness as well as individual and climate-neutral mobility.

References

Agarwal, R. (2000). Individual acceptance of information technology. In: R.W. Zmud (Hrsg.): *Framing the Domains of IT-Management*, Cincinnati, Pinnaflex, pp. 85-104.

Arndt, S. (2011). *Evaluierung der Akzeptanz von Fahrerassistenzsystemen: Modell zum Kaufverhalten von Endkunden*, Dissertation, Technische Universität Dresden, Wiesbaden, Gabler.

Beige, S. & Axhausen, K.W. (2012). Interdependencies between turning points in life and long-term mobility decisions. *Transportation*, *39*(4), 857–872.

Beiker, S. & Burgelman, R. A. (2020) The Future of the Automated Mobility Industry: A Strategic Management Perspective. *Stanford University Graduate School of Business Research Paper, 3866*.

Beller, J., Heesen, M., & Vollrath, M. (2013). Improving the driver–automation interaction: An approach using automation uncertainty. *Human factors*, *55*(6), 1130-1141.

Bengler, K., Dietmayer, K., Färber, B., Maurer, M., Stiller, C. & Winner, H. (2014). Three Decades of Driver Assistance Systems - Review and Future Perspectives. *IEEE Intelligent transportation systems magazine*, *6*(4), 6-22.

Bhattacherjee, A. & Sanford, C. (2006). Influence Process for Information Technology Acceptance: An Elaboration Likelihood Model, *MIS Quarterly*, *30*(4), 805-825.

Bigné-Alcañiz, E., Ruiz-Mafé, C., Aldás-Manzano, J., & Sanz-Blas, S. (2008). Influence of online shopping information dependency and innovativeness on internet shopping adoption. *Online Inf. Rev.*, *32*, 648-667.

Blythe, P. T. & Curtis, A. M. (2004). Advanced driver assistance systems: Gimmick or reality. Conference Proceedings at the *11th World Congress on Intelligent Transport Systems and Services.* 18-24 October 2004. Nagoya, Japan.

Braun, H., Gärtner, M., Trösterer, S., Akkermans, L. E., Seinen, M., Meschtscherjakov, A., & Tscheligi, M. (2019). Advanced driver assistance systems for aging drivers: Insights on 65+ drivers' acceptance of and intention to use ADAS. *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Utrecht, 123-133.

Chen, C.-F. & Chen, P.-C., (2011). Applying the TAM to travelers' usage intentions of GPS devices. *Expert Syst. Appl*., *38*(5), 6217–6221.

Chen, K. & Chan, A.H.S. (2011). A review of technology acceptance by older adults. *Gerontechnology*, *10*(1), 1-12.

Choi, J. K., & Ji, Y. G. (2015). Investigating the importance of trust in adopting an autonomous vehicle. *International Journal of Human-Computer Interaction*, *31*, 692–702.

Clark, B., Chatterjee, K. & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. *Transportation Research Part A: Policy and Practice*. *89*, 89‑105.

Davidse, R. (2007). *Assisting the older driver. Intersection design and in-car devices to improve the safety of the older driver*. Leidschendam, NL: SWOV-Dissertatiereeks.

Davis, F.D., Bagozzi, R.P. & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models, *Journal of Management Science, 35*(8), 982-1003.

De Groot, C.D., Mulder, C.H., Das, M., Manting, D. (2011). Life events and the gap between intention to move and actual mobility. Environ. Plan. A, 43(1), 48–66.

Deutsche Automobil Treuhand (2018). *DAT Report 2018*. [online] https://files.vogel.de/vogelonline/vogelonline/issues/kfz/sonst/2018/8803.pdf (Accessed 02 April 2021).

Elder, G. Jr (1994), "Time, human agency, and social change: perspectives on the life course", Social Psychology Quarterly, Vol. 57 No. 1, pp. 4-15.

European Comission (2019). *REGULATION (EU) 2019/2144 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*. [online] https://eur-lex.europa.eu/eli/reg/2019/2144/oj (Accessed 18 August 2021)

Gefen, D., Karahanna, E. & Straub, D. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly*, *27*(1), 51–90.

Gefen, D. & Straub, D.W. (1997). Gender Differences in the Perception and Use of E-Mail: An Extention to the Technology Acceptance Model. *MIS Quarterly*, *21*(4), 389-400.

Ghazizadeh, M., Peng, Y., Lee, J.D. & Boyle, L.N. (2012). Augmenting the Technology Acceptance Model with Trust: Commercial Drivers' Attitudes towards Monitoring and Feedback. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*(1), 2286–2290.

Hair, J. F., Hult, G. T. M., Ringle, C. M. & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2 ed.). Thousand Oaks, CA: Sage.

Hauk, N., Hüffmeier, J., & Krumm, S. (2018). Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Computers in Human Behavior*, *84*, 304–319.

Herrenkind, B., Brendel, A. B., Nastjuk, I., Greve, M., & Kolbe, L. M. (2019a). Investigating end-user acceptance of autonomous electric buses to accelerate diffusion. *Transportation Research Part D: Transport and Environment*, *74*, 255–276.

Herrenkind, B., Nastjuk, I., Brendel, A. B., Trang, S. & Kolbe, L. M. (2019b). Young people's travel behavior – Using the life-oriented approach to understand the acceptance of autonomous driving. *Transportation Research Part D: Transport and Environment*, *74*, 214-233.

Im, I., Kim, Y. & Han, H-J. (2007). The effects of perceived risk and technology type on users' acceptance of technologies. *Journal of Information & Management*, *45*(1), 1-9.

Johnson, D. S., Bardhi, F., & Dunn, D. T. (2008). Understanding how technology paradoxes affect customer satisfaction with self-service technology: The role of performance ambiguity and trust in technology. *Psychology and Marketing*, *25*(5), 416-443.

Kaur, K. & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management*, *48,* 87-96.

Kervick, A.A., Hogan, M.J., O'Hora, D. & Sarma, K.M. (2015). Testing a structural model of young driver willingness to uptake Smartphone Driver Support Systems. *Acci. Anal. Preven*, *83*, 171–181.

Koivumäki, T., Ristola, A. & Kesti, M. (2006): Predicting consumer acceptance in mobile services: Empirical evidence from an experimental end user environment. *International Journal of Mobile Communications*, *4*(4), 418-435.

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior, *Information Systems Research*, *13*(2), 205-223.

Lanzendorf, M. (2010). Key events and their effect on mobility biographies: the case of childbirth. International Journal of Sustainable Transportation, 4, 272–292.

Larue, G.S., Rakotonirainy, A., Haworth, N.L. & Darvell, M. (2015). Assessing driver acceptance of Intelligent Transport Systems in the context of railway level crossings. *Transport. Res. Part F: Traff. Psychol. Behav., 30*, 1–13.

Lee, M. S. (2019). Effects of personal innovativeness on mobile device adoption by older adults in South Korea: the moderation effect of mobile device use experience. *International Journal of Mobile Communications*, *17*(6), 682-702.

Lee, J. D. & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors*, *46*, 50–80.

Li, Y.-H. & Huang, J.-W. (2009). Applying Theory of Perceived Risk and Technology Acceptance Model in the Online Shopping Channel, *World Academy of Science, Engineering & Technology*, *53*(1), 919-925.

Liang, D., Lau, N., Baker, S.A. & Antin, J.F. (2020). Examining Senior Drivers' Attitudes Toward Advanced Driver Assistance Systems After Naturalistic Exposure. *Innovation in Aging*, *4*(3), 1-12.

Lu, J., Liu, C., Yu, C.S. & Wang, K. (2008). Determinants of accepting wireless mobile data services in China. *Information & Management*, *45*(1), 52–64.

Marsden, G. & Docherty, I. (2013). Insights on disruptions as opportunities for transport policy change. Transport. Res. Part A: Policy Pract, 51, 46–55.

Martens, B. & Müller-Langer, F (2018). Access to digital car data and competition in aftersales services. *JRC Digital Economy Working Paper*, No. 2018-06, European Commission, Joint Research Centre (JRC), Seville.

Maurer, M. (2012). Forward Collision Warning and Avoidance. In: A. Eskandarian (Ed.), *Handbook of Intelligent Vehicles*, Springer London, 2012.

Molnar, L. J., Ryan, L. H., Pradhan, A. K., Eby, D. W. St. Louis, R. M. & Zakrajsek, J. S. (2018). Understanding trust and acceptance of automated vehicles: An exploratory simulator study of transfer of control between automated and manual driving. *Transportation Research Part F*, *58*, 319-328.

Müggenburg, H., Busch-Geertsema, A. & Lanzendorf, M. (2015). Mobility biographies: A review of achievements and challenges of the mobility biographies approach and a framework for further research. *Journal of Transport Geography*, *46*, 151‑163.

Parasuraman, R., Sheridan, T. B. & Wickens, C. D. (2008). Situation awareness, mental workload, and trust in automation: Viable, empirically supported cognitive engineering constructs. *Journal of Cognitive Engineering and Decision Making*, *2*(2), 140–60.

Park, E. & Kim, K.J. (2014). Driver acceptance of car navigation systems: integration of locational accuracy, processing speed, and service and display quality with technology acceptance model. *Perso. Ubiquitous Comput.*, *18*(3), 503–513.

Pavlou, P.A. (2003). Consumer acceptance of electronic commerce – integrating trust and risk with the technology acceptance model, *International Journal of Electronic Commerce*, *7*(3), 69-103.

Rahman, M. M., Deb, S., Strawderman, L., Burch, R. & Smith, B. (2019). How the older population perceives self-driving vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*, 242–257.

Ram, S. (1987). A model of innovation resistance. *Adv. Consumer Res*, *14*(1), 208-212.

Roberts, S.C., Ghazizadeh, M. & Lee, J.D. (2012). Warn me now or inform me later: drivers' acceptance of real-time and post-drive distraction mitigation systems. *Int. J. Hum. Comput. Stud.*, *70*(12), 967–979.

Rodel, C., Stadler, S., Meschtscherjakov, A. & Tscheligi, M. (2014). Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. *Paper Presented at the Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. Seattle, WA, USA.

Ryu, M.H., Kim, S. & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC services. *Computers in Human Behavior, 25*, 619-632.

SAE International (2020). *Level 2+': Making automated driving profitable, mainstream.* [online] https://www.sae.org/news/2020/12/rise-of-sae-level-2 (Accessed 16 August 2021).

SAE International (2021). *Level 2+': Tailored ADAS Functions Fulfilling Local Market Expectations – Time Saving Approach Without Compromising the Performance Quality.* [online] https://www.sae.org/publications/technical-papers/content/2021-26-0038/ (Accessed 15 September 2021).

Schäfer, M., Jaeger-Erben, M. & Bamberg, S. (2012). Life events as windows of opportunity for changing towards sustainable consumption patterns?. *Journal of Consumer Policy, 35*(1), 65–84.

Scheiner, J., 2007. Mobility biographies: elements of a biographical theory of travel demand. Erdkunde, 61, 161–173.

Sharmeen, F., Arentze, T. & Timmermans, H. (2014). An analysis of the dynamics of activity and travel needs in response to social network evolution and life-cycle events: a structural equation model. Transport. Res. Part A: Policy Pract, 59, 159–171.

Sohn, K., & Kwon, O. (2019). Technology Acceptance Theories and Factors Influencing Artificial Intelligence-based Intelligent Products. *Telematics and Informatics*.

Souders, D. J. & Charness, N. (2016). Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles. Human Aspects of IT for the Aged Population. *Healthy and Active Aging*, 428-440.

Souders, D. J., Best, R. & Charness, J. (2017). Valuation of Active Blind Spot Detection Systems by Younger and Older Adults. *Accidental Analysis and Prevention*, *106*, 505-514.

Statistisches Bundesamt (2019). *Bevölkerung Deutschlands bis 2060: Ergebnisse der 14. koordinierten Bevölkerungsvorausberechnung - Hauptvarianten 1 bis 9*. [online] https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/bevoelkerung-deutschland-2060-5124202199014.pdf?__blob=publicationFile (Accessed 02 April 2021).

Trübswetter, N. & Bengler, K. (2013). Why should I use ADAS? Advanced driver assistance systems and the elderly: knowledge, experience and usage barriers. *Proceedings of 7th International Driving Symposium on Human Factors in Driver Assessment*, Training and Vehicle Design, University of Iowa, Bolton Landing, New York, USA, 495–501.

Trübswetter, N. M. (2015). *Akzeptanzkriterien und Nutzungsbarrieren älterer Autofahrer im Umgang mit Fahrerassistenzsystemen*. Ph. D. Dissertation, TUM School of Education, TUM, München, Deutschland.

Tussyadiah, I., Zach, F.J. & Wang, J. (2017). Attitudes Toward Autonomous on Demand Mobility System: The Case of Self-Driving Taxi. *Information and Communication Technologies in Tourism*, *17*, 24-26 Jan 2017, Rome, Italy.

Umweltbundesamt (2020). *Car-Sharing*. [online] https://www.umweltbundesamt.de/themen/verkehr-laerm/nachhaltige-mobilitaet/car-sharing#angebotsformen-des-car-sharing (18.08.2021)

van der Heijden, H., (2004). User Acceptance of Hedonic Information Systems. *MIS Quaterly*, *28*(4), 695-704.

van der Waerden, P., Timmermans, H. & Borgers, A. (2003). The Influence of Key Events and Critical Incidents on Transport Mode Choice Switching Behaviour: A Descriptive Analysis. 10th International Conference on Travel Behaviour Research, 1‑23.

Van Raaij, E.M. & Schepers, J.J.L. (2008). The acceptance and use of a virtual learning environment in China. *Computers & Education*, *50*(3), 838–852.

Van Westendorp, P. H. (1976). NSS Price Sensitivity Meter (PSM) – A new approach to study consumer perception of prices. *Proceedings of the 29th ESOMAR Congress*, 5-9 September 1976, Venice, Italy, 139-167.

Venkatesh, V., Morris, G.B., Davis, G.B. & Davis, F.D. (2003). User Acceptance of Information Technology: Towards a Unified View. MIS Quarterly, *27*(3), 425-478.

Wang, C.Y., Chou, S.T. & Chang, H.C. (2010). Exploring an individual's intention to use blogs: the roles of social, motivational and individual factors. *Pacific Asia Conference on Information Systems*, PACIS 2010, Taipei, Taiwan, 1656–1663.

Weiber, R. & Mühlhaus, D. (2014). *Strukturgleichungsmodellierung. Eine anwendungsorientierte Einführung in die Kausalanalyse mit Hilfe von AMOS, SmartPLS und SPSS (2. ed.)*. Berlin, Heidelberg: Springer Gabler.

Xu, C., Wang, W., Chen, J., Wang, W., Yang, C. & Li, Z. (2010). Analyzing travelers' intention to accept travel information. Transportation Research Record: Journal of the Transportation Research Board, *2156*(1), 93–100.

Yang, K.-C. & Shih, P.-H. (2020). Cognitive age in technology acceptance: at what age are people ready to adopt and continuously use fashionable products?. *Telematics and Informatics*, *51*, 101400.

Young, K., Koppel, S., & Charlton, J. (2017). Toward best practice in Human Machine Interface design for older drivers: A review of current design guidelines. *Accident Analysis & Prevention*, *106*, 460–467.

Zarmpou, T., Saprikis, V., Markos, A. & Vlachopoulou, M. (2012). Modeling users' acceptance of mobile services. *Electronic Commerce Research*, *12*(2), 225-248.

Zentralverband Deutsches Kraftfahrzeuggewerbe e. V. (2020). *Zahlen & Fakten 2019*. [online] https://www.kfzgewerbe.de/fileadmin/user_upload/Presse/Zahlen_Fakten/Zahlen___Fakten_2019.pdf (Accessed 02 April 2021)

Zhang, T., Tao, D., Qu, X., Zhang, X., Zeng, J., Zhu, H. & Zhu, H. (2020). Automated vehicle acceptance in China: Social influence and initial trust are key determinants. *Transportation Research Part C: Emerging Technologies*, *112*, 220–233.

DOI: 10.17185/duepublico/75461
URN: urn:nbn:de:hbz:465-20220316-154539-7