Tapping into market opportunities in aging societies – the example of advanced driver assistance systems in the transition to autonomous driving

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Abstract: The stagnation in car sales in the triad markets is forcing automotive companies to seek new market opportunities, e.g., in the aging society. The number of older drivers is growing, and they can afford safety- and comfort-related products which allow them to drive into older age despite physical and psychological restrictions. Therefore, potentials for advanced driver assistance systems for elderly drivers are likely to exist in these markets. By determining older drivers' willingness to pay for advanced driver assistance systems in the transition to autonomous driving, market opportunities can be identified. This study proves that there are market potentials for these systems in the 'silver market'. However, there is no simple linear relationship between age and willingness to pay. A more thorough examination is therefore needed.

Keywords: advanced driver assistance systems; autonomous driving; willingness to pay; silver market; older drivers; aging societies.

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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 and Herstatt, 2011; Matsuno and 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 and 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 e.V., 2020) and almost all of them state that they feel significantly restricted in their mobility without a car. Almost 60% 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 and Creighton, 2015; Musselwhite, 2018; Musselwhite and 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 and 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 and 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, 2013; Boot and 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 and 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 and 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).

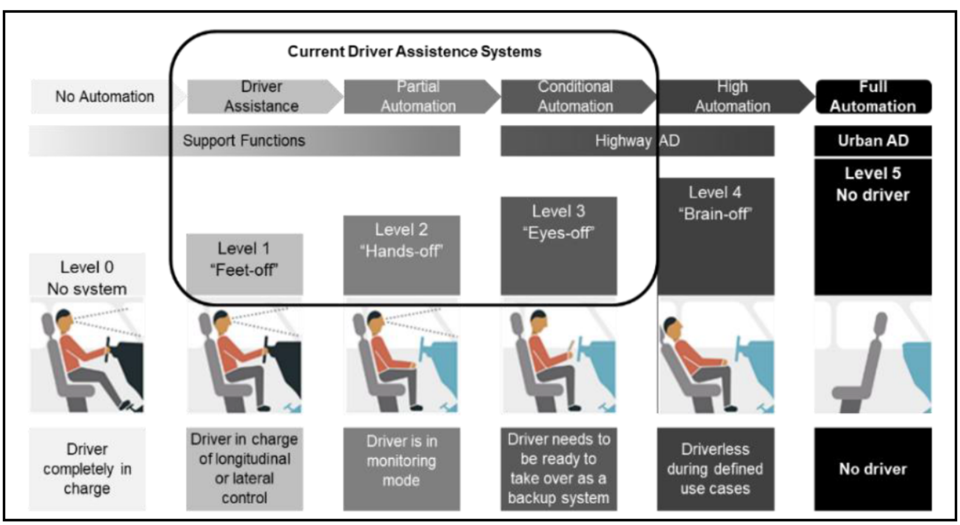
2 Literature review

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 (BSD), cross traffic alert (CTA), cruise control, emergency brake assist, intersection assistant, lane departure warning (LDW), lane keeping assistance, night vision, parking assistance, park distance control (PDC), tyre-pressure monitoring system (TPMS), 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 levels 3 and 4 as a transition technology for the moment.

Figure 1 Levels of automation (see online version for colours)



Source: Based on VDA (2015) and SAE International (2016)

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).

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 and 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 and 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 and Carswell, 2006). Therefore, cognitive performance is essential but decreases with age (Brand and Markowitsch, 2010). Especially cognitive functions such as memory performance and executive functions, i.e., planning, categorisation, monitoring processes and cognitive flexibility, decrease over time (Reuter-Lorenz and Sylvester, 2005; Uekermann et al., 2006; Ashendorf and McCaffrey, 2008; Hodzik and 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 USA, 39% of those aged 65 and older suffer with one or more disabilities in hearing, vision and cognitive abilities (Wan and 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) 2017/2018, 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 and 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 2017/2018, over 50% of the 381 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, CTA, PDC, BSD, LDW, and the 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 and 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 behaviour.

Travel behaviour research in general considers a number of sociodemographic factors like age, living situation and environment, life stages, expectations about transportation (Beige and Axhausen, 2008; Sun et al., 2009; Chatterjee et al., 2013; Clark et al., 2016; Beige and 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 and Haddad, 2010; Holley-Moore and Creighton, 2015; Musselwhite, 2018; Musselwhite and 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 and 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 and

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 and 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 behaviour 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 and Fojcik, 2014; based on Breidert, 2005; Potoglou and Kanaroglou, 2007; Diller, 2007; 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 and 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 and MEMA, 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 BSD 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

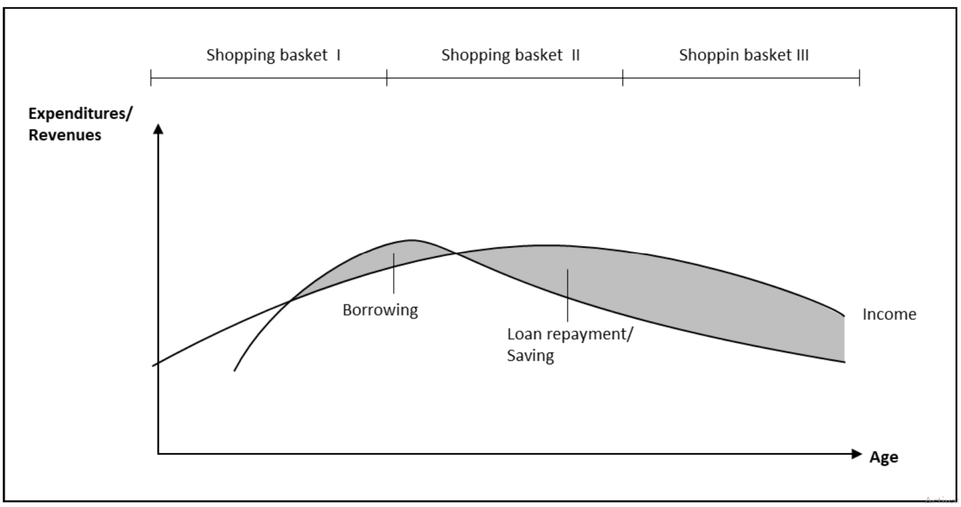
The above-mentioned importance of studies of older drivers' willingness to pay for safety-relevant solutions and the increasing physical limitations with age, which can be compensated for by the application of driver assistance systems, combined with the simultaneous research gap in this field emphasise 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 CTA, blind spot assistant or parking assistant makes it easier to handle driving tasks. Moreover, if visual and cognitive limitations are existent the LDW or the TPMS 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).

Figure 2 Demand for mobility (consumption) depending on the age of the consumers



Source: Proff (2019, p.127) based on Blundell et al. (1994)

Previous studies confirm that consumption expenditure is a bell curve over the life cycle (Fernández-Villaverde and 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 and Krueger (2007) model life cycle profiles of total expenditure peaking typically in the age group of 40 to 50 years.

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 2 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, 1998; Szmigin and 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 2, 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)
- 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 (Fisk et al., 2009; Truebswetter, 2015; Souders et al., 2017).

Because Elder (1994) and Silvers (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 e.V., 2020)
- physical limitations become increasingly severe around age 50 (Wickens and Carswell, 2006; Davidse, 2007; Fisk et al., 2009; Brand and Markowitsch, 2010; Hodzik and Lemaire, 2011; Wan and Larsen, 2014)
- 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: CTA, PDC, BSD, LDW, and the TPMS. It was assumed that not every driver has experience of using driver assistance systems. Therefore, a two-stage study design was required.

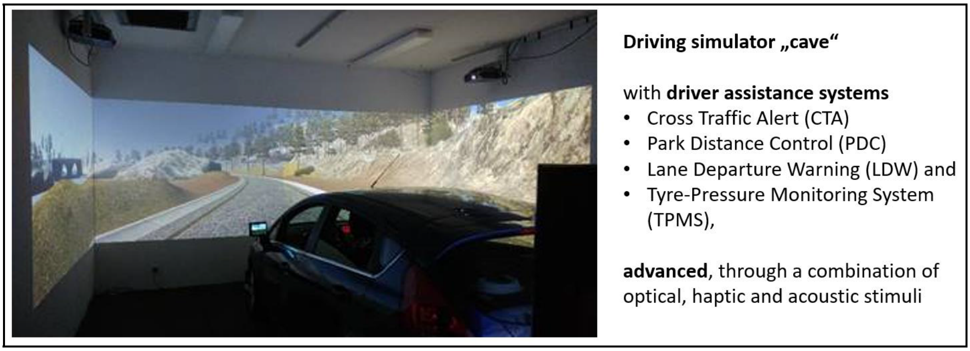
First of all, the participants tested the five selected advanced driver assistance systems in a driving simulator to ensure that all participants had the same level of knowledge about the functionality of these systems. A static driving simulator of a close-to-production vehicle of the compact class 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.

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 and Kanaroglou, 2007; Miller et al., 2011; Proff and 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 and Bijmolt, 2020)], with the help of individual partial values.

Figure 3 Driving simulator cave (own illustration) (see online version for colours)



The van Westendorp method was selected to determine the willingness to pay for an advanced driver assistance system (van Westendorp, 1976; Kloss and 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 CTA 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 seven-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 and 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, 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 Table 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.

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) BSD $r(181) = 0.197$, $p < 0.001$ and for the (9) TPMS $r(181) = 0.211$, $p < 0.001$. However, there was no significant correlation between age and the willingness to pay for the other three advanced driver assistance systems (CTA, PDC and LDW). 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 Table 2).

Table 1 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

These results are in line with Elder's (1994) observation 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.

Table 2 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	0.029	-							
3	Product knowledge	0.024	*0.708***	-						
4	Net income	–0.058	*0.241***	*0.363***	-					
5	WTP for CTA	0.084	0.053	0.009	0.019	-				
6	WTP for PDC	0.117	0.043	0.043	0.070	*0.652***	-			
7	WTP for BSD	*0.197***	0.131	0.009	0.123	*0.666***	*0.758***	-		
8	WTP for LDW	0.122	0.039	0.033	0.137	*0.666***	*0.655***	*0.688***	-	
9	WTP for TPMS	*0.211***	0.056	0.004	0.063	*0.507***	*0.607***	*0.579***	*0.580***	-

Notes: *correlation is significant at the 0.01 level (two-tailed).
**correlation is significant at the 0.05 level (two-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.

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 $p \leq 0.05$ (PDC 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.

Table 3 Willingness to pay for the advanced PDC by age group

Group	*N*	*Mean*	*SD*	*T*	*df*	*P*	*Hypothesis 2*
50–59	49	1.76	0.522	–2.208	123	0.029	Accept
60–69	76	2.00	0.653				
50–59	49	1.76	0.522	–1.738	103	0.085	Accept
70–90	56	1.96	0.687				
60–69	76	2.00	0.653	0.304	130	0.762	Reject
70–90	56	1.96	0.687				

Table 4 Willingness to pay for the advanced LDW by age group

Group	*N*	*Mean*	*SD*	*T*	*df*	*P*	*Hypothesis 2*
50–59	49	1.67	0.658	–2.082	123	0.039	Accept
60–69	76	1.93	0.699				
50–59	49	1.67	0.658	–1.713	103	0.090	Accept
70–90	56	1.89	0.652				
60–69	76	1.93	0.699	0.346	130	0.730	Reject
70–90	56	1.89	0.652				

Table 5 Willingness to pay for the advanced BSD by age group

Group	*n*	*Mean*	*SD*	*T*	*df*	*P*	*Hypothesis 2*
50–59	49	1.76	0.630	–2.692	123	0.008	Accept
60–69	76	2.09	0.715				
50–59	49	1.76	0.630	–2.681	103	0.009	Accept
70–90	56	2.11	0.705				
60–69	76	2.09	0.715	–0.120	130	0.905	Reject
70–90	56	2.11	0.705				

Table 6 Willingness to pay for the TPMS by age group

Group	*n*	*Mean*	*SD*	*T*	*df*	*P*	*Hypothesis 2*
50–59	49	1.61	0.533	–2.698	123	0.008	Accept
60–69	76	1.91	0.636				
50–59	49	1.61	0.533	–2.385	103	0.019	Accept
70–90	56	1.93	0.783				
60–69	76	1.91	0.636	–0.167	130	0.867	Reject
70–90	56	1.93	0.783				

Table 7 Willingness to pay for the CTA (CTR) by age group

Group	*n*	*Mean*	*SD*	*T*	*df*	*P*	*Hypothesis 2*
50–59	49	1.98	0.750	–0.984	123	0.327	Reject
60–69	76	2.12	0.783				
50–59	49	1.98	0.750	–0.669	103	0.505	Reject
70–90	56	2.07	0.657				
60–69	76	2.12	0.783	–0.365	130	0.716	Reject
70–90	56	2.07	0.657				

The advanced *PDC* 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.

For the advanced *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.

The analysis of the advanced *BSD* 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.

The *TPMS* 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.

For these four advanced driver assistance systems, Hypothesis 2 could be confirmed. Only the advanced CTA 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 CTA, 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).

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 (PDC, BSD, LDW, and TPMSs). Though not significant, tendencies towards an increased willingness to pay could also be observed in the case of the fifth assistance system, the CTA. 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 nonlinear, 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 (PDC and lane distance warning).

According to, e.g., Elder (1994), Silver (1997) and 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.

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