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Studies on the Human-Machine-Interface in Advanced Driver Assistance Systems towards Autonomous Driving



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Foreword by the editors

Advancing digitalization in various technological areas is increasingly leading to the ‘smartification’ of processes and products. Products are equipped with extensive sensor technology to collect usage and environmental data. Formerly analog processes are replicated as digital twins, translated into user interfaces and, where possible, enriched with additional functionalities. It is implicitly assumed that products and processes will always improve from the user's perspective through the integration of digital technologies. However, users not only experience the expected convenience and design options with digital end products, but also often experience increased effort when familiarizing themselves with digital interfaces and menus. The perception is that familiar analog processes that are perceived as ‘simple’ are displaced in favor of decidedly non-intuitive digital solutions.

Although sub-projects such as ‘Human Machine Interface’ and ‘User Experience’ are common in development projects today, user dissatisfaction with the digital end products suggests that user-centered aspects could be given much better consideration. This discrepancy underlines the need for a differentiated understanding of user experiences and preferences in the ongoing development of digital technologies. Addressing these challenges will contribute to the overall success of digital innovations and increase user satisfaction, which will promote a more seamless integration of digital technologies into everyday life.

Customized user interfaces contribute significantly to market penetration and user acceptance. A positive user experience promotes brand loyalty, encourages positive word of mouth and attracts a broader user base. In the competitive world of digital technologies, R&D efforts that emphasize buyer value in user interface design provide a strategic advantage in terms of market share.

The results of our studies in the field of advanced driver assistance systems in motor vehicles underline the need for a paradigm shift among stakeholders at all levels of the market value chain. The development departments of manufacturers and suppliers must create a new awareness of the central role of the end user. It is essential for these departments to better align technological possibilities with the actual application needs of users. To this end, there must be a willingness to identify user groups with different levels of technological affinity and provide them with tailored digital solutions. At an operational level, greater attention must be paid to ensuring that users are carefully introduced to innovative technologies. In sales and customer service, feedback from customers must be recorded and reported back to the development departments. When products are handed over to end users, it should be a matter of course that they are instructed in new technologies in order to prevent negative experiences during their first use. And in corporate communications, the expectations and fears of users should be addressed instead of making blanket claims that every digital innovation represents progress per se.

With this first volume of the 'User Acceptance Research' series, we would like to demonstrate the benefits of a stronger user perspective in the innovation process on the basis of empirical findings and offer initial pragmatic approaches to solutions in individual cases.

This volume is primarily intended to provide empirical results; it is explicitly not a scientific article and not a book of basic principles that is balanced in all aspects (all that already exists). Much of the text is presented in bullet points in order to provide a quick overview of key findings. Cross-references and the use of third-party sources have been avoided for the same reason. Readers may draw their own conclusions as to what the briefly presented findings mean for their company. In times of relevant AI text generation platforms, one can find appealing supplementary texts beyond empiricism created online free of charge.

Hof, December 2023

Joachim Riedl, Stefan Wengler

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Gender note:

For reasons of better readability, the masculine form is used for personal names and personal nouns in this report. Corresponding terms apply to all genders in the interests of equal treatment, unless gender-related differences are explicitly stated otherwise. The chosen language form does not imply any gender-related evaluation.

1 Foundation

1.1 Topic

The Empirical Research and User Experience (ERUX) group at the Institute for Information Systems at Hof University of Applied Sciences (iisys) has carried out four studies on the topic of “The Human-Machine Interface (HMI) in the context of self-driving cars” in the two funding periods 2019/20 and 2021/22. This scientific report states information on the investigations and results carried out during the course of the project.

1.2 ERUX research group

ERUX focuses its research on the topics of user experience and usability in conjunction with modern technological systems. This is entrenched in the idea that the thriving implementation of technological innovations (research focus of iisys) require the early analysis of customer benefits and their inclusion in the development trajectory.

Both, large-scale quantitative studies (customer -, as well as employee surveys, face-to-face, by telephone, online) and qualitative analyses (in-depth interviews, focus group interviews,

expert discussions), have been conducted. Non-verbal reactions have been examined through instrumental measurements of eye movements, skin resistance, brain waves, temperature,

facial expressions, voice tones, etc. Relevant software tools such as SPSS, R, SigmaPlot, Sawtooth, SmartPLS etc., are suitable for data analysis. The research is aiming to gain insights that contribute to enhance the interaction between humans and technology.

1.3 Project partner

The project partner for the conducted studies has been Valeo Schalter und Sensoren GmbH, one of the top manufacturers of sensor systems in the automotive industry. The listed company, headquartered in Paris, operates worldwide as an original equipment manufacturer for the automotive and commercial vehicle industry. The company employs 103,300 people at 184 production sites in 31 countries. Valeo Schalter und Sensoren GmbH owns 64 research and development centers, as well as 15 sales offices. Their turnover in the 2019 financial year amounted to 19.2 billion euros.¹ In the years 2016 and 2017, the company was French leader by the number of patent applications.

In consultation with the interests of the project partner, the content of the individual conducted studies was defined. This fully revised overall report constitutes the results of the study and does not contain any internal company data.

¹ Valeo Annual Report 2019.

1.4 Funding provider

Studies two to four were substantially financed by the Kronach Research Center at Hof University of Applied Sciences, funded directly by the Bavarian State Ministry of Science and Arts. The test vehicle in studies three and four was provided by our project partner Valeo, as were the templates for the concept test in study four. Studies one and two were supported by the non-profit research institute AccessMM.

Software and Hardware of the ERUX research group, as well as of the Laboratory for Marketing Research at Hof University of Applied Sciences were utilized during the course of the studies.

1.5 Project schedule

Throughout the two project phases, each lasting two years, the main perspective was to investigate possible obstacles in the acceptance of advanced driver assistance systems. Moreover, the study aimed to find out which means and measures were suitable for promoting the diffusion process of the new technologies. By combining quantitative and qualitative approaches, a profound understanding of the performance and user-friendliness of current advanced driver assistance systems has empirically been developed. This report summarizes the results of the conducted studies. Fig. 1 provides an overview:

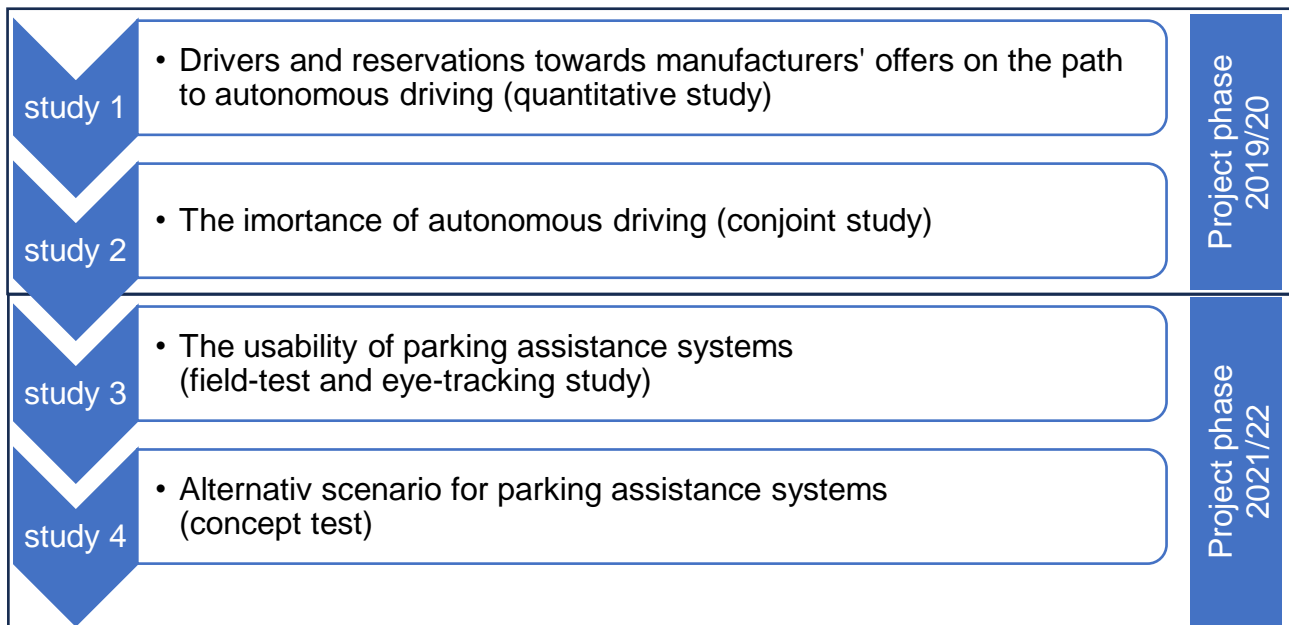


Fig. 1 Schematic representation of the project process

The functionality, design and effectiveness of advanced driver assistance systems, as well as the ramifications of these systems on the driving experience and on the user satisfaction have been examined. The outcomes of the study provide tangible approaches to further developments and optimizations of such advanced systems. This advice can not only benefit the automotive industry. However, these indications happen ultimately to also aid drivers by making technologies more effective, reliable and user-friendly.

2 Operators and drivers' reservations about manufacturers' offerings ahead towards autonomous driving

2.1 Description of the study

This study illustrates an evaluation of advanced driver assistance systems and autonomous driving from the perspective of the target group, namely the drivers. The assessments are derived from face-to-face surveys of 892 people, aged 18 to 88, in Germany.

The report displays how known advanced driver assistance systems are estimated and gauges the level of interest in using them. The survey of unsupported, free associations without specifications provides an insight into the current drivers and impediments. Quantitative evaluations make it feasible to identify distinctions in a multitude of sub-target groups. Thus, the study also indicates the psychological motive structure of drivers and its conjunction with the desire for advanced driver assistance systems and autonomous driving.

The results reveal a call for action in the automotive and supplier industry when it comes to accelerating the diffusion process of new technologies.

2.2 Investigation profile

2.2.1 Design and scope of the study

- Method: face-to-face surveys of drivers aged 18 and over in Germany.² Domestic data collection, completed in the first quarter of 2019.
- Concept development: preliminary draft, comprising actual customers from the target group, explorative preliminary study to determine the criteria relevant for the buying-behavior in the target group, online research, pre-test.
- Sample composition: quota sample with the following specifications: interviewees aged 18 and over, maximum of one interviewee per family, car driver or potential car driver. Quotas according to age, gender and level of education with the composition of the total population.
- Data collection: deployment of 37 trained interviewers (21 to 29 years old, university degree), as well as five additional expert interviewers (university lecturers).
- Average interview duration: approx. 20 minutes.
- Geographical dispersion: the interviews have been conducted at over 20 locations throughout Germany, with a focus on southern Germany. The respondents (Apn) derive from over 100 different regions throughout Germany.

² All statements in this part of the report refer exclusively to this target group.

- Return: unedited sample of 973 interviews. Incomplete and obviously inconsistent questionnaires have been eliminated. **In total 892 interviews** have been included in the analysis.
- Test quality: extensive tests (split-half reliabilities, interviewer reliability checks and expert judgments on content-related questions) confirm the reliability and validity of the study results.

2.2.2 Aim and content of the study

Car manufacturers and the supplier industry are aware of the reserved attitude of automotive customers about advanced driver assistance technologies without exactly knowing what this demeanor is based on.

The present study analyzes drivers and inhibiting factors towards available advanced driver assistance systems and autonomous driving, primarily in a quantified form.

The new assistance technologies on the road to autonomous driving are associated with high investments. Therefore, the industry shows great interest in identifying the drivers and their inhibiting factors to supply renewed offerings. Thus, if necessary, the industry counteracts with suitable developments and communication measures to accelerate the diffusion process and ultimately amortize investments.

Optimizations in the context of the human-machine interface (HMI) could potentially encourage to prevent or counteract reserved customer attitudes. Although individual customer opinions are repeated across a plethora of studies, there happens to be a lack of reliable, quantifiable data. Furthermore, there is no study existing in which the motivational personality type of the target group is examined as an explanatory variable for adoption behavior. This study provides an initial first element in closing this knowledge gap.

2.2.3 Sample

Purpose of the description is to illustrate the sample's composition. Moreover, to display the criteria used to classify the sample into subgroups for the subsequent analyses.

2.2.3.1 Gender

- The sample comprises 443 women and 449 men, which corresponds to a female share of 49.7 percent.

2.2.3.2 Age

Age group, years	Frequency	Valid percentages
18 to 20	72	8.1
21 to 29	284	31.8
30 to 49	236	26.5
50 to 65	210	23.5
66 and above (max. 88)	90	10.1
total	892	100

Fig. 2 Sample distribution according to age

- The respondents range in age from 18 to 88 years, with an average age of 40.6 years (median 35). The average age in this study is slightly lower than the one of the overall population in Germany (44 years). This is in accordance with the quota requirements: people over the age of 66 have been found to be slightly less relevant for this research, as individuals above this age are driving more seldom and as their purchasing behavior has become more established.

2.2.3.3 Residence size

Residence size, inhabitants	Frequency	Valid percentages
up to 4,999	244	27.4
5,000 to 24,999	242	27.1
25,000 to 99,999	221	24.8
100,000 to 999,999	86	9.6
1 million and more (max. 3,5 million)	99	11.1
total	892	100

Fig. 3 Sample distribution according to the respondents' place of residence

- The respondents originate from regions of all sizes, with smaller towns being slightly overrepresented. The average size of the place of residence is displayed with 223,000 inhabitants (median 17,750).
- All sizes of residential areas are sufficiently represented to conduct reliable sub analyses.

2.2.3.4 School education

Educational qualification	Frequency	Valid percentages
Up to secondary school	174	19.5
Intermediate secondary school certificate	202	22.6
A-levels (no university degree aspired)	148	16.6
university studies	355	39.8
others	13	1.5
total	892	100

Fig. 4 Sample distribution according to the respondents' place of residence

- All the four relevant educational levels are sufficiently represented to conduct reliable sub analyses.

2.2.3.5 Annual mileage

Mileage per year, km	Frequency	Valid percentages
up to 4,999	139	15.6
5,000 to 19,999	445	50.0
20,000 to 49,999	256	28.8
50,000 + (max. 120,000)	50	5.6
valid entries	890	100
uncertainty	2	

Fig. 5 Sample distribution by annual mileage of respondents

- The respondents personally drive distances ranging from zero to 120,000 kilometers annually by car. (average 16,650 km, median 14,000 km).

2.2.3.6 Willingness to spend money on a car

The question 'If you had to buy a car in your current life situation in the next few months, what is the maximum amount you would spend on it?' unleashes a wide variation of answers from 500 to 175,000 euros.³ The willingness to spend includes both, new and used vehicles.

- The average willingness to spend on a car is 21,340 euros (median 18,000).

³ Expenditure for a monthly financing or leasing installment was extrapolated to a fictitious purchase price.

Total (Euro)	Frequency	Percent	Valid percentages
up to 4,999	77	8.6	8.7
5,000 to 9,999	109	12.2	12.3
10,000 to 19,999	262	29.4	29.6
20,000 to 49,999	374	41.9	42.3
50,000 and more (max. 175,000)	63	7.1	7.1
valid entries	885	99.2	100
uncertainty	7	0.8	

Fig. 6 Willingness to spend money on a car

2.2.3.7 General psychological user motivation

Consumer behavior in reference to specific issues, such as the usage of advanced driver assistance systems, is not only determined by cognitive use expectations. However, also by psychological disposition. The so-called ‘Big Five’ are a standard empirical instrument for surveying the general psychological disposition of target groups, which was applied in a truncated version of ten individual questions.⁴

Dimension	Descriptive content	Real scale values (0...100) ⁵			
		Min.	Max.	Arithm. mean	Median
1 Extraversion	<i>I tend not to be reserved, I'm a sociable person, I don't get insecure easily.</i>	7	100	62	63
2 Openness and imagination	<i>I have an artistic interest, I have a broad imagination.</i>	0	100	54	52
3 Tackling things yourself instead of criticizing	<i>I don't avoid effort, I don't tend to criticize others.</i>	0	100	53	53
4 Working calmly and thoroughly	<i>I make a point of completing tasks thoroughly, I remain calm.</i>	5	100	71	70

Fig. 7 Psychological characteristics (self-assessment)

⁴ See Rammstedt et al. (2013).

⁵ Based on the assignment of the individual variables to the dimensions, sum indices were calculated which have the same scaling as the initial items (from 0 to 100) and are easier to interpret than z-transformed factor scores.

- The data set displays a factor structure including four personality dimensions: 'Extraversion', 'Openness and imagination', 'Tackling things yourself instead of criticizing' and 'Working calmly and thoroughly' (cf. Fig. 7). The four dimensions can then be examined in terms of their significance, concerning the advanced driver assistance systems.
- All four dimensions express 'positively' assessed personality traits. Compared to the theoretical average value (on a scale of 0 to 100, this would be 50), the self-assessments are slightly in the positive range, containing the top values in the dimensions 'Working calmly and thoroughly' (71) and 'Extraversion' (62).

2.3 User typologization according to the requirements of the car

Hinging upon previous studies and explorative analyses, eleven key criteria were defined for vehicles (sportiness, low fuel consumption, comfort, low price, low emissions, state of the art, safety, high-quality brand, reliability, plenty of space, great design). These eleven criteria have been complimented with the criterion 'innovative advanced driver assistance systems', as the main aim of the study has been the classification from the consumer's point of view.

Respondents have been inquired to classify the relevance of the twelve requirement criteria when buying a car. Based on these assertions, factor analysis can be used to determine⁶ how the individual criteria are grouped into dimensions (factors) in the perception of the target groups. Therefore, three key factors can be distinguished:

Requirement dimension	Contents	Real scale values (0...100) ⁷			
	Requirement criteria	Min.	Max.	Average	Median
1 High quality and state of the art (image factor)	sporty, high-quality brand, innovative advanced driver assistance systems , state of the art, great design	0	100	60	63
2 Economically and environmentally friendly	low emissions, low consumption, low price	0	100	71	74
3 Functional	Safe, reliable, plenty of space	30	100	80	83

Fig. 8 Average values of the sample in three requirement dimensions based on twelve defined requirement criteria for the car

⁶ Factor/main component analysis with varimax rotation, n= 892, KMO=.798, Bartlett chi² =3442.94, p<.001. cumulative variance of the three factors = 58.64 %. eigenvalues after rotation: F1=3.244, F2=1.948, F3=1.845.

⁷ Hinging upon the assignment of the individual variables to the dimensions, sum indices have been calculated, having the same scaling as the initial items (from zero to 100) and are simpler to interpret than z-transformed factor scores.

- The outcome indicates that advanced driver assistance systems, in conjunction with aspects such as high quality and modernity, belong to an (image) dimension of car assessment. This dimension is distinguished ('statistically independent') from the other two dimensions 'economically and environmentally friendly', as well as 'functionality'.

☞ Advanced driver assistance systems contribute more to the modern image perception of cars in customers' eyes than to their functionality.

- This is particularly remarkable, as the manufacturers assume (unevaluated) the functional benefits of assistance systems, such as park assist or ACC.

The factor analysis thus states why the assistance systems are not in demand by drivers - or, if ordered, not used the way that OEMs and suppliers expect them to: If customers predominantly perceive this as an aspect of image rather than a functional benefit, it won't firmly establish within the perception of the target groups, and consequently, there will be minimal change.

The study reveals deficits in the market development, especially in the communication and customer care of car manufacturers, triggering specific action requests:

☞ First and foremost, advertising should focus more on the functional benefits of the assistance systems, in order for customers to have the desire to 'own' and 'use' them. This advertising can certainly be done in terms of emotional means and measures, viz. *without talking about* a technical product description. However, it is pivotal to bring the assistance systems to the forefront in terms of wording and placement if aiming to accelerate their spread. With features that require explanation, manufacturers cannot assume that diffusion in the market will skyrocket on its own.

☞ Secondly, actual 'testing' of assistance systems must be provided more extensively in terms of customer service at the dealership for prospective buyers .

☞ Thirdly, after the purchase, vehicle handovers mentioning '*do you need a briefing or can you manage on your own*' must no longer occur. The manufacturer's specification has to state that there is a detailed briefing for every customer. Each buyer has the right to try out all systems and user interfaces under various conditions, make blunders, 'play' with the controls and have questions about usage answered.

2.4 Experience and desire for advanced driver assistance systems

2.4.1 Unsupported positive associations

Category	Assistance system	Individual statements	n
comfort, support (n=322, 46.1%)	ABS	convenient, useful	6
	ACC	renders long journeys more pleasant and stress-free	36
		useful	26
	hill start assist	starting aid helpful on hills	7
	parking assistant	useful, convenient and simple	9
	light assistant	automated dimming up and down highly convenient	3
	fatigue warning system	aids a lot in terms of long journeys	4
	emergency brake assistant	can be helpful	3
	park steering assistant	renders parking easier	34
		oneself can pull into a parking space otherwise too narrow	5
		reduces parking time	3
	parking sensors	useful, aids when driving a big car	8
		spacers especially useful for elderly people	1
	rear view camera	much helpful, useful for maneuvering	14
	lane departure warning system	convenient and increases comfort	17
		functional on the highway	8
	lane change assist	useful	4
	traffic jam assistant	renders traffic jams more relaxed	11
		useful	12
	cruise control	comfortable and convenient	20
		relaxed feeling on the highway	5
	dead angle assistant	useful for lane changes	11
	FAS in general	endows a good feeling and aids with driving	25
		support on long journeys	11
		relieving, convenient, stress-free, comfortable	39
safety, accident avoidance (n=195, 27.9%)	ABS	secure in adverse road conditions	7
		oneself can steer while braking	4
	ACC	increases safety reliably	33
		avoids accidents	21
		useful in challenging traffic situations	4
	ESP	explicitly useful in snow	1
		stayed on the road despite excessive speed	1
	light assistant	automatic bend lighting; dipped beam increases safety	1
	fatigue warning system	useful for decreasing concentration, fatigue	11
		reminder to take necessary rest	13
	night vision system	highly useful, security	1
	emergency brake assistant	highly useful when driver is distracted	7
		collision warning as mere meaningful FAS	1
		possibly alleviates dangerous situations	9

(continuation of the table on the following page)

	Park steering assistant	contributes to safety	5
	parking sensors	Park Distance Control prevented an accident	2
	lane departure warning system	increases safety by shaking people awake	8
		aids avoiding accidents	9
	dead angle assistant	increases safety	9
		reduces the risk of accidents	3
	traffic jam assistant	in traffic jams the car brakes automatically	2
	FAS in general	reacts faster than humans	3
		overconfidence is prevented	1
		avoidance of errors and accidents	15
		reduces risks when driving	24
generally positive (n=162, 23.2%)	ABS	decent, favorable, etc.	2
	ACC		36
	ASR		2
	hill start assist		9
	ESP		5
	FAS in general		13
	light assistant		3
	fatigue warning system		2
	emergency brake assist		3
	parking assistant		17
	lane departure warning system		38
	traffic jam assistant		18
	cruise control		10
	dead angle assistant		4
other (n=20, 2.9%)	ACC	pleasant gimmick on the highway	2
	citystop assistance	favorable	1
	FAS in general	nice to have, not absolutely necessary	7
		reliable	1
		save fuel	1
	parking assistant	fun, however, not necessary	4
	lane departure warning system	works well in the Tesla	1
	cruise control	saves gasoline	3
Total, (multiple) replies from 892 respondents			699

Fig. 9 Positive experiences with advanced driver assistance systems (unaided survey)

- The positive associations are dominated by the aspects comfort and support, as showcased by the most frequently occurring descriptive wording ('more pleasant', 'less stressful', 'easier', 'convenient', 'comfortable', 'relieving', etc.).
- Potential safety benefits are also frequently mentioned in conjunction with the terms 'prevented accidents' and 'increased overall safety'.

2.4.2 Negative experiences with advanced driver assistance systems

Category	Assistance system	Individual statements	n
unreliable, immature (n=276, 51.4%)	ACC	shifting gears with manual transmission nevertheless required	1
		brakes too often, too harsh	27
		no reaction at all or response too late	4
		not fully developed, poor recognition	5
	in general	dangerous, accidents, system failures	57
		immature, lack of infrastructure	12
		malfunctions (in general / weather-related)	32
	ASR	slows down significantly in slippery conditions, engine stalls	1
	high beam assistant	dimmed too late or incorrectly	3
	pedestrian warning	often not comprehensible (Audi)	1
	speed detection	not working with every sign	1
	fatigue warning system	does not function properly	43
	emergency brake assist	brakes in underground car park or due to blade of grass when reversing, bend not recognized	6
	parking assistant	not working well enough	23
	PDC	Spacers peep incorrectly	21
	automatic windshield wipers	not working properly	1
	lane departure warning system	malfunction at roadworks, driving too fast in bends, bad weather conditions, switches off after 10s	33
refusal (n=69, 12.8%)	ACC	ACC redundant	5
	in general	unnecessary, deliberately opposed to, not helpful	31
	fatigue warning system	redundant fatigue warning system	16
	parking assistant	much too slow, more efficiently if doing by oneself	14
	lane departure warning system	lane departure warning system: unnecessary	3
lack of trust (n=42, 7.8%)	ACC	distance warning system: lack of trust	4
	in general	no trust, smarter human being, dilemmas	34
	navi	navigation systems can cause problems	1
	Autonomous parking	elicits a doubtful feeling	2
	cruise control	lack of trust	1

(continuation of the table on the following page)

other (n=150, 27.9%)	ACC	prefer to choose the distance at which you feel safe yourself	1
		annoying, distracting signals, huge space at traffic lights	4
		beep, function takes some time to get used to	2
	in general	Audi / VW strong influence and intervention, lack of coordination between various car manufacturers hinders traffic flow	2
		familiarization: incomprehensible, complex, much English language, insufficient information, difficulties when switching between cars, confusion due to too many systems, untrained sales staff	25
		malfunctions can no longer be rectified by the driver, driver renders fewer decisions himself, restricted driving experience	14
		drivers are quickly overwhelmed when systems break down, forget how to drive properly	4
		questionable who is liable when an event of damage is occurring, failure difficult to prove	3
		detrimental media reports about Tesla etc. on television	2
		highly expensive to purchase and repair, often not available in the basic version	18
		skepticism of suitability for everyday use, legal feasibility	1
		systems intervening too often, too hectic, too nervous and unjustified	4
		resistance of the system often very high	1
	safety belt	disturbing peeping	2
	autopilot	unfamiliar, uncomfortable	1
	cruise control	complains: constant warning	1
	nightvision	nightvision is partially distracting while driving	1
	parking assistant	unfamiliar, chafing oneself, practice necessary	9
		very loud, too much peeping, annoying	4
	lane departure warning system	Intervenes too much, uncomfortable, not feasible with poor markings, obstructive when driving, no lane changes without flashing/strong counter-steering dangerous	51
Total, (multiple) replies from 892 respondents			537

Fig. 10 Negative experiences with advanced driver assistance systems (unaided survey)

- The prevailing criticism states that the systems are not yet fully developed or even called unreliable. This category accounts for more than half of the replies.

2.4.3 Overall analysis of the desire for and experience with advanced driver assistance systems

From the wide range of advanced driver assistance systems available today, six of varying complexity and prevalence (from ‘fatigue warning’ to ‘autonomous parking’) have been selected. On the basis of preliminary studies, we empirically determine.

- who has experience with the assistance systems and
- who desires them.

According to the illustration, experiences with these specific assistance systems align with expectations, varying from just below 60 percent for ACC to slightly under 10 percent for ‘autonomous parking’.

Assistance system	Having <u>experience</u> (percentage of respondents)	<u>Desire for this assistance system</u> (ranging from 0 - 100)		In percentage, how much does experience increase desire?	Desire ‘with/without experience’ stat. significantly different?
Fatigue warning system	Yes (56.6%)	53	Ø 52.5	1.9	no
	No (43.4%)	52			
ACC	Yes (59.9%)	73	Ø 66.0	32.7	yes (p=.000)
	No (40.1%)	55			
Lane departure warning system	Yes (55.4%)	61	Ø 56.7	19.6	yes (p=.000)
	No (44.6%)	51			
Parking assistant	Yes (49.4%)	59	Ø 51.2	34.1	yes (p=.000)
	No (50.6%)	44			
Traffic jam assistant	Yes (33.6%)	70	Ø 58.1	34.6	yes (p=.000)
	No (66.4%)	52			
Autonomous parking	Yes (9.9%)	46	Ø 33.3	43.7	yes (p=.000)
	No (90.1%)	32			

Fig. 11 Experience and desire for advanced driver assistance systems

- 56.6 percent of the respondents already have experience with the **fatigue warning system**. This assistant places no special requirements on the driver and is already part of the standard equipment in a plethora of cars. Customer enthusiasm for this 'minor' feature is constrained: solely around 52% of drivers desire to have their cars equipped with the assistant. Moreover, there happens to be no significant distinction between customers 'with' and 'without' experience. The benefit of the fatigue warning system is obviously overall not rated as highly useful. This is consistent with the fact that drivers often consider, when being asked in open questions, the fatigue warning system as not reliable (*"reports tiredness although I am not tired at all" or "when I am really tired, it doesn't notice"*).
- 59.9% have experience with **ACC**. The desire to own this assistance system is in average at 66 index points on a range from 0 to 100. Already having experience with ACC increases the desire for this assistance system by 43.7 percent.
- 55.4 percent of the respondents have experience with the **lane departure warning system**. The average desire is 56.7 index points. Experience increases the desire for this assistance system by 19.6 percent.
- 49.4 percent have experience with the **parking assistant**. The average desire to buy the assistant is at 51.2 index points. Experience increases the desire for this assistance system by 34.1 percent.
- 33.6 percent already gained experience with the **traffic jam assistant**. The average desire is at 58.1 index points. Already having experience with this assistant increases the desire by 34.6 percent.
- Solely 9.9 percent have experience with **autonomous parking**. The average desire for this assistant is at 33.3 index points. Experience increases the desire by 43.7 percent, which is the top increased rate of all the assistance systems examined here.

☞ The desire to own a advanced driver assistance system lies in averages between 33 and 66 index points on a scale from 0 to 100. We conclude that the target groups **portray interest** in advanced driver assistance systems. However, there is still **room to improve this desire**.

☞ A key driver for the desire to own a advanced driver assistance system is, whether someone has already gathered experience with them. Apart from the 'small feature' fatigue warning system, the following applies: present experience with an advanced driver assistance increases the desire to purchase one, when ordering in the future. Thus, 19.6 percent would buy a vehicle with a lane departure warning system and 43.7 percent of respondents would purchase an autonomous parking assistant.

☞ Therefore, it is critical for OEMs to get customers in touch with the assistance systems.

2.4.4 Differences by age and gender

Gender	Percentage of the sample	Experience with assistance systems (scale 0...100)	Desire for assistance systems (scale 0...100)
Women	49.7	38.0	53.6
Men	50.3	46.3	51.8
Age, years			
18-20	8.1	41.4	52.0
21-29	31.8	48.7	54.5
30-49	26.5	48.0	51.2
50-65	23.5	35.9	49.1
66 and above (max. 88)	10.1	22.0	60.0

Fig. 12 Advanced driver assistance systems depending on driver age and gender

- Women have significantly less experience with assistance systems in comparison to men. This distinction is statistically highly significant.⁸
- In contrast, there is no essential difference in the desire of owning an assistance system. The preference is only marginally higher among women.
- With increasing age, practical experience with advanced driver assistance systems tends to decrease.
- The desire for assistance systems does not clearly correlate with age. However, the group with the eldest people (aged 66 and over), possesses a significantly higher desire for assistants. Apparently, advanced driving assistants are seen as helpful in terms of compensating increasing physical limitations.

⁸ Anova, $p < .001$.

2.4.5 Differences according to educational level

Conclusion	Percentage of the sample	Experience with assistance systems (Scale 0...100)	Desire for assistance systems (Scale 0...100)
Up to secondary school	19.5	32	54
Intermediate secondary school certificate	22.6	37	49
A-levels (no university degree aspired)	16.6	41	49
University studies	39.8	50	56
Others	1.5	47	44

Fig. 13 Experience with advanced driver assistance systems and desired features depending on the driver's level of education

- Experience with assistance systems tends to grow alongside higher levels of education.
- The desire for assistance systems does not unequivocally correlate with the various levels of education. However, this desire is significantly higher among university graduates than among the average of all respondents.

2.4.6 Differences according to the size of the place of residence

Population of the place where the driver currently lives	Percentage of the sample	Experience with assistance systems (Scale 0...100)	Desire for assistance systems (Scale 0...100)
up to 4,999	27.4	43	49
5,000 to 24,999	27.1	41	51
25,000 to 99,999	24.8	41	55
100,000 to 999,999	9.6	42	58
1 million and more (max. 3.5 million)	11.1	48	56

Fig. 14 Experience with advanced driver assistance systems and desired features depending on the driver's place of residence

- The desire for assistance systems is more pronounced amongst people from larger residential areas.

2.4.7 Differences according to willingness to spend on a car

Willingness to spend (Euro)	Percentage of the sample	Experience with assistance systems (scale 0...100)	Desire for assistance systems (scale 0...100)
up to 4,999	8.7	39	52
5,000 to 9,999	12.3	34	51
10,000 to 19,999	29.6	37	52
20,000 to 49,999	42.3	45	53
50,000 + (max. 175,000)	7.1	64	57

Fig. 15 Experience with advanced driver assistance systems and desired features depending on willingness to spend money on a car

- Experience with assistance systems tends to enhance as the willingness to spend money on the car increases.
- Thus, also the desire for assistance systems gravitates towards intensification as the willingness to spend on a car augments. The argument 'the desire is greater than the real experience' holds true for all groups of people with the propensity to spend. However, this is not the case for persons who are willing to spend more than EUR 50,000 on a car. The study suggests that this group has by far the highest experience with assistance systems (in any case).

- ☞ The lower the willingness to spend on a car, the better the ability to increase the desire for advanced driving assistants by **providing** drivers with the **opportunity to experience these systems**. This is a clear-cut requirement for OEMs and their dealerships.
- ☞ As real-life experiences step up, the desire for advanced driver assistance systems increases at a disproportionately low rate. Hence, we deduce that there is both, a need to **further tweak** these **systems, as well as to** communicate their **use and benefits**.

2.4.8 Differences according to annual mileage

Individual mileage with vehicle per year, km	Percentage of the sample	Experience with assistance systems (Ø on the scale 0...100)	Experience with assistance systems (median)
up to 4,999	15.6	35	33
5,000 to 19,999	50.0	39	33
20,000 to 49,999	28.8	49	50
50,000+ (max. 120,000)	5.6	56	67
Total	100.0	42	50

Fig. 16 Experience with advanced driver assistance systems as a function of annual mileage

- People with amplifying mileage exhibit linearly increasing experience with advanced driver assistance systems.

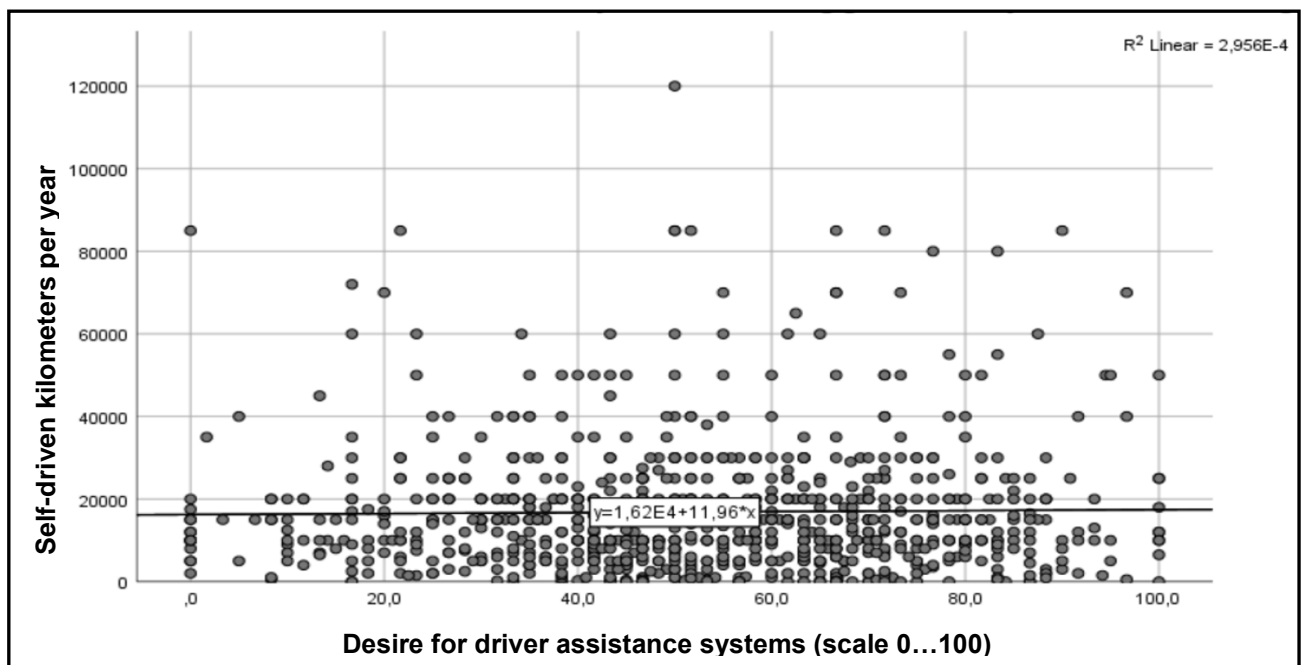


Fig. 17 Overall desire for assistance systems as a function of annual mileage

- In contrast, there happens to be no universal picture in the matter of the desire for assistance systems (Fig. 17): The desire varies significantly on an individual basis. One can find drivers with a high mileage preferring to drive without assistants, as well as drivers who travel less by car, but request to own as many assistants as possible.

2.4.9 Differences according to brand preference

It can be assumed that the desire for advanced driver assistance systems differs among the car enthusiasts of various brands. It is to be expected that customers purchasing premium brands demand an above-average number of assistance systems, especially as these are associated with significant costs.

The database enables analyses according to 51 different manufacturer brands. The subsequent table compares the desire for advanced driver assistance systems, as expressed by potential Tesla customers, with potential customers of the French manufacturers Citroen, Peugeot and Renault.

If we take a look at the average desire across all six advanced driver assistance systems examined (compare last line of the figure 'Index desire all'), the expected outcome is illustrated. Meaning, that the potential Tesla customers⁹ displays a higher average desire for assistance systems than the likely customers of the three French manufacturers.

Desire for...	Respondents who would buy a Tesla		Respondents who would buy a Peugeot, Renault or Citroen	
	Average	Median	Average	Median
Fatigue warning system	60	70	49	50
ACC	73	80	63	70
Lane departure warning system	60	70	52	55
Parking assistant	57	60	55	62
Traffic jam assistant	76	88	59	65
Autonomous parking	50	50	28	15
Index desire for all of the above	63	66	51	51

Fig. 18 Desire for advanced driver assistance systems depending on preferred car brand

Concurrently it should be adhered:

- Concerning individual assistance systems, desires deviate. Potential Tesla customers request lane departure warning systems or autonomous parking more frequently than customers of French manufacturers. However, there are only minor differences when it comes to parking assistants.

⁹ The situation with 'Mercedes customers' is similar to that of potential 'Tesla customers'.

- ☞ Overall, there are less contrasts between customers of different brands than of drivers 'with' and 'without' experience regarding advanced driver assistance systems. It is therefore less critical for the dissemination of these assistants to be aware of which manufacturer brand a customer leans towards. Moreover, the key distinction is made whether someone has already used the assistance systems or not.

2.4.10 Desire for assistance systems hinging upon the essential requirements of a car

The requirements for a car, derived above, (Fig. Fig. 78) can be examined to determine whether they are systematically correlating to the desire for advanced driver assistance systems. To put it differently, whether they 'provide an explanatory contribution'.

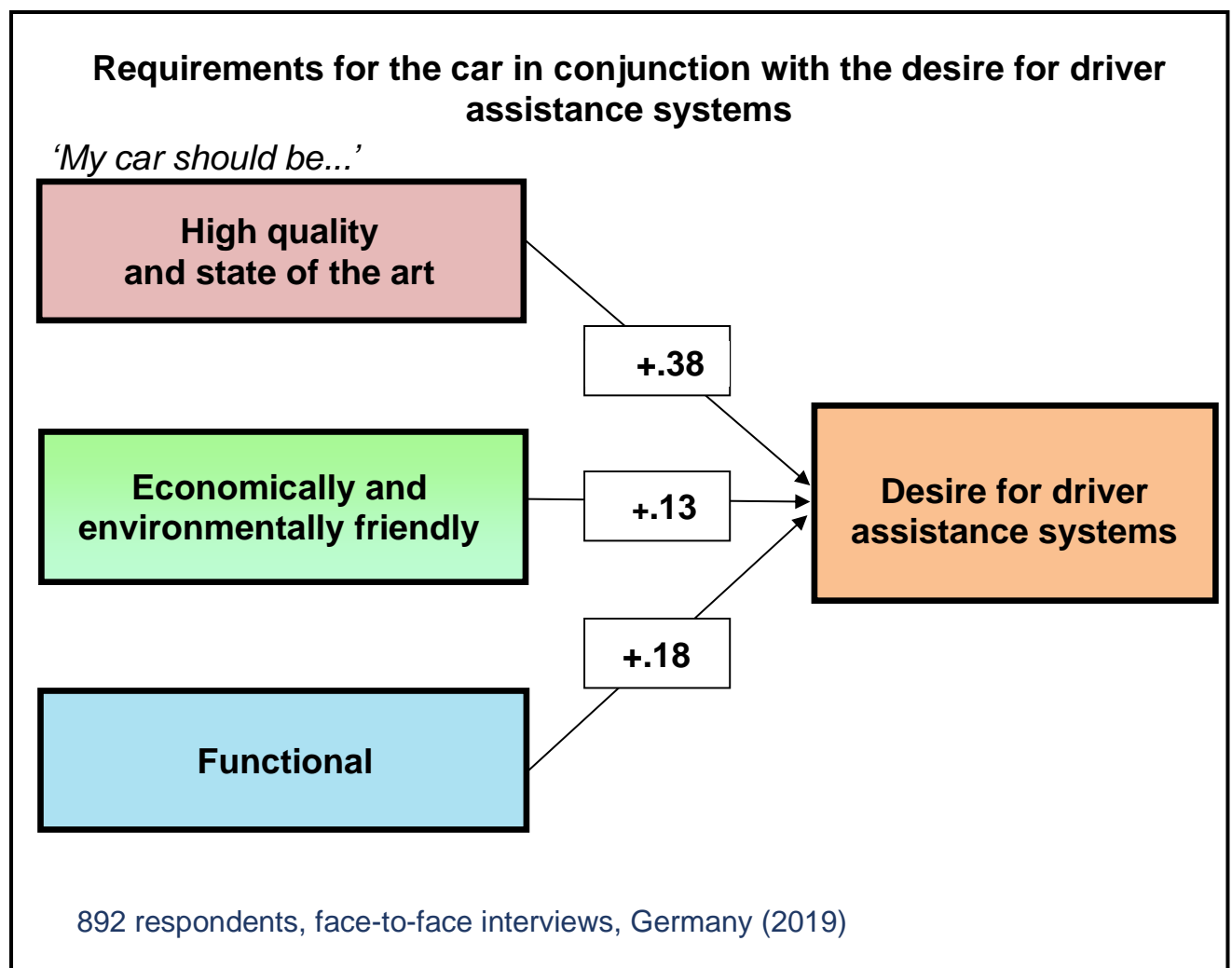


Fig. 19 Influence of three main car requirements on the desire for advanced driver assistance systems¹⁰

¹⁰ Interpretation of the values in the white boxes: So-called beta values of the regression analysis can lie between 0 and 1. The higher the value, the greater the influence on the dependent variable (in this case: the desire for driver assistance systems)

- All three requirement dimensions provide a statistically significant contribution to the desire for advanced driver assistance systems.
- The desire for a 'high-quality and state of the art vehicle' is most strongly associated with the desire for advanced driver assistance systems.¹¹
- The correlation between the requirements 'functionality', as well as 'economically and environmentally friendly' with the desire for advanced driver assistance systems is much lower, although statistically significant.

- ☞ Broadly speaking, the higher the requirements potential car customer place on a vehicle, the greater is their desire for advanced driver assistance systems.
- ☞ Advanced driver assistance systems are most likely to be requested by people demanding a high-quality and state of the art car ($\beta=.38$). Not even half as significant is the leverage of a preferred car functionality on the desire for advanced driver assistance systems ($\beta=.18$).
- ☞ OEMs must intensify their efforts to communicate the functional benefits of advanced driver assistance systems.

2.4.11 Personality dimensions and the desire for advanced driver assistance systems

Above, four general personality dimensions for the sample have been derived (extraversion, openness and imagination, tackling things yourself instead of criticizing, working calmly and thoroughly). In contrary to the explanation of the desire for autonomous driving (as stated below), there are *no* pertinent and significant correlations of the four personality dimensions with the desire for advanced driver assistance systems.¹² Therefore, an illustration is redundant.

- ☞ The desire for advanced driver assistance systems is not explicitly depending on a specific general psychological personality type of car buyers. The communication strategy of OEMs regarding the promotion of the benefits of assistance systems does not need to pay attention to specific general personality types.

¹¹ Significance of the three factors: F1/high-quality and state of the art: $t=12.47$, $p<.001$, F2/frugal and environmentally friendly: $t=4.299$, $p<.001$, F3/functional: $t=6.022$, $p<.001$. Overall model regression: $R=.443$, $R^2=.196$, $F=69.908$, $p<.001$.

¹² Beta-values and significances for the four personality dimensions: 'Extraversion': $\beta=.01$, $t=.409$, $p=.682$ (n.s.), 'Openness and imagination': $\beta=.05$, $t=1.491$, $p=.136$ (n.s.), 'Tackling things yourself instead of criticizing': $\beta=-.01$, $t=-.373$, $p=.709$ (n.s.), 'Work calmly and thoroughly': $\beta=-.01$, $t=-.144$, $p=.886$ (n.s.); dependent variable: overall desire for the six assistance systems, scale 0...100. Overall model regression: $R=.054$, $R^2=.003$, $F=.634$, $p=.639$ (n.s.).

2.5 Prospect: Desire for autonomous driving

2.5.1 Unsupported associations

Associations on the topic of autonomous driving have been gathered in an unsupported manner, i.e. without guidelines and information at an early stage of the survey. Thus, the respondents have not already been influenced by subject-specific questions. The answers are differentiated according to whether the participants expressed affirmative or adverse assessments.

Unsupported associations regarding the benefits of autonomous driving		
Category	Individual entries	n
Personal convenience (n= 491, 35.2%)	Laid-back driving, stress-free	142
	Time for other things while driving	135
	convenient, comfortable	71
	Car drives on its own, no driver required	58
	Relieving the driver, handing over responsibility	38
	Assistance systems	31
	Flexible and individual usage	10
	Car thinks for itself	6
Safety (n=331, 23.7%)	Accident prevention, no human blunders, etc.	153
	Road safety on the rise	135
	Problem of tiredness solved, sleeping in the car feasible	29
	Alcohol problem solved	14
Traffic optimization (n=157, 11.3%)	Avoidance of traffic jams, route optimization	81
	Adequate for long distances	27
	Optimized parking facilities, parking becomes easier	11
	Fast / constant traffic flow	10
	Traffic rules are observed better	8
	Choice of public transportation (subway, bus, cab)	7
	suitable for transportation of goods	6
	Reduction of traffic volume	4
	Improving urban transportation	3
Tendency over time (n=112, 8.0%)	Future, technical progress about to come	88
	Innovative, state of the art, digital age	24
Increase in mobility (n=82, 5.9%)	adequate for the elderly, disabled, with impairments etc.	75
	Aids with poor eyesight etc.	4
	Increasing mobility	3
Economic benefits (n=59, 4.2%)	Cutting down on costs, frugal driving, efficiency	40
	Suitable for frequent travelers and business travelers	10
	New business models, new jobs	5
	Driving license no longer required	4

(continuation of the table on the following page)

Generally suitable (n=57, 4.1%)	Great idea, suitable, reasonable, desirable, etc.	38
	Practical, helpful	19
Environment (n=32, 2.3%)	Environmentally friendly	27
	Reduces consumption	5
Other (n=74, 5.3%)	Being tested everywhere	26
	Tesla, Google and Uber are pioneers	23
	Technology offers many possibilities, is reliable	14
	Prerequisites a networked collective	11
Total (multiple answers from 892 respondents)		1395

Fig. 20 Unsupported associations with the benefits of autonomous driving

- As the table displays, respondents primarily expect autonomous driving to enhance their personal comfort. This category accounted for 35.2% of responses, followed by the topic of an increased road safety (23.7% of responses) and the optimization of traffic flow (11.3%).
- In contrast, solely 4.2 percent refer to economic benefits and only 2.3 percent relate to positive environmental aspects.

Fig. 21 shows an overview of the main categories.

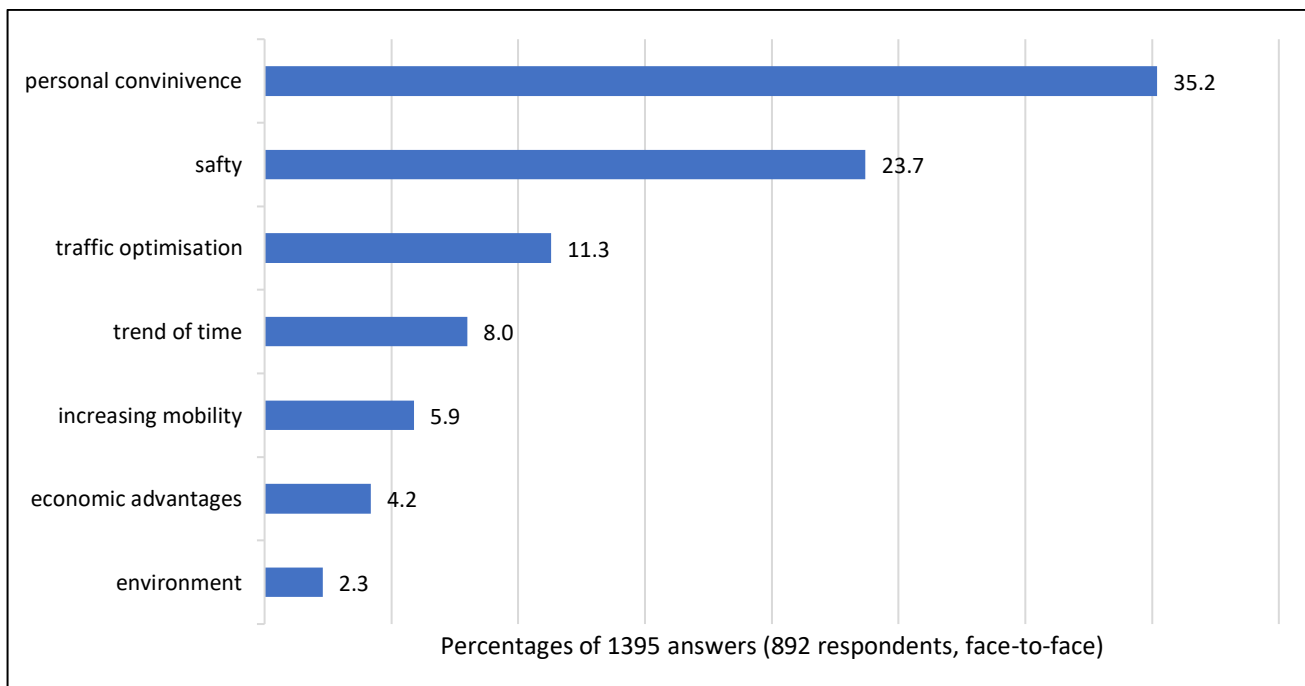


Fig. 21 Key arguments in favor of autonomous driving

2.5.2 Unsupported dismissive associations

Unsupported associations in contrary to autonomous driving		
Category	Individual entries	n
Risk of accidents, safety, reliability, trust (n=481, 28.8%)	No trust in technology, fear of failure	168
	Fear for safety	106
	Accidents at Tesla, Google etc.	58
	Prone to failure, malfunctions of technology, software, sensors, grid	55
	Questionable reliability	38
	Risk of accidents increasing	33
	Hazardous	13
	Machines and computers render blunders, too	7
	No possibility to reach the destination if system breaks down	3
Not yet good to go for series production (n=214, 12.8%)	Not yet good to go for series production, still requiring development, still takes a long time	194
	Still in test stage, 5th level not yet reached	12
	The infrastructure is not yet ready	4
	It is not yet determined how everything will work	4
Loss of control, desire to drive on one's own (n=200, 12.0%)	Loss of control, incapacitation, loss of independence	129
	Desire to drive and steer on one's own	32
	Dependency on technology, machines, computers	18
	No longer feasible to intervene yourself	7
	Not wanting to put one's life in the hands of a machine	5
	Lack of individuality (do I want to drive fast / slow / fuel-efficient)	4
	Fear of being restricted in my freedom wherever I go	2
	Unimaginable to leave everything to technologies	2
	Not knowing in advance how the car will react	1
Categorical rejection (n=169, 10.1%)	I am opposing it, no need, no interest, nobody has the need of it	38
	Creepy, scary, crazy, stupid	19
	Unfathomable, science fiction	16
	Does not work out, too complex	16
	People always being better than systems	18
	Very skeptical, would never rely on	14
	Not fully enforceable	10
	Can drive, has a driver's license, therefore redundant	7
	Better to extend and use public transport	6
	Those who can't drive should take the bus	6
	Autonomous driving does not have a promising future	5
	No longer at my age	5
	I would not use it	3
	Unsuitable for highway	3
	A plethora of influences cannot be predicted in city traffic	2
	Airplane traffic is also not automated	1
Legal and ethical problems (n=136, 8.1%)	Liability / responsibility in the event of an accident vague	79
	Still a host of unresolved legal issues	29
	Ethical discussion due to accident scenarios	24
	No legal requirements in Germany	4

(continuation of the table on the following page)

Loss of driving pleasure (n=111, 6.6%)	Lost pleasure of driving	75
	Boredom instead of pleasure while driving	17
	Driving is fun, therefore not an option	11
	Sports drivers disadvantaged	2
	Far too slow, slower than normal driving	6
Costs (n=92, 5.5%)	Price increase for vehicles and driving in general	39
	Expensive, high price, only for wealthy people	39
	Expensive maintenance and repair	7
	Expensive changeover	3
	Electronics are costly	2
	zero-defect tolerance costly	1
	Retrofitting cars being expensive or unfeasible	1
Data protection and security (n=76, 4.5%)	Hacking, manipulation by third parties	35
	Data protection and privacy unresolved, monitoring	21
	Big data analysis, data misuse	7
	Manipulable (without the driver's knowledge)	7
	Total control	4
	AI can be programmed incorrectly	1
	AI being harmful	1
'Stultification' (n=51, 3.1%)	Forgetting how to drive	21
	Attention in terms of road traffic decreases	16
	People's laziness is being supported	4
	Loss of own driving experience	3
	Independent thinking decreases	2
	Any fool can then drive around	2
	People no longer know what to do in case of a system failure	2
	People tend to become less independent when everything has been handed over to machines	1
Distribution, grid connection (n=37, 2.2%)	Problem mixture autonomous - non-autonomous	16
	Inadequate infrastructure in Germany	8
	Only in metropolitan areas, not feasible in rural areas	6
	Road grids are not construed for this	3
	All participants must always be online	2
	Cannot be used everywhere, communication problems	2
Job losses and economic disadvantages (n=18, 1.1%)	Jobs of professional drivers, cab - and bus drivers	13
	Losses in cab business	4
	Losses for car dealers & suppliers	1
Problems of elderly people (n=10, 0.6%)	Elderly people don't apprehend all the technology	4
	Elderly people already having no confidence in technology	4
	Operating problems of the elder generation	2
Other (n=76, 4.5%)	Personality and human interaction are missing	5
	Driver must still be attentive	4
	Technology makes people redundant	4
	Challenging implementation	4
	Rethinking required in the automotive industry	3
	Costly to test autonomous cars on all road sections	2
	Ease of use of modern technologies	2
	Human intervention questionable in case of an emergency	2
	Different assessment of man and machine	2
	Driving license redundant	2

(continuation of the table on the following page)

	Takes time getting used to	2
	No advantage as long as I have to remain attentive as a driver	2
	No cross-border solution	2
	Working even harder - while driving	2
	Even more cars on the road, due to everyone being able to use	2
	Too little providers	2
	Alcohol and drugs on the steering wheel	1
	Car must be able not to use the brakes in case of (e.g.) swirling leaves	1
	Concerns that animals are being recognized too late or not recognized at night	1
	Ideally only auxiliary usage	1
	Traffic in Germany would have to change.	1
	Germany is worse than USA	1
	Features of the car lose value e.g. horsepower	1
	Requires rethinking	1
	Question of longevity of such systems	1
	I feel uncomfortable as a passenger	1
	Technology difficult to understand for end users	1
	No synergies (as with public transportation)	1
	Short-term lane changes might trigger problems	1
	Machine must recognize hazards	1
	Mobile robot, technology that doesn't inspire	1
	Inadequate, you should drive wisely	1
	Not necessarily more environmentally friendly	1
	Nice to have (bells and whistles)	1
	Does the car react as swiftly as I do	1
	Response too complex, unconventional situations	1
	Difficult on poorly lit roads	1
	Challenging in city and urban traffic	1
	Difficulties in programming	1
	State loses money if no more usage of speed cameras	1
	State will not raise alcohol limit for autonomous cars	1
	Systems not synchronized well enough	1
	Overvalued	1
	Transition from free to autonomous driving dangerous	1
	Driving school paid in vain	1
	Unsure whether assistance systems offer a bevy of advantages	1
	Incomprehensible	1
	Minimization of threats (e.g. driving with a cell phone)	1
	Unsure	1
	Useless for working on the construction site	1
Total (multiple) answers from 892 respondents		1671

Fig. 22 Unsupported associations in contrary to autonomous driving

- The host of possible points of criticism, some of them formulated in harsh language, illustrate the majority of drivers' negative attitude towards advanced driving assistant systems at the present time. Media reports about accidents in the USA, juridical dilemmas, insurance issues, etc. have become ingrained in the minds of German drivers, long before autonomous driving is on the glimpse of becoming reality.

- The 'playful' interest in new technologies, being found in Asia, as well as to some extent also in the USA, can solely be observed among a handful of German drivers.
- While the assumed advantages of autonomous driving are seen more as a vague promise of increasing convenience, German drivers are able to picture the potential disadvantages notably Pronounced fear of loss (control, independence, driving pleasure, data security, etc.) are evident.

Fig. 23 displays an overview of the main arguments in contrary to autonomous driving.

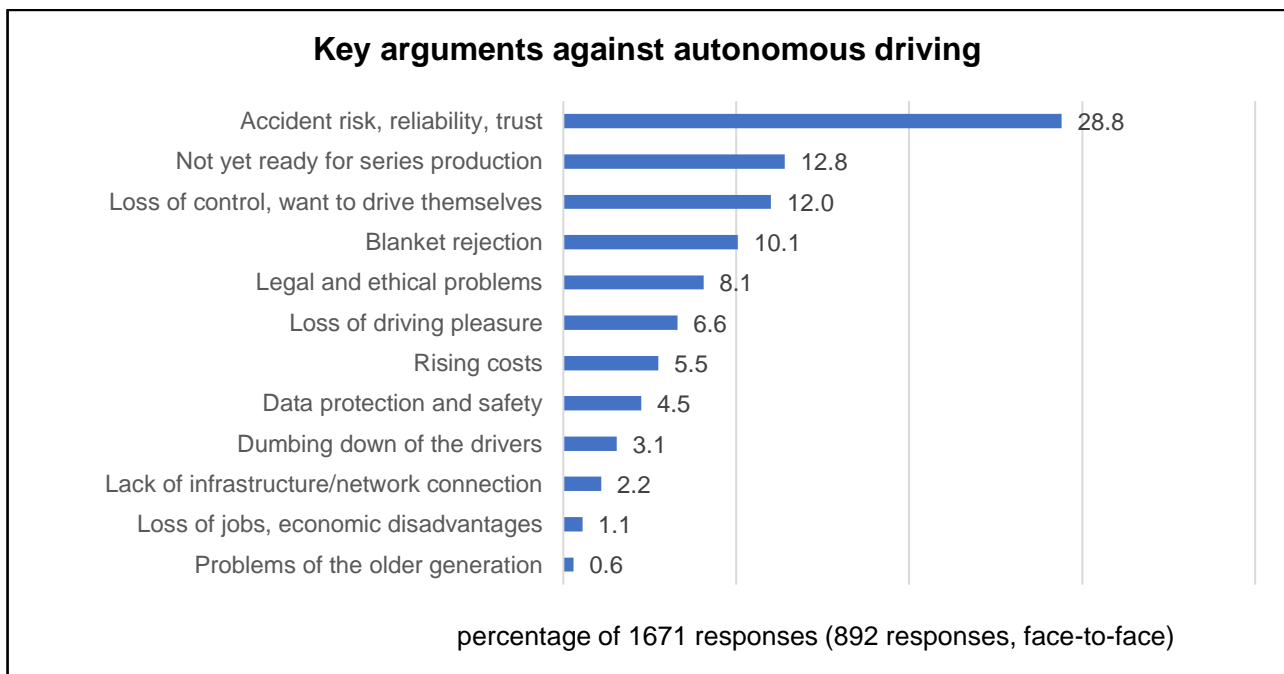


Fig. 23 Key arguments against autonomous driving

Comparison of advantageous arguments and points of criticism:

- The numerical comparison of the unsupported advantageous arguments (1395), as well as of the critical points (1671), mentioned by 892 respondents, illustrate that the concerns are prevailing.
- The particularly critical aspect of 'safety / accidents' is stated 331 times as a possible advantage. However, 481 times it is mentioned as a problem.
- A general approval of 57 people (6.4 percent of the sample) faces a broad refusal of 169 people (18.9 percent of respondents).

- ☞ The manufacturers and suppliers, working thoroughly on advanced driving assistance systems, have not yet succeeded in creating a positive sentiment. There is no joint image campaign of the manufacturers.
- ☞ The realization that the well-known beneficial arguments do not have the expected positive effects on the overall view is probably due to the entire car industry losing credibility in recent years. Thus, also the image of autonomous driving has been negatively implicated.

2.5.3 Overall wish

Fig. 24 displays the intensity of the desire for autonomous driving.

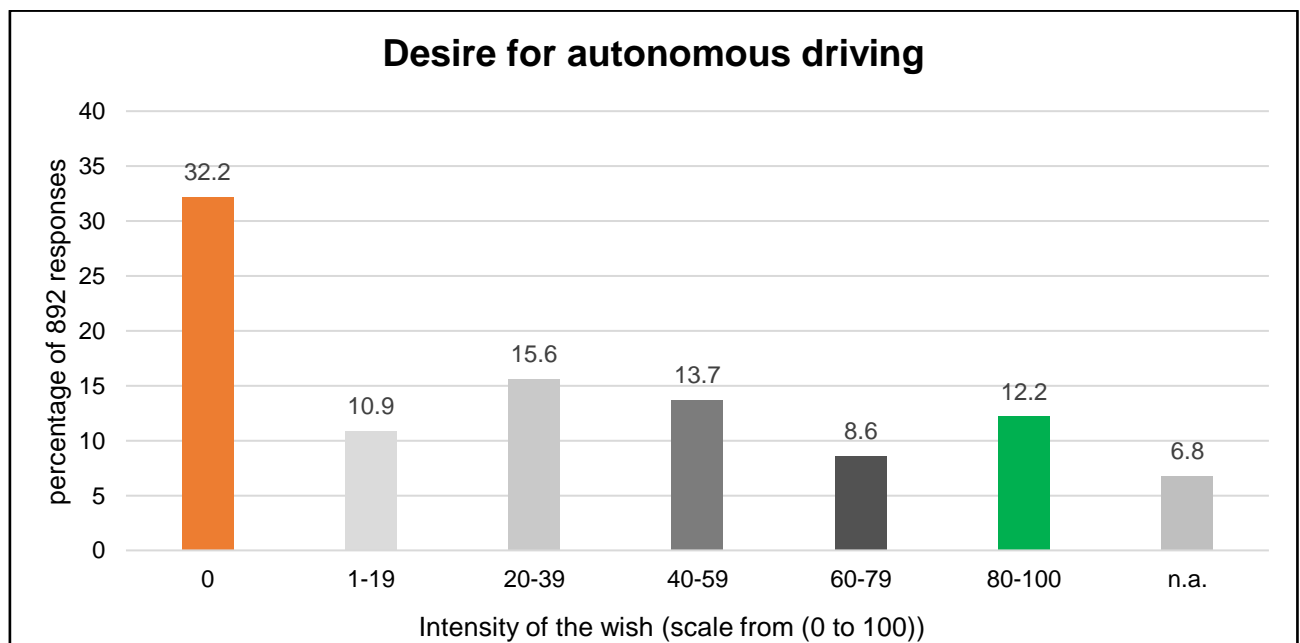


Fig. 24 *Desire for autonomous driving*

- On the 'preference scale' ranging from 0 to 100, the theoretical mean value would be 50. However, reality portrays that the wish for autonomous driving is significantly lower in the mean of the valid answers in the sample, namely at solely 30.0 (median 20.0).
- Many drivers, of which around a third rejects autonomous driving entirely (desire '0'), are not yet able to imagine themselves driving autonomously.
- As of yet, only one in eight drivers (12.2 percent), possessing a desire of 80 - 100 index points, can be considered a persuaded advocate of autonomous driving.

- ☞ German drivers are currently dominated by skepticism towards autonomous driving.

2.5.4 Correlation with brand preferences

As expected, distinct differences are portrayed in the desire for autonomous driving, when surveying drivers with different brand preferences. For instance, the desire for autonomous driving among drivers who intend to buy a *Porsche* or an *Alfa Romeo* has a mean value of merely 24 (median 5). Thus, it is significantly below the overall average. This value corresponds with unsupported statements such as 'loss of driving pleasure', 'loss of control', as well as 'loss of competence'.

2.5.5 Desire for autonomous driving depending on socio-demographic and behavioral criteria

The following analyses reveals that there are numerous differences in sub-target groups when in terms of the desire for autonomous driving (Fig. 25, following page).

- Men are significantly more open towards autonomous driving than women.
- Increasing level of education corresponds with a greater desire for autonomous driving.
- The inclination toward autonomous driving tends to increase in larger cities. However, this no longer applies to metropolitan areas with a population of 1 million or more. The individual analysis of the open responses indicates that inhabitants of cities with a population over 1 million increasingly prefer the use of public transport or demand its further expansion instead of autonomous driving. Thus, it is critical insofar as opinions are prevailing being shaped in metropolitan areas (media, political parties, etc.).

☞ If the automotive industry wants to pave the way towards autonomous driving, special campaigns are needed in metropolitan areas with a population of 1 million or more.

- As annual mileage increases, the desire for autonomous driving tends to rise.¹³
- As the willingness to spend money on cars augments, the desire for autonomous driving tends to rise.

¹³ In contrary to the overall trend, drivers with the lowest mileage, the youngest drivers and those with the least willingness to spend, displayed an increased desire. This presumably reflects a basic attitude of 'you can wish for it, even if it is not very realistic that I can afford it.' This does not change the overall significant correlations (increasing desire with increasing age, increasing mileage and increasing willingness to spend).

Split criterion	Desire for autonomous driving (scale 0-100)	
Gender Group differences statistically significant, $p=.023$	Female	28
	Male	32
School-leaving qualification Group differences statistically significant, $p=.005$	up to secondary school	25
	Intermediate school leaving certificate	25
	A-levels (no university studies)	29
	University studies	37
	Others	25
Age (years) Group differences statistically significant, $p=.005$	18 to 20	36
	21 to 29	33
	30 to 49	32
	50 to 65	24
	66 and above (max. 88)	24
Size of the current place of residence (Inhabitants) Group differences statistically significant, $p=.001$	up to 4,999	27
	5,000 to 24,999	27
	25.000 to 99,999	30
	100.000 to 999,999	43
	1 million and more	33
Annual mileage (km) Group differences not statistically significant, $p=.085$	up to 4,999	31
	5,000 to 19,999	27
	20,000 to 49,999	32
	50,000 and more (max. 120,000)	37
Willingness to spend money on a car (Euro) Group differences not statistically significant, $p=.096$	up to 4,999	35
	5,000 to 9,999	28
	10,000 to 19,999	28
	20,000 to 49,999	30
	50,000 and more (max. 175,000)	39

Fig. 25 Desire for autonomous driving in various sub-target groups

- While elderly individuals generally appreciate being driven, their interest in autonomous driving diminishes progressively and significantly with age. Evidently, most seniors either lack awareness of the potential benefits or are unable or unwilling to envision the advancements in fully autonomous driving technology. This stands out, especially considering that, concerning individual advanced driver assistance

systems, the desire to possess one actually rises with age, as indicated in the aforementioned study.

- Individual responses suggest that concerns exist within the older demographic regarding relinquishing a degree of autonomy by engaging in autonomous driving. This issue is already acknowledged, as mandatory driving tests for older individuals are socially unfeasible due to resistance from the elderly and politicians fearing voter backlash if they address the issue.

Press reports mentioning 'accident dilemma' (if an accident is unavoidable, should the autonomous vehicle then choose who is more likely to be injured, e.g. are elderly people more likely to be run over than younger people? etc.) may have also contributed to the fact that elderly people are rather holding a critical view in terms of autonomous driving.

- ☞ People in retirement age increasingly display the need for helpful advanced driver assistance systems, however, not autonomous driving.
- ☞ Elderly people want to continue to be able to drive on their own. They fear that implementing autonomous driving results in a loss of individual freedom rather than a profit.

2.5.6 Desire for autonomous driving hinging upon the requirements of a car

As mentioned above, we derived that drivers currently have three main requirements for their cars. It is feasible to analyze the conjunction between these main requirements and the desire for autonomous driving among car customers.

- The desire for a 'high-quality and modern vehicle' is associated with the desire for autonomous driving.¹⁴
- The requested 'functionality' of a car is hardly related to the desire for autonomous driving.
- There is no essential correlation between the requirement 'economically and environmentally friendly' and the desire for autonomous driving.

- ☞ Research displays that, similar to advanced driver assistance systems, it has not yet been possible to convince customers of the functional benefits of autonomous driving.

¹⁴ essential for the three factors: F1/high-quality and state of the art: $t=7.742$, $p<.001$, F2/frugal and environmentally friendly: $t=-0.569$, $p=.569$ (not significant), F3/functional: $t=2.127$, $p=.034$.

2.5.7 Desire for autonomous driving hinging upon personality type

As illustrated above, we have deduced four general personality dimensions. Two of the dimensions display tenuous, but statistically significant correlations with the desire for autonomous driving (Fig. 26).

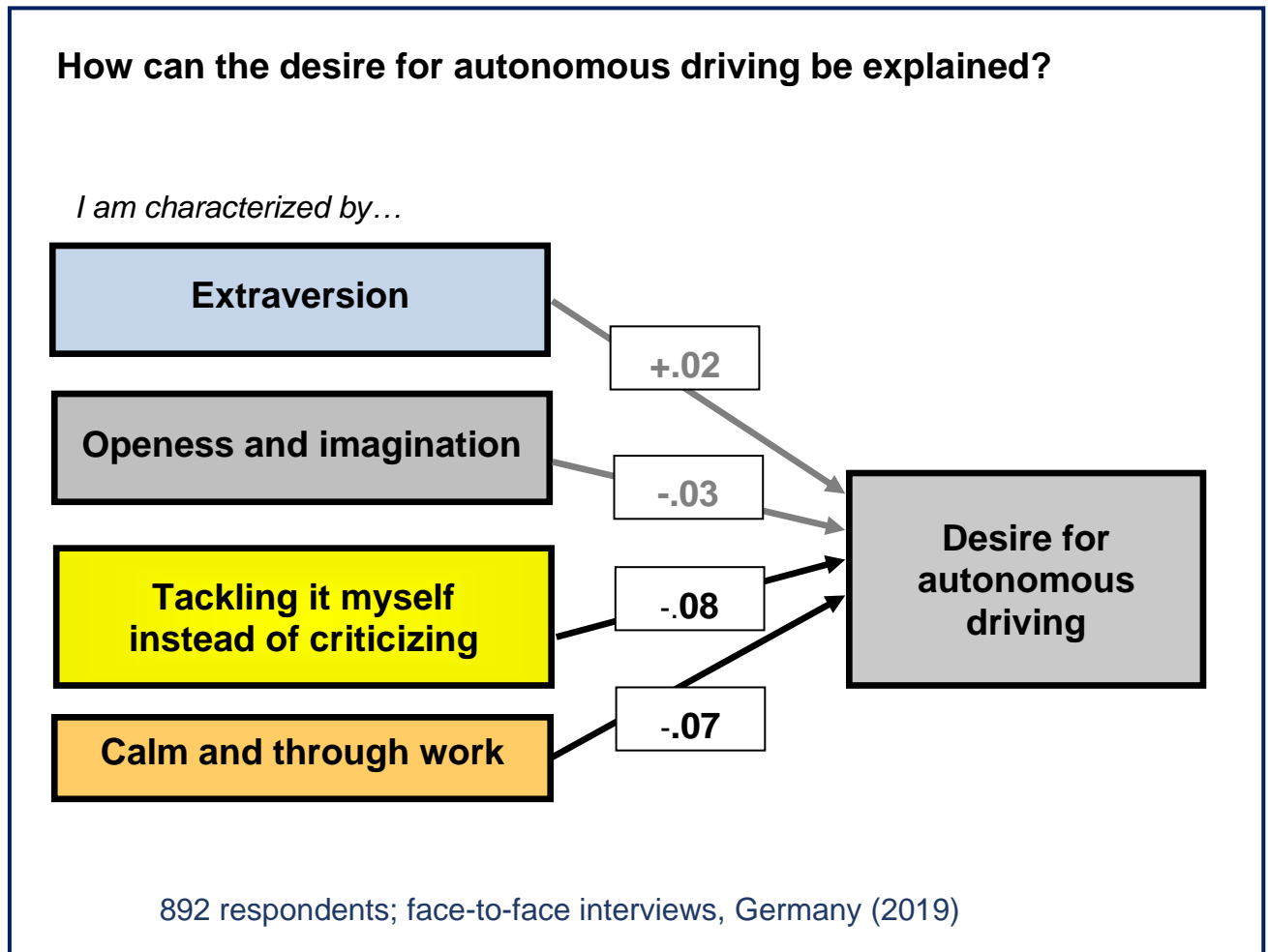


Fig. 26 Explanation of the desire for autonomous driving by general personality characteristics

- The more a person is characterized by the term 'tackling things themselves instead of criticizing', the less interested they tend to be in autonomous driving.
- The more someone is characterized by 'working calmly and thoroughly', the less interested they tend to be in autonomous driving.
- The personality dimensions 'extraversion', as well as 'openness and imagination' are not essentially connected to the desire for autonomous driving.

Considering the limited correlations, it is not given to draw any conclusions. It is hardly surprising that the two personality dimensions, associated with active motivation, tend to have a negative conjunction with the desire for autonomous driving. The 'doers' literally do not want to hand over control concerning the steering wheel.¹⁵

It is discouraging that regarding the other two personality dimensions, especially 'openness and imagination', no positive correlation to the desire for autonomous driving has been noticed. Study suggests that the reluctance of drivers towards the topic of autonomous driving prevails across all personality types. Thus, not even the more imaginative users (characterized by openness and imagination) face this topic open-minded.

☞ If the desire for autonomous driving should be more disseminated among the population, car manufacturers still face a long road to go. Broadly speaking, 'open-minded' people are not particularly open-minded towards autonomous driving. 'Doers' tend to be slightly averse towards autonomous driving.

2.6 Management Summary

2.6.1 On advanced driver assistance systems:

☞ Customers perceive that advanced driver assistance systems contribute more to the modern image of cars than to their functionality.

☞ Advertising should focus much more on the functional advantages of the assistance systems. Thus, customers demand to 'own' and 'use' them. This advertising can certainly be done by applying marketing methods concerning the emotional functionality. If we want to accelerate the diffusion of assistance systems, it is vital to bring them to the forefront in terms of wording and placement. Manufacturers cannot assume that diffusion in the market gets going on its own if certain features require explanation.

☞ When providing customer support to prospective buyers at the dealership, real-life 'testing' of assistance systems must be carried out more widely.

¹⁵ Significance for the four factors: 'extraversion': $t=.064$, $p=.949$ (not significant), 'openness and imagination': $t = -.975$, $p=.330$ (not significant), 'tackling things yourself instead of criticizing': $t=-2.184$, $p=.029$, 'work calmly and thoroughly': $t=-1.969$, $p=.049$.

- ☞ After purchase, vehicle handovers stating '*do you need instruction or can you manage it yourself*' must no longer occur. A detailed briefing for every customer needs to be displayed in the manufacturer's guideline for authorized car dealers.

- ☞ The desire for advanced driver assistance systems averages between 33 and 66 index points on a scale from 0 to 100. On the one hand interest on the part of the target groups **is given**. However, there is still **room for improvement**.

A key driver in terms of the desire for advanced driver assistance systems is whether someone has already had experience with them. Existing experience increases the desire to order the corresponding assistance system next time potential customers place an order by between 19.6 percent (lane departure warning system) and 43.7 percent (autonomous parking). It is therefore critical for OEMs to **get customers in touch with the assistance systems**.

- ☞ The lower the willingness to spend on a car, the more can the desire for advanced driver assistance systems be increased by **giving** drivers the **opportunity to test out these systems** (always keeping in mind the limits of what buyers can actually afford).

- ☞ As real-life experience increases, the desire for advanced driver assistance systems enhances at a disproportionately low rate. This displays that there is a need to **further improve these systems, as well as to** communicate their **use and benefits**.

- ☞ Disseminating advanced driver assistance systems, the customers' preference of a manufacturer's brand plays a less critical role. However, it is rather pivotal whether someone has already used the assistance systems or not.

- ☞ The higher the demand a potential car customer places on their vehicle, the greater their desire for advanced driver assistance systems.

- ☞ Advanced driver assistance systems are most likely desired by people wanting a **high-quality, state of the art** car. The influence of the desired **functionality** of the car on the desire for advanced driver assistance systems is not even half as significant. Therefore, OEMs must work harder to communicate the functional benefits of advanced driver assistance systems.

- ☞ The desire for advanced driver assistance systems is not clearly intertwined with a particular general psychological personality type of a car buyer. The communication of the benefits of assistance systems, as part of the OEM's communication policy, does not need to focus on specific general personality types.

2.6.2 On autonomous driving:

- ☞ Manufacturers and suppliers have not yet succeeded in creating a positive image towards autonomous driving. A joint image campaign of manufacturers has not been launched yet.

- ☞ Ultimately, the image of autonomous driving faces a lost credibility in the entire automotive industry over recent years.

- ☞ Skepticism towards autonomous driving clearly currently dominates among drivers.

- ☞ If the automotive industry wants to pave the way for autonomous driving, special **campaigns** are needed **in metropolitan areas** with a population of 1 million or more.

- ☞ People in retirement age increasingly display a desire for helpful advanced driver assistance systems, however, not autonomous driving.
Elderly people want still to be able to drive independently. Thus, they fear that autonomous driving results in a loss of individual freedom.

- ☞ As with advanced driver assistance systems, findings confirm that it has not yet been feasible to convince customers of the functional benefits of autonomous driving.

- ☞ If the desire for autonomous driving shall increase among the population, car manufacturers still have a bevy of **educational work in front of them**. 'Open-minded' people are not particularly overt towards autonomous driving. 'Doers' are rather holding an adverse opinion of autonomous driving.

3 The importance of autonomous driving (conjoint analysis)

3.1 Investigation profile

3.1.1 Definition of the problem

Standardized quantitative surveys are commonly used to determine customer assessments and wishes. As part of cooperation projects, the ERUX research group and AccessMM¹⁶ have conducted such surveys and displayed how drivers evaluate offered advanced driver assistance systems (compare e.g. Driver Assistance System Report 2019 - previous chapter).

Standardized surveys illustrate certain method-related deficits regarding querying the importance of various features:

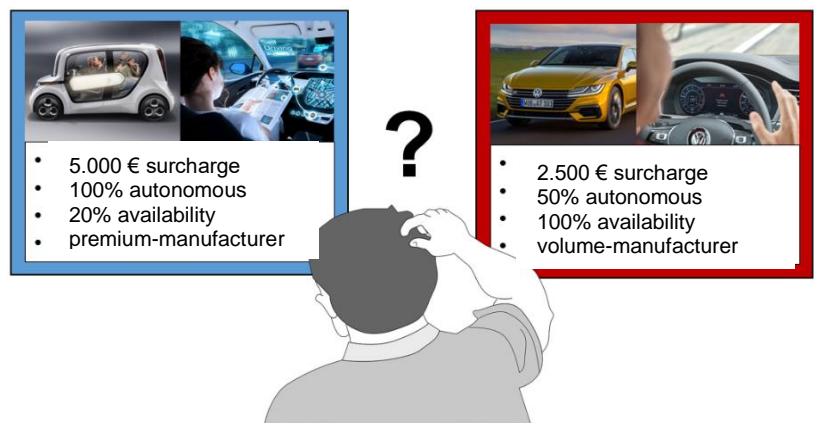
- When asking respondents how critical they consider each characteristic to be, they often rate **'everything' as being pivotal** ('demand inflation').
- This suggests that the statements on the importance of equipment features may not correctly reflect the real decision-making situation when buying a car. Reality portrays that buyers are not willing or able to afford all offered features. Buyers must therefore decide what is **'truly' fundamental** to them.
- The real importance of price in relation to the other decision criteria is therefore not correctly reflected in an independent direct survey.

Methodologically, a conjoint analysis offers solution to this problem. Respondents are not being asked about the importance of each individual characteristic. Instead, the respondents are presented several **combinations** of characteristics **close to reality**, which they must compare to each other (*'which alternative would you prefer?'*).

Based on the assessment of various combinations of features and characteristics, the statistical procedure calculates the

utility value buyers assigns to the individual features. Buyers with similar benefit profiles can be grouped and further analyzed ('women have a different benefit profile than men, younger people a different one than elderly people', etc.).

As it enhances the realism of the conclusions, the data thereby obtained is a vital addition to the results from quantitative surveys.



¹⁶ AccessMM is an independent, non-profit scientific research institute. Cf. www.accessmm.de.

3.1.2 Selection of decision criteria

The conjoint method requires **attributes**¹⁷ and **characteristics to be** defined (example: attribute: 'size', characteristics: 'small-medium-large'). It is pivotal to limit yourself to the most critical criteria and characteristics, as otherwise the number of combinations, assessed by the

respondents, would be too big. In many studies, a set of three to five attributes, each with three to four characteristics, has proved to be successful. The following **four criteria** have been chosen for the survey:

- **Surcharge:** Price is one of the major criteria for any purchase. However, as it is difficult to define a specific price point for a vehicle and as the market segments for passenger cars show considerable price ranges, the surcharge in relation to the other criteria was included in the study instead of the price. The respondent must therefore always consider whether the stated surcharge warrants the displayed alternative.
- **Autonomous driving:** Autonomous driving is the main focus of this survey. The term 'autonomy' states that a vehicle is 100 percent capable of driving on its own. However, conjoint measurements require that gradations for assessment are presented to the respondents. The present study referring to 20%, 50% or 75% 'autonomy' (cf. Fig. 27), means that a vehicle is equipped with a host of or with a few assistance systems.
- **Availability of a vehicle:** Changing mobility requirements are a challenge for the automotive industry. The car's predominant role as a mean of transportation by choice is 'threatened' by new multimodal concepts. Leasing and car-sharing offers are also modifying the ownership structure. The extent to which customers are prepared to sell their own vehicle and use alternative concepts instead is therefore of interest.
- **Manufacturer image:** A plethora of studies portray that purchasing decisions are strongly influenced by image. Image therefore influences whether a customer puts trusts in a manufacturer to create a future-oriented vehicle concept.

Four possible values were determined for each of the attributes. The values have to be realistic and need to reflect the spectrum of possible alternatives broadly, however, without extremes.¹⁸

¹⁷ Attributes are referred to as properties, characteristics, aspects, criteria, etc.

¹⁸ Care was taken to ensure that all attributes and their respective characteristics are at a comparable level of abstraction. For the sake of readability, no further methodological principles and prerequisites are stated in this report.

Fig. 27 illustrates the four attributes used in the conjoint analysis, each comprising four values.¹⁹

Attribute	Characteristics and explanatory text
Surcharge	7.500 €
	5.000 €
	2.500 €
	1.000 €
Scope of autonomous driving functions	Fully autonomous (100 percent): Self-driving car in which the steering wheel is solely operated optionally
	Highly autonomous (75 percent): Highly automated car that rarely needs to be manually controlled. As soon as the car drives by itself, other activities are possible for the driver
	Partially autonomous (50 percent): Vehicle with additional assistance systems that must actively be switched by the driver to intertwine in vehicle control (traffic jam pilot, lane departure warning system, etc.)
	Slightly autonomous (20 percent): Car with assistance systems that are required by law (emergency brake assist) or are already widespread (cruise control, parking sensors and faigue warning system)
Availability of the vehicle	Full availability (100 percent): Own car
	High availability (75 percent): You can define the group of people who have access to the vehicle via app
	Low availability (50 percent): Others can access the vehicle at specified times; however, you cannot determine who has access
	Dependent availability (20 percent): Your own trips are prioritized, otherwise the vehicle can be booked by third parties at any time
Image	Premium manufacturer: The vehicle is fabricated by an established manufacturer of high-quality vehicles.
	Volume manufacturer: The vehicle is produced by a well-known manufacturer of mass-market vehicles
	Niche manufacturer: The vehicle is built by a still establishing manufacturer, producing rather small quantities
	New manufacturer: The vehicle is fabricated by a newly founded manufacturer and is its first vehicle

Fig. 27 Design of the conjoint-study: attributes and characteristics

¹⁹ This results in $4 \times 4 \times 4 \times 4 = 256$ combinations. Study suggests that the number of characteristics and values must be limited. Moreover, the characteristics cannot represent all conceivable (extreme) values. Thus, they must be limited to a spectrum of frequently occurring, realistic values. Fortunately, modern conjoint analyses are structured in a way that the individual respondent no longer has to assess all conceivable combinations.

3.1.3 Design and scope of the study

This study describes the benefit expectations and preferences of consumers when choosing different vehicle concepts. The various possible characteristics relate to autonomous driving, shared mobility, manufacturer image and the surcharge for different combinations of features.

- The aim of the study has been to determine the benefit contribution of different levels of vehicle autonomy without the biases typically associated with ‘entitlement inflation’ in quantitative market research. Thus, we can validate the results of the other conducted studies.
- For further analysis, the study contains socio-demographic characteristics of the test subjects (age, gender, level of education), behavioral characteristics of the test subjects (driving performance, experience with assistance systems), psychographic characteristics (driver type, propensity for innovation), as well as the driving environment (city, country road, highway) as a situational factor.
- Method: Online survey in Germany, completion of the survey in the first quarter of 2020.
- Concept development: Preliminary draft including expert interviews and pre-studies, exploratory research to identify relevant criteria of smart mobility, online research, evaluation of existing studies, own studies, pre-test.
- Sample composition: Convenience sample with focus on younger drivers.²⁰
- Geographical distribution: The respondents answered the questionnaire within the federal territory of Germany. Rural regions and small towns are disproportionately represented, compared to national average.
- Average survey completion time: 16 minutes.
- Sample size: unedited return of 325 data records. Of these, 286 have been included in the analysis. Others have been eliminated due to inconsistent or incomplete responses.²¹

²⁰ All statements in this report relate exclusively to this target group.

²¹ In contrary to the face-to-face interview method by qualified interviewers, control over the survey situation regarding the online questionnaire is not given. This renders it necessary to check the data particularly rigorously to ensure the reliability and validity of the results. Starting points for the elimination of data sets include: Extreme response behavior (e.g. age above 100, 0 km annual mileage), total response time too short (less than 2 seconds per question), etc.

3.1.4 Sample

The sample description serves the purpose to display the composition of the sample, as well as the criteria used to divide it into subgroups for subsequent analyses.

3.1.4.1 Gender

- 156 women (54.5 percent) and 129 men (45.2 percent) took part in the survey. This illustrates that the gender ratio is approximately balanced and represents the share of the overall population. One respondent (0.3 percent) stated that they did identify with either gender.

3.1.4.2 School education

Educational qualification	Number of test subjects	Percentage share
University studies	144	50.4
A-levels	94	32.9
Intermediate school leaving certificate	20	7.0
Completed training / apprenticeship	20	7.0
Secondary school leaving certificate	8	2.8

Fig. 28 Distribution of school-leaving qualifications

- People with higher educational qualifications are overrepresented in the sample. This is beneficial, as such people have, broadly speaking, a higher affinity for new technologies, as well as they are usually provided with more financial resources. Talking about the diffusion process of new technologies, these people are therefore more able to provide information; they also tend to pursue a purchase decision sooner than people with other educational levels. The 'innovators' and 'early adopters' should therefore be consulted for decisions regarding the development process. In case of automotive technology, they are found to be above average among the financially stronger sub-target groups with a higher level of education.

3.1.4.3 Age

Age group	Number of participants	Percentage share
18-22 years	74	25.9
23-29 years	134	46.9
30-49 years	54	18.9
50 years and above	24	8.4

Fig. 29 Distribution of age groups

- At the time the survey has been conducted test subjects were between 18 to 69 years old, with an average age being 29. Elderly people were deliberately not included in the study, as a certain degree of affinity for innovation, as well as a profound understanding of modern mobility concepts was required.

3.1.4.4 Residence size

In terms of the test subjects' origin, care was taken to ensure that all residential sizes were represented to a sufficient extent. Thus, corresponding evaluations of possible differences in benefit preferences could be conducted.

Residential size	Number of test subjects	Percentage share
Country (up to 5,000 p.e.)	84	29.4
Small towns (over 5,000 and up to 70,000 p.e.)	138	48.3
Cities (over 70,000 to 500,000 p.e.)	36	12.6
Metropolitan areas (over 500,000 p.e.)	28	9.8

Fig. 30 Origin of the test subjects

3.1.4.5 Annual mileage

Four groups can be distinguished according to annual mileage (Fig. 31).

Annual mileage (in km)	Number of test subjects	Percentage share
Low mileage (100 to 3,000 km)	55	19.2
Occasional driver (over 3,000 to 13,000 km)	87	30.4
Frequent driver (over 13,000 to 20,000 km)	84	29.4
Frequent driver (over 20,000 km)	60	21.0

Fig. 31 Annual mileage of the test subjects, grouped

- The average mileage of the test subjects has been 16,226 km annually. This is slightly above the total mileage of German drivers²². Thus, it corresponds to the objective of slightly underweighting drivers with a low annual mileage in the sample, as they are less able to provide information. Moreover, the underweighting of elderly drivers contributes to the fact that the mileage of the sample is above the overall average of German drivers.

²² According to the German Federal Motor Transport Authority (KBA), there have been 31,030,000 petrol vehicles (65.9% of all registered cars) with an average mileage of 10,562 km in 2019. Thus, also 15,150,000 diesel vehicles (32.2%) with a mileage of 19,884 km have been listed. The overall average is then percentagewise: $(0.659 \cdot 10,562 \text{ km}) + (0.322 \cdot 19,884 \text{ km}) = 13,362 \text{ km}$, other drive types not included. Cf. KBA, Traffic in kilometers - Domestic mileage, Fig. 30, https://www.kba.de/DE/Statistik/Kraftverkehr/VerkehrKilometer/vk_inlaenderfahrleistung/, 24.07.2020.

3.2 Pre-disposition and attitudes of the test participants

In addition to the conjoint analysis, several questions with a psychographic background have been asked to subsequently assess and group the test subjects.

3.2.1 Importance of a car in everyday life

Question: *Please answer the following questions. Type in a number from 0 to 100 (0 = not at all/none; 100 = very strong/very high)*

- *How personally interested are you in the topic of cars in general?*
- *How well informed do you feel about the topic of 'autonomous driving'?*
- *What significance does the car have for you personally in your daily life?*

Results of the three asked questions found out:

	Interest in cars	Informed about autonomous driving	Importance of a car in everyday life
	Scale from 0 - 100		
Average (n=286)	62.4	40.2	67.2
Median	70	40	75
Standard deviation	28.9	26.5	29.8

Fig. 32 Importance of the car in respondents' everyday lives

- The test subjects have been very interested in the topic of cars and attribute a high significance to them in everyday life.
- In conjunction with the annual mileage, it is confirmed that this sample consists of individuals with a high involvement with cars.
- Although a car is of great importance to the respondents, according to their own assessment, they are rather poorly informed about autonomous driving.

3.2.2 Experience with advanced driver assistance systems

To gain experience with advanced driver assistance systems, six systems (adaptive cruise control [ACC], fatigue warning system, traffic jam pilot, reversing camera, lane departure warning system, parking assistant) were specified and respondents were questioned:

Question: *“Which of the following systems have you already gained experience with?” (usage: at least once in your own or in another person's vehicle)*

The selection was based on the fact that advanced driving assistants with varying degrees of novelty and prevalence should be included. To exclude sequence effects, an arbitrary succession of the advanced driver assistance systems mentioned above has been implemented in the survey, varying from respondent to respondent.

By summing up the amount a respondent answered 'yes' to the six alternatives, we get a measure of the overall experience of used advanced driver assistance systems, displaying values between 0 and 6.

Fig. 33 illustrates the distribution of the results:

Total number of advanced driver assistance systems that were ticked with 'Yes'. The test subjects have experience with...	Frequency	Percentage
... no advanced driver assistance system (0)	30	10.5
... one FAS (1)	39	13.6
... two FAS (2)	45	15.7
... three FAS (3)	43	15.0
... four FAS (4)	56	19.6
... five FAS (5)	42	14.7
... six FAS (6)	31	10.8

Fig. 33 Experience in dealing with advanced driver assistance systems

- Experience in interacting with advanced driver assistance systems is distributed fairly even. The sample comprises test subjects with 'every' level of experience.
- Average of the sample is at 3.1 (median 3) advanced driver assistance systems.
- Gender-specific differences: average experience with assistance systems for women: 2.7, for men: 3.6.²³
- As expected, experience with assistance systems enhances with increasing annual mileage.
- By age group: 18-22 years: 2.7, 23-29 years: 3.1, 30-49 years: 3.6, 50 years and above: 3.0. Experience with assistance systems therefore initially augments with age. However, the conducted study displays no increase after the age of 50.

²³ Statistically significant difference, $p < .001$.

3.2.3 Intention to use autonomous driving according to driving situation

The test subjects were given four environmental conditions (highway driving, driving on country roads, in small towns, in large cities) and questioned about them:

Question: *To what extent could you envision wanting to use a fully autonomous vehicle in the following environments?*

(0 = never; 100 = always, if it is feasible)

Asking the respondents about their personal intention to use autonomous driving cannot be equated with their actual *future* use. Rather, the responses can be used to illustrate the present extent of a general willingness to use autonomous driving functions depending on the situation.

	To what extent can you imagine using a fully autonomous vehicle?			
	Highway drive	Driving on country roads	Small towns	Large cities
Average (n=286) <i>(scale from 0-100)</i>	72.1	54.1	42.9	43.6
Median	87.5	60.0	40.0	40.0
Standard deviation	34.3	33.0	32.8	36.2

Fig. 34 Intended use of fully autonomous vehicles in various situations

- Fig. 34 displays that the test subjects are most likely to imagine themselves using an autonomous vehicle in conjunction to drive on a highway. With an average of 72.1, the value is well above the theoretical mean value of the scale. The median is with 87.5 even more positive.
- On the other hand, the test subjects were less able to imagine themselves driving on country roads in fully autonomous vehicles – moreover, even less in cities, regardless of whether they are small or large.

☞ Obviously, the drivers' trust in the ability of autonomous vehicles, tackling potentially complex situations, in cities is still limited.

- Skepticism and a lack of trust in the technology are seen as impediments to implement highly automated driving functions in complex driving environments. Breaking down resistance involves more effort than, for instance, establishing a 'highway pilot'.

3.2.4 Individual propensity to innovate

The participants had state their consent or refusal to ten statements, aiming to measure the individual propensity to innovate.

Question: *Please indicate the percentage to which the following statements apply to you (0 = does not apply at all; 100 = applies very strongly)*

1. *Friends often ask me for advice when talking about innovative topics*
2. *I am generally rather cautious in case of accepting new ideas.*
3. *I am generally rather suspicious of innovations*
4. *I believe that I play an influential role in my social environment*
5. *I consider myself to be creative and original in my thoughts and actions*
6. *I am an imaginative person*
7. *I do not try out new behaviors until I see that they work for other people.*
8. *I feel challenged by tricky problems*
9. *I only consider buying new products when I see other people owning them*
10. *Unresolved questions challenge me.*

Responses to the individual statements have then been summarized.²⁴ Thus, a measure of the respondents' propensity to innovate was obtained. Based on this index, the respondents can be divided into four groups:

Value range index	Designation	Frequency	Percent
0 to 55	Reserved	114	39.9
56 to 70	Midfield	102	35.7
71 to 85	Innovative	59	20.6
86 and more	Pioneer	11	3.8

Fig. 35 Innovation propensity index of the test subjects, grouped

- The measured value range of the personal willingness to innovate is between 19 (min.) and 93 (max.), the calculated average is at 59.4 (median 60).
- Overall, the self-assessment of the sample is slightly above the theoretical average of the scale (50) and thus at a level comparable to other studies.

²⁴ The oppositely coded questions 2, 3, 7 and 9, which express a lower propensity to innovate, have been recoded beforehand. The sum of the values of the ten individual statements was divided by 10, resulting in a scale for the index of 0 to 100.

3.2.5 Driver type

It can be assumed that the type of driver has an essential influence on the assessment of autonomous driving. In order to categorize the respondents, four statements have been presented for them to evaluate:

Question: “*Please take a look at the following statements. On a scale from 0 - 100, decide how strongly the statements personally apply to you. (0 = does not apply at all; 100 = applies very strongly)*”

1. *I like driving and enjoy driving myself.*
2. *I enjoy good infotainment equipment in a car.*
3. *I enjoy to drive as comfortable as possible, as well as to use advanced driver assistance systems to help make driving simpler.*
4. *I want to be able to concentrate on driving as unrestrictedly as possible.*

The first and third questions cover (with different polarity) the desire to drive, respectively to steer the vehicle. The second and fourth question are each aimed towards the driving adventure, as well as to which extent the control and use of an infotainment equipment is desired.

	Type questions			
	1. <i>having fun driving</i>	2. <i>enjoying infotainment</i>	3. <i>enjoying to drive comfortably</i>	4. <i>want to concentrate</i>
	Scale 0 - 100			
Average (n=286)	77.2	61.9	55.3	68.1
Median	90.0	70.0	60.0	75.0
Standard deviation	27.1	30.2	31.8	27.9

Fig. 36 Questions about the driver type

- The sample portrays that there is a strong conjunction with ‘having fun while driving’. Of all of the four questions, this one achieved the highest average agreement.
- Compared to the other statements, the ‘comfort provided by assistance systems’ is the least requested, without considering this criterion as undesirable.
- Altogether, the well-known phenomenon of a demand inflation is evident: nothing is ‘insignificant’, all of the displayed statements are significantly above the theoretical average of the scale (50).
- The respondents clearly have in mind to keep their options open. Driving is not a one-dimensional process. However, rather various requirements must be met equally.

Two dimensions emerge that express basic attitudes towards driving, when summarizing the four questions about types of drivers using the factor analysis:²⁵

- **‘Car enthusiasts’** suggests that the comfort while driving, as well as the pleasure of infotainment are valued.
- **‘Driving purism’**, on the other hand, emphasizes the fun of driving. However, ‘concentrating while driving’ is usually carried out at the same time.

3.3 Excursus: Competence attributed to companies

An open-ended question aimed to determine from which companies the participants expect the most significant contributions to autonomous driving.

Question: *Which companies do you expect to make the biggest contributions towards autonomous driving? Please indicate three companies of your choice (regardless of industry)*

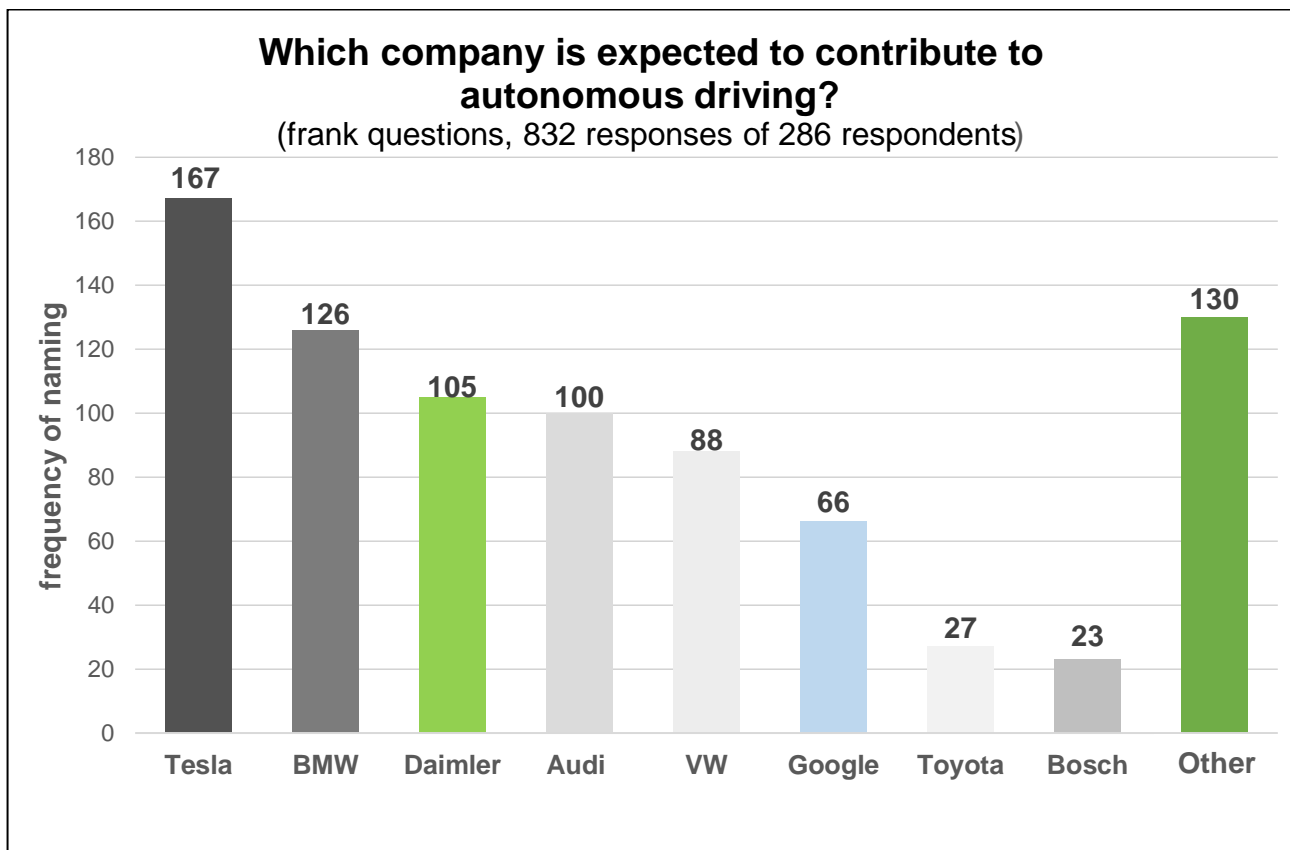


Fig. 37 Companies that drivers trust to contribute to autonomous driving

²⁵ This study does not claim to be a complete representation of possible driving needs or a typification of all conceivable driver types based on these needs, as this was not the objective of the survey. The aim was merely to analyze if and to what extent different motives for driving have different utility values in relation to the automation of driving (see below, 4.7). The rudimentary differentiation of two motives on the basis of only four initial questions is sufficient for this purpose. The statistical indicators of the factor analysis are not presented here.

- Respondents primarily think of car manufacturers, when being asked this question. An internet company, Google, has only been mentioned in sixth place. Moreover, the interviewees solely suggested a supplier, Bosch, in eighth place.
- As the figure displays, the (merely German) respondents are most likely to attribute the relevant competency of contributing to autonomous driving to the US company Tesla.

If the responses are being grouped according to the parties involved in the value creation process, we receive the following illustration:

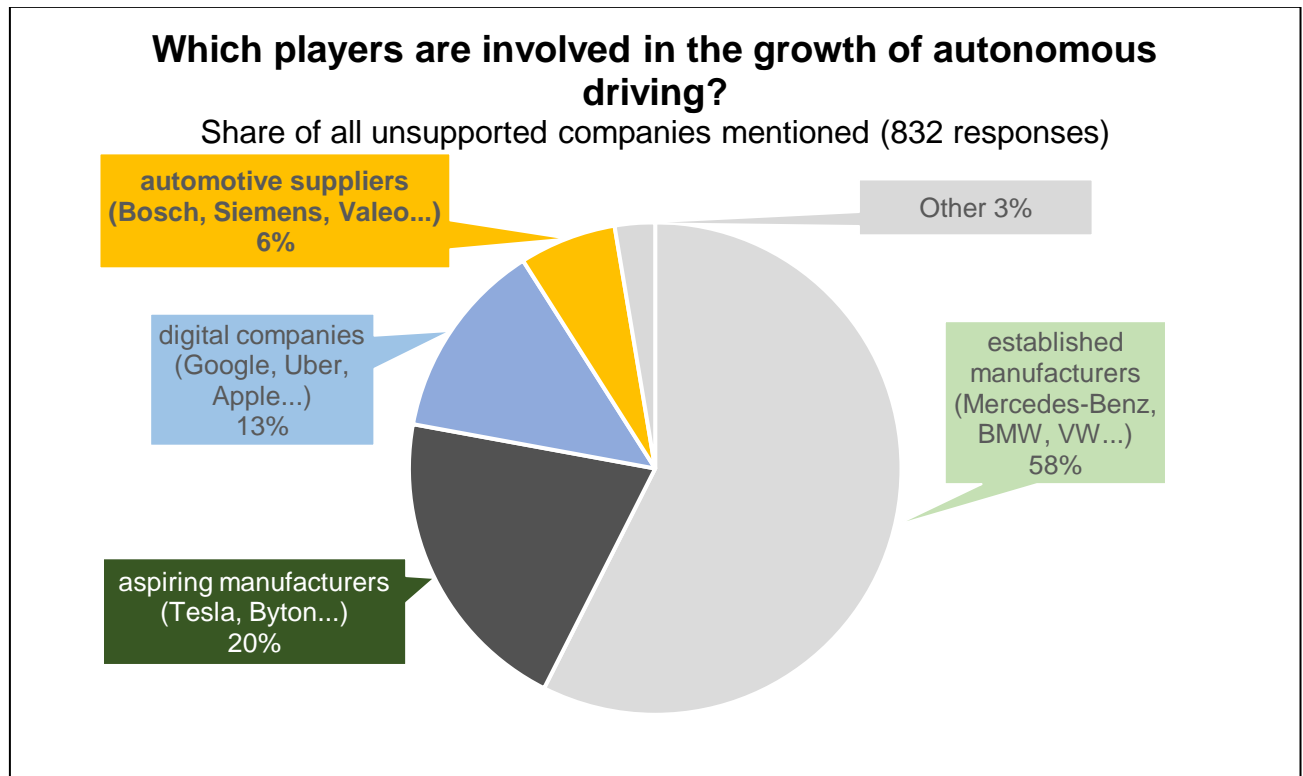


Fig. 38 Attribution of competence for autonomous driving from the driver's perspective

- Although suppliers, in particular tier 1 suppliers, are significantly involved in the progress, it is not reflected in the responses of the interviewees. In reality, the subsystems required for DAS are developed as a whole by suppliers. Nevertheless, the systems are perceived by car buyers as the car manufacturers' own creations.

- ☞ Car buyers attribute the capabilities and potential shortcomings of advanced driving assistance systems in the automotive industry to the OEMs, instead of to the suppliers involved.
- ☞ Suppliers of components, respectively of complete modules in the field of advanced driver assistance systems, known as 'original equipment manufacturers (OEMs),' are practically unfamiliar to private end consumers in the automotive sector.

3.4 Conjoint analysis: evaluation of the four attributes surcharge, availability, manufacturer image, degree of autonomy

First and foremost, the overall mean values of the sample are displayed separately for each attribute to gain an overview of the preference structure. Differences between sub-target groups are not yet taken into account, nor are the correlations between the various attributes.

3.4.1 Utility values of the attribute 'surcharge '

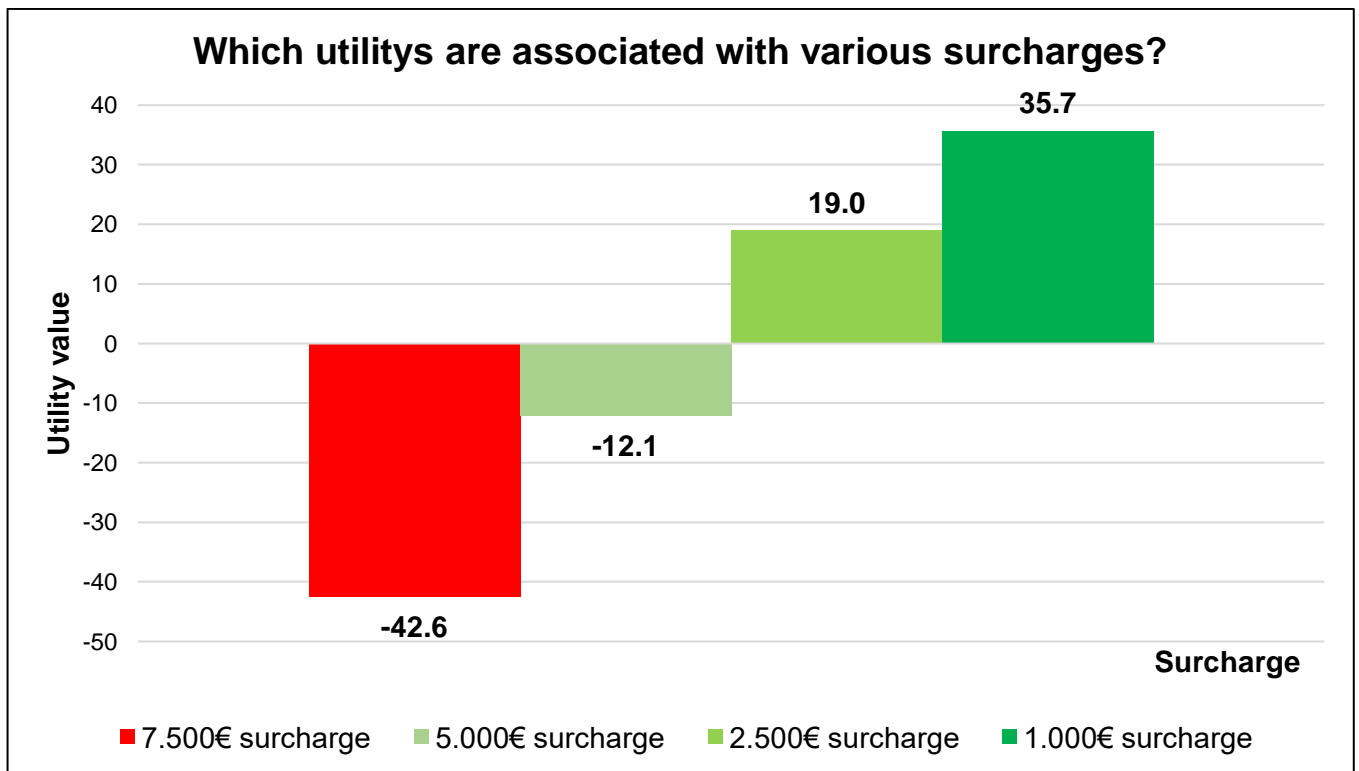


Fig. 39 Utility values of the 'surcharge' attribute

- Study suggests as expected, respectively little surprising, that the lower the surcharge for a feature combination, the higher is the utility value²⁶. This result can be seen as a confirmation of the validity of the study.
- The gradations of the utility values are congruent with the price intervals; the gradations are depicted 1:1.

²⁶ The utility values portrayed do not have an absolute scale. However, they do show how the various characteristics contribute to the overall benefit (overall presentation in Fig. 42).

3.4.2 Utility values of ‘availability’

Many concepts regarding the access to autonomous vehicles are conceivable in the future. It was suggested that car owners would receive compensation when providing their vehicles to others. Thus, this payment depends on the extent to which their own vehicle is integrated into the pool of bookable cars (the scope and type of compensation were deliberately not specified, as this would have further complicated the survey).

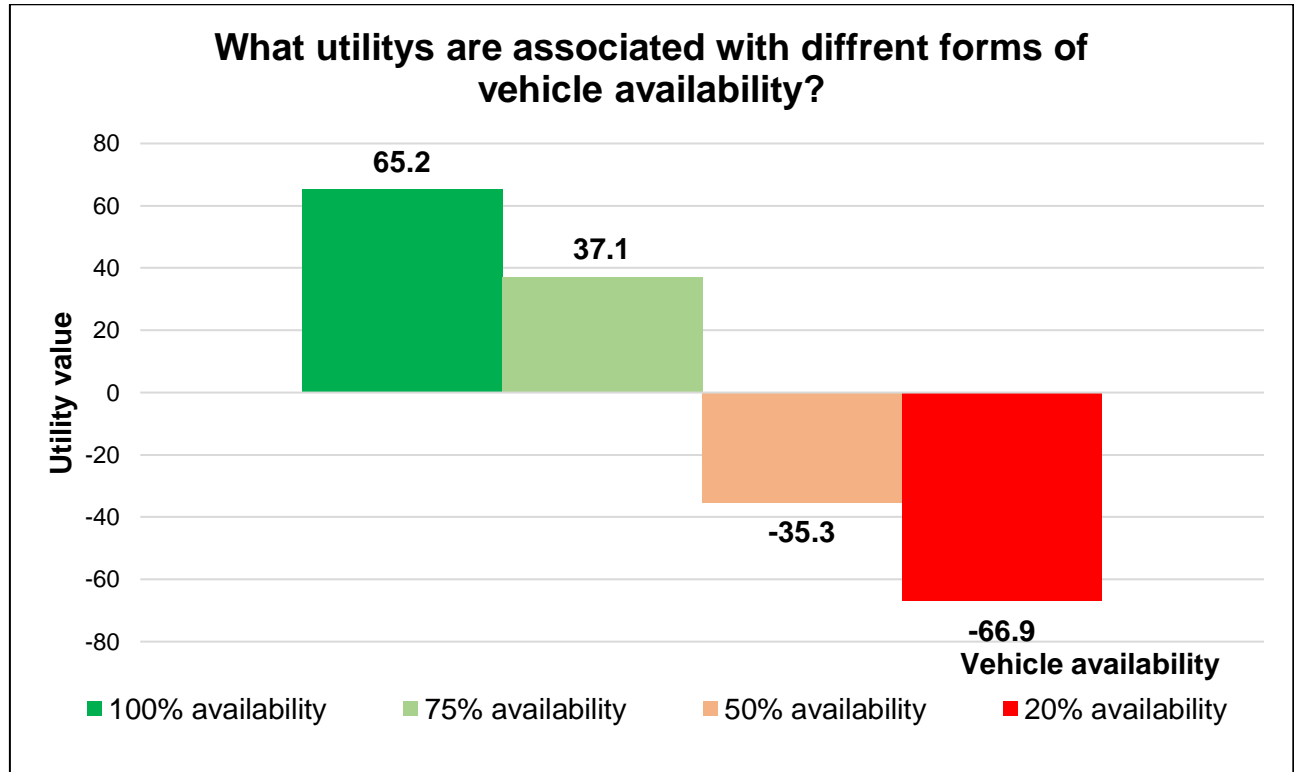


Fig. 40 Utility values of the ‘Availability’ attribute

- The test subjects clearly correlated the degree of personal availability of the vehicle to the benefits offered.
- The range of the utility values (with 132 between highest and lowest availability) is even higher than for the price (79). Therefore, it indicates that it is extremely pivotal for drivers (on average) to display control over their vehicle.

3.4.3 Utility values of the 'Manufacturer image'

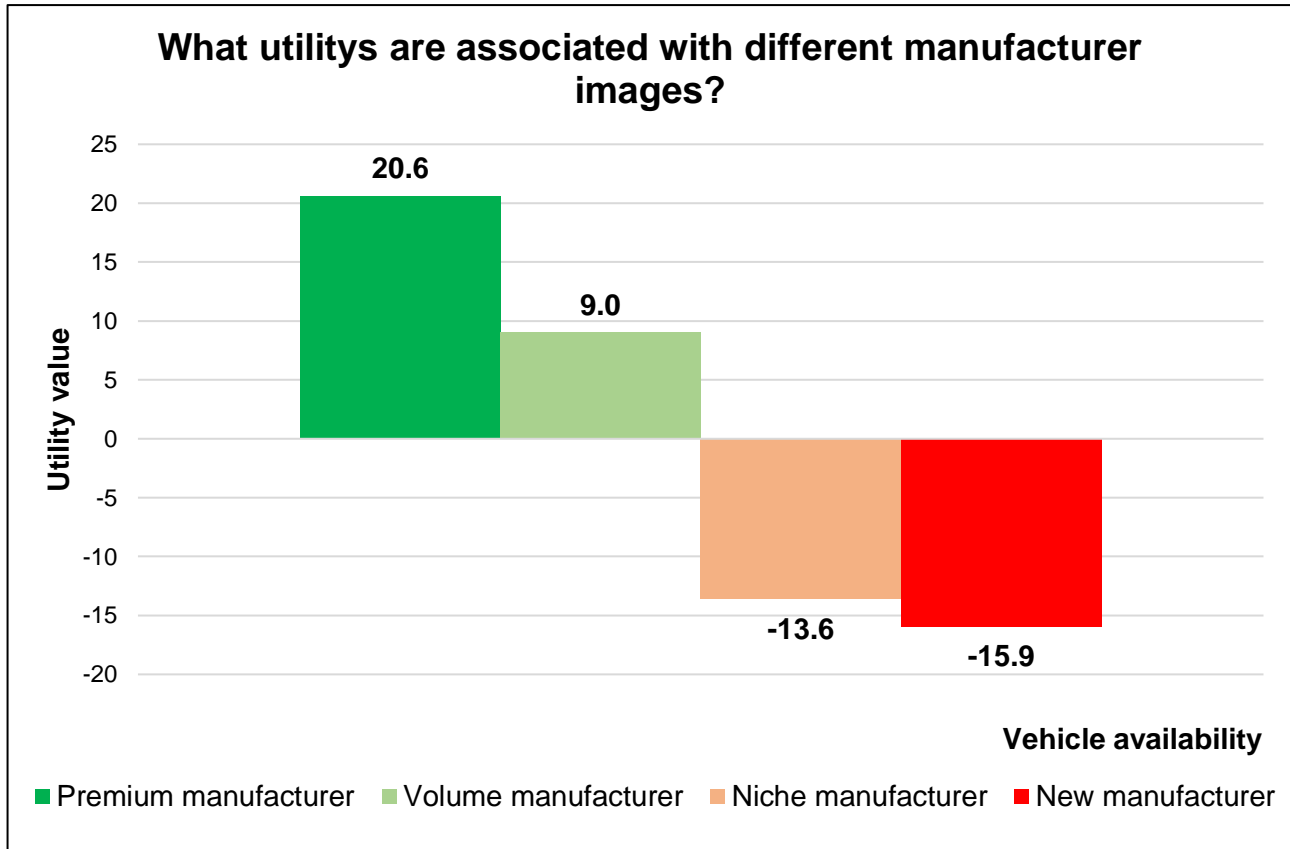


Fig. 41 Utility values of the attribute 'Manufacturer image'

- As expected, the higher manufacturer image displays a higher benefit contribution.
- However, striking the attention is that the range of utility values with 'solely' 37 is lower than with the surcharge (79) and availability (132).
- Little difference is shown between niche manufacturers and new manufacturers. There is a clear leap in terms of benefits compared to volume manufacturers (23).
- There is still an increase of 11.4 utility points between the volume manufacturers and the premium manufacturers.

3.4.4 Utility values of the ‘scope of autonomous driving functions’

The utility values calculated for the various autonomous driving functions differ from the linear pattern of the utility curve of the other attributes:

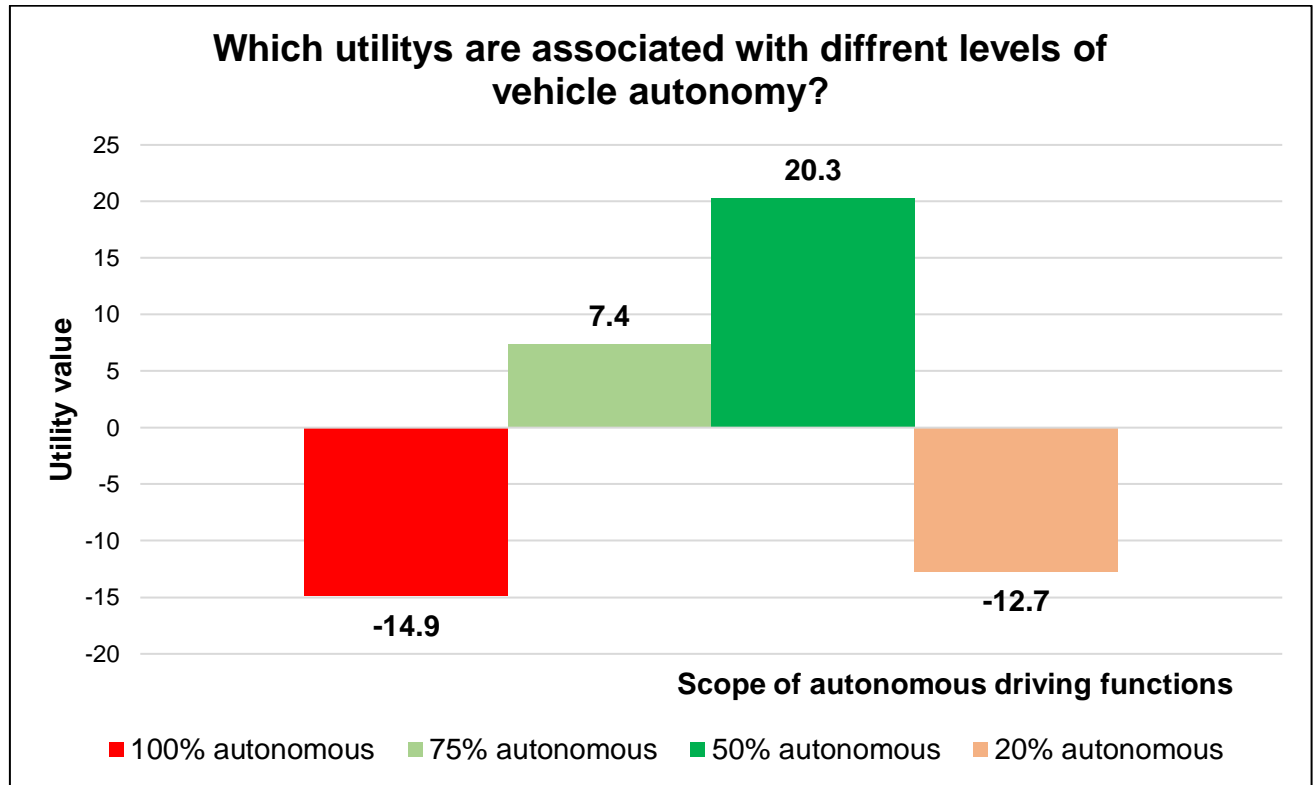


Fig. 42 Utility values of the attribute ‘scope of autonomous driving functions’

- Average degrees of autonomy are preferred, with ‘50 percent autonomous’ being the most favored.
- In contrast, the highest autonomy (100%) is rejected, as much as ‘lowest’ degree of autonomy (20%). As a matter of fact, this results in an inverted U-shaped progression of utility values.

☞ This result can be interpreted as the ‘**intermediate status of drivers’ habituation** with **the** idea of autonomous driving’: driving ‘without’ assistance systems is already outdated; on the other hand, complete vehicle autonomy is still unfamiliar to drivers.

3.4.5 Overview of partial and overall utility values

Fig. 43 illustrates an overview of the partial utility values of the various characteristics shown above, as well as of the overall utility values of the attributes. If the purchase decision is made on the basis of the four attributes included in the analysis and of their characteristics, the overall utility contribution has to be methodically interpreted as the percentage share that an attribute renders for car buyers.²⁷

Attribute	Characteristic	Partial benefit	Std. dev.	Total benefit contribution of the attribute
Surcharge	7.500 €	-42.6	30.97	21.1
	5.000 €	-12.1	17.44	
	2.500 €	19.0	18.32	
	1.000 €	35.7	27.36	
Availability of the vehicle	100% availability	65.2	47.95	37.5
	75% availability	37.1	25.37	
	50% availability	-35.4	28.26	
	20% availability	-66.9	40.74	
Manufacturer image	Premium manufacturer	20.6	28.17	14.6
	Volume manufacturer	9.0	19.85	
	Niche manufacturer	-13.7	19.96	
	New manufacturer	-15.9	15.91	
Scope of autonomous driving functions	100% Autonomous	-14.9	51.47	26.8
	75% Autonomous	7.4	34.62	
	50% Autonomous	20.3	28.96	
	20% Autonomous	-12.7	57.27	

Fig. 43 Partial utility values per attribute and characteristic

²⁷ It should be noted that the results only refer to the attributes included in the conjoint analysis. This corresponds to the special aim of the procedure, which is to assess the importance of the attributes included in a realistic relation. In contrast, it is not feasible to transfer the results to other, not queried attributes.

- In the overall analysis, the availability of the vehicle (→ among the examined attributes) is currently the most important criterion for drivers. The majority of drivers are still strongly interlinked with the idea of displaying full control over their own car, even if there are already signs of a change in awareness in some target groups,²⁸. There is a pronounced 'ownership culture', clearly aligning with the strong individuality of consumers nowadays.
- Surprisingly, the range of autonomous driving functions is already in second place. Therefore, these assistants seem to have a higher significance for the benefit of drivers than the manufacturer's image and the surcharge. The significant differences of view, between 100% and 20% autonomy, indicate that variously motivated sub-target groups are portrayed here.

☞ Study suggests that advanced driver assistance systems 'on the road to autonomous vehicles' are already a key decision criterion for drivers when purchasing a car.

- Whereas many practitioners assume that high price responsiveness is the most critical characteristic of the German car buyer, surcharge is 'only' portrayed in third place. On the contrary, it is evident that in a direct comparison, the utility contribution of the low price is to be displayed as only one of several criteria, by no means however, the most pivotal criteria.
- Manufacturer image is in last place and contributes less than 15 percent to the overall benefit in relation to the four attributes. In direct comparison, (perfectly functioning) assistance systems show almost twice as much benefit compared to the manufacturer image. Study indicates that manufacturers, most of whom refuse to allow suppliers to brand their own products, benefit more from the suppliers' services than vice versa. To put it in other words: the customer benefit associated with functioning assistance systems tends to contribute to the manufacturer's image. These outcomes provide suppliers with the necessary arguments for confidently negotiating with OEMs.

²⁸ This can be seen from the relatively high standard deviations of 100% and 20% availability: the opinions regarding the objectives of the respondents differ greatly, however, not identifiable from the mean value.

3.5 Detailed analyses on the benefits within the scope of autonomous driving functions

Further research regarding the investigation of the assessment of autonomous driving is of particular interest for the automotive and supplier industry, although the survey design was not solely intended to portray it.

3.5.1 Utility values by age

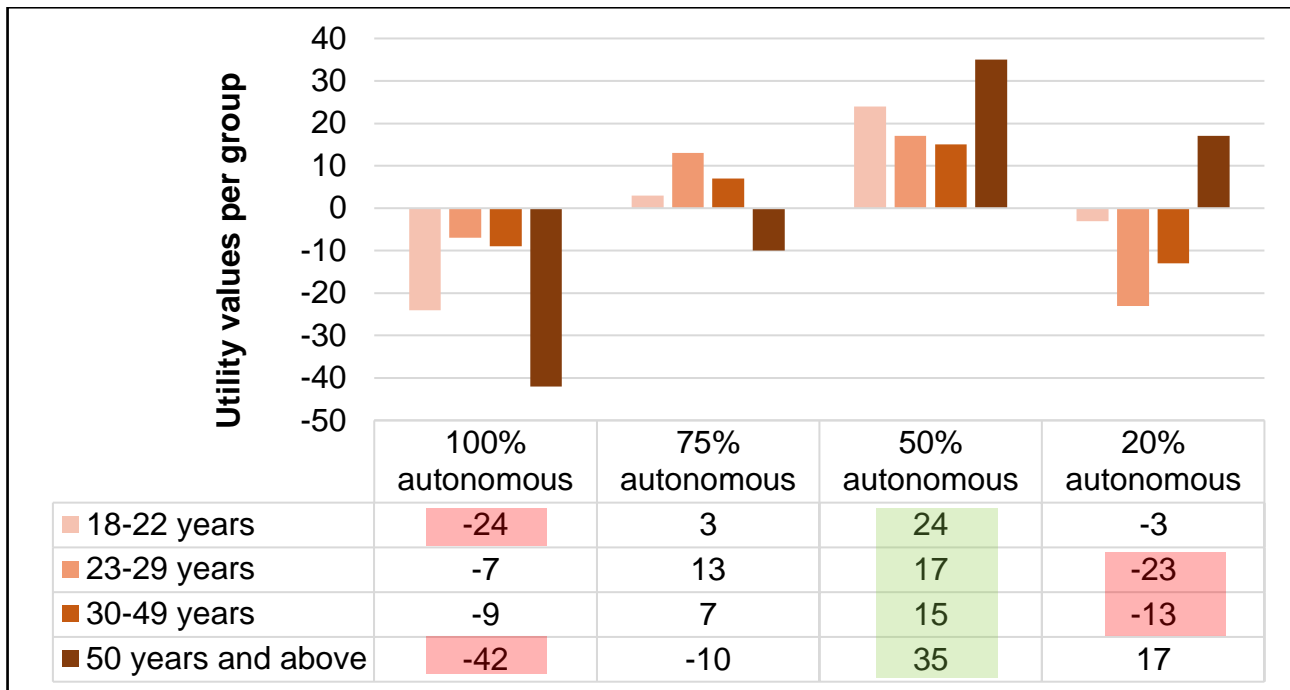


Fig. 44 Benefits of the scope of autonomous driving functions in the opinion of different age groups

- As already shown above in the overall assessment, ‘medium degrees regarding the autonomy of vehicles’ are preferred by drivers.
- Fig.44 illustrates that fully autonomous driving (100%) is strongest rejected by the oldest age group (50+), as well as it is strongly dismissed by the youngest age group. It is reasonable to assume that elderly people reject fully autonomous driving as they have ‘always driven the cars themselves’. Keeping this in mind, they do not want to change it. On the contrary, the youngest age group has the desire to ‘finally drive on their own’. Thus, they do not want to gain their driving experience in a fully autonomous vehicle.
- As a result, the study indicates that the middle age groups are most likely to be able to imagine themselves using higher levels of automation (100% and 75%) when driving.²⁹

²⁹ The benefit values for the different age groups differ significantly in all four levels of autonomy (analysis of variance, $p < 0.05$).

3.5.2 Utility values by gender

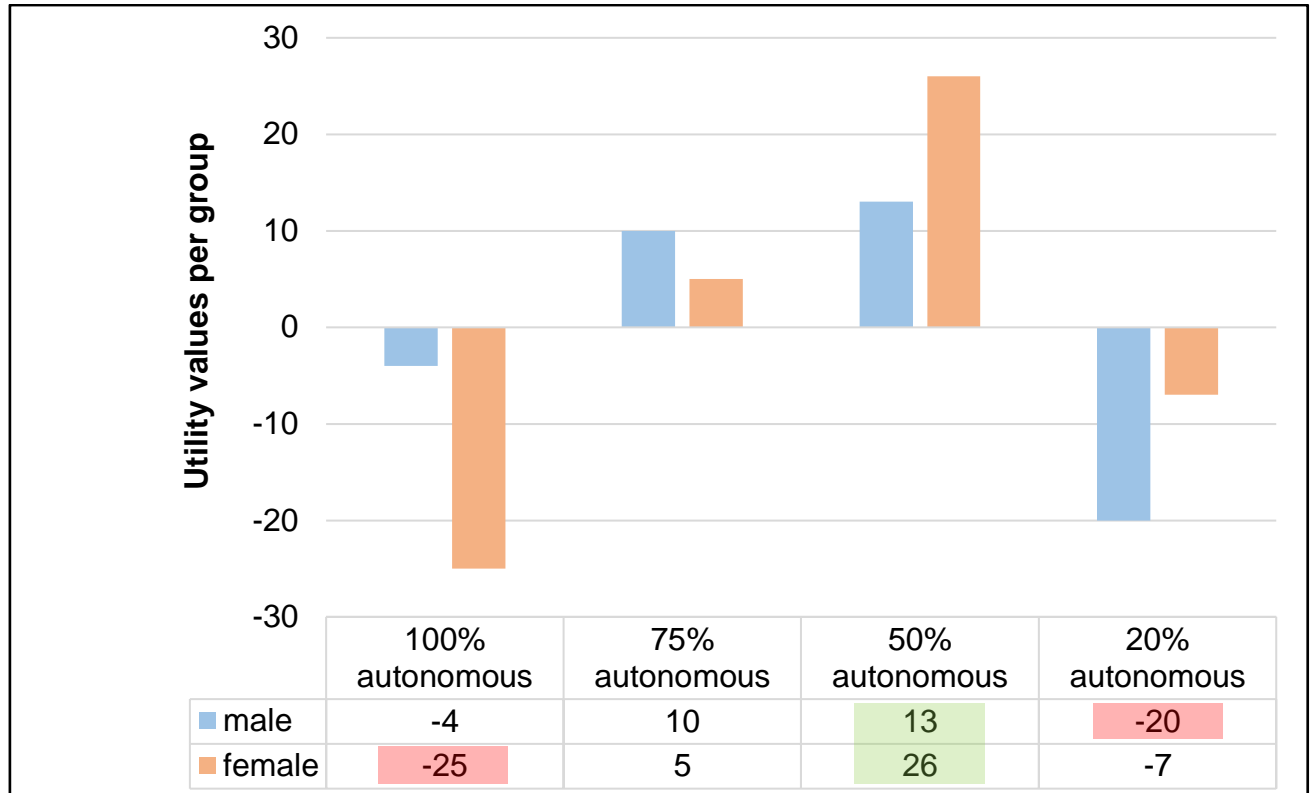


Fig. 45 Use of the scope of autonomous driving functions by gender

- Men refuse cars without state-of-the-art advanced driver assistance systems (20% autonomous). Thus, they are more open towards higher levels of autonomous driving. To them, there is almost no difference in the utility value between the levels of 75% and 50% autonomy.
- Women attribute the least utility to the fully automated vehicle. However, they particularly appreciate the increase in comfort associated with medium levels of autonomous driving.
- Currently, both genders associate 100% autonomous driving with a reduction of the utility.

3.5.3 Utility values by size of residence

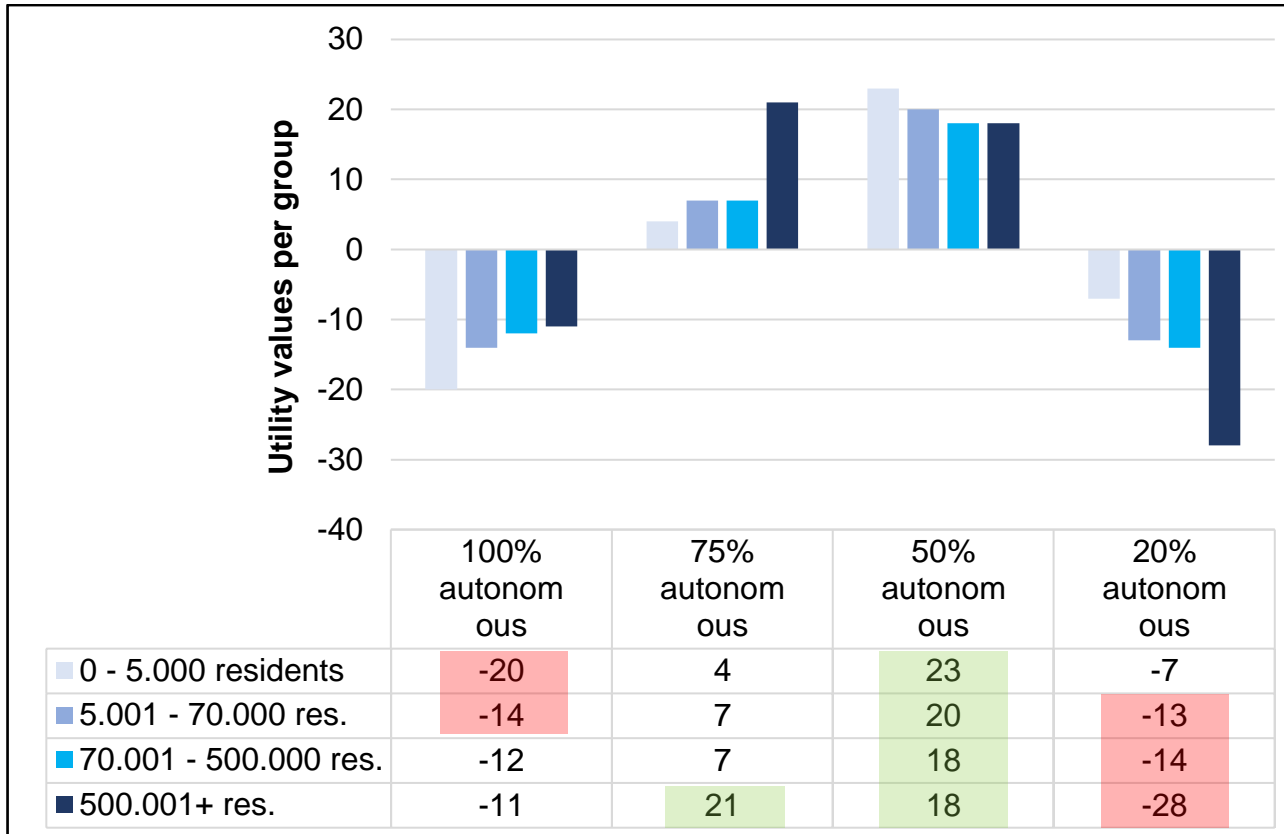


Fig. 46 Use of the scope of autonomous driving functions by size of residence

- Residents of larger cities and metropolitan areas associate fully autonomous driving with a relatively minimal loss of utility. On the contrary, vehicles with a low degree of autonomy promise the lowest benefits to them.
- The opposite holds true for inhabitants of smaller towns.
- The results confirm the findings of the other conducted studies. Overall, this presentation displays clearly that cars equipped with fewer assistance systems have as much of a loss of benefits as completely autonomous vehicles do. At the moment, the majority of drivers appreciate the support functions of assistance systems. However, they *do not* want to hand over their control over the vehicle in terms of driving.

3.5.4 Utility values by level of education

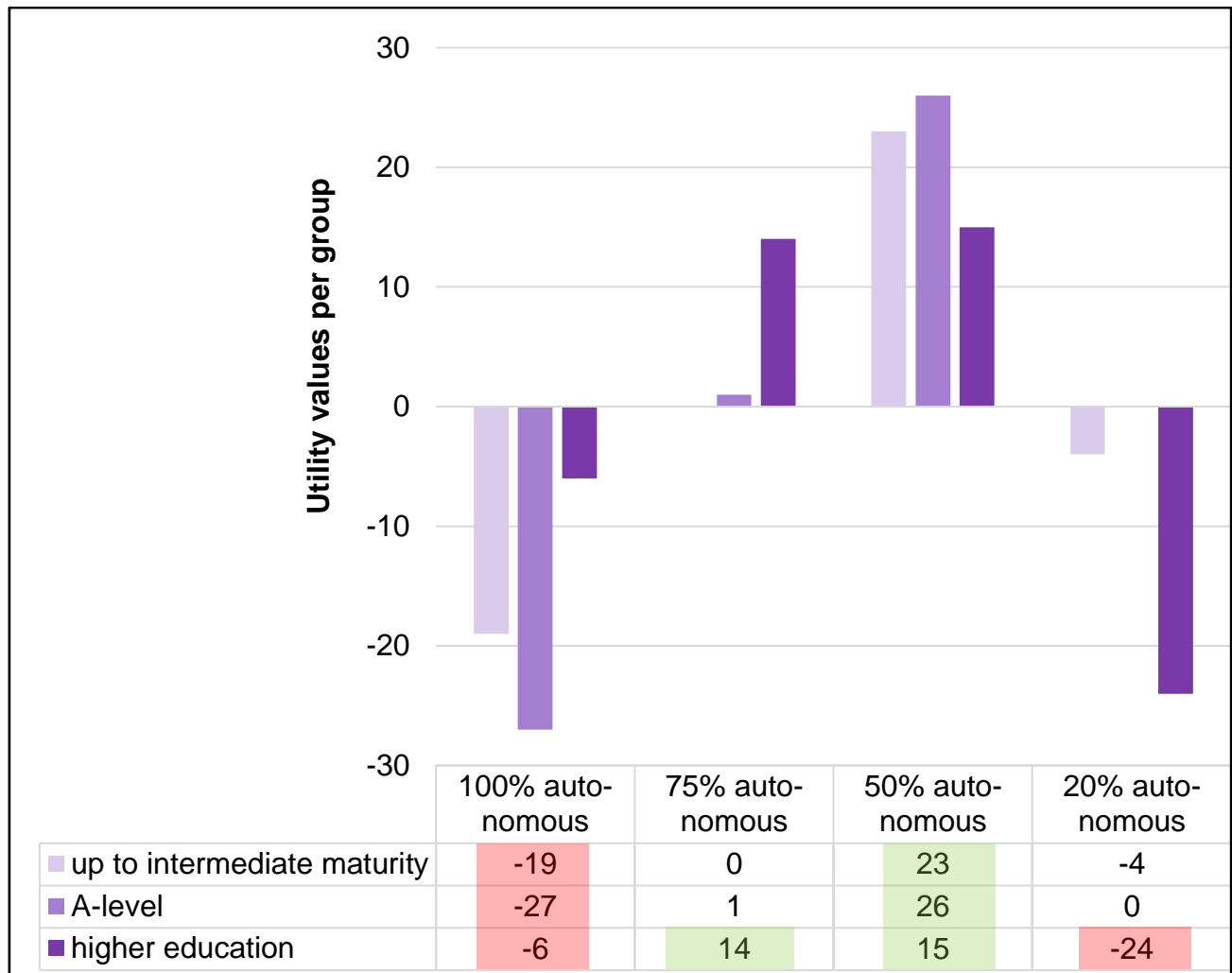


Fig. 47 Use of the scope of autonomous driving functions according to school education

- University graduates are more open towards highly or fully autonomous driving. Academics also rate vehicles with only few autonomous driving functions as very unappealing.³⁰
- A supplementary analysis displays that academics have a higher propensity to innovate.³¹

³⁰ The benefit values for the three education groups differ significantly in all four levels of autonomy (analysis of variance, $p < .05$).

³¹ Average propensity to innovate (scale 0-100): Academics 62; high school graduates: 58; rest: 53.

3.5.5 Utility values according to experience with advanced driver assistance systems

The test subjects were asked which assistance systems they had already gained experience with. The answers were used to calculate an 'index of experience with assistance systems', valuing between 0 and 6 (see chap. 3.2.2). Moreover, this index can also be seen as an indicator of the drivers' *behavior*.

The utility values of the four degrees of autonomy (100%, 75%, 50%, 20%) can also be used to calculate an 'index of the utility of autonomous vehicles' for each test person.³²

Correlating this knowledge about assistance systems with the benefits of autonomous vehicles, we can see the extent to which previous experiences triggered drivers to rate the benefits of the increasing automation higher.

Correlation according to Pearson ³³	Benefits of vehicle autonomy (index)
Experience in handling advanced driver assistance systems	.12

Fig. 48 Correlation between experience in handling DAS and the benefits of autonomous driving functions

- Study suggests that a greater level of experience tends to go hand in glove with a higher perception of the benefits of automation among drivers.
- Detailed analysis (without illustration): However, the strongest correlation is not displayed with the fully automated vehicle (100%), but with the 75% automated vehicle.³⁴
- Therefore, this various methodological approach confirms the previous findings, stating that medium levels of automation are currently preferred.
- At the same time do these findings from quantitative studies confirm that it is of high in the interest of the automotive industry to actively introduce drivers to automation technology. Especially for drivers who have not yet used many assistance systems, the following applies: additional experience unleashes a greater understanding of the benefits of these systems.

³² Calculation: Sum of (utility value of 100% autonomy * 100, utility value of 75% * 75, etc.). The scaling of this index is extraneous (it assumes values between +9285.96 and -12682.04 in the sample). However, it can be understood as an interval-scaled measure of the benefit of autonomy and is therefore suitable for any form of further calculation.

³³ The correlation is at the limit of the statistical significance ($p = .051$).

³⁴ The correlation is at .15 for 75% autonomy of the vehicle and at .09 for 100% autonomy.

In addition, the correlation between the perception of benefits and the annual mileage of the test subjects has been examined. No significant correlations have been found here. Thus, the results are not displayed in this research paper.

☞ The decisive factor for the perception of benefits is not the annual mileage, however, it is the existing experience of drivers with advanced driver assistance technologies.

3.5.6 Utility values according to driving environment

The driving environment, as a *situational characteristic*, imposes very diverse demands on the technologies of autonomous driving. It is to be expected that drivers themselves will associate various situational conditions with the different benefits of autonomous driving.

If we establish a correlation between the benefits of different levels of autonomy and the benefits of different driving environments (city, country, highway), the following picture emerges:³⁵

Correlation according to Pearson ³⁶		Benefits of vehicle autonomy (index)
utilization intention	when driving on the highway	.55
	on country roads	.48
	in small towns	.38
	in large cities	.34

Fig. 49 Correlation between the driving environment and the expected benefits of vehicle autonomy

- If drivers associate a positive utility with the increasing autonomous vehicles, they depict this benefit primarily when it comes to driving on highways and secondarily on country roads. They intertwine this beneficial use less with small towns and least of all with large cities.

☞ From the driver's point of view does the proportionate monotony of highway driving pave the way towards autonomous vehicles.

³⁵ NB: The figure does not illustrate utility values, but correlations between the two variables are included.

³⁶ All correlations are highly significant ($p \leq .001$).

3.5.7 Utility values according to individual innovation propensity

The respondents' identified individual propensity for innovation (as stated above) can also be linked to their expectations of the benefits of autonomous driving:

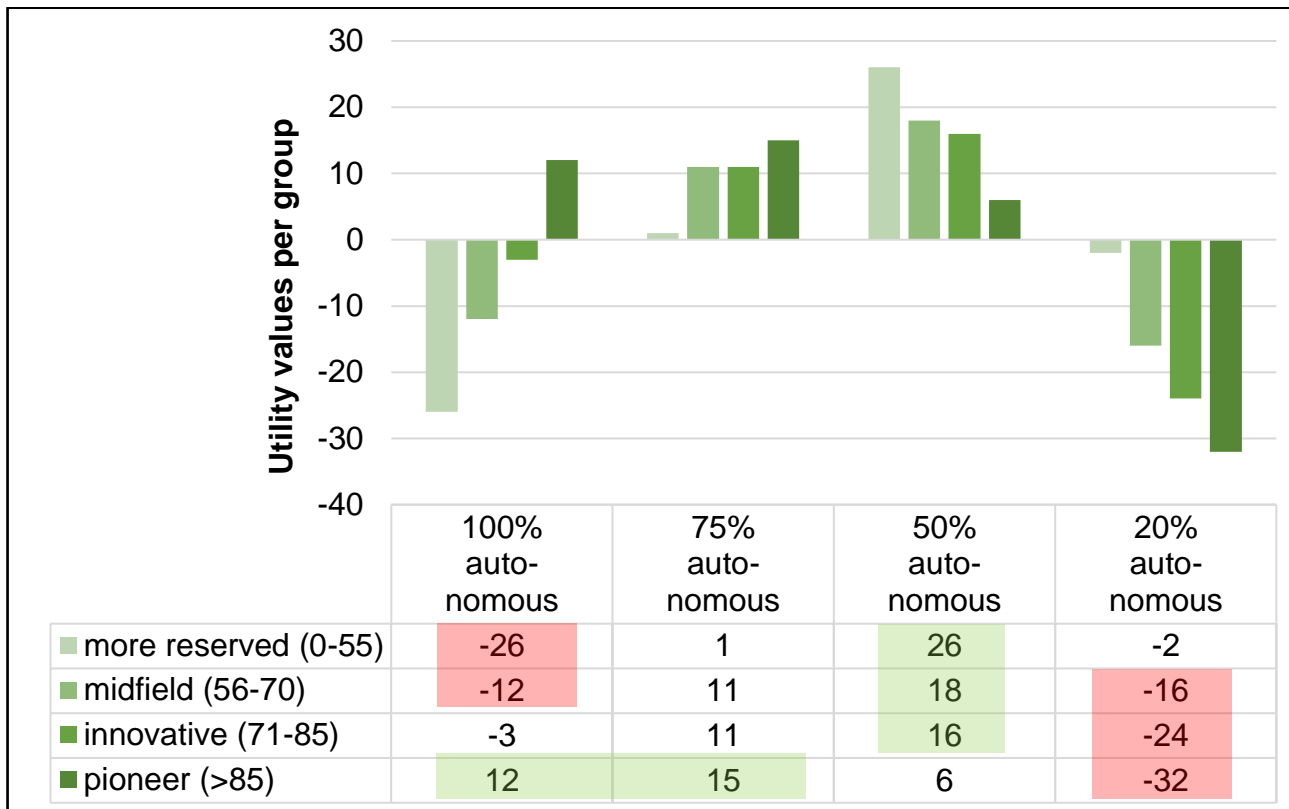


Fig. 50 Benefits of the scope of autonomous driving functions depending on users' individual propensity for innovation

- People with a low propensity to innovate (ranging from reserved ones to the 'midfield') associate a 100% vehicle autonomy with a loss of benefits.
- People with the highest propensity to innovate (pioneers) are the only subgroup to interlink a beneficial gain with a 100% autonomous vehicle.
- Very low levels of autonomy (20%) are already perceived as a loss of benefit by almost all drivers nowadays. This holds even more true the greater the individual inclination for peoples' propensity to invest is.

☞ Summing the study up, it is displayed that users, who are characterized by a higher propensity to innovate, clearly associate increasing levels of automation with enhancing utility values.

3.5.8 Utility values according to trip type

In chapter 3.2.5 two different types of drivers (in the sense of personality traits) have been identified. This is now examined in the following table to find out if they differ in terms of their expectations of the benefits of autonomous driving.

Correlation according to Pearson ³⁷		Characteristics			
		100% Autonomous	75% Autonomous	50% Autonomous	20% Autonomous
Preferred driving type	'Car enthusiasts'	0.37	0.41	-0.27	-0.44
	'Driving purism'	-0.25	-0.31	0.24	0.29

Fig. 51 Correlation between driving type and expected benefits of vehicle autonomy

- Those who associate driving primarily with pleasure and comfort tend to see greater benefits in autonomous driving.
- The opposite is true of 'driving purism': those who practice it, want to drive themselves. Moreover, they associate a loss of benefits with autonomous driving. The targeted use of advanced driver assistance systems, on the other hand, is portrayed with a certain benefit gain in this basic disposition.

- ☞ In summary, the study suggests that *psychographic* criteria (driving type, propensity for innovation) of drivers display a clear correlation with benefit expectations regarding autonomous driving.
- ☞ The different benefit expectations of driving require the automotive industry to develop target group-specific arguments.

³⁷ All correlations are highly significant ($p \leq 0.001$).

3.6 Management Summary

☞ The **vehicle availability** contributes the most to the overall benefit for drivers, with 37.5% of the four characteristics included. The greater the availability, the greater the benefit contribution from the perspective of potential customers. The majority of drivers do not want to hand over full control to advanced driving assistant systems. The term for this is 'ownership culture'.

☞ The **scope of autonomous driving functions** ('below' 100% fully autonomous driving, this refers to equipping the vehicle with assistance systems) contributes to 26.8%, with the four attributes included, in second place to the overall benefit for drivers. Characteristics: A medium degree of autonomy is preferred, with '50% autonomy' being the most favored. In contrast, complete autonomy (100%) is rejected as much as 'lowest' (20%) autonomy. This result can be interpreted as the '**intermediate status of drivers' familiarization with the** idea of autonomous driving': Driving 'without' assistance systems is already outdated. On the contrary, complete vehicle autonomy is still extrinsic to drivers.

☞ The **surcharge contributes** 21.1 percent to the overall benefit of the four included attributes. Characteristics: The lower the surcharge, the lower the loss of utility. The fact that the surcharge ranks only third in terms of its utility contribution among the four attributes indicates that the 'price responsiveness' of German car buyers requires further consideration. The study suggests that there is definitely a certain willingness to spend money on valued features. When wanting to enhance the customer benefit, low prices are in fact not the most critical attribute.

☞ The **manufacturer image** contributes 14.6 percent to the overall benefit of the four attributes included. Therefore, it is the attribute from which the relatively lowest customer benefit is derived. Characteristics: The better the image, the greater the benefit contribution. In direct comparison, (perfectly functioning) assistance systems provide almost twice as much customer benefit as the manufacturer image. It can be assumed that manufacturers benefit more from the performance of suppliers than vice versa from the image of the OEM. The customer benefits associated with functioning assistance systems tend to contribute to the manufacturer's image. With the knowledge of these results, suppliers are able to negotiate confidently with OEMs.

➤ Detailed analyses of the benefits of the scope of autonomous driving functions:

☞ According to the **drivers' age**: the middle age groups are most likely able to imagine themselves using higher levels of automation (100% and 75%). Fully autonomous driving (100%) is mostly opposed by the oldest age group (50+). Moreover, the youngest age group also tends to reject autonomous driving. It is reasonable to assume that elderly people reject fully autonomous driving as they have 'always driven the cars themselves'. Keeping this in mind, they do not want to change it. On the contrary, the youngest age group has the desire to 'finally drive be able to drive on their own'. Thus, they do not want to gain their driving experience in a fully autonomous vehicle.

☞ By **gender**: Women and men prefer a medium degree of automation (50%). Women oppose complete autonomy (100%) significantly more than men. Women in particular need to be convinced of the increasing levels of vehicle autonomy.

☞ According to the **size of the place of residence**: the larger the place of residence, the less drivers perceive fully autonomous driving as a loss of benefit. At the same time, study suggests that the larger the place of residence, the more negative the benefits of a low degree of automation.

☞ By **level of education**: university graduates are more open towards highly, respectively fully autonomous driving. According to the academics, vehicles with few autonomous driving functions are rated as unfavorable.

☞ According to the extent of **previous experience with assistance systems**: higher experiences go hand in glove with a higher perception of the benefits of automation among drivers.
The strongest correlation is currently not achieved with full automation (100%), however, with the highly (75%) automated vehicles.

☞ Findings from the quantitative studies confirm that it is of great interest of the automotive industry to actively introduce drivers to automation technology. The more experience, the greater the understanding of the benefits of these systems.

☞ According to the **driving situation**: In drivers' assessment, driving on highways and, to some extent on country roads, high levels of automation provide the greatest utility. Although city residents favor automation most (cf. above), the highest beneficial use for automated driving is currently seen by all respondents, especially when driving on country roads.

☞ According to **individual propensity to innovate**: People with a low propensity to innovate (ranging from 'Reserved ones' to 'Midfield') relate a loss of benefit with 100% autonomous vehicles. In contrary, people with the highest propensity to innovate (pioneers) are the only subgroup to associate a benefit gain with 100% autonomy.

☞ Low levels of autonomy (20%) are already perceived as a loss of utility by all drivers. However, the greater the individual's propensity to innovate, the greater their perception of a utility loss. For the vast majority of drivers today, a car being 'completely without assistance systems' is no longer an option.

☞ According to the **driver type**: *car enthusiasts* expect great benefits from high levels of autonomous vehicles. The opposite holds true for *driving purists*: those who practice driving purism want to drive on their own. Moreover, they associate a loss of benefits with autonomous driving.

☞ Putting it simply, *psychographic* criteria (driver type, propensity to innovate) of car drivers display a clear correlation with benefit expectations regarding autonomous driving. To meet the utility expectations of various sub-target groups, OEM's communication must adapt in terms of scope, focus and choice of media. There is not 'the one' argument in favor of autonomous driving for all drivers. By all means, it is especially not the price.

☞ An additional analysis illustrates that, with regard to the development of autonomous driving technologies, German drivers put more trust in the US manufacturer Tesla than in all well-established German manufacturers. Thus, active communication measures are strongly required. Above all, however, analyses suggest that domestic manufacturers should enhance getting drivers in touch with these new technologies in order to convince them of their competences.

☞ Based on the insights gained, suppliers can argue towards OEMs that their technological performance is already significantly contributing to the manufacturer's image - always assuming that customers get in touch with the technologies and their advanced driving assistants working flawlessly.

☞ Large suppliers with sustainable technological expertise should consider whether they could incorporate their own branding along the lines of 'intel inside'. Co-branding would also be an option. In order to carry this out, resistance of OEMs must be overcome. On the contrary, there are indeed examples from the past where suppliers have succeeded in penetrating the awareness of end customers (Bosch injection systems, ABS etc. in conjunction with Daimler Benz etc.).

4 Practical test on the operation of parking assistants by users (eye-tracking study)

4.1 Investigation profile

4.1.1 Design and scope of the study

- Method: A sample of users with heterogenous experience background, conducted several practical parking maneuvers with an automatic parking assistant (PAS). For this purpose, a Mercedes-Benz A-Class (W177), model year 2019, with installed parking system, as well as a reversing camera, has been used. The aim of the practical test was to provide the test subjects with an equal level of knowledge regarding the current technology of the parking assistant. Thus, we wanted to ensure sufficient information, as well as the validity of the results. The test subjects were observed using eye-tracking glasses and separate video cameras. At the same time, their behavior was monitored and recorded by test supervisors.
- Concept development: Outline of the study in cooperation with *Valeo Schalter und Sensoren GmbH*. Inquiry of relevant criteria for the evaluation of vehicles, characteristics of trust and propensity to innovate, as well as obtaining feedback on designs for future parking assistance systems.
- In field-test, a longitudinal parking situation, as well as a lateral parking situation have been tested, each with one repetition. Therefore, one test person conducted a total of four parking maneuvers. Moreover, the automatic parking function has been tested out.
- Instructions: The test subjects were requested to not be distracted by the eye-tracking glasses and other technical equipment, in order to fully concentrate on the vehicle functions. No instructions have been given on the function of the parking assistant. Instead, test subjects should attempt to understand them as independently as possible.
- Time sequence: conducting of a pre-survey, followed by a practical test, as well as a post-inquiry, template and assessment of the alternative scenarios by the test subjects.
- Test participants: Drivers aged 20 and over in Germany.³⁸ Quota sample with the following specifications: maximum of one interviewee per family, driver's license, balance in terms of age, education and previous experience in handling autonomous parking assistance systems, 62 test subjects in total.
- Domestic data collection, at three regions in Bavaria (Hof, Weidenberg, Munich). Test subjects are from these cities, respectively their immediate surroundings.
- Engagement of four trained test supervisors to ensure the quality of the data collection.

³⁸ All statements in this report are exclusively related to this target group.

- Average duration per respondent just below 40 minutes. Completion of the field phase in the third quarter of 2019.

4.1.2 Aim and content of the study

The aim of this sub-study is to reveal operating patterns of the PAS and the way test subjects interact with this system. Possible user errors should be identified, and improvement potentials should be derived. In order to optimize the human operating performance, the communication between a vehicle and the driver is particularly vital in terms of human-machine-interaction.

4.1.3 Test schedule

The study has been conducted from July to September 2019 in three regions with different sizes: Weidenberg (rural region), Hof (small town) and Munich (large city). The testing took place at least two days at each of the three locations. The test subjects are from the test locations, respectively their immediate surroundings. Thus, they have been familiar with their driving environment.

Test procedure: In order to reduce possible fears of contact, the test subjects were first welcomed in a friendly manner, as well as introduced to the subject matter of the experiment. Followed by a pre-questionnaire with progressively more specific questions about driver assistance systems, autonomous driving and the test subjects' expectations. At the beginning of the subsequent driving test, participants have been given the opportunity to drive a short introductory lap away from the test site to get used to the vehicle and the measuring instruments. They then drove to the parking test location and conducted the practical test comprising the several parking attempts. Lastly, the follow-up survey and the evaluation of the alternative scenarios to the PAS took place.

- There were no concerning situations during the test period. After the short introductory lap, the participants mastered the vehicle independently.
- Even though the curb was highlighted with white paint and the two vehicles parked in front of and behind the parking space were parked correctly, the PAS of the test vehicle repeatedly drove over the curb during the longitudinal parking maneuver in Weidenberg. Thus, a malfunction was identified.

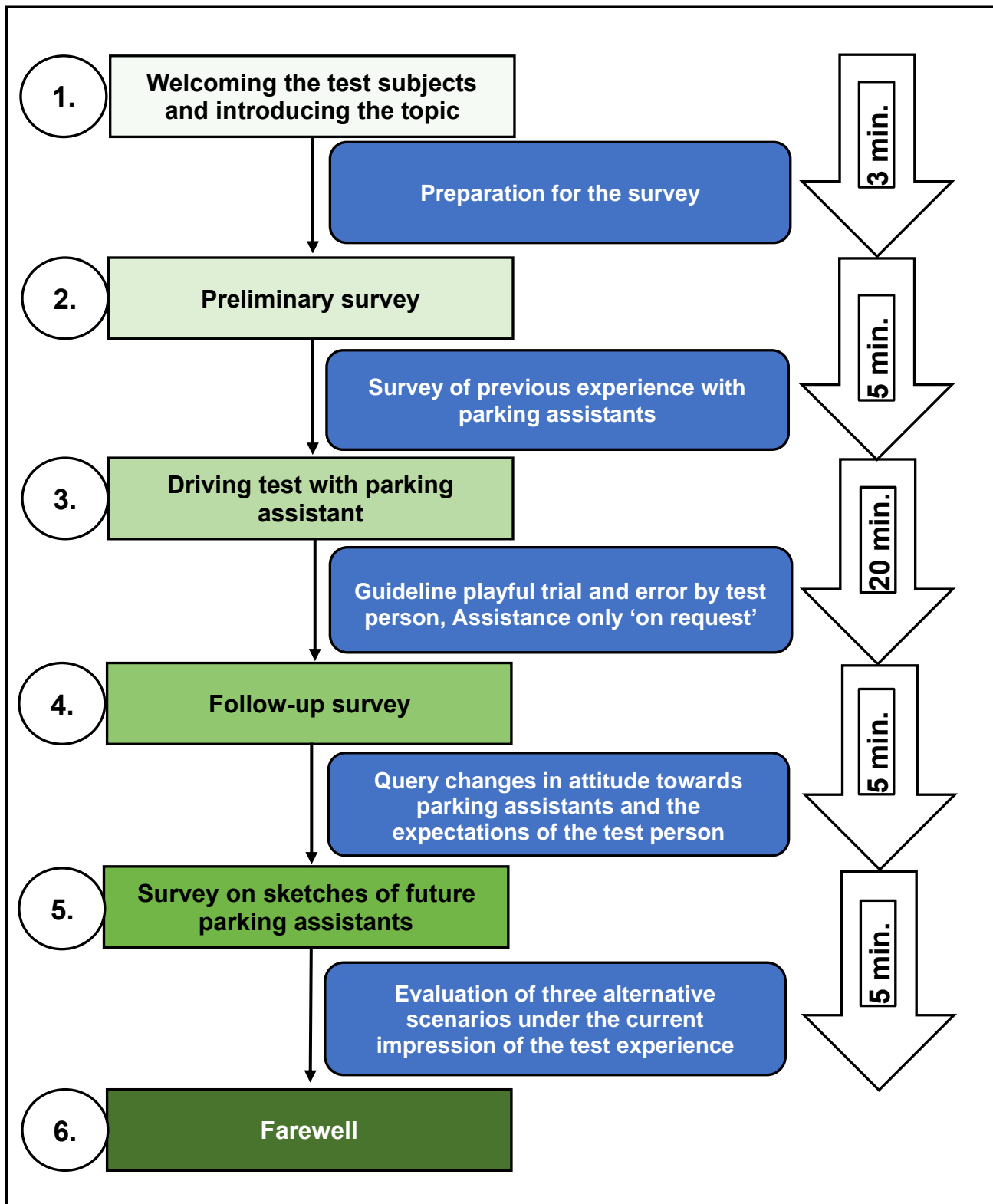


Fig. 52 Timing schedule of the test procedure



Usable recordings with eye-tracking glasses are available from 47 of the 62 test subjects. Those can be comprised in further evaluations.³⁹

To assess the suitability of the parking assistant based on the eye-tracking data, the following target variables have been considered:

- Operating speed (the faster, the better)
- Operating accuracy (the higher, the better)
- Attention required (the less, the better)

The attention required corresponds to the cognitive effort that the driver has to exert in order to operate the parking assistant.⁴⁰

4.1.4 Sample

The purpose of the test description displays the composition of the sample, as well as the criteria used to divide it into subgroups for further analyses.

4.1.4.1 Gender

- 32 women (51.6%) and 30 men (48.4%) took part in the survey. Thus, the gender ratio is almost equal and represents the shares of the overall population.

4.1.4.2 School education

Educational qualification	Number of test subjects	Percentage share
University studies	36	58.1
A-levels	11	17.7
Intermediate school leaving certificate	11	17.7
Secondary school certificate	4	6.5

Fig. 53 Distribution of school-leaving qualifications

- People with higher educational qualifications are overrepresented in the sample. When talking about the diffusion process of new technologies, such as parking assistants, higher qualified respondents are more willing to provide information. They are also inclined to make a purchase decision earlier than persons with other educational levels. The 'innovators', as well as the 'early adopters' should be consulted for decisions

³⁹ The remaining images have not been included in the analysis due to artifacts in the data so as not to distort the results. Reasons for such blunders are, for instance, incorrect recognition of pupils, blending due to changing light conditions or incorrect recognition due to worn glasses.

⁴⁰ Wickens et al. (2012), Engineering Psychology and Human Performance, p. 2f.

regarding the development process. These groups of people are, in the case of automotive technology, found to be above average among the financially stronger sub-target groups with a higher level of education.

4.1.4.3 Age

Age group	Number of test subjects	Percentage share
20-25 years	21	33.9
26-39 years	24	38.7
40-64 years	17	27.4

Fig. 54 Distribution of age groups

- At the time the survey was conducted, the test subjects were aged between 20 and 64. Elderly people were deliberately not included in the study, as a prerequisite of the test was a certain degree of affinity for digital operation. Moreover, the test subjects had to adapt to the unfamiliar test situation as quickly as possible.

4.1.4.4 Residence size

- To capture the variable disposition of individuals from different residence sizes, tests were carried out in three different regions. The test subjects were originally from these cities, respectively from the surrounding areas: Weidenberg (6,000 inhabitants), Hof (47,000 inhabitants) and Munich (1.45 million inhabitants).
- Reality portrays that the test subjects come from places with between 650 and 1,450,000 inhabitants, with a mean value of 396,000 (median 45,000) inhabitants. Three groups can be formed:

Residential size	Number of test subjects	Percentage share
Country	17	27.4
Small town	29	46.8
Big city	16	25.8

Fig. 55 Origin of the test subjects

4.1.4.5 Willingness to spend money on a car

- The test subjects were asked to give a price that corresponded to their own budget, either when buying a new car, purchasing a used vehicle or in form of a monthly installment
- The calculated willingness to spend is between €5,000 and €60,000. In average, respondents would be willing to spend around €26,800 (median €25,000) on a car. This

sample data corresponds with the average purchase prices for cars calculated by the German Association of the Motor Trade for 2019: According to them, the average purchase price for a new vehicle was €33,580. In contrary, people were willing to spend €16,470 for used cars from brand dealerships.⁴¹

- Based on the distribution of the test participants, two groups regarding the willingness to spend can be formed: 'Lower' (5,000-28,000) and 'Higher' (30,000 - 60,000).

4.2 Feedback and evaluation of the parking assistance system

4.2.1 Influence of the practical test on the subjects' judgment

Before the driving test, participants were asked to name the following systems they already had experience with: Parking sensors, reversing camera, parking assistant, automatic parking assistant; operationalization: used at least once themselves, 'yes' = 1, 'no' = 0.

The four assistance systems were weighted as follows: Parking sensors = 1, reversing camera = 2, parking assistant = 3, automatic parking assistant = 4. This displays that the test subjects have different levels of experience with more or less advanced assistance systems. By multiplying experience and weighting, an experience index was calculated for each respondent, resulting in values on a scale from 0 to a maximum of 10 ($[1 \times 1] + [1 \times 2] + [1 \times 3] + [1 \times 4] = 10$).

- The outcome indicates that the test subjects' experiences (index values) is between 0 and 10. Thus, they represent the entire range of the index. The mean value of the 62 test subjects is at 3.7.

An evaluation towards PAS has been collected before and after the test.

- The practical test led to a deterioration in the assessment of six test subjects. Eight evaluations did not display any change and 48 showed an improvement. On a scale from -100 (maximum possible deterioration) to +100 (maximum possible improvement), the average score of the test subjects has been a positive result of 24.9.

Based on these facts, we investigated whether the subjects' previous experience with PAS (index values, as calculated above) is correlated to the fact that the assessment of PAS changes after conducting the test. The following figure illustrates the results of all.

⁴¹ Cf. DAT statistics on motor vehicle trade in Germany 2019, long-term tables, https://www.kfzgewerbe.de/fileadmin/user_upload/Presse/Aktuelle_Meldungen/JPK_2020/Langzeittabellen.pdf, 08.07.2020

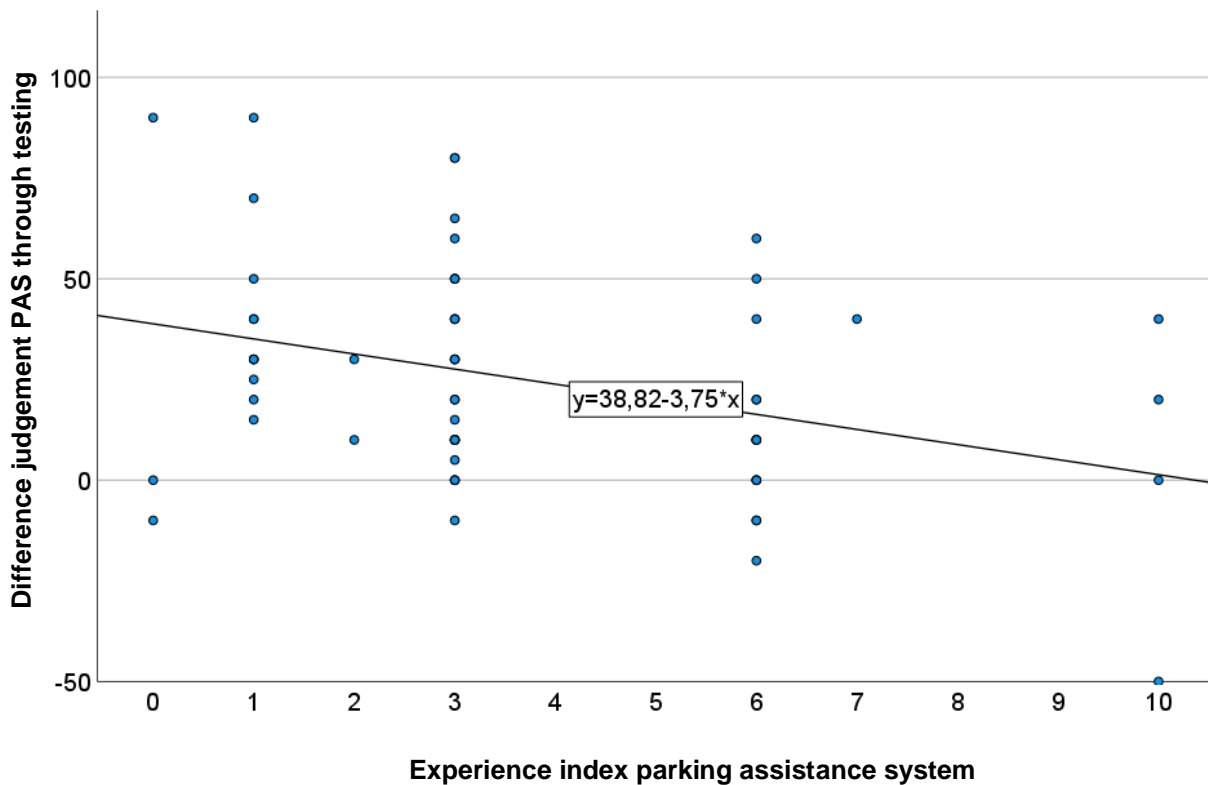


Fig. 56 Scatter diagram of the PAS experience index and change in the assessment of PAS as a result of practical tests

- As the scatter diagram shows, there is a negative correlation displayed. This means that respondents who already have experience in dealing with parking assistance systems are less significantly influenced by their experiences in the test. On the contrary, interviewees who had little to no experience with advanced driver assistance systems have been influenced strongly and positively.
- A correlation analysis yields a value of -0.344 ($p = 0.006$). Thus, it confirms the visual impression of the opposing connection between experience and the effect of the test on the users' assessment.
- This result is consistent with the experience gained from previous reports and studies.

- Once again, it is clearly portrayed that experience with state-of-the-art assistance systems has a strong influence on the users' evaluation. Manufacturers and dealers need to display a great interest in explaining the features of a new car to every customer, as well as to allow them to test them out under instructions. In view of further developments of such assistants, a casual 'let the customer try it out for themselves' is obviously not adequate.

4.2.2 Button search and start of the PAS

Finding the button to start the parking assistant is the first necessary step for the user in order to activate the system. The time required for this was investigated using eye-tracking.

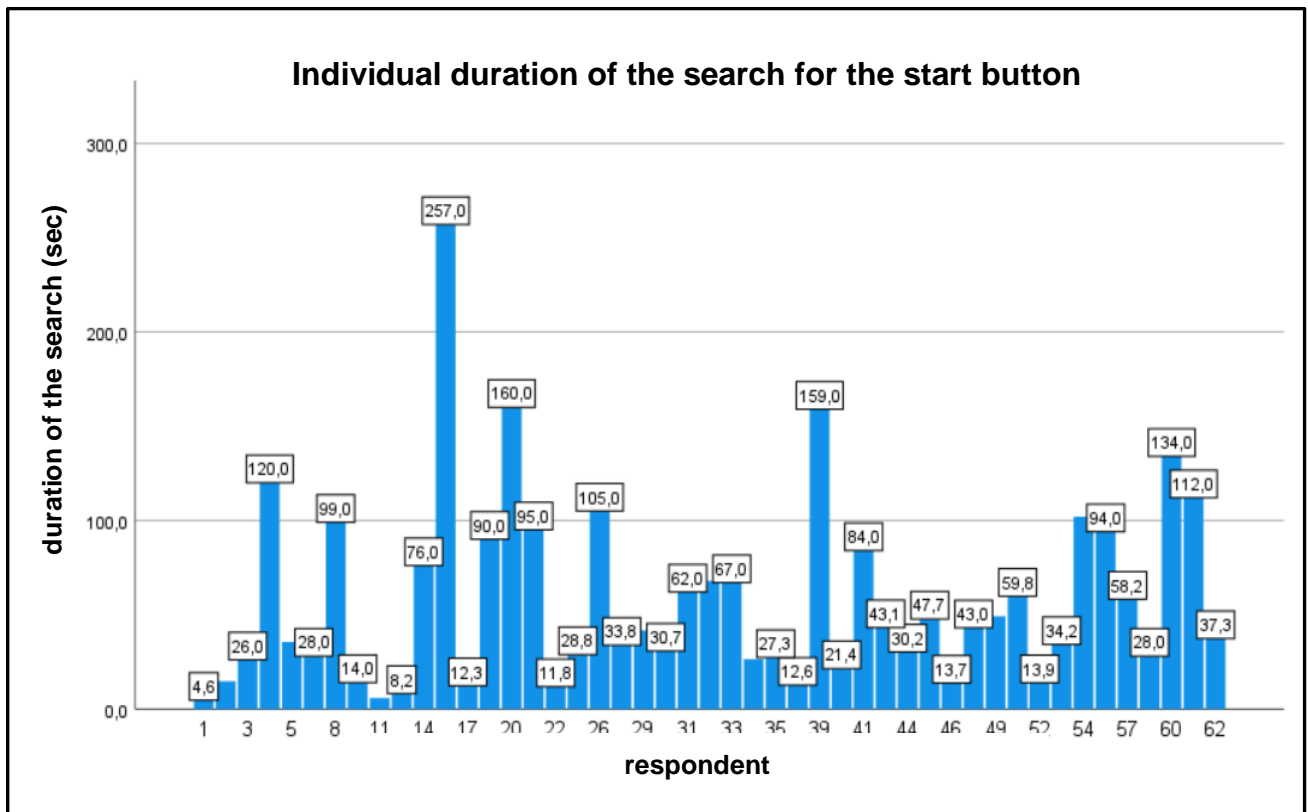


Fig. 57 Duration of the search for the parking assistance button

- The figure indicates that the test subjects needed between 4.6 and 257 seconds to find the start button.
- The average search time has been 58 seconds. Subjects with previous experience (n=15) with parking assistants needed an average of 49.5 seconds, those without experience 62 seconds, i.e. over a minute.
- A host of test subjects needed more than a minute to find the button and start the function. This may not seem much at first glance, however, in actual road traffic it is an unacceptably long period of time, related to obstructions and endangering other road users. User showed the impression of being stressed and overwhelmed.

Areas of interest (AOI) can be defined to analyze the course of the eye movement in order to measure how long users look at individual object areas of interest.

Fig. 58 illustrates five predefined AOIs: display on the left (central display), steering wheel, display on the right, top center console, as well as bottom center console. This also represents the order in which most of the test subjects looked around (red arrows). The ‘time to first fixation’ is shown in the figure below, i.e. how long an AOI is viewed, when looking at it for the first time, on average by the respondents.⁴²

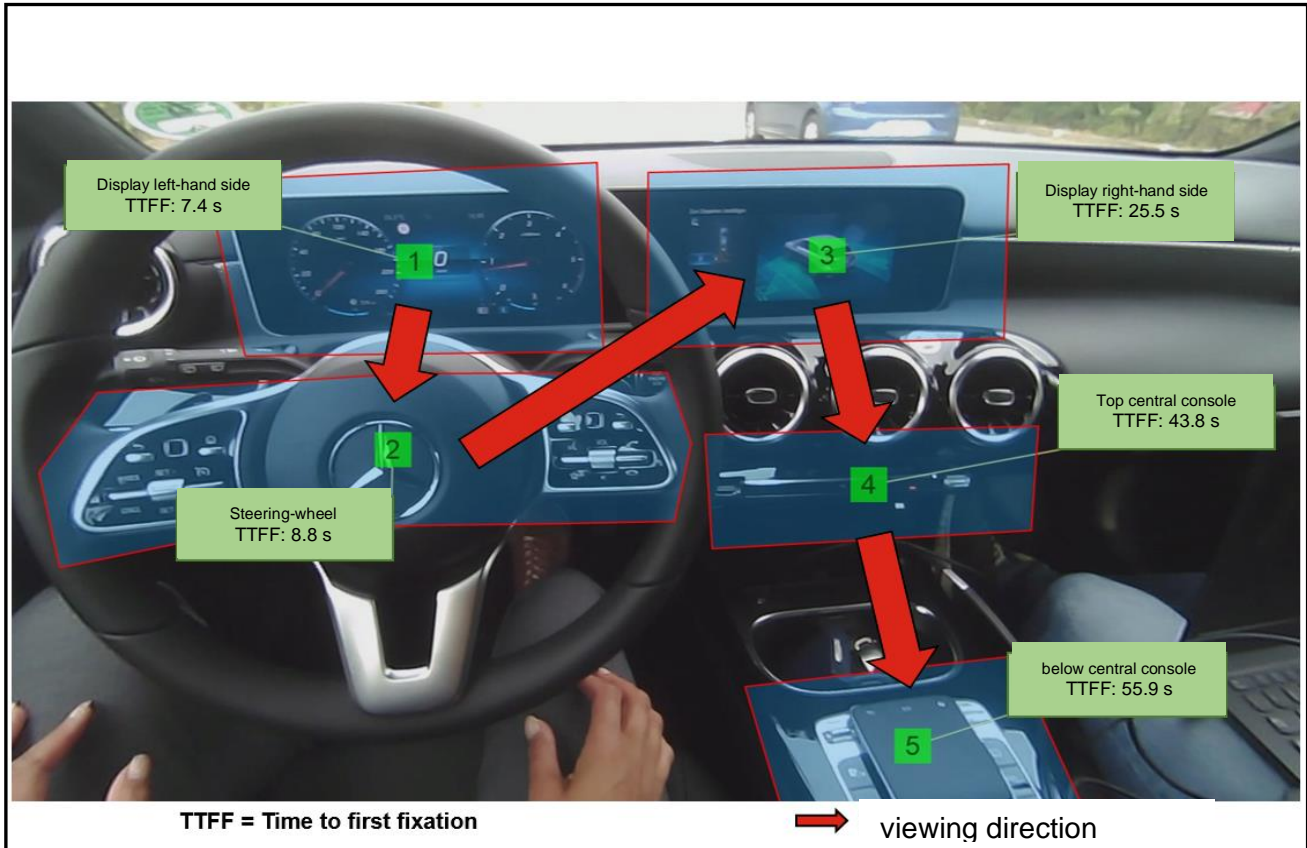


Fig. 58 Areas of interest (AOI) button search, aggregated representation of gaze patterns (n=47)

- Test subjects with no experience of the specific parking assistant look from ‘top left’ to ‘bottom right’, as repeatedly observed in eye-tracking studies on all kinds of subjects. Taking into account this trivial result, which has been known for decades, it is counterproductive for a manufacturer to place the start button at the ‘bottom right’, as it is the place where the majority of users search last.

⁴² It should be noted that the main eye movement shown does not take into account the multiple back and forth movements of individual gaze trajectories realized in practice. Therefore, it cannot be concluded that the eye movement remains permanently on an object before the next fixating the next: Subtractions of TTFF values from the figure do not provide any useful facts of how long a preceding object has been fixated.

The heat map (sum of the eye movement patterns of all test subjects) shows that users spend the longest time looking for the start button in the area of the steering wheel and the central display.

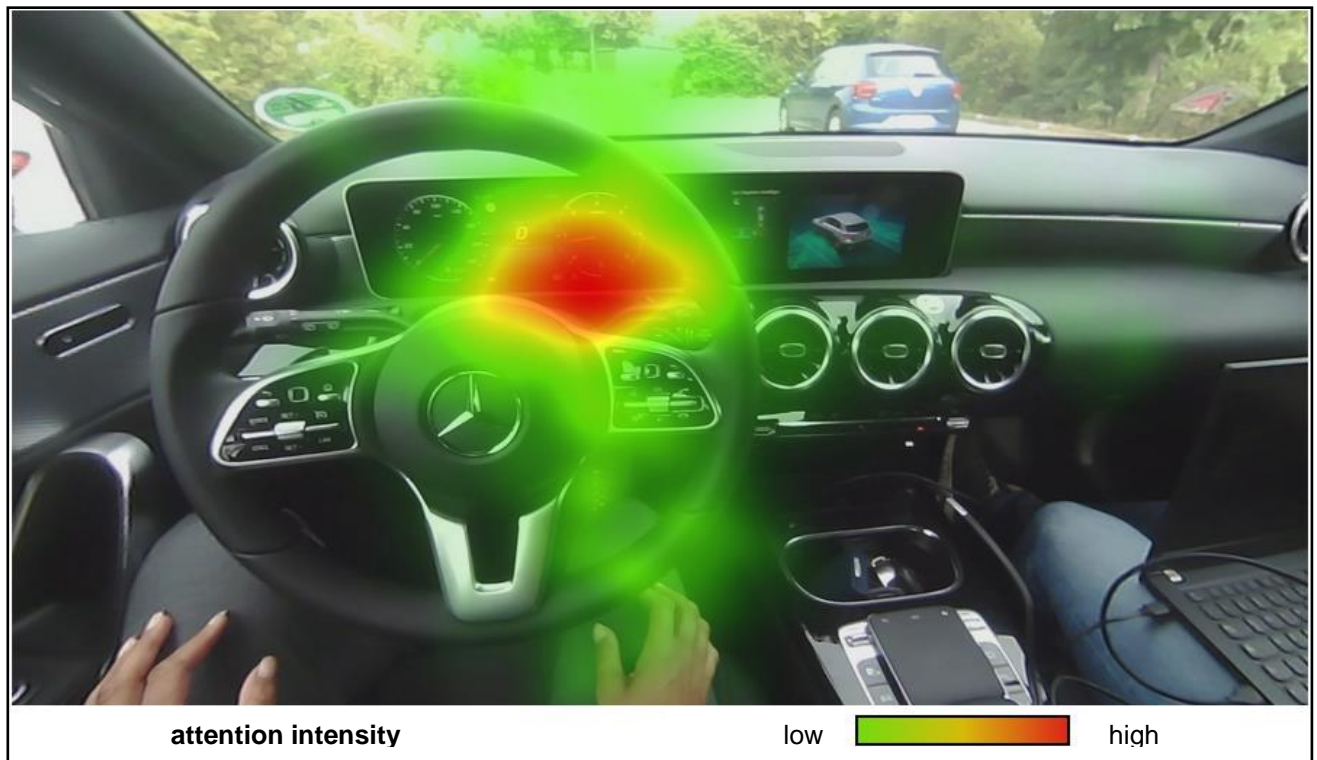


Fig. 59 Heatmap button search

- As a matter of fact, it can be argued that the search problem could be overcome with a glance at the instructions. Test subjects who have successfully used the PAS once also immediately learn where to look out for the button. However, the manufacturer's task is to offer an intuitive solution that quickly leads to the goal, even if having no pre-experience. Depending on the manufacturer, completely different placements for the starting button are obscured in the vehicles. Some manufacturers even vary the button placement from model to model within their vehicle range. There may be favorable *'technical'* reasons for this in individual cases, however: *customers'* expectations and behavior are largely ignored. It is particularly concerning that, in the majority of cases, the opportunity to introduce customers to the parking assistance systems during prior interactions, such as dealership visits, contract signings, and vehicle deliveries, remains largely untapped.
- With 'changing the vehicle', a user is once again facing the problem of searching for the buttons. The eye-tracking processes display that a plethora of test subjects spend a long time unsuccessfully 'looking around' in the menus on the right-hand display. Parallel verbal statements express helplessness and even annoyance towards the technology, programmer and manufacturer.

- It is questionable whether a driver in the actual (stressful) situation of moving traffic is at all willing and able to search for a start button for the PAS for up to a minute or even longer. It is more likely that the driver will then try to solve their parking problem by parking on their own. Anyone who experienced a negative situation easily develops an aversion to the technology in their own car (verbatim: “*is not helpful*”, “*too cumbersome*”, “*takes too long*”, etc.).
N.B.: We are not yet talking about feasible problems regarding the parking space recognition, the parking process itself, etc. Instead, we solely considered the very first step of finding the start button. It is of no wonder that a host of car buyers state “*I have got this in my car, but I don't use it.*”

- ☞ Only few users are able to find the start button for the PAS intuitively and quickly. Based on the usual human search pattern ‘from top left to bottom right’, this start button has been placed in the driver's field of vision where they take their last look (bottom right).
- ☞ If there are technical reasons for such placement, not instructing users in the PAS is then downright questionable. Manufacturers are thus causing vehicle customers to oppose to this innovative and sophisticated technology.
- ☞ The refusal of drivers towards using PAS is caused by the manufacturers. There is no need to look for user characteristics in order to determine which type of driver is more comfortable with the modern technologies: the manufacturers themselves are hindering the diffusion process of the new technology by failing to take the user experience into account.

Further evaluations of the search for the start button:

- The greater the existing experience with parking assistants, the less time the test subjects needed to find the button ($r = -0.208$). Most vehicle manufacturers use a button to push. Thus, experienced users at least know that they do not have to look for the start button on displays. Given the limited number of participants in the field-test, the identified correlation, though in line with expectations, is not statistically significant ($p = 0.162$), rendering it irrelevant.
- The overall feeling of comfort of the test subjects during the practical test was essentially related to how long they had to look around for the start button ($r = -0.338$, $p = 0.022$). Having to search for an operating function in moving traffic is perceived as a dangerous situation.

4.2.3 Analysis of the operating attempts

4.2.3.1 Heatmap first operating attempt

Starting an operating attempt begins when the start button is pressed and lasts until the vehicle takes over full control for parking.



Fig. 60 Heatmap of first operating attempt

The heat map of the first operating attempt displays how attention shifts to the outside area once the PAS has been started.

- The test subjects takes a look at the happening in the area of the speedometer display and the parking space in front of him.
- The area under consideration (red-yellow-green) is relatively wide, as the driver's eye movement often wanders from the speedometer display to the outside situation and back.

For further analysis, a distinction into subcategories is made. In accordance with common research practice on human-machine-interfaces, the three sub-areas information processing, decision-making and action implementation are differentiated.

The degree of automation realized by the PAS is based on an expert assessment and varies between 'no automation' (the driver parks without any assistant system) and 'complete automation', (self-parking of the vehicle based on the 'parking instruction', even if the driver has left the car).

4.2.3.2 Information intake and processing

This is about the functions and information that the driver has to find himself after they have been provided by the vehicle.



Fig. 61 Example of a display that is difficult to identify

- Few elements are miniscule and thus not adequately recognizable. As for instance the red frame in the illustration shows, the area for an indicated parking space by the system (blue P symbol) is only a few mm in size. Even smaller is the white arrow next to the 'P' symbol, which portrays the direction in which the found parking space is located.
- A user who is unaware that there will be a display at this part of the screen may easily overlook it. Keep in mind that the test subjects needed to look to the bottom right shortly beforehand in order to start the system. The continuation of the PAS action is therefore not portrayed clearly.
- Even if you know exactly where to look, the symbol is far too small. Eye problems of elderly drivers do not seem to be taken into consideration by the OEMs.
- Regardless of the user's previous experience and age, the need to concentrate on such small displays inevitably diverts their attention from the surrounding traffic.
- In the test vehicle, the screen on the right can be switched on by pressing the PAS button. After doing so, the parking space display appears there as well - larger, more visible and in conjunction with an audible signal for parking space detection. The problem remains that the user must be aware of this option in order to switch it on.
- According to the test subjects, the scanning of parking spaces by the PAS could be enhanced. First and foremost, as drivers need to completely drive past the parking space in order for the system to recognize it. At the same time, some users have

difficulties identifying the gap detected by the system in the actual vehicle environment, as only a schematic representation appears on the display, however, no image of the actual environment. This identification is vital, as the user has to take action in order to use a detected gap.

- The test subjects have a strong tendency to operate the vehicle solely with the help of the screen. When prompted to engage reverse gear, they tap the reverse gear symbol on the display. Merely when they understood that there is no action being taken at this point they engage reverse gear using the car's 'gear lever'. Clearly, users have difficulties with the required interplay between digital and analog vehicle operation.



Fig. 62 Example of an attempt to engage reverse gear by tapping the display

- In addition, study suggests that the detection of parking spaces is inconsistent: a parking spot was detected on the first attempt, however, not on the third.

- ☞ Operating the digital displays requires a high level of attention. The test subjects are tempted to look for all critical functions on the central display of the center console.
- ☞ Several users consider a bird's eye view of the actual environment as helpful. The distances to physical objects could also be shown.
- ☞ Indications of special situations (e.g. existence of a bicycle lane) would be useful.

4.2.3.3 Decision making

The focus displayed on the extent to which the assistant aids finding the right parking space and which options are shown.

- Apart from the availability of a parking space, there is no other information. It is not feasible to determine when and why a parking space is not recognized.
- For each parking space, the user's scope of decision is limited to approving or disproving the spot and, if offered, parking forward or backwards. If the situation remains unchanged, the system allows on occasion for a selection option, sometimes not, without the user being able to understand why.
- Changing the type of parking maneuver cannot be done. In view of the limited scope of influence, no operating errors occur.

☞ The selection of detected gaps works overall well. Options of selecting the driving maneuver (forward or reverse parking) would be desirable from the point of view of experienced users. Moreover, it could increase drivers' satisfaction.

4.2.3.4 Implementation of the campaign

Carrying out the operation concerns the individual steps conducted by the system.



Fig. 63 Heatmap of fourth operating test (n=47)

After users select the parking space, they need to engage the reverse gear. The vehicle will then autonomously maneuver into the parking spot.

- As the lower scattering of the eye movement patterns in the heat map indicates (Fig. 63), test subjects are already a lot more focused when performing the action compared to the first user test.
- The view constantly changes focus between the area of the speedometer and the road, while other things fade into the background.
- The screen on the right is hardly ever looked at. Users have learned that they only need to slightly tap the display to select the parking space.
- In individual cases, a test person released the brake and the vehicle began to roll before parking was confirmed. If the car moves slightly before the user has made a decision, the system resets itself. There is a small potential for improvement by allowing a little more tolerance before interrupting the process.

- ☞ Users quickly gain confidence when operating the system.
- ☞ The operating test works well overall.

In addition, we investigated whether test subjects with and without previous experience differed in terms of the time required for the operating test.

Duration of operating attempts (in seconds)	Test subjects' experience with PAS	
	Hardly/no experience (n=32)	Previous experience (n=15)
First operating attempt	114	72
Fourth operating attempt	32	25

Fig. 64 Time required by test subjects with and without experience in using PAS for the first and last operating attempt

- Fig. 64 suggests that test subjects with previous experience can complete both operating attempts faster when comparing them to test subjects without experience.⁴³
- As the number of operating attempts augments, the difference in time between the two groups decreases. The system is therefore easy to understand and learn.

⁴³ T-test with independent samples: significant difference between the two groups ($p=.010$) after the first operating attempt, no significant difference after the last operating attempt.

4.2.4 Analysis of the automatic parking maneuver

When the test person passes on control to the vehicle, the parking maneuver starts. The process is completed when the right-hand screen of the vehicle switches back to starting position and the menu for the parking assistant disappears.

The system states that the vehicle's surroundings must always be observed by the driver during the maneuver. The heat map displays that the systems' advice is being followed, as the test subjects' view is clearly directed outwards. Infrequently interviewees also observe the interior mirror. The test subjects primarily concentrate on controlling the vehicle maneuver and monitor the functions of the PAS.

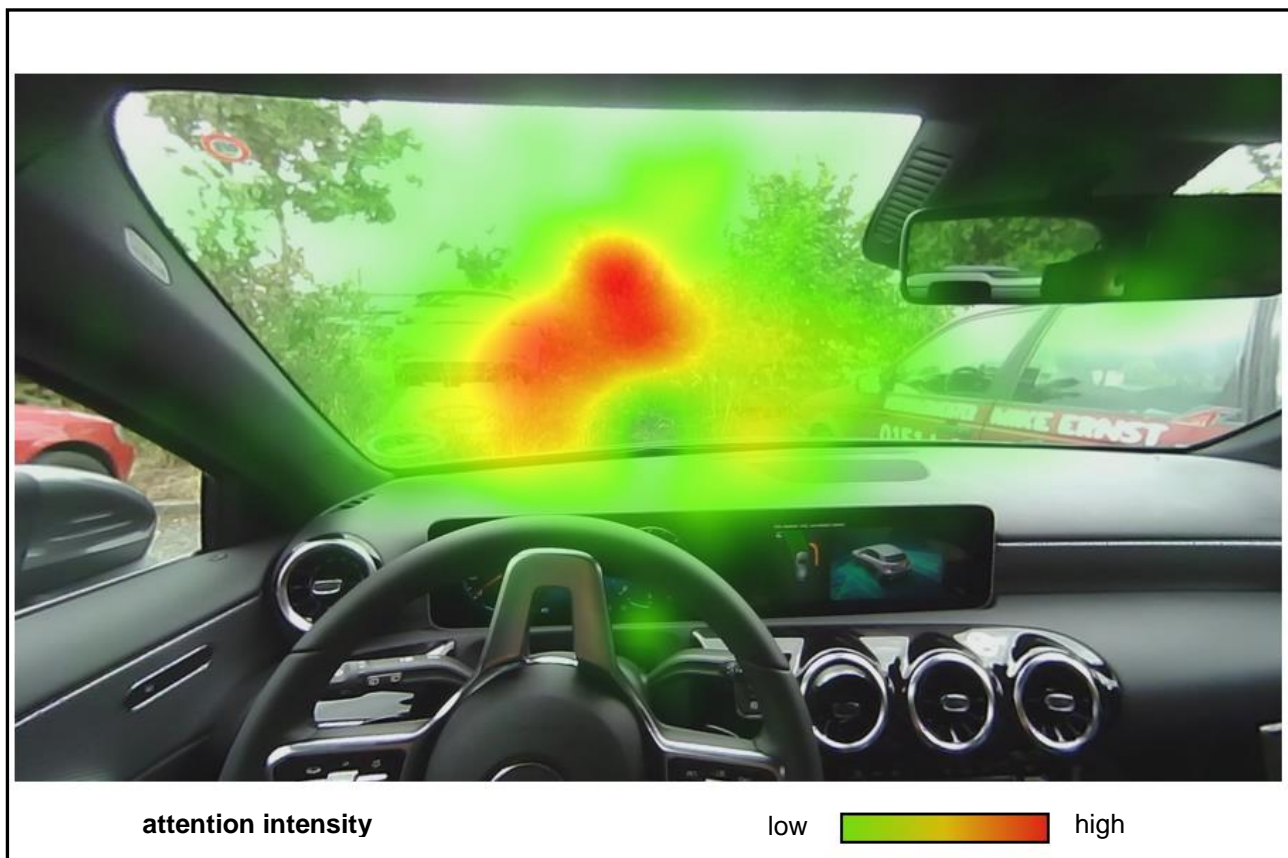


Fig. 65 Heatmap first parking (n=47)

- The test subjects pay close attention to the road in front of them, their view is mostly directed forwards.
- The area around the center of the vision field is being viewed consistently. The dispersion of the view is relatively pronounced in contrast to the control attempt.

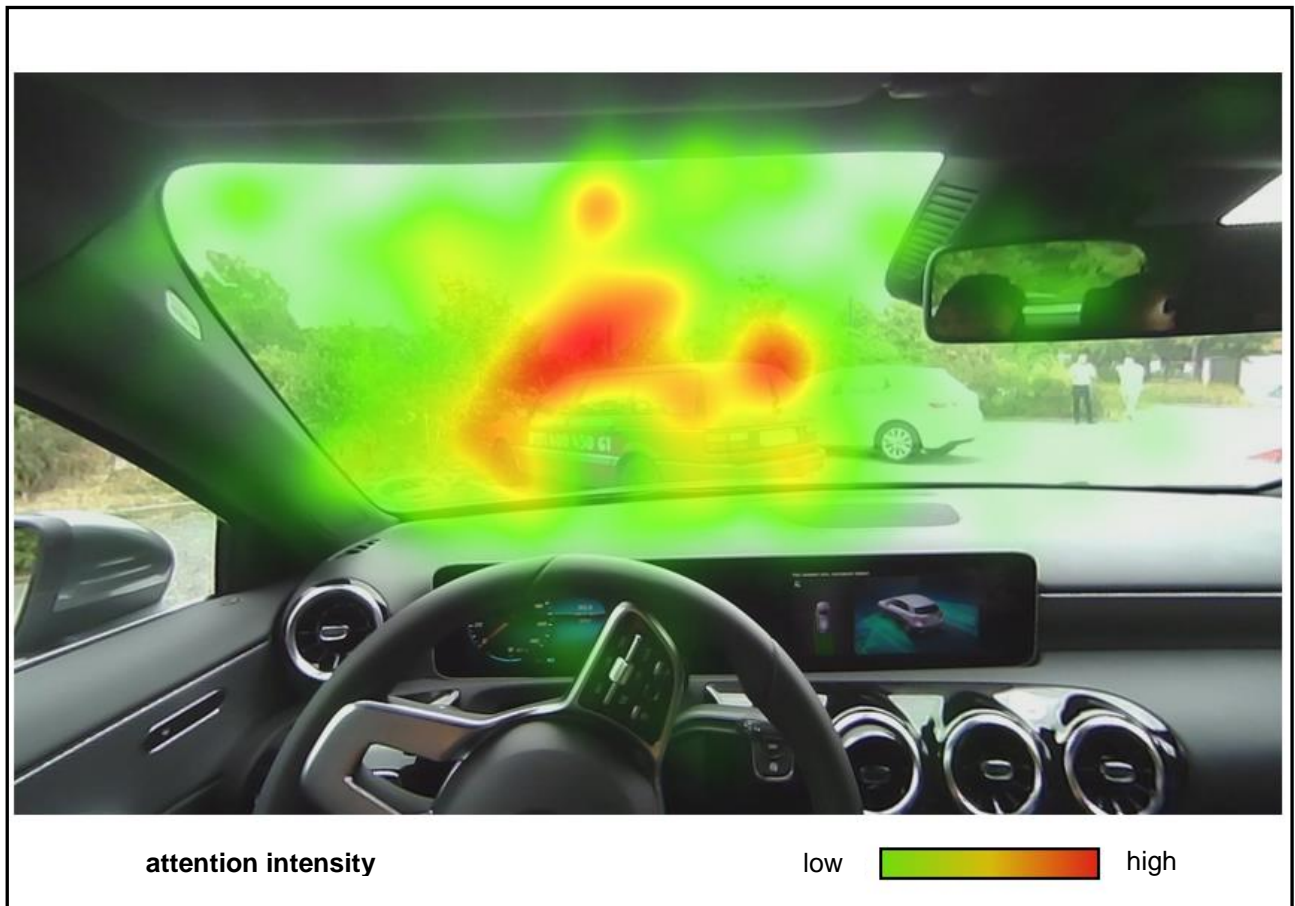


Fig. 66 Heatmap fourth parking (n=47)

The heat maps indicate that the drivers are mainly occupied with monitoring the parking process and remaining ready to intervene. The reason for this is the system taking charge and being responsible for both the driving maneuvers and maintaining distances.

- During the fourth parking maneuver, the view of the test subjects wandered a little more around than during their first attempt. They have already gained more confidence and are sanguine enough to look further around.

☞ With increasing experience, users pay more attention to traffic and other surrounding elements when parking.

The PAS is essentially accountable for carrying out the process. Upon acknowledgement, the vehicle autonomously decides which path to take, which is the required speed, etc.

- The parking maneuver itself operates reliably. During the test period, around 290 automatic parking maneuvers have been conducted. The vehicle did not make contact with surrounding cars or other obstacles, even during particularly tight maneuvers, as well as narrow gaps. As already mentioned, there has solely been one point in Weidenberg where the curb was not reliably detected. However, no damage occurred here either.

- During the test, a single, miniscule branch, being no threat to the vehicle, covered one of the sensors at the front left. The system reacted swiftly by braking hard and immediately using the handbrake to avoid a collision. Overall, the system's decision-making is sophisticated. However, some users perceive a few reactions of the vehicle as too abrupt.
- The parking maneuver itself has also been interrupted in a few cases by severe, sudden and often incomprehensible braking maneuvers. The vehicle does not slow down smoothly, but instead initiates heavy braking. The noise generated during these abrupt maneuvers is unpleasant, impacting the physical comfort of the test subjects.
- Some users felt the desired parking precision being too exaggerated. In a few cases, the PAS carried out up to three correction attempts (forward/backward correction), resulting in a barely relevant optimization of the parking position. At times, the vehicle even maneuvered out of the space several times merely to gain a few centimeters in total. Users complained about the loss of time and the suspected abrasion of the steering wheel, as well as of the tires and the chassis.

- ☞ The PAS must be controlled in a way that allows for a smoother response in the vehicle's movement.
- ☞ An individual adjustment of the parking accuracy would be favorable. Users display various ideas about what parking accuracy is desirable according to them.

4.3 Open suggestions for improving the PAS

After the field-test, an unaided questionnaire was used to investigate how the participants suggested to improve the PAS. The following tables distinguish between the assertions of participants whose overall assessment of the PAS either enhanced, remained the same or worsened as a result of the practical test.

Individual entries	n	Category I = Information; D = Decision-making A = Action implementation
Voice control and clear audio instructions from the system (as for instance the navigation)	5	I
Simplified operation, self-explanatory if you aren't used to the car	3	A
Adjustable speed of the system (too fast, too slow)	3	A
Offering all-round camera (360°)	2	I
Fewer maneuvering movements, parking right into the gap within first attempt	2	A
Less sudden driving, braking, parking	2	A
Button for PAS instead of searching on the screens	1	I
Visualize parking space detection	1	I/D
Detecting a parking lot at first glance, as humans do	1	I
Enhance space utilization, maneuvering tighter	1	A
Being able to react swiftly	1	A
Practice necessary, instruction, putting trust in the system	1	I
Conjunction of optical and acoustic signals	1	I
Video feed	1	I

Fig. 67 Suggestions for enhance the PAS from test subjects whose judgment was improved by the test

- Test subjects, whose evaluation enhanced during the tests, would primarily prefer voice control, as well as a simplified operation.

- Test subjects, whose assessment did not change based on the test also primarily desired voice control, as well as a simplified operation.

Individual entries	n	Category I = Information; D = Decision-making A = Action implementation
Voice control and clear audio instructions from the system (as for instance the navigation)	8	I
Simplified operation, self-explanatory if you aren't used to the car	7	(other)
Less sudden driving, braking, parking	7	A
Fewer maneuvering movements, right into the gap at the first attempt	6	A
Less marshalling movements, avoiding mechanical exposure and creaking noises	5	A
Recognize and display gaps better	5	I/D
Feedback on what the car sees and intends to do	2	I
Adjustable speed of the system (too fast, too slow)	2	A
When coming to a stop, a menu 'Park?' appears, and you simply press ok.	1	D
Visualize parking space detection	1	I/D
Indicator must illustrate where he wants to move next	1	I
Set indicators automatically	1	A
Save custom parking spots and then drive away	1	(other)
Parking without a driver, by remote control	1	(other)
Detecting a parking lot at first glance, as humans do	1	I
Button for PAS instead of searching on the screens	1	A
System info, how far I have to drive	1	I
Enhance and develop technology	1	(other)

Fig. 68 Suggestions for enhance the PAS from test subjects whose judgment was not changed by the test

- Even test subjects, whose evaluation deteriorated during the tests, would prefer voice control, as well as a simplified operation.

Individual entries	n	Category I = Information; D = Decision-making A = Action implementation
Voice control and clear audio instructions from the system (as for instance the navigation)	11	I
Simplified operation, self-explanatory if you aren't used to the car	8	(other)
Adjustable speed of the system (too fast, too slow)	7	A
Detecting a parking lot at first glance, as humans do	5	I
Fewer maneuvering movements, right into the gap at the first attempt	5	A
Less sudden driving, braking, parking	4	A
Button for PAS instead of searching on the screens	2	I
Enhance space utilization, maneuvering tighter	2	A
Offering all-round camera (360°)	2	I
Enhance and develop technology	2	(other)
Practice necessary, instruction, putting trust in the system	2	(other)
Provide the option of stopping, e.g. when maneuvering	1	D
Instructions on screen	1	I
Enhance display	1	I
Apps knowing where the nearest parking space is	1	(other)
Indicator must illustrate where he wants to move next	1	A
Indicators should be louder	1	A
Feedback on what the car sees and intends to do	1	I/D
Better warnings of feasible threats when parking	1	I
Consistency in the selection options	1	D
Steering wheel operation	1	I
Recognize and display gaps better	1	(other)

Fig. 69 Suggestions for improving the PAS from test subjects whose judgment was worsened by the test

- To sum the results up, the most frequently mentioned suggestions for enhancing the systems by all test participants have been, regardless of how they assessed the study, voice control, as well as a simplified operation.

- Based on the test experience, test subjects thus provide vital suggestions for improvement: The search for the right buttons and controls, along with the necessity of simultaneously monitoring the surroundings, leads many participants to a sense of current overwhelm in visual perception and haptic actions. In contrast, the ears have not been overloaded: As an additional layer of input, useful auditory information can be assimilated *at any given time* without impairing the visual observation of the surroundings and orientation in the vehicle. Similarly, when overwhelmed, participants posed questions to the test leaders and anticipated (auditory) responses.

☞ As parking assistants have been available for years and there has been plenty of time for such user tests, it must come as a surprise that the options to aid drivers with voice assistants have not been taken any further.

In order to consolidate the results from the three tables above, suggestions for improvement have been weighted. We assumed that the urgency of the recommendations felt by the test subjects is particularly high if their assessment of the PAS has deteriorated as a result of the test.⁴⁴

The following figures result for the weighted improvement suggestions in three user experience categories:

	Weighted number of suggestions for improvement			
User experience category	The subjects' opinion of the PAS was confirmed by the practical driving test...			Total
	...improved	..not changed	...deteriorated	
Information	11	38	75	124
Decision making	1	14	9	24
Implementation of the campaign	9	44	60	113

Fig. 70 Frequency of naming by test persons after change in judgment

- The majority of improvement suggestions relate to information presentation and processing. This holds true for the overall number of statements. Similarly, this applies to participants whose evaluations either improved or deteriorated during the practical test.

⁴⁴ Weighting factors therefore: deteriorated *3; neutral *2, improved *1.

- Suggestions for enhancing the implementation of the process are in second place.

☞ Therefore, information, as well as the implementation of actions hold the greatest potential for a better reception of PAS in the future.

- Additional information for the driver, as well as an improvement in the vehicle's awareness of its surroundings are desirable.
- Smooth driving behavior can particularly be emphasized during conducting these processes.

The most critical individual suggestions for improvement are:

- *Voice control and clear audio instructions from the system (as for instance the navigation)*
- *Being able to adjust the speed of the parking maneuver*
- *Less sudden driving, braking, parking*
- *Detecting a parking lot at first glance, as humans do*

☞ Drivers base their assessment of the PAS on their own proven patterns of action. Overall, the improvement suggestions express the desire of the test subjects that the system should function in a more 'human-like' way.

4.4 Backing out of the parking space

Another anomaly occurred while backing out of a parking space, i.e. when automatically exiting the gap. Ending the autonomous unparking, a symbol for resuming manual control suddenly appears without prior warning or a 'countdown'. A brief and silent system sound marks the moment at which the driver is expected to take over control again and continue driving without the assistants.

- Some participants display a noticeable delay in responding to the instruction of taking over control of the vehicle.
- As there is no countdown, drivers have no opportunity to prepare for the moment in which they need to take over control of the car again. Also, the system sound is silent.
- Study suggests that it is challenging for drivers to learn about the relevant time of the vehicle takeover, as the moment at which the system hands over control of the car is inconsistent. Mostly, the vehicle then ends up at a considerable angle to the rest of the traffic, potentially unleashing the driver to take further action. The following illustration illustrates a test person in this given situation.



Fig. 71 Missing subject reaction

It is inconceivable, why there is no voice statin: 'Parking process complete' or 'Please take over the control again' instead of an overmodulated system. Manufacturers may suspect that such a message could be perceived as 'annoying' after using the PAS multiple times. However, this does not justify leaving drivers with little experience to cope with the sensation of lacking support on their own. It should be borne in mind that prolonged hesitation of a driver whose vehicle is already in the lane for a longer period of time poses a significant safety risk.

Due to the lack of instruction from the car dealerships when the vehicle is handed over, customers are left alone with the feeling of being overwhelmed, or at least with a lack of support. A lack of empathy from the OEMs (development, IT, but also customer service) towards the experience of their own customers becomes apparent.

Any visual signal that distracts the driver from the traffic (while being left alone with steering the vehicle again at that moment) is suboptimal. However, an acoustic signal, on the other hand, does not interfere with the visual awareness. The visual signal could be combined with the option to be switched off by experienced users feeling disturbed. This mechanism is already feasible with many other assistance systems.

- ☞ The handing over of the vehicle's control after the parking maneuver has been conducted, urgently needs to be enhanced. The current solution is vague to inexperienced drivers and thus, poses a safety risk.
- ☞ Voice instructions that the driver needs to take over control of the vehicle again would be a simple solution to the problem.

4.5 Management Summary

Experiences and their influence:

- ☞ People who have no experience with parking assistance systems (PAS) are significantly more influenced by a practical test in their assessment than users with such experience.
- ☞ It is therefore necessary to instruct new customers and get them in touch with the PAS. Imparting a positive initial impression of such systems is crucial for influencing later purchase intentions.

Button search:

- ☞ Drivers with an affinity for technology and innovation are more open towards PAS. These drivers also find the start button more swiftly.
- ☞ The eye-tracking data displays that the test subjects need in average almost a minute before finding the button and starting the PAS.
- ☞ The button for starting the parking assistance system is located relatively close to the steering wheel and the touchscreens. The button arrangement should be reconsidered.

Operating test:

- ☞ Despite no modified situations, the detection of parking spaces mostly remained inconsistent. Example: a space that was recognized on the first attempt has not been identified during the third one.
- ☞ The digital screen, as well as its operation require a high level of attention and concentration from the user. The test subjects are tempted to search for all critical functions on the central display of the center console. The dissemination of information, as well as of the operating elements across various screens and buttons is not intuitively understood.
- ☞ With increasing use, drivers swiftly become more confident in operating the PAS. Overall, the conducted operating tests obtained a pleasing outcome.

Parking maneuver:

- ☞ With increasing experience, the test subjects learn to pay more attention to the traffic than to the parking maneuver itself.
- ☞ Additional auditory information could help to keep an eye on the traffic situation during the parking maneuver.
- ☞ The PAS should enable a smoother response behavior of the vehicle movement, especially when braking. A customization option for vehicle movements (faster - slower maneuvers) is desired to meet the individual suggestions of users.

Open improvements:

- ☞ The system should operate more 'human-like' in terms of recognizing parking spots and maneuvering the vehicle.
- ☞ The user taking control of the vehicle, after the parking maneuver has been conducted, poses a safety risk. Auditory aids could be a solution to this issue.

5 Alternative scenarios of parking assistance systems (concept test)

5.1 Investigation profile

5.1.1 Design and scope of the study

- Method: Face-to-face survey to assess three predefined scenarios of the parking assistant. The survey was conducted after each individual test subject had completed a real driving test with the current parking system using a Mercedes A-Class car. The purpose of the preceding driving test was to ensure that the test subjects had the same level of knowledge regarding the current technology of the parking assistant. Thus, we could ensure an increased ability to provide information, as well as the validity of the results.
- Concept development: draft in cooperation with Valeo. Inquiry of pertinent criteria for the evaluation of vehicles. Surveying characteristics of trust, as well as willingness to innovate. Moreover, asking the representants to provide feedback on drafts for future parking assistance systems.

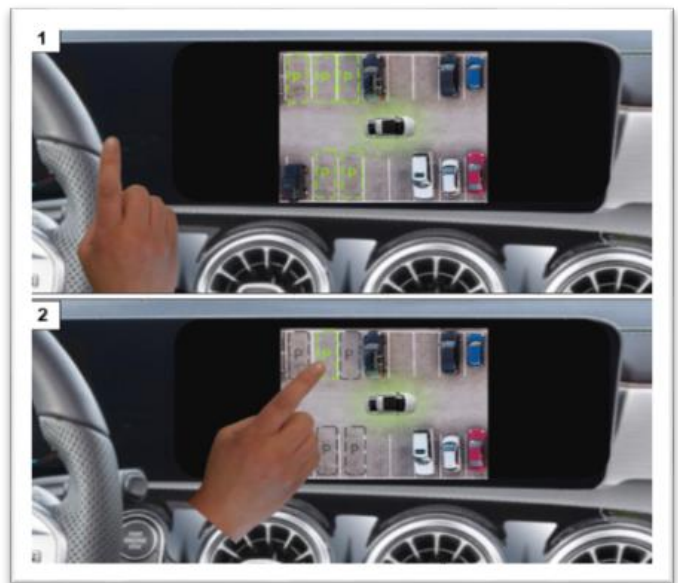


Fig. 72 Example scenario

5.1.2 Aim and content of the study

This report grapples with the evaluation of three alternative concepts ('scenarios') for the parking assistant. The concept test has been carried out by confronting users with image templates and simultaneously conducting quantitative and qualitative surveys.

All test subjects had completed the practical test directly beforehand (c.f. previous chapter), enabling them to assess the concept drafts capably on the basis of their developed experience.

The data from the various sub-surveys has been merged into a standardized data set for each respondent. By carrying this out, cross-project evaluations were possible. For a description of the sample, c.f. Chap. 4.1.4.

This study gained the following knowledge objectives:

- How do participants, who have been placed in an identical experience situation with regard to current technology by an actual previous test, assess alternative scenarios for a future parking assistant?
- Is it feasible to distinguish subsamples of test subjects, assessing the scenarios differently, to derive conclusions and arguments for various target groups?
- How should the results be classified in terms of supporting Valeo's short and medium-term development decisions?

5.2 Feedback and evaluation of the PAS scenarios

5.2.1 Setting for the assessment

The visual presentation of the three scenarios was related to following explanations:

- **Explanation:** *Several cameras generate a 360-degree all-round view from a bird's eye perspective. This supports the selection of parking spaces.*
- *It is ensured that the vehicle recognizes obstacles and prevents damage. Occupied parking spaces are not being approached.*

The purpose of this description was to illustrate the initial situation to the test subjects in a standardized way and to give them an idea of how the PAS works. The number of technical details was deliberately kept to a minimum, as assistance systems should be as generally understandable as possible. Moreover, they should not create unnecessary hurdles due to the need for 'familiarization'. Instead, the PSA-systems should encourage the most intuitive use possible. In the interests of customers and drivers, the objective is based on fulfilling the need 'I want to park' as simply as possible.

The test subjects were initially able to view all three scenarios. Afterwards, they gave an assessment, also including an internal comparison.

5.2.2 Description and assessment of the scenarios

5.2.2.1 Scenario 1: 'Choose a Place'

Scenario 1 displays a parking lot with parallel parking spaces, as known from supermarkets. The screen of the vehicle depicts this parking lot illustrated in a realistic environment.

Based on the image template and the explanations, test subjects should comprehend that the all-round cameras provide a realistic view of the surroundings. Feasible parking spaces are recognized by the system and can be selected by the driver. After selection and confirmation by the driver, the vehicle then parks autonomously.

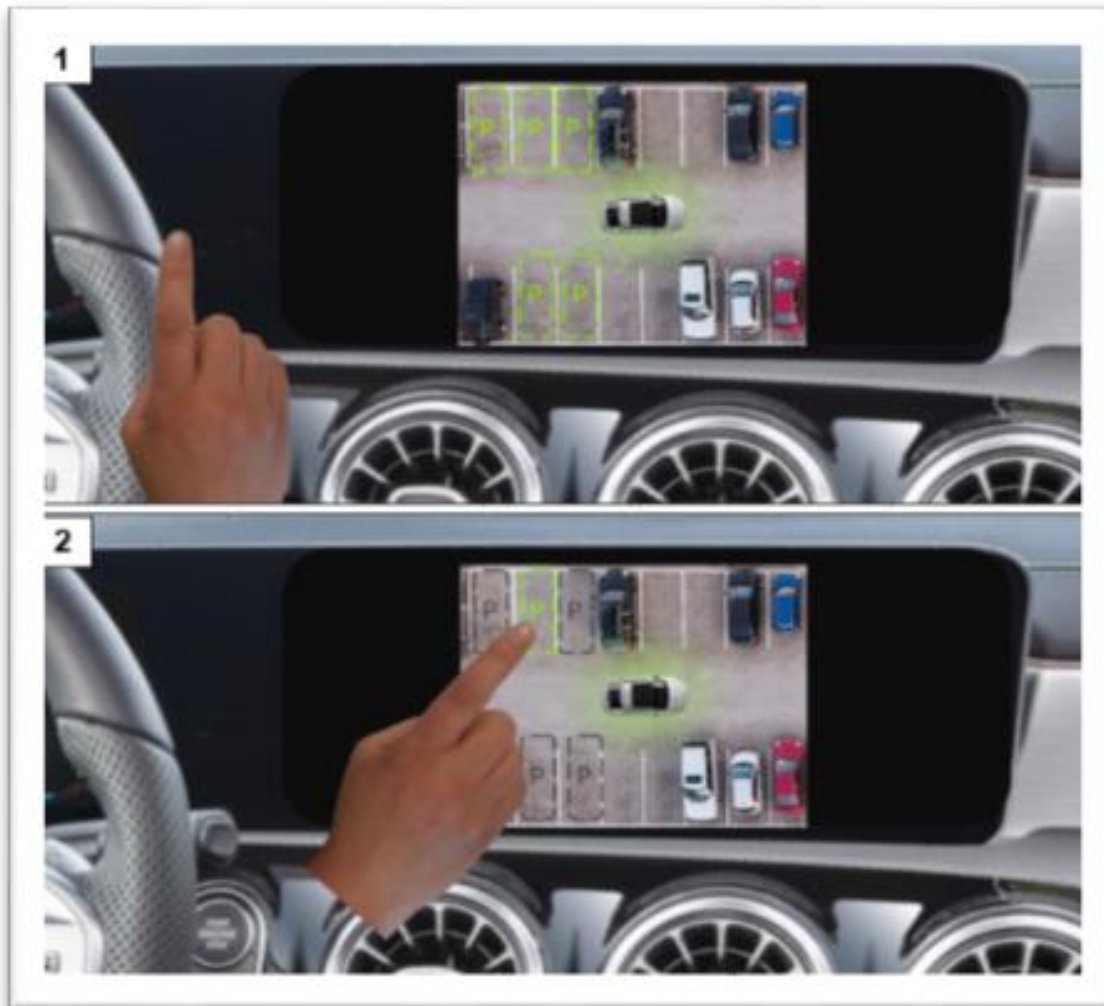


Fig. 73 Image template scenario 1

The respondents were asked to evaluate this concept proposal in an open questionnaire without being influenced by the interviewers:

“Could you share your immediate thoughts on this, please?”

(Information of the interviewer: follow-up questions: understanding, favorable/adverse assessment, reservations, etc.) “In which everyday situations would it be useful to have such a PAS?”

The responses can be grouped into three categories: positive, neutral and negative (c.f Fig. 74):

Category	Individual entries	n
Positive (119 entries, 80.4%)	Good/sweeping approval	29
	It is great to have a direct choice	14
	Clear, comprehensible	12
	Bird's eye view/realistic representation is great	11
	Good that places are recognized by lines	9
	Practical/useful	8
	Useful when shopping	7
	Useful in the parking garage	6
	Corresponds to your own idea	6
	Best of the three scenarios	5
	Not having to park right next to another car	3
	Better than the current system	3
	Good if the entirety of parking spaces is displayed	2
	Conceivable to use in any everyday situation	2
	Good in case of events	1
	Very appealing in city traffic	1
Neutral (12 entries, 8.1%)	Underground parking/parking garage	4
	Does not have to recognize every parking space	1
	Usual situation	1
	Combination of systems: Car should weigh up	1
	Given parking lot	1
	Direct display	1
	With bird's eye view	1
	Shopping center	1
	Good in itself, however, inadequate for open spaces	1
Negative (17 entries, 11.5%)	Only detects parking spots behind the car	5
	Not necessary, why would you need it	3
	Bird's eye view difficult to understand	3
	Not flexible, no free parking, no parking options	3
	Critical if technology does not recognize the parking spots cor-	2
	Someone could drive into your chosen gap	1
Total (multiple answers from 62 respondents)		148

Fig. 74 Frank assessment of scenario 1 'Choose a Place'

- Over 80 percent of the open responses have been favorable, with the majority rating the scenario as good. The concept is approved, as it is immediately understandable.

➤ Scenario 1 convinced the majority of test subjects, as the screen and operation were perceived as intuitive and easy to understand.

- The representation of the real environment on the display facilitates the rapid and precise comprehension of the situation. In contrast to the existing PAS, users have the impression that they have a choice regarding the parking space.

☞ Simple and intuitive personal control options are rated as favorable by users.

- The most frequently criticized aspect is the lack of anticipatory parking space detection in front of the vehicle: as parking spaces are only detected after the vehicle has driven past them, swift and anticipatory parking is preempted from the participants' perspective. In everyday life, drivers prefer to head for a space as directly as possible. In the concept situation described, the free parking spaces could also be approached by driving forward in one go. Keeping in mind these circumstances, the interviewees conceive it as counterintuitive, to firstly drive past the space before parking in reverse. The parking assistant contradicts the desire for a direct solution to the problem.

☞ Users also rely on their own established parking practices, even with advanced driver assistance systems. Where it is feasible to enter a parking space directly. Users do not want to drive past it before it is recognized.

- Despite being mostly open-minded to this scenario, test subjects naturally expect other relevant parameters, such as the reliability of parking space detection, the speed of the parking maneuver, as well as the smoothness of the driving and braking processes, to be designed according to their wishes.

5.2.2.2 Scenario 2: 'Add a Space'

The second scenario not solely detects parking spaces corresponding to the pattern of already parked vehicles. In addition, the driver can indicate a preferred parking space by tapping the screen. Thus, the drivers' are given the option of parking away from the recognized parking spaces.

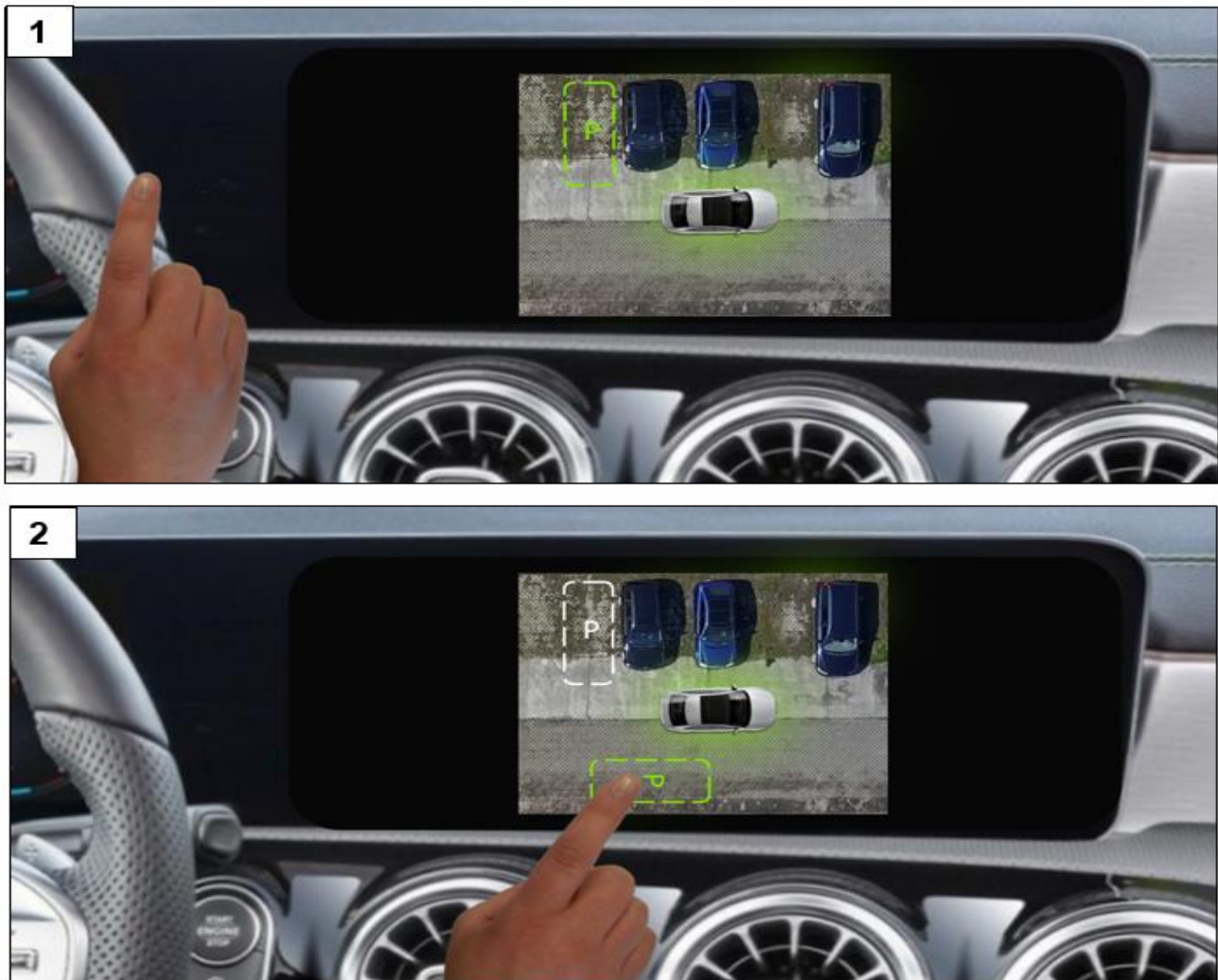


Fig. 75 Image template scenario 2

- This concept also illustrates more favorable than adverse or neutral comments (c.f. table below): of the 141 open statements, 81 are positive. This corresponds to 57% of the statements. However, approval is not as clear-cut as for scenario 1.
- We noted positively that the additional option creates a new framework of flexibility. Thus, making it feasible to communicate with the system. This could enable responses to specific situations that do not fit into the usual patterns. Such capability is perceived as a practical benefit.

- However, approval of the additional degrees of freedom is not unanimous. Some users prefer stick to following a specific system proposal. The degrees of freedom offered by scenario 2 polarize the test subjects. It apparently depends on the type of user as to whether they recognize advantages or anticipate problems. The situation of daily experience also influences the assessments: Those who live in a big city and constantly face the challenge of finding an adequate parking lot are less likely to emphasize the need to strictly limit themselves to designated parking spaces.

Category	Individual entries	n
Positive (81 entries, 57.4%)	Desired parking space is a good extension	22
	Better than scenario 1	11
	All-round good, very good	11
	Good in certain situations	10
	Useful, practical	6
	Having a choice is good	5
	Best of all three scenarios	4
	Flexible	3
	Everyday life	2
	Useful in city centers/urban traffic	2
	Realistic scenario	2
	Good for own driveway	2
	Useful when shopping	1
Neutral (7 entries, 5.0%)	Parking lots are usually specified	2
	Not specified	1
	Not bad, however, not vital	1
	System does not have to be able to do everything on its own	1
	System displays whether it is possible	1
	Would take free parking space	1
Negative (53 entries, 37.6%)	Desired parking space superfluous, pointless function	12
	Too complex/challenging (in operation, understanding)	9
	No-parking zones being a threat, must be avoided by PAS	9
	Categorical rejection	8
	Parking must be safe (reliability/obstacles)	6
	Better to follow the specific system proposal	5
	Other options required	1
	What about other cars?	1
	Parking spaces too arbitrary	1
	Are there situations for this in everyday life?	1
Total (multiple answers from 62 respondents)		141

Fig. 76 Frank assessment of scenario 2 'Add a Space'

- ☞ Scenario 2 is by the majority of respondents rated as favorable due to the driver gaining degrees of freedom with this concept.
- ☞ Surprisingly, the additional degrees of freedom are not unitarily evaluated as positive. Some users have a lack of confidence in the technology and fear parking the wrong way, as well as them being worried to overlook obstacles.

- Among the negative statements, the argument stating that the desired parking space is a pointless function dominates.
- It is also suspected that the use could be too complex and difficult to operate.
- Several test persons emphasized that penalties for incorrect parking must be excluded. An autonomous parking system would need to consider no-parking zones. Therefore, the fact that corresponding zones and signage are recognized is a critical feature.

5.2.2.3 Scenario 3: ‘Create a Lot’

In the third concept proposal, the vehicle can be parked automatically on a free space. By using touch or the drag-and-drop function it is able to move the vehicle around on the screen. The all-round cameras create an image of the actual environment, which is used for relative orientation. Therefore, the car must recognize obstacles and take an available route on the way to the ‘virtual parking space’, even with the absence of displayed markings and other vehicles as orientation points.

With this design of the parking assistance system, the vehicle can be parked completely free. Scenario 3 is therefore the alternative with the greatest options for the driver. It is of particular interest to see how the test subjects assess such degrees of freedom.

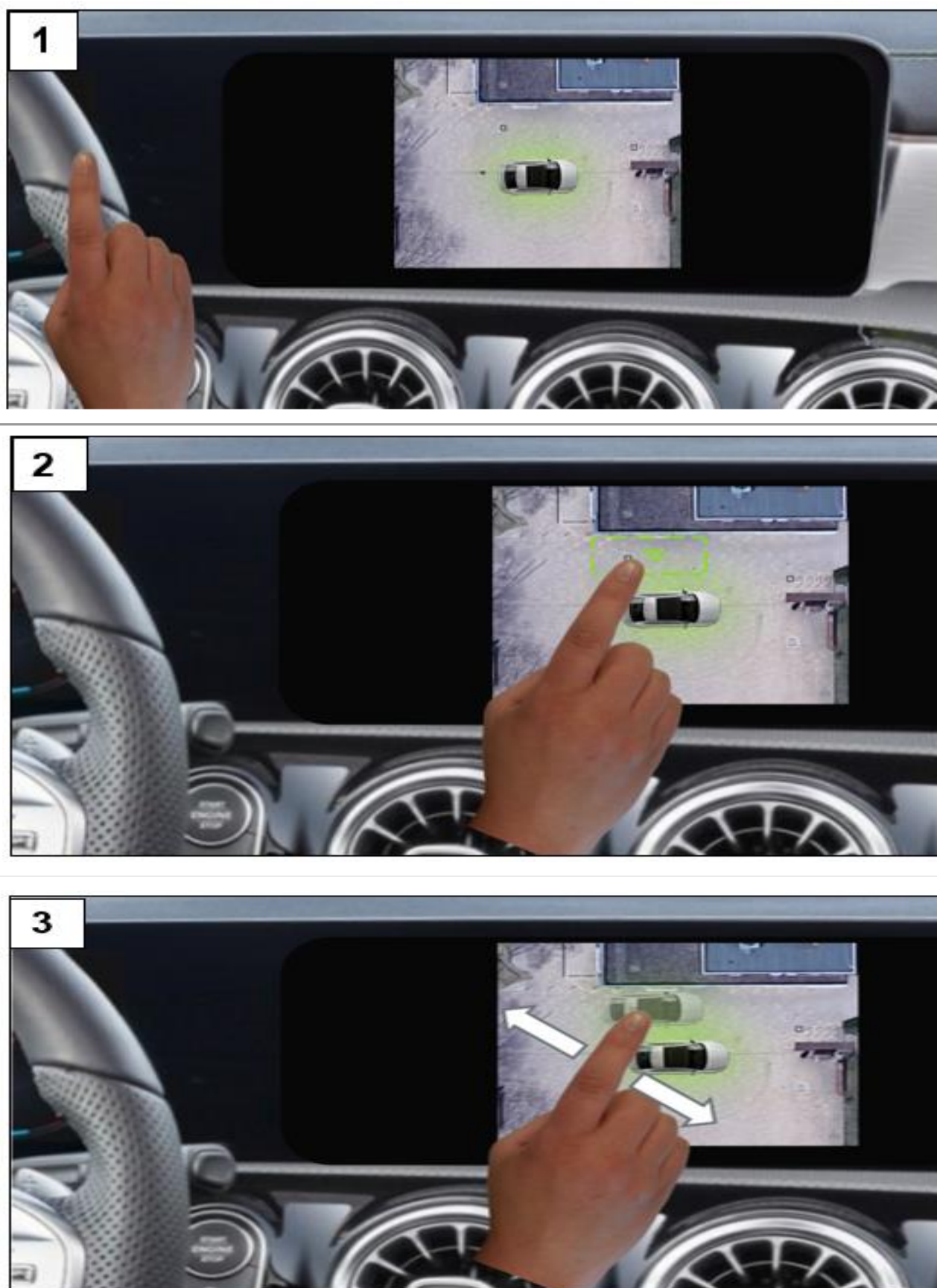


Fig. 77 Image template scenario 3

Category	Individual entries	n
Positive (28 entries 19.2%)	Creating your own parking lot is great, flexible	9
	Generalized: good	6
	Helpful in conjunction with other scenarios	3
	Useful/meaningful	2
	Can be used in a courtyard	2
	Can be used on sidewalks	1
	Useful in a big city	1
	Good for elderly people	1
	Can help to communicate with PAS	1
	Fascinating that the car can be moved via screen	1
	Improves the assessment	1
Neutral (18 entries, 12.3%)	situation is rather rare and very individual	9
	Not bad, however, not vital	3
	Parking in designated spaces	2
	No places are being displayed, as there are no indications	1
	difficult to say whether good or bad	1
	on unpaved roads	1
	Just like scenario 2	1
Negative (100 entries, 68.5%)	Categorical rejection	17
	Vehicle should provide concrete specifications	17
	Complicated/time-consuming use	14
	Parking yourself is easier/faster	14
	Unnecessary/meaningless function	12
	Lack of trust in technology/communicating with car	9
	No-parking areas must be detected by the vehicle	8
	No improvement compared to scenarios 1 and 2	7
	Exaggerated function in view of the situation	2
Total (multiple answers from 62 respondents)		146

Fig. 78 Frank assessment of scenario 3 'Create a Lot'

- Statements in favor were dominated by the joy of being able to create something yourself. This implies flexibility and, not least, a form of communication with the system, a benefit that was also repeatedly required in other parts of the study. The user moves away from the role of a mere 'cog in the machine' and gains the sense of directing the technology themselves.

- Overall, 68.5 percent of the remarks are of a critical nature. A host of users express a desire for the vehicle to indicate instructions. These drivers state that making their own decisions seems inappropriate for the situation, respectively, too complicated or unnecessary. These users see parking as a regulated process, the rules of which must be adhered to for better or worse. Individuals aim to swiftly deal with parking as a 'necessary chore' and ponder solely on whether the PAS aids in this process or not. The playful function of 'I design my own space' does not correspond to these users' own experiences of parking.
- Whether such negative comments reflect a 'typical German' character trait ('rules must be adhered to' or 'additional degrees of freedom are questionable') cannot be answered on the basis of the present study, as comparative data with users of other nationalities is not available.
- The objections 'Self-parking is easier/more swiftly' and 'needless/meaningless function' express the fact that in the situation described, you could 'drive there yourself'. Stopping and indicating the assistant where you want to park by a simple finger touch is not clear to users. The offered advantage 'you can design it yourself as you like' contradicts to the objection: 'I don't need an assistant for that, I'll drive there myself'.

☞ Additional degrees of freedom polarize (German) drivers. The more additional options offered, the more users put forward counter-arguments. They reject these options perceived as 'playful'. Such users also proactively oppose the possibility of deviating from predefined rules.

☞ For the majority of people 'virtual' solutions are not perceived as an advantage if they seem more complicated than analog reality. As long as users still have a steering wheel and pedals at their disposal, driving and parking are seen less as a computer game and more as a tangible process. This means that every assistance system will be viewed from the perspective of whether it renders things really simpler for the user or complicates driving.

☞ The current counter arguments may change in the future when reaching advanced stages of autonomous driving. In a car interior situation of being 'without a steering wheel', a system with the function 'Create a parking lot' may be indispensable. Development decisions must therefore always be based on the current level of consumer acceptance under the given conditions. What users currently refuse is not dismissed for future implementation.

5.2.2.4 Quantitative assessment of the scenarios

A quantitative user assessment can be derived from the upfront question about the intention of use:

Question: *“What is your personal inclination to use such a parking assistant (scale from 0-100).”*

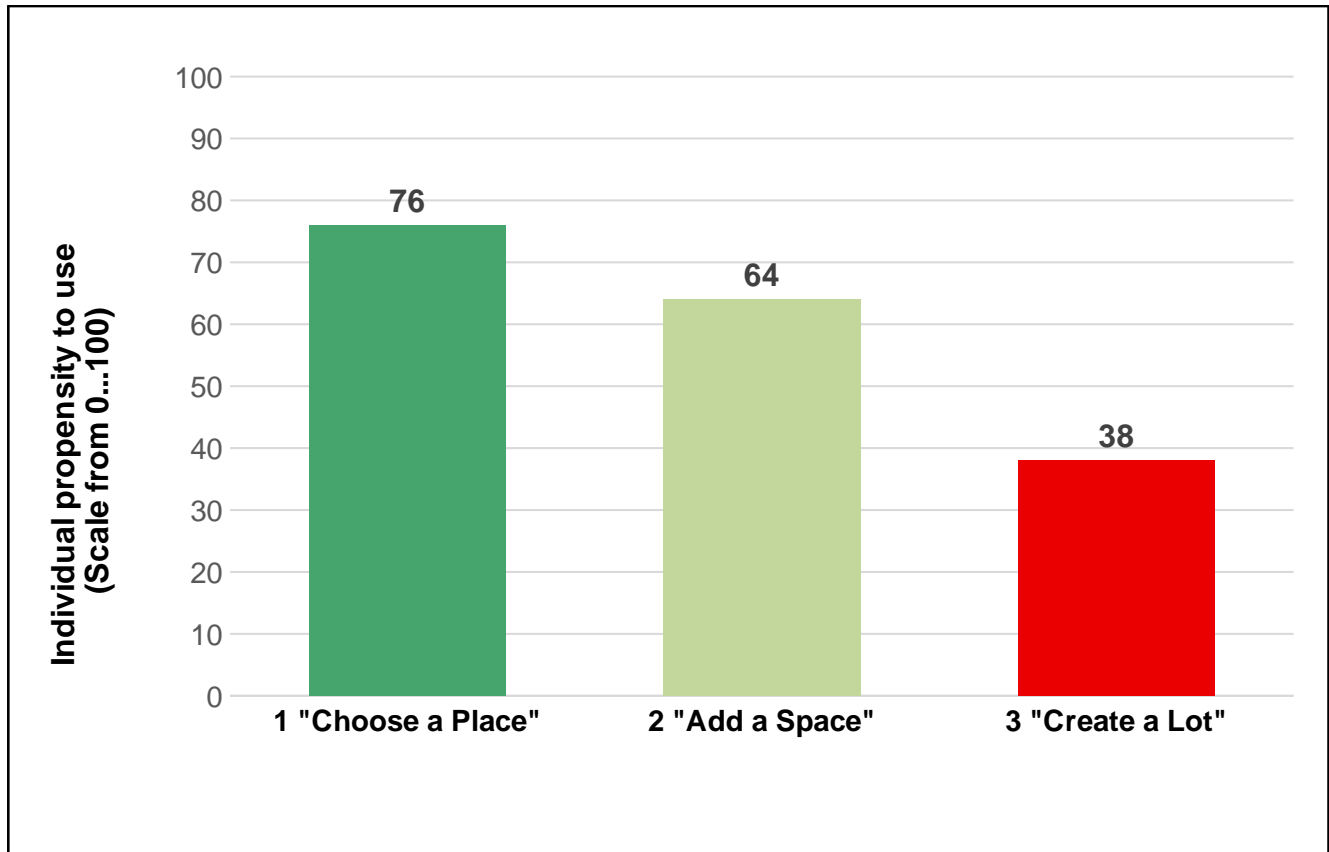


Fig. 79 Tendency to use the scenarios

- With slightly different numerical values, however, identical in the order of evaluation and the basic statement, the direct survey gets to the same conclusion as the open user comments: Scenario 1 is rated best, followed by Scenario 2 and Scenario 3.
- Quantitative and qualitative analyses thus seem to superficially confirm that scenario 3 is not highly valued overall.

It is worth investigating whether additional insights can be gained from various subsamples, understanding the reasons behind this and its implications for future use.

5.2.2.5 The three scenarios in subsamples

For the examination of the three scenarios in terms of subsamples, the most suitable approach is the quantitative survey of the intention to use, as presented last above. In the first step, socio-demographic subsamples are being illustrated.⁴⁵

Criterion	Characteristic	Ø Tendency to use the scenario (scale 0-100)			Significance ⁴⁶
		Scenario 1	Scenario 2	Scenario 3	
By age	20 to 25 (n=21)	75	69	37	No
	26 to 39 (n=24)	77	68	36	
	40 to 64 (n=17)	75	53	41	
By Gender	Female (n=32)	76	60	35	No
	Male (n=30)	76	69	41	
According to Size of the place of residence	Country (n=17)	71	60	39	No
	Small town (n=29)	73	62	37	
	Large city (n=16)	86	74	39	
According to level of education	Until secondary school	68	61	48	No
	Intermediate school leaving certificate, vocational college	82	69	34	
	A-levels without studying	67	54	46	
	Studying at university	78	67	36	

Fig. 80 Assessment of the three scenarios in socio-demographic sub-target groups

- Regardless of the considered socio-demographic criterion, the personal propensity to use is consistently highest in scenario 1 and lowest in scenario 3. This outcome can therefore be displayed as stable.
- The age criterion illustrates that those aged 40 and above rate scenario 2 slightly worse than other age groups do.
- There are no significant differences according to gender. Scenario 2 is somewhat evaluated better by men than by women.
- Based on the number of inhabitants, study suggests that people living in cities are generally more inclined to use a parking assistant.

⁴⁵ There are restrictions to the possibilities of forming subgroups within a limited overall sample, as feasible for a field design with real driving tests (in this case n=62). The formation of two to three subgroups is mostly possible. Therefore, the cell sizes are then classified partly below the n=30 (rule of thumb) as reliable by the statistician. The results are exploratory in nature. However, they can provide a good insight into the preference structure of the target group due to their high internal consistency.

⁴⁶ All significances were determined using an analysis of variance. The differences for the three scenarios in any of the criteria presented are not essential. However, statistical significance can hardly be achieved due to the small group sizes.

- There is no clear correlation according to the level of education.⁴⁷

Criterion	Characteristic	Ø Tendency to use the scenario (scale 0-100)			Significance ⁴⁸
		Scenario 1	Scenario 2	Scenario 3	
According to willingness to spend on a car	Lower, <28,000 (n=37)	74	61	40	No
	Higher, >30,000 (n=25)	79	70	34	
By interest in the car ⁴⁹	Low (n=11)	71	60	30	No
	Medium (n=23)	74	62	41	
	High (n=28)	79	68	39	
According to changed evaluation pared to PAS through driving test ⁵⁰	deteriorated (n=17)	70	56	29	No
	unchanged (n=29)	84	73	44	
	enhanced (n=16)	71	65	44	
According to the individual propensity to invest ⁵¹	Low (forecast)	52	40	13	Yes ⁵²
	Medium (n=31)	68	56	30	
	High (n=31)	84	72	46	

Fig. 81 Assessment of the three scenarios in psychographic sub-target groups

⁴⁷ When interpreting the results, it should be noted that the graduates with an intermediate school-leaving certificate/vocational school solely included employed people, while those with a higher degree also included some students who were not working a job. The results by level of education could therefore be influenced by the variable 'employment/earned income', which was not included.

⁴⁸ All significances were determined using an analysis of variance. The differences are not significant for the three scenarios in the first three displayed criteria.

⁴⁹ Question: How interested are you in cars in general? (Scale from 0-100). Average 61.0, median 60. Classification: low: 0-30, medium: 40-65, high: 70-100.

⁵⁰ As mentioned at the beginning, this report is part of a larger overall study. As part of this, real driving tests were carried out with a current PAS. The test subjects were before and after the test asked to evaluate PAS. Therefore, a possible change in attitude as a result of the driving test can be calculated with the three characteristics enhanced, unchanged and improved.

⁵¹ Calculated using a 20-item battery to measure the innovation. The innovation level determined for the test subjects is between 46 and 96.25 index points on a 100-point scale. Overall average score of the test subjects: 69.9, median 69.7. This means that there are no people with an explicitly 'low' propensity to innovate in the sample. Group classification: 45-69.99 points 'medium', 70-100 points 'high' propensity to innovate. The values printed in gray for low propensity to innovate are based on a trend extrapolation resting upon the values of the other two groups.

⁵² The between-group comparison of high and medium innovation propensity displays a result of: $p = .031$ for scenario 1, scenario 2: $p = .043$, scenario 3: $p = .033$.

- As anticipated, the inclination to utilize the Parking Assistance System (PAS) is notably higher when there is a greater readiness to invest in a car. However, this solely applies to scenarios 1 and 2. It is noteworthy to mention that scenario 3 is assessed even worse by people with a higher willingness to spend. The value of 34 is also one of the lowest of all subsamples.
- The willingness to use the PAS augments as a respondent's interest in cars enhances. This also merely applies to scenarios 1 and 2, however, not to scenario 3.
- People whose opinions towards the PAS (PAS based on current technology) remained consistent after conducting an actual driving test, evaluated the three scenarios better than interviewees whose statements deteriorated or even (!) enhanced. This suggests that the scenarios are particularly well-rated when there was already a positive predisposition that did not need to be altered by a test.⁵³
- Finally, if we take a look at the individual propensity to innovate, we witness the biggest distinction between the subsamples: People with a high propensity to innovate have a significantly higher tendency to apply all three scenarios.

☞ In summary, it can be seen that the **psychographic characteristics**, such as willingness to spend, interest in the car and personal inclination to innovate, of test persons have a greater influence on their choice behavior regarding the three scenarios than the **socio-demographic characteristics**. However, this does not apply to the residential area size. The residential size also has a significant influence, as the 'parking problem' is somewhat more aware for people living in cities than for residents of smaller towns.

Following the logic of market segmentation, further investigation involves examining subsamples based on the *actual behavior* of target groups. As parts of the surveys conducted, the self-reporting of the test persons is available to determine the extent of their previous *experience with parking assistants*. This data can be correlated with the propensity to use the three scenarios (Fig. 82):

⁵³ An additional analysis suggests a similar interpretation. The desire for a PAS expressed *before the test* correlates significantly with the willingness to use the scenarios (Sz1: $r=.386$, $p=.002$, Sz2: $r=.266$, $p=.037$, Sz3: $r=.257$, $p=.044$), however, the same applies to the desire expressed *after the test* (Sz1: $r=.330$, $p=.009$, Sz2: $r=.284$, $p=.025$, Sz3: $R=.256$, $p=.044$).

Tendency to use...	Experience with the autonomous parking assistant	
	Pearson correlation	Statistical significance (2-sided)
Scenario 1	.143	No, $p=.268$
Scenario 2	.091	No, $p=.480$
Scenario 3	-.038	No, $p=.769$

Fig. 82 Correlation between experience with PAS and the propensity to use the scenarios

- First and foremost, it should be noted that none of the correlations displayed are of pivotal importance. This is due to the small sample size. Theoretically can be assumed that the propensity to use the scenarios depends on a large number of possible determinants (cf. all socio-demographic and psychographic characteristics mentioned above, among others). That illustrates that the variance explanation contribution of (solely) previous experience is necessarily limited. Moreover, these correlations establish a connection between an actual variable (previous experience with existing systems) and a hypothetical construct (future use of a previously unknown alternatives), also influencing the level of possible correlations.
- Irrespective of their statistical significance, however, the correlations can be utilized in an exploratory way to comprehend the target groups. There is for instance an indication that the propensity to use scenario 1 and 2 tends to augment with an increasing experience in parking assistants.
- In contrast, the propensity to apply scenario 3 does not enhance with upscaled experience. Since scenario 3 is the scenario with the greatest distance to the actual parking situation and the existing PAS compared to the other two scenarios, we deduce:

- ☞ Drivers are biased by previous experience in their assessments. Innovations that extend far into the future and deviate significantly from the current state are initially assessed with caution.
- ☞ Alternative technologies must overcome resistance to change. If the advantage of a new technology is not immediately portrayed, target groups prefer a stepwise enhancement over a radical change.

The preceding analysis rests upon the test subjects' previous experiences with parking assistants. These experiences may vary in scope and could have taken place at different points in the past.

It should therefore also be considered whether the recent, immediately preceding driving test with a current parking assistant (A-Class, 2019) has an effect on the test subjects' assessment of the scenarios. Proximately after the driving test, the respondents were asked about their trust in the just experienced parking assistance technology:

“To which extent do you trust the automatic parking assistant?(Scale from 0-100)”

This renders it feasible to determine the conjunction between trust in technology and the propensity to use the three alternative scenarios:

Tendency to use...	Trust in the automatic parking assistant	
	Pearson correlation	Statistical significance (2-sided)
Scenario 1	.290	Yes, p=.022
Scenario 2	.350	Yes, p=.005
Scenario 3	.071	No, p=.582

Fig. 83 Correlation between confidence in the automatic parking assistant (after an immediately preceding driving test) and the propensity to use the scenarios

- Fig. 83 confirms the outcomes of previous analyses: in the case of scenarios 1 and 2, despite the small sample, statistical significance can be observed: Those who trust the parking assistant based on the immediately preceding driving test also show a greater tendency to use the assistants in scenarios 1 and 2. This confirms the recurring finding within the overall project from various perspectives that real experiences are the decisive lever for users to embrace a new technology. Therefore, OEMs must express a great interest in enabling potential buyers to ‘experience’ the new technology. Parking assistants and others are more likely to be convincing when being tried out, rather than on the basis of traditional advertising.
- Simultaneously, the above finding about the resistance to change among target groups manifests when it comes to technologies that are perceived as ‘far removed’ from current experiences. The third scenario is currently unimaginable for the overall target group. Therefore, it is challenging to picture this assistant, even on the basis of a driving test with current technology.

5.2.2.6 Additional analyses for scenario 3 or the free 'Create a Lot'

Scenario 1 and scenario 2 are predominantly positively assessed. The open connotations of the participants regarding these scenarios relate to the recognized benefits they offer. With that being displayed, further analyses can be omitted.

Scenario 3, on the other hand, is critically assessed in the quantitative analyses. Further considerations are useful to illustrate why it is evaluated that way. Another objective is to find out whether such a system of completely free parking space definition by the user is 'unfavorable' for further development or whether this should be considered in a differentiated way. The survey includes the quantitative question:

Would you be interested in the function of creating a free parking space?

- As a result, **33 of the 62 test subjects (53.2%) confirmed the question, indicating that there is** clearly no general rejection, even if scenario 3 is evaluated worse than the other two.

The respondents were also asked which application they could imagine for a system like the one in scenario 3. It makes sense to structure this open information according to whether the test subjects suggest the free creation of parking spaces as interesting or not.

Category	Individual entries	n
'solely criticism'	Easier, faster to park manually yourself, do it alone	6
	Rather unnecessary, no need	3
	Difficult if PAS is not networked with other cars	1
	A proposal by the PAS makes it easier	1
	Where there are no obstacles, I can park myself	1
	Too much doubt about recognizing obstacles	1
	If someone starts off wrong, there may be too many parking spots	1
Suggestions for improvement	Better: larger area marked in green	1
	If you can save a parking space, then yes!	1
Conceivable application	Perhaps when reversing	1
	Perhaps interesting in old age	1

Fig. 84 Additional connotations of persons in principle rejecting to the free creation of parking spaces by the driver

- It turns out that despite the question (about feasible application), the mainly critical respondents solely keep problematic points in mind. This mainly revolves around the fact that they do not see the benefit of such an option if they can simply drive themselves to where they want to park their vehicle. The arguments already mentioned above repeat themselves.

- Two suggestions for improvement are mentioned: firstly, that it could be useful if the system 'at least' suggests a **green area** where you can park the vehicle yourself. Secondly, the test subjects proposed that it should also be feasible to **save** such an empty parking space in the system. That way, you can directly drive and park there the next time without having to stop and operate the system again.
- The 'application ideas' of the mainly critical participants are evidently not meant seriously. However, they rather stem from the effort to at least respond something relatively friendly.

The answers of the test persons who find the free creation of parking space generally interesting are somewhat more instructive:

Category	Individual entries	n
'Nevertheless Concerns'	Are you allowed to park there? Solely for actual empty spaces	2
	Uncertainty at first	1
	Too simple a situation in this scenario	1
	Depends on personal situation	1
	Not suitable for everyday use	1
Suggestion for improvement	But then it has to operate swiftly	2
Positive, applications	Useful, good in itself, great principle, one of the best	8
	Officially non-designated spaces can also be used	7
	Provides freedom, flexibility	5
	Would like to leave this option open for me to decide	4
	IN case that my suggestion is better than that of the car	4
	Excellent for emergency vehicles	1
	There are still options when the parking lot is full	1
	Relief	1
	Short parking in a restricted no-parking zone	1
	You can't park everywhere, however, in some places	1

Fig. 85 Additional connotations of persons in principle agreeing to the free creation of parking spaces by the driver

- One suggestion for improvement is that this option should be able to operate swiftly.
- Many respondents were generally in favor. Interviewees evaluated as positive that you remain **flexible** here, that you **can make** your own **decisions** and that it is feasible to park the vehicle in a desired way, even though the system has not previously detected a parking space. The **joy of being able to intervene yourself** is clearly the decisive factor here. This is particularly pivotal for people who don't solely want to be 'technology's sidekick', but rather being able to render their own decisions.

5.3 Implications for development

☞ Scenario 1 and scenario 2 are assessed positively a) overall and b) by all relevant sub-samples. The development should be maintained.

Scenario 3 offers the greatest freedom. At the same time, it represents the greatest distance from the respondents' previous experience. Overall and in almost all sub-samples, scenario 3 is currently rejected by the vast majority.

Nevertheless, the open evaluations indicate that a plethora of test persons can recognize advantages in the free allocation of an unmarked parking space: Flexibility, freedom of choice, opportunities for 'creative' parking in situations of parking space shortage, etc. These are application situations that residents of large cities have in mind from daily experience. To that extent, the option of 'Create a Parking Lot' for inhabitants from cities is less associated with the situation of a completely available parking space (as illustrated in scenario 3). It is rather connected to the idea of a completely full lot, where people 'somehow still want to find a place' to park.

The study reveals that drivers with a high personal propensity to innovate assess, in particular scenario 3, clearly and significantly better than those with a lower propensity to innovate. This corresponds to the textbook knowledge that the 'more innovative people' are more likely/better capable to picture the new technology. They are as well more open to the positive arguments of advanced driver assistance systems, while the less innovative always initially display more worries and cannot really imagine the systems' benefits. Additionally, the 'concerning attitude' may be a phenomenon that is potentially typical of Germans. It can be assumed that target groups in USA or Asia respond differently and may be able to spontaneously recognize benefits much more.

It is a matter of fact that the development towards autonomous driving will continue. The fully autonomous vehicle of the future may no longer contain a steering wheel or pedals at all. This eliminates the most significant criticism from today's target groups regarding Scenario 3. While they state: *"Why should I stop the vehicle first (i.e. let go of the steering wheel and pedals) and after doing so tell the system where to go when I can drive/park there myself?"*. This loss of time may no longer hold true in an autonomous vehicle of the future without a steering wheel and pedals. However, this could enable a desirable gain in individual intervention options.

☞ For the mentioned reasons, it is by no means advisable to halt the development of Scenario 3. Scenario 3 is not a system that is urgently needed in short term due to the degree of vehicle automation and customer requirements. In the medium and long term, however, such a system is likely to be beneficial for users.

Regarding all scenarios, the extent to which the test subjects' criticisms and suggestions for improvement can be taken into account must be examined. I.e:

- it must operate as swiftly as feasible,
- it must be ensured that existing no-parking zones are recognized,
- it must be ensured that no obstacles are overlooked,
- no space should be wasted when parking.

Statements such as 'too complicated' are verified by tests in the simulator, as well as later on in development vehicles. This is where pictorial sketches reach the limits of the test subjects' imagination.

The current driving tests also display that a host of inexperienced test subjects swiftly build up trust in the systems, after the use of these is explained to them. Moreover, they can develop their own (positive) experiences. The greater the concerns beforehand, the greater the 'aha' experience when operating with this technology. The opposite also holds true: the greater the trust in technology, the greater the disillusionment when, for instance, the parking assistant drives over the curb.

5.4 Management Summary

☞ As part of a larger study with quantitative and qualitative surveys, eye tracking and camera observation, three alternative scenarios for the automated parking assistant were displayed to evaluate.

☞ Scenario 1 ('Choose a Place') contains parking by touching a screen in the vehicle. In 80 percent of all open statements, test subjects assessed the scenario as favorable. On a scale of 0 to 100, the tendency of the participants to use such a concept is 76.

☞ In terms of content, aspects such as the good overview thanks to the bird's eye view, easy orientation and simple operation are praised.

☞ Criticism primarily concerns the assumption that the advanced driving assistant solely recognizes parking spaces once the vehicle has driven past them.

- ☞ Scenario 2 ('Add a Space') in addition to scenario 1, this test provides the option to select and navigate to a desired parking space outside the defined and marked ones by touching the screen. In 57 percent of all open statements has this scenario been evaluated as favorable. The tendency of the test persons to use this concept is on a scale of 0 to 100 at 64.
- ☞ Criticism mainly relates to the fact that safety appears questionable and it is doubted whether the system recognizes no-parking zones.

- ☞ Scenario 3 ('Create a Lot') offers the highest degree of freedom: regardless of markings, a parking space can be defined at any point. Users simply need to touch the screen and show the vehicle where they want it to park. Solely 19 percent of all open statements from the test subjects were assessed as positive, while almost 72 percent had a negative outcome. On a scale from 0 to 100, the tendency of the test subjects to use this concept is evaluated with 38.
- ☞ Users are bothered by the fact that, as drivers, they could directly approach an unmarked parking space without needing stop first to inform the PAS where they want to park.

- ☞ If we take a look at the subgroups of drivers, we witness that people from large cities have an above-average interest in these displayed scenarios. The same applies to people with a particular affinity for cars, as well as to persons with a greater willingness to spend money on a vehicle. Those who have had previous experience with other parking assistants are also more open-minded towards the three scenarios.

- ☞ The individual propensity to innovation provides the largest and most significant explanatory contribution to whether someone is interested in a Parking Assistance System (PAS). 'Innovative' people also fancy scenario 3 more than persons who are less innovative. This suggests that it makes sense to further pursue scenario 3 in the development process.

6 Executive Summary

This overall report summarizes the studies conducted by the EMPIRICAL RESEARCH AND USER EXPERIENCE (ERUX) research group of the Institute for Information Systems (iisys) at Hof University of Applied Sciences on the topic of 'Human-machine interface in advanced driver assistance systems on the way to autonomous driving' in the years 2019-2021. This is a multi-method research project focusing on the human-machine interface [HMI], by utilizing the example of the automatic parking assistant in the car. The methodological diversity serves the depth of the analysis and the validity of the results.

First and foremost, the starting point of the study has been that the demand for parking assistants had fallen considerably short of manufacturers' expectations. Secondly, empirical evidence displays that customers who already had a parking assistant installed in their own vehicle often did not use them at all. In summary, the adoption of the new technology by drivers appeared unsatisfactory. The representatives of the automotive and supplier industry were unable to explain consumers' reluctance to purchase and use the technology, as they considered automated parking to be a particularly beneficial innovation for drivers. Accordingly, the studies presented in this overall report aimed to identify the key issues for the car buyer's reluctance. Moreover, resting upon the outcomes of the research, the aim is to derive measures for the automotive and supplier industry to increase the likelihood of adoption among private end customers.

The first study used a quantitative face-to-face survey to investigate the operators and reluctance of German drivers towards advanced driver assistance systems on the road to autonomous driving. The assessment of these advanced driver assistance systems, as well as the autonomous driving has been exclusively carried out from the drivers' perspective. The three key findings from this study are:

- The current customer perception, advanced driver assistance systems contribute more to the 'modern image' of a car than to the improvement of its functionality. This is opposing to the manufacturers' perspective. They are convinced of the functional benefits of their advanced driver assistance systems. In order to overcome this difference in perception, manufacturers need to put their focus on the functional benefits of advanced driver assistance systems when interacting with the customer (→ content). Given this suggestion, customers truly 'want' and 'desire' to use these assistance systems. Nevertheless, the implementation (→ design) needs to occur in an emotional way and must not be limited to purely technical product descriptions. As the benefits of advanced driver assistance systems are independent of specific car brands of car buyers, the automotive and supplier industry should consider industry-wide, as well as cross-manufacturer communication campaigns.
- Experience with advanced driver assistance systems boosts the desire of customers to order the respective system, by up to 40 percent during their next purchase. Manufacturers should therefore get their customers in a targeted manner in touch with

the assistance systems to unleash their desire for them. Customer advisors at the dealership must enable prospective buyers to 'test drive' the advanced driver assistance systems in real life and actively encourage their use. When the vehicle is handed over, every customer should receive a detailed briefing in which they are supposed to try out all systems and the user interfaces under various conditions. Moreover, buyers should have no open answers regarding the operation of the assistance systems.

- The automotive industry has not yet managed to create a positive atmosphere for autonomous driving. The stated arguments in favor of these advanced driving assistance systems are not sufficiently recognized by drivers. A possible reason for that could be due to a loss of credibility on the part of the players in this industry. Elderly people increasingly desire helpful advanced driver assistance systems. However, they oppose autonomous driving, as they fear a loss of individual freedom. If a person is generally more 'open-minded', this does not mean that they are also particularly open towards autonomous driving. 'Doer types' tend to be slightly averse to autonomous driving. Accordingly, the automotive and supplier industry still has a lot of educational work to do if they aim to enhance the desire for autonomous driving among the population.

The second study utilizes conjoint-measurement to examine the significance of autonomous driving. The aim is to focus on the benefit expectations and preferences of consumers when choosing different vehicle concepts:

- Drivers' trust in autonomous vehicles is still limited. At present, customers can hardly imagine that autonomous vehicles are capable of handling potentially complex situations in cities without facing any problems.
- Despite this skepticism of the customers, it is clear that a 'medium' level of advanced driver assistance systems is already a significant benefit for a plethora of people when purchasing a vehicle. The top priority for drivers is being able to display control over their (own) car. This obviously expresses a strong 'ownership culture' and clearly fits in with the pronounced individuality of consumers today. However, assistance systems are already in second place in terms of priority, followed by the surcharge (3rd place) and the manufacturer's image (4th place). The conjoint measurement indicates that (perfectly functioning) advanced driver assistance systems deliver almost twice as much benefit for drivers as the manufacturer image.
- Autonomous driving vehicle development competence is primarily attributed to traditional automotive manufacturers by drivers. However, not to suppliers, even though the latter contribute significantly to the essential development work. The suppliers of components or complete modules in the field of advanced driver assistance systems are practically unknown to private end customers as 'brand manufacturers'. Accordingly, the OEMs, most of whom refuse to allow suppliers to brand the components and systems they install, benefit more from the suppliers'

services than vice versa. These outcomes are part and parcel for suppliers to confidently negotiate with OEMs.

- Experience with assistance systems tends to go hand in glove with a higher perception of the benefits of automation among drivers. It is therefore of pivotal importance for the industry to particularly introduce those drivers to assistance systems of automation technology who have not yet gained a lot of experience with them.
- Psychographic criteria (e.g. type of driver, propensity to innovate) of car drivers display a clear correlation with benefit expectations regarding autonomous driving. The various benefit expectations therefore render it vital for the automotive industry to develop target group-specific arguments according to the different types of users.

In the third study, practical driving tests regarding the operation of a parking assistance have been carried out. Aim was to analyze the system and document results using eye tracking, among other things. Moreover, the objective of this study was to identify operating patterns of the PAS, as well as ways in which the test subjects interacted with the system, in order to uncover possible operating errors and to derive potential for improvement.

- This study also indicates the pivotal importance of experience with the parking assistant for its use and evaluation. Once again, the results emphasize the need to provide users with adequate instructions on such innovations. Furthermore, study suggests that the more users utilize the system, the more they swiftly gain confidence.
- The positioning of control elements should be intuitive in order to avoid unnecessary disorientation. So far, completely different placements for the 'PAS' control element have been realized depending on the manufacturer. In some cases, the placements even differ between various car models of a manufacturer. As a result, manufacturers generate resistance among vehicle customers towards innovative and sophisticated technology. The refusal of car drivers to use PAS is therefore home-made. The manufacturers themselves are continuously hindering the diffusion process of the new technology by not taking the users experience into account.
- Among the test participants' comments, voice control and simplified operation were the most frequently mentioned suggestions for improvement. For instance, when maneuvering out of a parking space, drivers state that it would be extremely helpful if the system would indicate them to take back control of the vehicle by ushering in a corresponding announcement.

The final concept test (Study 4) evaluates alternative scenarios for the future design of the parking assistant.

- It turns out that simple and intuitive control options are rated positively. Moreover, users prefer established practices when being in the advent of using assistance systems. Additional degrees of freedom regarding the parking are assessed

differently; some users view them rather skeptically. Ultimately, study found out that drivers' opinions are influenced by previous experience. Innovations reaching far into the future, as well as significantly differing from the current situation are initially assessed with caution. Alternative technologies have to overcome resistance to change. If the advantage of the new technology is not immediately apparent, target groups prefer a gradual improvement over a radical change. Accepting new innovations can therefore change over time. For this to happen, however, customers must recognize meaningful application possibilities for themselves.

- In addition, the concept test confirms that psychographic characteristics such as *willingness to spend*, *interest in the car*, and *personal inclination towards innovation* of the test persons influence their choosing behavior more strongly regarding to the design of parking assistants, than the socio-demographic characteristics do.

In the context of this overall report on four studies in the field of 'Human-machine interface in advanced driver assistance systems on the road to autonomous driving', one main conclusion can be drawn: Pursuing very different methodological research approaches, one critical finding (which can therefore be regarded as valid and assured) repeatedly emerged. Outcome displays that real experiences are the decisive lever for users to engage with a new technology. Parking assistants and others are more convincing when being tested out. Compared to fundamental advertising or abstract benefit arguments, it should be ensured that customers get in touch with the various advanced driving assistance systems.

Manufacturers and suppliers must therefore indicate a great interest in allowing potential buyers to 'experience' new technologies. There is a lot of catching up to do, as it is evident that until now people have assumed that innovations in the field of assistance systems will spread on the market 'by themselves'. Actively introducing potential users to the new technologies is primarily needed to be implemented by OEMs and their broad sales organization, as this is where most customer interaction takes place. To implement this, it would be expedient if central departments for communication and market development at the OEMs would conjoin with customer advisors at the authorized dealers. This ensures that market launch strategies obviously need to be implemented not only vis-à-vis the end customer, however, also within their own organization. Simultaneously, OEMs are encouraged to incorporate the insights of customer advisors regarding customer expectations and concerns more extensively into their development endeavors than they have done in the past.

Studies on the Human-Machine-Interface in Advanced Driver Assistance Systems towards Autonomous Driving

This book summarizes studies conducted by the Empirical Research and User Experience (ERUX) research group at the Institute for Information Systems (iisys) at Hof University of Applied Sciences over the period 2019 to 2022. The main topic focuses on “The Human-Machine-Interface in Advanced Driver Assistance Systems towards Autonomous Driving”, investigated using the example of automatic parking assistant in cars. A broad spectrum of methods was used to ensure comprehensive analyses and valid results.

Starting situation for the studies has been the industry's realization that the demand for parking assistants had fallen short of expectations. Moreover, they concluded that many owners of driving assistant system do not use them. This indicates an unsatisfactory acceptance of new technologies on the part of car drivers. The aim of the studies was therefore to determine the reasons for this restraint, as well as to derive measures to increase acceptance of this systems among end customers.

The first study focused on operators and the restraint of German drivers towards driver assistance systems. The results of this quantitative study displayed that although the modernity of these systems has been identified, the functional enhancements they offer are insufficient. In order to overcome this discrepancy, manufacturers are advised to emphasize the functional advantages more strongly when communication with the end customer. Study also suggested that direct experience can significantly increase customers' willingness to purchase such a system. Therefore, it is of pivotal importance to introduce customers to the new technologies in a targeted manner.

Using conjoint measurement, a second study illustrates driver assistance systems already representing a significant benefit when purchasing a car, even though the trust in fully autonomous vehicles is still restricted. Drivers favor established car manufacturer in terms of the development of autonomous vehicles.

The third study utilizes eye-tracking to examine operating patterns of parking assistance systems. Moreover, it derives potential for improvement in terms of intuitive design and user experience.

Fourthly, alternative scenarios for the design of parking assistants are evaluated in a concept test. This indicated the vital importance of simple and acquainted operating options.

Across all methods, the customer actually being able to experience driving assistance systems is a decisive matter for the acceptance of these new technologies. Therefore, manufacturers should emphasize their focus on getting customers in touch with these systems, as well as offering them targeted usage options. In addition, the integration of customer feedback into development efforts is essential to produce intuitive, user-friendly user interfaces and thus promote the diffusion process of new technologies.

