Subjective Evaluation of Driver Assistance Systems in an International Sample

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Abstract

The following research focused on the subjective evaluation of driver assistance systems in an international sample. Longitudinal and lateral driver assistance systems as well as parking support systems were evaluated using survey data. The question was how the systems are evaluated subjectively and how the evaluation depends on demographic factors like home country, age, gender, yearly mileage, and system experience. Based on the available literature in this research area, differences with regard to the subjective evaluation of the systems as well as with regard to the demographic factors were expected. The first study focused on gathering qualitative data on lateral and longitudinal driver assistance systems. The data was further analyzed quantitatively. The second study focused on a quantitative survey evaluating the importance and annoyance of longitudinal and lateral driver assistance systems. The third study was also a survey, gathering the usage frequency and usefulness rating of parking driver assistance systems. The fourth and final study featured an evaluation of a prototype remote parking aid system during real usage. Its rating was compared to the data from the survey in the third study. The results showed a positive rating of the information only blind spot detection system. The actively intervening lateral support system lane keeping aid received a high annoyance rating. Parking driver assistance systems were in general positively evaluated. Only a valet parking aid function that requires the driver to stay in the car was less appreciated. There was a higher prevalence of perpendicular parking in the USA compared to other countries, which hardly influenced the rating of parking driver assistance systems. There was no meaningful influence of demographic factors such as home country, age, gender, yearly mileage, and system experience on the rating of adaptive cruise control and semi-automated parallel and perpendicular parking as example systems. The evaluation of the remote parking aid system presented in the final study showed a high similarity to the data gained from the survey in the third study. The results are partly in line, and partly contradict the findings in the available literature. The validity of the results is discussed, as a convenience sample from an international automotive manufacturer was used for the studies. Finally, ideas for future research are generated.

Kurzfassung

Die folgende Forschungsarbeit beschäftigte sich mit der subjektiven Bewertung von Fahrerassistenzsystemen in einer internationalen Stichprobe. Longitudinale, laterale und den Parkvorgang unterstützende Systeme wurden mit Hilfe von Befragungsdaten bewertet. Die Frage war, wie die Systeme subjektiv bewertet werden und wie die Bewertung von demografischen Faktoren wie Heimatland, Alter, Geschlecht, jährlicher Fahrleistung und Systemerfahrung abhängt. Basierend auf der vorhandenen Literatur auf diesem Gebiet wurden Unterschiede erwartet in Bezug auf die subjektive Bewertung der Systeme und in Bezug auf die demografischen Faktoren. Die erste Studie bezog sich auf qualitative Daten über laterale und longitudinale Fahrerassistenzsysteme. Diese Daten wurden weiterhin quantitativ analysiert. Die zweite Studie betraf eine quantitative Befragung zur Bewertung der Wichtigkeit und auch der Belästigung durch longitudinale und laterale Fahrerassistenzsysteme. Die dritte Studie war ebenfalls eine Befragung, welche die Nutzungshäufigkeit und das Nützlichkeitsrating von Parkassistenzsystemen aufzeigte. Die vierte und letzte Studie stellte die Bewertung des Prototyps eines ferngesteuerten Parksystems während der tatsächlichen Verwendung dar. Die Ergebnisse zeigten eine positive Bewertung des Totwinkelassistenten, welcher nur informiert. Das aktiv eingreifende laterale Spurhaltesystem erzielte ein hohes Belästigungsrating. Parkassistenzsysteme wurden im Allgemeinen positiv bewertet. Nur ein Einparkassistent, bei welchem der Fahrer im Auto bleiben muss, wurde weniger wertgeschätzt. Es gab in den USA mehr perpendikulare Einparkvorgänge als in den anderen Ländern. Dies beeinflusste aber kaum die Bewertung der Parkassistenzsysteme. Es gab keinen bedeutsamen Einfluss von demografischen Faktoren wie Heimatland, Alter, Geschlecht, jährlicher Fahrleistung und Systemerfahrung auf die Bewertung des Abstandsregeltempomaten und des halbautomatischen parallelen und perpendikularen Parksystems als Beispielsystemen. Die Bewertung des ferngesteuerten Parksystems aus der vierten Studie zeigte eine hohe Ähnlichkeit zu den Daten aus der Umfrage in der dritten Studie auf. Die Ergebnisse stimmen teilweise mit der vorhandenen Literatur überein, teilweise widersprechen sie dieser. Die Validität der Ergebnisse wird diskutiert, da eine Gelegenheitsstichprobe eines internationalen Automobilherstellers für die Studien verwendet wurde. Schlussendlich werden Ideen für zukünftige Forschungen generiert.

1 Introduction

1.1 Topic and Structure

The series of studies presented here deal with the question of how driver assistance systems are subjectively evaluated in an international sample. Modern vehicles are much better equipped than they used to be in the past. A lot of features are added, most of them coming from the area of information and communication technology. Therefore, it is possible to offer many infotainment and driver assistance system related functionalities to the driver, which are handled via the vehicle's human-machine interface. The question to be answered here was how a set of modern driver assistance systems is evaluated subjectively and how the evaluation depends on demographic factors like the home country, age, gender, yearly mileage, and experience with the systems under investigation.

To start with, an introduction to today's vehicle human-machine interface and driver assistance systems is given. Usability, workload, driver behaviour, culture, and other concepts are explained. The introductory part finishes with an overview of research results in the field of subjective driver assistance system evaluation and the influence of demographic factors on these evaluations. Research questions are derived from this. Subsequently, a series of studies is presented on the subjective evaluation of driver assistance systems. This is split into four different parts: First, an interview study is presented, showing qualitative data on how driver assistance systems were perceived. The second study evaluated the same systems quantitatively via rating scales. The third study was looking specifically at the quantitative evaluation of parking driver assistance systems, as well as parking behaviour. The fourth and final study dealt with the evaluation of a remote-controlled parking aid system during a test drive and compared the gained results to the survey in Study 3. Finally, the results are discussed and ideas for future research are generated.

According to Rossi and Freeman (1993), an evaluation is the systematic application of research methods in order to appraise social intervention programs. Of course, other evaluation objects are possible as well, such as systems, research itself, persons, methods, or products as in this case (Wottawa & Thierau, 2003). According to Bortz & Döring (2006), the research done here is a summative evaluation. An object, the driver assistance system, is evaluated. There is no need to further develop the systems based on the results of this work, as it is usually done in the process of formative evaluations.

Psychology as a science offers a variety of research methods. An overview can be found, for instance, in Bortz and Döring (2006) or in Wottawa and Thierau (2003). For the field of traffic psychology, Vollrath and Krems (2011) also offer a comprehensive overview. With regard to metrics that can be applied to evaluate driver assistance systems, there are subjective and objective variables available. Objective variables comprise, for instance, lane keeping data or eye tracking metrics. The research presented here focused on subjective evaluation. Rating scales can be used in case of subjective variables. This was done in Studies 2, 3, and 4. Standardized or open interviews may be used to gather data on, for instance, preferences and opinions (e.g. Fisseni, 2004). Qualitative analyses of the content are common (Mayring, 2010). The method of interviews, including a quantitative analysis of the data, was used in Study 1.

1.2 Technology

1.2.1 Vehicle Human-Machine Interface

Figure 1 shows an example of a modern vehicle cockpit, in this case a 2015 Ford Focus with an 8” touch screen system. There are several input/output modalities available like the touch screen, the display in the instrument cluster, the various steering wheel stalks and controls, and the remaining hard buttons in the center stack console. Although it is not evident from the picture, voice control is also available.

Figure 1: Ford Focus cockpit (Source: Ford)

Other automobile manufacturers have a central controller to operate the display in the center stack, which is non-touch screen in this case. Others also offer a touch pad in some models. This way, letter and number input is possible. A promising technology is the head-up display, which shows driving relevant information in the windshield. Information can be directly presented in the line of sight of the driver, diminishing the problems associated with driver distraction (see section 1.3.2).

The vehicle human-machine interface is used in order to perform many operations. Next to the very basic handling of turn indicator, wiper, or the radio, many new functions have lately entered the automotive area. For instance, trip computers displaying the trip odometer or the distance to empty fuel are available. GPS based navigation systems are used for route guidance. Bonding a cell phone to the vehicle is possible, as are the usage of smartphone apps and internet browsing. Driver assistance systems (see section 1.2.2) require a lot of interaction with the driver, as information and warnings need to be displayed. In addition, settings have to be adapted according to the driver's preferences.

1.2.2 Driver Assistance Systems

The following section gives an overview of some of the driver assistance systems on the market today. The key characteristic of driver assistance systems is that some kind of sensor is applied to monitor the surroundings. This can range from a camera sensor to radar, lidar (laser), or ultrasound. In some cases, the gathered data is used to present information or a warning to the driver. In other cases, the data is used to control actuators like the brakes or the steering wheel to either intervene in a critical situation or to continuously help with the lateral and/or longitudinal control of the vehicle. The final section will focus specifically on parking aids and automation. Almost all driver assistance systems presented here require the driver to still have the hands on the steering wheel. The only exceptions are the active park assist systems, as they automatically turn the steering wheel. Driver assistance systems have an enormous potential to improve traffic safety (Gelau et al., 2009). They have made driving much safer and more comfortable (Engeln & Wittig, 2005).

Adaptive cruise control

Adaptive cruise control helps the driver to automatically maintain a desired speed and sufficient distance to the vehicle in front. Usually a radar sensor measures the distance to the vehicle in front, automatically braking and accelerating, if necessary. This is an extension of the conventional cruise control.

Lane departure warning

Lane departure warning uses a camera to monitor the lane markings on the street. In case the vehicle deviates from the street, the steering wheel will begin to vibrate in order to warn the driver.

Lane keeping aid

Lane keeping aid uses the same camera as lane departure warning to monitor the lane markings. In case the vehicle deviates from the street, the steering wheel will automatically turn slightly to the other side to get the vehicle back into the lane.

Lane centering aid

Lane centering aid uses the same camera as lane departure warning to monitor lane markings. It is a continuous, automatic support of the steering wheel to keep the vehicle within the lane.

Blind spot detection

Blind spot detection uses a sensor to monitor the blind spot, which cannot be seen by the driver when looking into the outside mirror. In case there is an object in the blind spot, like a bicyclist or a car, the presence of this object is indicated via a flashing LED in the mirror (see Figure 2).

Figure 2: Ford blind spot detection visual indication (Source: Ford)

Forward collision warning

Forward collision warning uses the same sensor as adaptive cruise control. It does not automatically maintain the distance to the lead vehicle, but warns the driver if the vehicle is about to collide with the one in front (see Figure 3).

Figure 3: Ford forward collision warning visual alert (Source: Ford)

Traffic jam assist

Traffic jam assist allows automated driving in traffic jam situations. Steering, acceleration, and braking are done automatically as long as there is a vehicle in front. The system does not change lanes automatically and works up to a speed of 60 kph.

Parking driver assistance systems

Acoustic parking aid

Acoustic parking aid indicates the distance to adjacent vehicles via a sound signal.

Visual parking aid

Visual parking aid indicates the distance to adjacent vehicles via distance bars in a display.

Rear-view camera

A rear-view camera shows the area behind the vehicle while parking in a display.

Semi-automated parallel/perpendicular parking aid

The semi-automated parallel/perpendicular parking aid helps the driver to get into a parking space without having to steer manually. After a parking space is found, the driver only has to apply the gas pedal and brake. Turning the steering wheel, including any correctional moves, is done by the vehicle itself. Semi-automated parking can be applied to both parallel (see Figure 4) and perpendicular (see Figure 5) parking.

Figure 4: Parallel parking

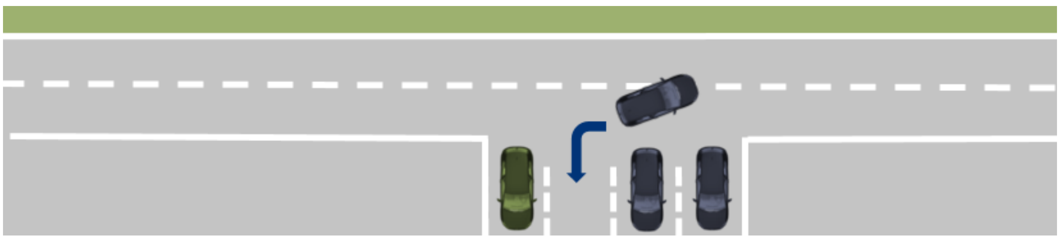


Figure 5: Perpendicular parking

Fully assisted parking aid

The fully-assisted parking aid is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel and actuates the brake and accelerator to park the car. The driver still remains in the vehicle during the parking process.

Remote parking aid

The remote parking aid is a function that enables the driver to exit the vehicle and to start the perpendicular parking manoeuvre from outside. Pulling out from tight parking spaces is also offered with this feature.

Valet parking (with driver in car)

The valet parking aid feature automatically drives the vehicle from the beginning of a parking lot to one of the available parking spaces. Afterwards, the vehicle can also pull out and drive back to the entrance of the parking lot, where the driver takes over again. The driver remains in the vehicle.

Valet parking (without driver in car)

This is basically the same feature as mentioned above, but the driver exits the vehicle before the system takes over. The vehicle drives itself from the beginning of the parking lot and back without a driver on board. Afterwards, the vehicle can also pull out and drive back to the parking lot, where the driver takes over again.

An overview and more detailed information on driver assistance systems is presented by Winner, Hakuli, and Wolf (2009).

1.3 The Driver

1.3.1 Driver Behaviour

Driving is a task that is performed on a daily basis by millions of people. It can be subdivided into three hierarchical levels according to Gstalter (1988): Navigation, lane keeping, and stabilization. These three levels correspond to the three levels of work complexity as shown by Rasmussen (1983): Knowledge (for navigation), rules (for lane keeping), and skills (for stabilization). A different classification is offered by Bubb (1993). In this classification three task levels exist while driving. The primary one is about lane keeping, distance keeping, and navigation. Secondary tasks are about turn indicator and rear mirror usage, traffic sign reading, but also navigation destination entry. Tasks not relevant for driving are tertiary according to Bubb, like communicating with the co-driver, as well as radio, phone, and audio player operation. They can impair the primary driving task, as they distract the driver. Driver assistance systems offer the possibility to take over some aspects of the driving task. This potentially offers a safety benefit, as about

90% of all traffic accidents can be traced back to driver mistakes (Smiley & Brookhuis, 1987).

Next to the classification of the driving task itself, it is also important to look at the theories of driver behaviour. Notable are the theory of risk homeostasis (Wilde, 1982) and the theory of task difficulty homeostasis (Fuller, 2005). The former one argues that drivers maintain a certain level of anxiety while driving, based on subjective estimates of the probability of collision. Fuller (2005) instead argues that the driver actually maintains a task difficulty homeostasis while driving, depending on the difficulty of the task and the personal driving skills. According to Fuller, risk homeostasis as mentioned by Wilde (1982) is only a special case of this. With an anti-lock braking system, drivers had a lower time distance to the cars in front than without (Sagberg et al., 1997). This can be explained both by risk and task difficulty homeostasis.

The Driver Behaviour Questionnaire (Reason et al., 1990) is the most commonly used instrument to measure driver behaviour. Originally, it contained 50 items of self-reported driver behaviour. Parker et al. (1995) published a short version of it with 24 items. Both versions yield three dimensions on a factor analysis: Lapses, errors, and violations. Lapses can be regarded as simple mistakes, without consequences for other drivers. Errors are severe mistakes that can be risky for others. Violations are intended malpractices while driving. The Driver Behaviour Questionnaire has been used and analyzed widely. Ingham (1991) showed a high correlation between observations on a 40 km drive and self-reported driving behaviour in the Driver Behaviour Questionnaire. Lajunen and Summala (2003) argued that the bias to respond in a socially desirable manner is very low. The stability of results was also subject to investigation by Özkan et al. (2006), showing that most items are stable. An overview on recent Driver Behaviour Questionnaire research can be found in de Winter and Dodou (2010). Next to this self-reporting instrument, the Wiener Fahrprobe (Risser & Brandstätter, 1985) is also noteworthy. It is a driving probe under supervision of an evaluator used in order to representatively evaluate actual driving behaviour.

1.3.2 Usability, Workload, Driver Distraction, and Situational Awareness

When discussing technologies in modern vehicles, and especially driver assistance systems, it is important to keep in mind the concepts explained in this section. They are part of driver assistance systems' properties, thus they will also affect their evaluation. The term usability is defined in the DIN EN ISO 9241-11 norm and refers to the efficiency, effectivity, and satisfaction when using a man-made object. Thus, usability can apply to virtually all possible user interfaces and, of course, also to a vehicle human-machine interface or user interface, respectively. Efficiency in this case refers to the level of effort that is required to achieve a specific goal. Effectivity asks about the extent to which it is possible to achieve a certain goal with a user interface. Satisfaction refers to the level of satisfaction a user has when operating such an interface. There is a list of seven dialogue principles available in the DIN EN ISO 9241-110 norm (see Table 1 for an overview). By following these principles during the design of a user interface, a sufficient degree of usability will be secured. Furthermore, the principles can be used as a guideline in the evaluation of user interfaces.

Table 1: Principles of dialogue between humans and information systems

- *Suitability for the task*: Is the user interface appropriate for the given task?
- *Suitability for learning*: Does the user interface support the user in quickly learning how it works?
- *Suitability for individualization*: Is it possible to adapt the user interface to individual differences and preferences?
- *Conformity with user expectations*: Does the design of the user interface match the mental model of the users?
- *Self-descriptiveness*: Is the user interface self-explaining?
- *Controllability*: Is it possible to reach a user goal in a flexible way?
- *Error tolerance*: Are corrections of user interactions possible?

Several methods to measure usability are available, such as the System Usability Scale (Bangor et al., 2008) or the questionnaire for the evaluation of software ergonomics by Prümper and Anft (1993).

User experience is defined in DIN EN ISO 9241-210. It complements the concept of usability by addressing the emotions, perceptions, and responses associated with the usage of a product. This is comparable to the concept presented by Hatscher (2001). He differentiates between the joy of use and the ease of use. The joy of use is comparable to user experience, the ease of use to usability. One further concept should be mentioned, although it goes beyond user interfaces or human-machine interfaces, respectively. Hacker and Richter (1980) presented a hierarchical system in order to evaluate work conditions. The four criteria of this system are explained in Table 2. Intentionally, the German terms are used for this. Their meaning is evident through the definitions given.

Table 2: Criteria to evaluate work conditions according to Hacker and Richter (1980)

- *"Persönlichkeitsförderlichkeit"*: The worker shall be able to further develop his or her own personality, skills, and interests in the course of the work
- *"Beeinträchtigungsfreiheit"*: Performing a work task shall not lead to any disadvantages for the worker that result, for instance, in a deprived social life, a lack of skills and interest, or mental deprivation
- *"Schädigungslosigkeit"*: Performing a work task shall not end up in any physical and/or psychological impairment for the worker
- *"Ausführbarkeit"*: The work must be executable. A work task that cannot be executed is meaningless. This is the most basic principle

It should be noted that this is a truly hierarchical system. "Ausführbarkeit" is the prerequisite of "Schädigungslosigkeit", which is the prerequisite of "Beeinträchtigungsfreiheit" and so on. A well done overall system design including the user interface supports the criteria listed by Hacker and Richter (1980). This is especially true for professional drivers, who must operate their vehicles for a living.

The concept of efficiency in DIN EN ISO 9241-11 is closely related to the concept of workload. According to Wickens (1984), workload is defined as the demand a task puts upon someone who is trying to accomplish it. Of course, workload differs from individual to individual, as it is highly depending on the resources, both physical and psychological, of a single person. Workload plays a crucial role, as it needs to be optimized in order not to overwhelm, but also not to underchallenge the user. There are several methods available to measure workload, for example the NASA-Task Load Index (Hart & Staveland, 1988) or the Subjective Workload Evaluation Technique (Reid & Nygren, 1988). Quite similar to the workload concept presented by Wickens (1984) is the so-called stress and strain concept by Rohmert (1984). The pertaining norm is DIN EN ISO 10075-1. Rohmert differentiates between the factors of the environment, which serve as stress, and the reaction of the human to this stress, which is called strain. Depending on the kind of environmental influence and a person's resources, strain has positive or negative consequences. Positive consequences are about gaining skills and self-confidence when mastering a task. Negative consequences are, to name two, failing to achieve a task and dissatisfaction.

In a vehicle environment, a possible negative outcome of too much workload is driver distraction, which has a manual, visual, and cognitive component to it (Tijerina, 2001). Driver distraction caused by in-vehicle systems is supposed to be minimized. There are regulations in place like, for instance, the European Statements of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems (European Commission, 2008). Thirty-two principles list how information and communication with the vehicle human-machine interface should look like in order to improve it and minimize driver distraction. The National Highway Traffic and Safety Administration (NHTSA, 2013a), the Alliance of Automobile Manufacturers (AAM, 2012), and the Japan Automobile Manufacturers Association (JAMA, 2004) also offer guidelines on how to cope with the issue of driver distraction in automobiles. Several methods are available to quantitatively measure this kind of distraction. They range from the Lane Change Task (Mattes & Hallen, 2009) to the Occlusion Method (Krems et al., 2000) up to the Peripheral Detection Task (Martens & van Winsum, 2000).

Not the same, but related to driver distraction, is the concept of situational awareness. It is a term defined by Endsley (1988; p. 97), comprising "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". Situational awareness means that a situation is evaluated adequately, which is also the precondition for acting appropriately (Rauch et al., 2008). The term can be applied to all kinds of environments and was first mentioned in conjunction with process control system operators and aircraft pilots. Billings (1997) gives an overview on aviation, and presents research on the consequences of automation. For process control systems, this is, for instance, dealt with in Edwards and Lees (1974) and for ships in Sarter and Woods (1995).

It also makes sense to apply this concept to modern vehicles with a variety of driver assistance systems, as they can probably lead to a loss of situational awareness caused by the high level of automation. Information regarding this can be found, for instance, in Niederée and Vollrath (2009) and Vollrath, Schleicher, and Gelau (2011). Situation Awareness Rating Technique and Situation Awareness Global Evaluation Technique are methods used to measure situational awareness. The former by Charlton (2002) is a questionnaire-based method. The latter by Endsley (1995) is a probe technique, asking participants for the last image they saw in the scenery before the screen in a driving simulator was blacked out.

The concept of situational awareness can be traced back to the so-called Yerkes-Dodson Law (Yerkes & Dodson, 1908). It states that the optimal performance of a task is achieved in case of a medium arousal level for difficult tasks such as decision making or working memory related tasks (see Figure 6). If the arousal is too high, the performance deteriorates. However, the same also applies in case of a low arousal level that might be induced by a driver assistance system degrading the driver to the level of a system monitor. For simple tasks requiring focused attention, the curve in Figure 6 presents a different trend, as task performance becomes better with a higher arousal, up to a saturation point.

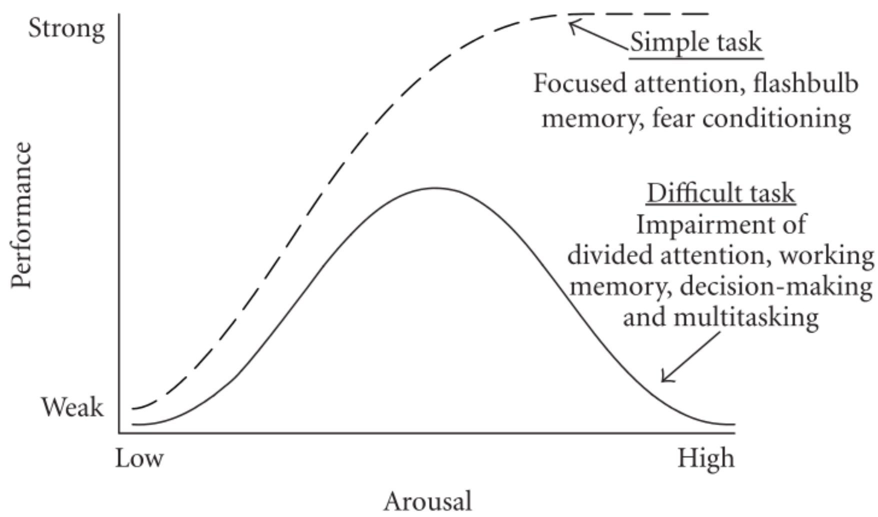


Figure 6: Yerkes-Dodson Law

Closely related to this is the work of Bainbridge (1983). She made a list of so-called ironies of automation, which can also be applied to the world of driver assistance systems. The key point is that the degradation of the driver from being the actual operator of a vehicle to being only the monitor will lead to a loss of skills and situational awareness, making it hard for the driver to take over again when necessary. Zimmer (2002) states that using driver assistance systems often can lead to dependency and a loss of competency. In case of active interventions, this might lead to a low level of self-efficacy, which lowers the attractiveness of actions according to Bandura (1997). In turn, this can lower the acceptance of a driver assistance system (Arndt, 2011).

In case of modern driver assistance systems, there are still a lot of left-over tasks for the driver (Walker, Stanton, & Young, 2001), especially because of system malfunctions or when system limits are reached. It is still a long way to full automation that completely takes the task of driving away from the driver.

For a definition of vehicle automation degrees from the German Bundesanstalt für Strassenwesen (Gasser et al., 2012), see Table 3. Five levels from manual driving only to full automation are listed (Gasser & Westhoff, 2012; p. 3). Comparable classification levels are available by the Society of Automotive Engineers (SAE, 2014) and the National Highway Traffic and Safety Administration (NHTSA, 2013b). Almost all driver assistance systems investigated here are on the level of driver assistance or partial automation, as they still require a permanent interaction with the driver. The only exception is the valet parking system with the driver leaving the car during the parking process. Depending on the system design, it might be high or full automation.

Table 3: Definition of vehicle automation degrees by Bundesanstalt für Strassenwesen

- *Driver only:* The human driver executes the manual driving task
- *Driver assistance:* The driver permanently controls either longitudinal or lateral control. The other task can be automated to a certain extent by the assistance system
- *Partial automation:* The system takes over longitudinal and lateral control, the driver shall permanently monitor the system and shall be prepared to take over control at any time
- *High automation:* The system takes over longitudinal and lateral control; the driver must no longer permanently monitor the system. In case of a take-over request, the driver must take over control within a certain time buffer
- *Full automation:* The system takes over longitudinal and lateral control completely and permanently. In case of a take-over request that is not carried out, the system will return to the minimal risk condition by itself

A comprehensive overview on usability and human factors engineering in general is found in Dipboye et al. (1994), Wickens et al. (2003), Nielsen (1993), Norman (2002), Wickens and Hollands (1999), and Schmidtke (1993).

1.3.3 The Concept of Culture

The manner in which people deal with technology is also based on culture (Honold, 2000). This does not only apply to PC software or smartphones, but also to modern vehicles. There are various definitions existing for culture. No clear or generally accepted explanation is available. According to Hofstede and Hofstede (2004), culture may be regarded as a tendency of people belonging to a certain group (e.g. a nationality like German) to think, feel, and behave in a certain way. Usually people regard their own culture as a standard and judge others from their point of view (Maletzke, 1996). The iceberg model from Hoft (1996) nicely exemplifies that only 10% of the attributes of a culture are visible and conscious. The remainder, the unconscious and invisible parts of culture, are below the water surface.

It should be taken into account that culture is not only a concept differentiating between people from different countries, nationalities, or regions. It also serves as a framework to explain differences in organizational climate, gender differences, or differences between younger and older people. In the course of this work, one of the demographic variables under investigation is the home country. Cultural differences between specific countries play an important role, but, finally, the impact of home country on the data collected will also depend on other factors like infrastructure, social, or economic variables.

If the users' culture is different from the developers', cultural aspects have to be taken into account during system development (Honold, 2000). An appropriate usability of a system depends on the compatibility between the users' and system designers' mental models (Herczeg, 2009). In order to achieve this, Heimgärtner (2012) proposes an intercultural usability engineering process for a technical product in global markets.

The following section presents an outline of the various research findings and theories in the field of cross-cultural psychology. The most-acknowledged theory is that of Hofstede (Hofstede & Hofstede, 2004). Other theories are also laid out.

Hofstede's Cultural Dimensions

Hofstede (Hofstede & Hofstede, 2004) was the first social scientist who quantitatively investigated cross-cultural differences. His so-called cultural dimensions were derived from a large-scale survey conducted within the IBM organization. IBM, as an international organization, has facilities in many different countries. About 116000 IBM employees in 40 different countries participated in his study. By concentrating on IBM employees only, Hofstede was able to exclude the impact of organizational culture as an extraneous variable. Factor analysis conducted with the obtained questionnaire data yielded at first four, later five independent cultural dimensions (see Table 4).

Table 4: Cultural dimensions according to Hofstede

- *Power distance (PDI)*: This is the magnitude to which members of a society expect and accept that power is distributed unequally among them
- *Individualism (IDV)*: It is the degree of people having rather loose ties to fellow members of their society. The opposite is collectivism, which refers to a strong integration of the individual into the society, protecting the individual while at the same time demanding its loyalty to the group
- *Masculinity (MAS)*: It refers to a society with a large difference between gender roles. Masculine societies place an emphasis on assertion and competitiveness
- *Uncertainty avoidance (UAI)*: This is the magnitude to which members of a culture feel threatened by uncertain and unknown situations
- In subsequent studies, an additional dimension, primarily relating to Asian cultures, was discovered. This is the so-called *Long-term orientation (LTO)*: It comprises attitudes like virtue, perseverance, and respect for tradition that are prevalent in Asian cultures

As of now, Hofstede's approach is regarded as the most comprehensive one (Eckhardt, 2002). Comparison of various different cultures can be done using his dimensions (see http://www.geert-hofstede.com). Figure 7 presents a comparative example of these five cultural dimensions between Germans and Chinese.

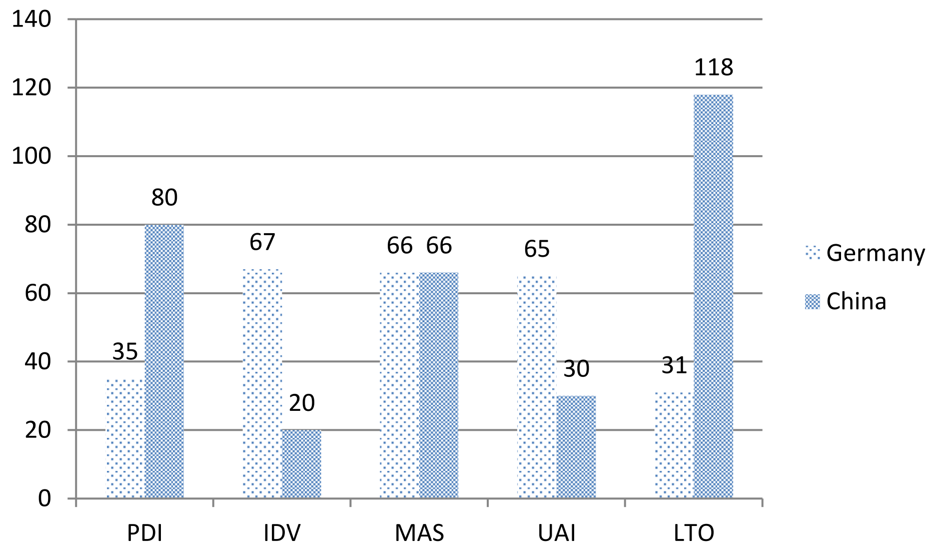


Figure 7: Hofstede's five Dimensions for Germans and Chinese

The data shows that Germans have a lower power distance than Chinese. Individualism is higher for Germans than for Chinese. Masculinity shows basically no difference. Uncertainty avoidance is higher for Germans. The biggest difference can be found in Long-term orientation, as Chinese value it much higher.

The GLOBE Study (House et al., 2002) was another large scale cultural study that yielded nine different cultural dimensions. In this case, the sample consisted of more than 17000 managers from 951 companies in 62 countries. The derived dimensions are presented in Table 5 (House et al., 2002; pp. 5-6).

Table 5: Cultural dimensions according to the GLOBE Study

- *Uncertainty avoidance*: This is defined as the extent to which members of an organization or society strive to avoid uncertainty by reliance on social norms, rituals, and bureaucratic practices to alleviate the unpredictability of future events
- *Power distance*: It is defined as the degree to which members of an organization or society expect and agree that power should be equally shared
- *Collectivism I*: Social collectivism reflects the degree to which organizational and social institutional practices encourage and reward collective distribution of resources and collective action
- *Collectivism II*: In-group collectivism reflects the degree to which individuals express pride, loyalty, and cohesiveness in their organizations or families
- *Gender egalitarianism*: It is the extent to which an organization or a society minimizes gender role differences and gender discrimination
- *Assertiveness*: The degree to which individuals in organizations or societies are assertive, confrontational, and aggressive in social relationships

- *Future orientation*: It defines the degree to which individuals in organizations or societies engage in future-oriented behaviours such as planning, investing in the future, and delaying gratification
- *Performance orientation*: The extent to which an organization or society encourages and rewards group members for performance improvement and excellence
- *Humane orientation*: The degree to which individuals in organizations or societies encourage and reward others for being fair, altruistic, friendly, generous, caring, and kind

Hofstede (2006) commented on the GLOBE Study, claiming that the dimensions identified by GLOBE can actually be traced back to his original five dimensions.

The Cultural Theory of E.T. Hall

Hall (1959) was one of the first researchers who focused on cultural differences, applying rather qualitative interview methods. Basically, Hall sees culture as a communications system, which may be verbal or non-verbal. Through this approach, he gained several cultural dimensions. Table 6 shows the details.

Table 6: Cultural dimensions according to Hall

- *High-/Low-Context:* Low-context cultures show a rather loose net of relationships among people, thus the inter-human communication is quite straightforward and clear. High-context cultures show long-term, in-depth relations among people. This results in a context dependent communication
- *Space:* Cultures differ with respect to their understanding of private sphere and territory. In some cultures, the personal room can easily be intruded by others, in other cultures this is highly disregarded
- *Monochronic/Polychronic Time:* In a monochronic time culture, things occur one after another, whereas polychronic time cultures regard time as circular. Things can be done or happen at the same time
- *Fast/Slow Message:* In some cultures there is a high velocity of information flow; in others this velocity is low

Other authors like Kluckhohn and Strodtbeck (1961), Trompenaars (1993), and Schwartz (1994) came up with their own concepts of culture. Notable is also the so-called culture assimilator approach from Thomas (1993). It is based on Thomas' concept of cultural standards, which are about the typical attributes of a certain culture. In his theory, cultural standards are a learned culture specific orientation system. It was primarily developed for the cross-cultural awareness training of expatriates and confronts them with problematic situations they usually encounter abroad. However, the proposal by Thomas cannot be measured quantitatively, which makes it hard to work with (Heimgärtner, 2012).

1.3.4 Subjective Evaluation of Driver Assistance Systems

The subjective evaluation of driver assistance systems has been present in literature since the 90s. One of the first studies to be conducted was by Underwood (1992). In an expert survey, he showed that adaptive cruise control would most likely be a driver assistance system technology gaining widespread installation in vehicles. Bekiaris et al. (1996) distributed a questionnaire in European countries, trying to evaluate whether driver assistance systems would be welcomed. While supportive systems were positively evaluated, the idea of fully automated driving was rejected. Wevers et al. (1999) demonstrated that people were indifferent to lateral support systems actively intervening. Instead, they had a preference for warning systems. People had a negative opinion of automatic interventions in general. Charles River Associates (1998) gained study results indicating adaptive cruise control would have limited acceptance as it automatically controls the car. Collision avoidance systems were favored in their study. Marchau et al. (2001) showed, in a survey on driver assistance system preferences, on the average a mediocre rating of attractiveness for systems like distance keeping, speed limit adaptation, and navigational support. Mariani et al. (2000) presented results supporting a preference for information and warnings instead of driver assistance system action. Chalmers (2001) conducted a study in which longitudinal control systems were better accepted. According to Regan et al. (2002), participants liked the idea of lane departure warning. Piao et al. (2004) gained results demonstrating that lane departure warning was rated much lower than adaptive cruise control and intelligent speed adaptation, which either adapts the speed automatically to the current speed limit or gives information on speed limits. Blythe and Curtis (2004) revealed a preference for collision warning and prevention as well as adaptive cruise control and driver alertness monitoring. Half of their participants thought driver assistance systems should warn only, the other half that they should intervene. Marchau et al. (2005) collected data for an intelligent speed adaptation system. People were able to understand the advantages of such a system, but were only willing to buy it depending on the costs and the functionality. Van Driel and van Arem (2005) conducted a survey comparing people’s needs on driver assistance systems. It showed that especially blind spot detection and downstream traffic information was favored. Also, help with critical situations (e.g. imminent crash) and adaptive cruise control like systems were favored.

Arndt (2011) developed a model in order to analyze and forecast the acceptance of driver assistance systems. Factors like usability, traffic safety, image, driving pleasure, trust, comfort, environmental friendliness, and system control play a key role and should be taken into account when designing them. According to a survey of car drivers by

Trübswetter and Bengler (2011), both safety and comfort can be increased by driver assistance systems helping, for instance, with changing lanes, overtaking, or driving in the dark. Planing (2014) stated in his research work, based on interviews and questionnaire data, that people's desire to exert control most strongly supports resistance to this kind of technology. At the same time, perceived safety and comfort benefits most strongly support its acceptance.

Kyriakidis et al. (2014) conducted an online survey evaluating user acceptance of fully automated vehicles in an international sample. Results from 109 countries were collected, although the direct comparison between different countries was not in focus. Finally, after accepting only the ones with at least 25 respondents, 40 countries remained in the sample. Altogether, results for the overall sample revealed that people still enjoyed manual driving. At the same time, they regarded fully automated driving as fascinating. Fully automated cars were not deemed as important in a study by Missel (2014).

Eimler and Geisler (2015) conducted a survey on fully automated vehicle acceptance. People were less familiar with this topic. They trusted the systems, but at the same time did not want to use them. Sommer (2013) showed that his participants considered fully automated driving as useful. Still, they were altogether rather scared of the prospect of such a vehicle. In a study by Ernst and Young (2013), it was shown that drivers preferred to buy fully automated vehicles as long as they still have the ability to intervene, if necessary. In case this possibility was not given, they were less likely to buy them.

Data is also available when considering the question of how the evaluation of driver assistance systems differs between various countries. Lindgren et al. (2008) demonstrated in a series of comparisons between Swedish and Chinese drivers that there are differences with regard to the design requirements of driver assistance systems. Blind spot detection and forward collision warning were positively evaluated and regarded as useful in everyday traffic by the Chinese in their home country. In contrast, adaptive cruise control and lane departure warning were rather negatively evaluated. For adaptive cruise control, the road conditions were seen as being too complex. For lane departure warning, missing lane markings posed a problem. Lindgren et al. (2008) argued that situations regarded as dangerous by Westerners might have a totally different meaning for the Chinese. As many driver assistance systems do not only have imminent but also cautionary warnings, especially the latter ones need to be adapted. Drivers might become annoyed by many cautionary warnings in a country like, for instance, China. The driving environment in China is rather chaotic and there are a lot of bicyclists and pedestrians on the roads (Huang et al., 2006).

Marchau et al. (2001) showed in a European survey on driver assistance systems a rather mediocre rating of preference for distance keeping, speed limit adaptation, and navigational support. The country of origin revealed differences in the evaluation. The driver assistance systems were regarded as most attractive by Greek, followed by Dutch, Czech, Italian, and German people, who gave a neutral rating. Finnish people gave the driver assistance systems a rather unattractive rating.

Sommer (2013) presented data that their participants considered fully automated driving as useful. Still, they were altogether rather scared of the prospect of such a vehicle. Samples from Germany, China, Japan, and the USA were employed for this. People in Germany and China were more aware of vehicle automation than people in Japan. Kyriakidis et al. (2014) conducted their online survey evaluating user acceptance of fully automated vehicles in an international sample with 40 countries. Altogether, more developed countries showed a prevalence of concerns regarding a fully automated vehicle transmitting data. There were no other differences between the countries.

Larsson (2012) tackled the question of how driver experience affects driver assistance system evaluation. She distributed a questionnaire to experienced adaptive cruise control users. Her results indicated that limitations of the system become more obvious the longer people use it. Furthermore, as adaptive cruise control is not perfect and drivers have to take over control now and then, this seems to help, as people are better prepared for unexpected situations. Planing (2014) gained results on prior experience. It improved the acceptance of driver assistance systems. Haupt et al. (2015) conducted a questionnaire study in order to evaluate safety relevant attitudes regarding driver assistance systems. Results showed that the more experienced drivers were at using a driver assistance system, the higher they judged it in terms of safety.

Gender is another factor that might have an influence on driver assistance systems and their acceptance. Results from Rienstra and Rietveld (1996) showed the following: Women preferred systems regulating the vehicle’s speed more than men did. Mariani et. al. (2000) conducted a survey in which no gender differences for driver assistance systems were found. Marchau et al. (2001) showed in a European survey on preferences for systems like distance keeping, speed limit adaptation, and navigational support the following: Results were depending on other variables. On average, these systems were more preferred by women than by men.

Women were rather more willing to accept help from their cars compared to men, according to Chalmers (2001). Blythe and Curtis (2004) had the opposite result: Driver assistance systems were more accepted by men such that taking over control from the driver was more accepted than by women. In a study by Piao et al. (2004), men liked adaptive cruise control best, while women preferred intelligent speed adaptation. Planing’s (2014) data showed that females were more likely to buy driver assistance systems compared to males. Haupt et al. (2015) conducted a questionnaire study in order to evaluate safety relevant attitudes regarding driver assistance systems. No general effects were found in regard to gender.

Missel (2014) found that men deemed fully automated vehicles as more important than women. Casley et al. (2013) also presented data concerning the adoption of fully automated cars. They were more likely to be adopted by men compared to women. Male people had a higher usage interest in fully automated driving than females, according to the results by Payre et al. (2014). Buying interest was in general less than usage interest, but also buying interest was higher for males compared to females. Males also had a more positive attitude towards fully automated driving than females.

An analysis of the age of new car buyers yielded that they were, on average, getting older (CAR, 2009). By 2020 more than one third of all German car drivers will be over 60 years of age (Winterhoff et al., 2009). Schlag (2008) showed in an overview about elderly drivers a higher risk for accidents, as they have a tendency for impairments of cognitive functions necessary for safe driving. Thus, driver assistance systems may be highly beneficial for older drivers. There is a possibility for driver assistance systems to help especially older people with impairments in regard to information perception, processing, and reaction (Fisk et al., 2009).

For older drivers, compared to younger ones, technology is less accepted and used, according to a study by Czaja and Sharit (1998). Marchau et al. (2001) showed in a European survey on driver assistance system preferences that results were highly depending on the participants' age. On average, older drivers seemed to prefer the systems more than younger ones. Older drivers were more positive on driver support systems than younger ones, as shown by Chalmers (2001) and Piao et. al. (2004).

Adell (2009) conducted studies indicating that older drivers had a higher satisfaction with and perceived usefulness of a speed adaptation system. Still, compared to middle aged drivers, their willingness to keep the system was lower. Trübswetter and Bengler (2013) presented an interview study of elderly drivers on driver assistance systems. The lack of perceived usefulness was a main reason why older people did not use them. Missel (2014) demonstrated that older people believed fully automated cars to be less important than younger ones. Planing (2014) compared purchase interest and came to the following conclusion: Younger people were more likely to buy driver assistance systems. In a questionnaire study done by Haupt et al. (2015) in order to evaluate safety relevant attitudes regarding driver assistance systems, driver age had an effect, as there were more safety related attitudes to the systems the older people were.

Another factor is the influence of yearly mileage. Marchau et al. (2001) showed in their survey for drivers with lower mileage a higher attractiveness of driver assistance systems than for people with higher mileage. They argue that higher mileage drivers might think they are more capable and do not need such systems.

2 Research Questions

The first research question was how driver assistance systems are evaluated subjectively. It was assumed that there are differences with regard to the perceived importance and usefulness of the systems described in section 1.2.2. Study 1 was supposed to yield some qualitative insights. Study 2 on driver assistance systems in general as well as Study 3 on parking driver assistance systems were designed to clarify whether there are quantitative rating differences between them. Study 2 furthermore made it possible to also look at the perceived annoyance, if any, caused by the systems. The literature review on subjective driver assistance system evaluation did not really show a clear-cut preference for any kind of system. Taking into account the point made by Planing (2014), the desire to exert control was found to most strongly support resistance to driver assistance systems. This is also in line with the results from Wevers et al. (1999), Charles River Associates (1998), and Mariani et al. (2000), who found a better evaluation of information and warning compared to acting systems. Thus, systems that intervene were supposed to be evaluated as being less important and more annoying. This refers to adaptive cruise control, lane keeping aid, lane centering aid, and traffic jam assist in contrast to systems that are informing and warning only, such as lane departure warning, forward collision warning, and blind spot detection.

The second research question was how demographic factors have an impact on the subjective evaluation of driver assistance systems. Studies 1, 2, and 3 were used to answer this question. In case of Study 1, the qualitative evaluations were analyzed quantitatively in order to attain a comparison of three countries, the USA, Germany, and China. Also the impact of gender and age group was investigated. In case of both Study 2 and Study 3, the four countries with most participants, namely the USA, Germany, the United Kingdom, and Brazil, were used in order to quantitatively compare the subjective evaluations of the driver assistance systems. Based on the available literature, though not clear-cut, it was assumed that the home country had an effect on the driver assistance systems. This was also based on the fact that different countries comprise different cultures as well as infrastructural properties. Further demographic factors were available and could be used to evaluate their impact on driver assistance systems. They include age group, gender, system experience, and yearly mileage. These comparisons were drawn for both Study 2 and 3. It was assumed that there is an impact of age and gender. This difference might be in any direction, as there were contradicting results available in the literature. Finally, at least for driver assistance systems like adaptive cruise control and semi-automated parallel/perpendicular parking, there was a sufficient number of experienced users available. It was assumed that there is a difference between experienced and unexperienced users of these systems. Based on the literature, experienced users were expected to more positively evaluate driver assistance systems. The yearly mileage was also supposed to have an influence: The higher it is, the less people appreciate the systems.

The third research question referred to parking driver assistance systems, thus to Study 3 only. It was assumed that the four countries with the highest number of participants differ with regard to their parking behaviour. It was specifically hypothesized for the USA, a country with a lot of available space, to have less need for parallel parking compared to the other three countries. Based on this and the fact that parking spaces are on the average larger, it was furthermore hypothesized that advanced active parking aids are evaluated as being less useful by US participants compared to participants from the other three countries. Still, the effect proposed might be offset by larger cars, which require larger parking spaces.

The fourth and final research question asked if the survey data gathered on a driver assistance system not yet available on the market can be compared to its evaluation in a study with a prototype vehicle. Based on the literature, experienced users were supposed to more positively evaluate driver assistance systems. Thus, it was hypothesized that the actually experienced prototype system for remote parking in Study 4 is better evaluated than the same, but only narratively described system in Study 3.

3 Results

3.1 Subjective Evaluation of Driver Assistance Systems – Interview

3.1.1 Research Questions

In order to gain a better understanding of the expectations and acceptance of driver assistance systems in Germany, the USA, and China, the results of interviews are reported. This aimed at collecting qualitative data on driver assistance system evaluation. Furthermore, the qualitative data was also analyzed quantitatively. It was hypothesized that there are differences with regard to the subjective evaluation of driver assistance systems in the three different countries, comparing positive, negative, and neutral comments. Differences were expected, as shown by Lindgren et al. (2008) and Marchau et al. (2001). Although Sommer (2013) as well as Kyriakidis et al. (2014) did not find differences between countries that can be compared to this kind of study, it was still assumed this way, as China, Germany, and the USA are examples of distinct cultures (Hofstede & Hofstede, 2004) with different infrastructural and demographic backgrounds. Furthermore, the impact of gender and age group was investigated.

3.1.2 Method

An open-ended questionnaire was distributed among German, Chinese, and American employees of an international automotive manufacturer in order to collect insights about their opinion on driver assistance systems. None of the participants included worked in the area of driver assistance systems. However, they were only asked to participate if they had experience and a sufficient understanding of the systems under investigation. It was a convenience sample, as people with private and business contacts to the author were employed. The driver assistance systems that are part of this study are shown in Table 7.

Table 7: Included driver assistance systems (for more details, see section 1.2.2)

- Adaptive cruise control
- Forward collision warning
- Lane departure warning
- Lane keeping aid
- Lane centering aid
- Blind spot detection
- Semi-automated parallel/perpendicular parking
- Traffic jam assist

Participants were asked to comment on the perceived usefulness, annoyance, and their general opinion of several driver assistance systems. It was emphasized to take into account the region where they live for the evaluation, because it was assumed that this makes a difference. The items were based on expert discussions. The questionnaire was pre-checked for comprehensibility by an internal group consisting of human factors experts who were asked for their feedback. Also, some non-experts completed the questionnaire and provided their feedback. The questions were sent via eMail in a MS Excel 2010 format and also answered via eMail in the same format. The questionnaire was handed out in English. Most responses were in English as well. Some of the responses were in Chinese and translated into English by a native speaker. The explanation given for each driver assistance system was basically the same as in section 1.2.2.

As the gained raw data was based on free associations of the participants, each individual response was put into a comment category. As expected, some similar comments were mentioned several times. This way it was possible to come up with several comment categories for each driver assistance system. Afterwards, the gathered comment categories were classified according to three categories: positive comments, negative comments, and neutral comments. Positive comments were defined as highlighting the benefits of a system. Negative comments were defined as expressing concerns with regard to a system. Neutral comments could neither be classified as positive or negative, but rather represent suggestions. This way a 3-point scale was derived, ranging from negative to neutral to positive. The rating was done by the author alone. Thus, no inter-rater reliability was calculated. Statistical tests were done using SPSS version 23. As this was a convenience sample, and it was not possible to determine the number of participants in advance, no a priori power calculations according to Faul et al. (2009) were done. Furthermore, it was not possible to know in advance how many comments would be made by the participants. Post hoc power calculations were not done either, as they directly depend on the calculated p-value. Low p-values correspond to high power and vice versa. Thus, the post hoc power does not change the interpretation of the data (Hoenig & Heisey, 2001).

Demographic information was also collected (see Table 8). Not all participants from the USA indicated their gender. All participants had a valid driver's licence and were driving on a regular basis. As the independent variable, the home country, could not be randomly assigned to the participants in this study, the design was quasi-experimental (e.g. Bortz & Döring, 2006). The same applies to the other demographic variables.

Table 8: Sample demographics

Home country	**Sample size**	**Average age (in years)**	**Age range (in years)**	**Male**	**Female**
USA	14	46	29-63	5	5
Germany	17	36.9	29-59	13	4
China	27	29.8	24-40	24	3

The questionnaire used is included in the Appendix. It is a transcription, as the original was distributed as a MS Excel file.

3.1.3 Results

Tables 9 to 16 show the results for the driver assistance systems listed in Table 7. Included in the table is the frequency of mentioning a specific comment for each home country. Empty cells mean that for the respective home country, no such comment was counted. The comments are rated in the last column.

Table 9: Comments on adaptive cruise control for all three countries

Comment	USA	Germany	China	Rating
Slows vehicle down	3			negative
Makes people inattentive	1		3	negative
Prevents fatigue			1	positive
Interaction with human-machine interface complicated			2	negative
Traffic dynamic too high for adaptive cruise control			1	negative
Too intrusive			1	negative

Table 10: Comments on forward collision warning for all three countries

Comment	USA	Germany	China	Rating
Helps distracted drivers	2	3	1	positive
Causes false alarms, which is annoying	2	2	3	negative
Forward collision warning sound too loud	1	1		negative
Forward collision warning sound important			3	positive
Needs to work with pedestrians			1	neutral
Driver can react quicker than forward collision warning			2	negative

Table 11: Comments on lane departure warning for all three countries

Comment	USA	Germany	China	Rating
Helps distracted drivers	2	3	2	positive
Causes false alarms, which is annoying	4	3	2	negative
Risk homoeostasis: people drive more risky because of this feature		2		negative
Human-machine interface is well done	1	1		positive
Poor street markings make usage impossible			2	negative
Vibrations are an inappropriate alarm			2	negative
Turn indicator is not used that often, which leads to false alarms			2	negative

Table 12: Comments on lane keeping aid for all three countries

Comment	USA	Germany	China	Rating
Helps distracted drivers	2	1	1	positive
Causes false alarms, which is annoying	2	2		negative
Too intrusive	4	1	5	negative
Turn indicator is not used that often, which leads to false alarms			1	negative
Poor street markings make usage impossible			1	negative

Table 13: Comments on lane centering aid for all three countries

Comment	USA	Germany	China	Rating
Helps distracted drivers	2		1	positive
Causes false alarms, which is annoying		2		negative
Too intrusive	3	3	2	negative
Turn indicator is not used that often, which leads to false alarms			1	negative
Poor street markings make usage impossible			1	negative

Table 14: Comments on blind spot detection for all three countries

Comment	USA	Germany	China	Rating
Indicator should be better visible	1	2		neutral
Causes false alarms, which is annoying		1	1	negative
Risk homoeostasis: people drive more risky because of this feature		1		negative
Needs to also detect pedestrians and bicycles			1	neutral
Voice warning for objects recommended			1	neutral
Prefer automatic steering intervention, if necessary			1	neutral

Table 15: Comments on semi-automated parallel/perpendicular parking for all three countries

Comment	USA	Germany	China	Rating
Helpful for beginners	1	3	7	positive
I prefer to park myself	3	5	1	negative
Disadvantage: I still need to brake myself		3		negative
When I use it, I will forget my skills		3		negative
Needs training to be operated correctly	1			neutral
Remote control would be appreciated			1	neutral

Table 16: Comments on traffic jam assist for all three countries

Comment	USA	Germany	China	Rating
Too intrusive	5	2	3	negative
Hand over to driver must be made explicit	2	3		neutral
Would encourage distraction / secondary tasks	3		1	negative
System limited up to 60 kph			2	negative
Does not work in mixed traffic with non-equipped vehicles			1	negative

Table 17 shows the number of positive, neutral, and negative comments for all three countries. There were in general more negative comments, followed by a number of positive comments, and finally a few neutral comments, which can also be regarded as recommendations. Descriptively, there was no big difference between the three countries if one takes into account the quality of the comments. The frequency of mentioning comments with positive, negative, and neutral denotations was comparable. The χ^2-test with $\chi^2(4, 153) = 0.41$, $p = .981$, and $w = .05$ showed a non-significant result. Thus, based on this data, there was no difference in the subjective evaluation of the driver assistance systems with regard to the home country.

Table 17: Number of comments for all three countries

Rating	**USA**	**Germany**	**China**
Positive	10	11	16
Neutral	4	5	5
Negative	31	31	40

Table 18 shows the number and quality of comments for males and females. The difference between both genders was not significant with $\chi^2(2, 149) = 0.20$, $p = .904$, and $w = .04$. Thus, there was no significant difference between males and females with regard to the subjective evaluation of driver assistance systems.

Table 18: Number of comments for gender

Rating	**Male**	**Female**
Positive	29	7
Neutral	12	2
Negative	82	17

Table 19 shows the number and quality of comments for each age group. The difference between the age groups was not significant with $\chi^2(8, 153) = 6.73$, $p = .566$, and $w = .21$. Thus, there was no significant difference between the age groups with regard to the subjective evaluation of driver assistance systems.

Table 19: Number of comments for age group

Rating	Under 31	31-40	41-50	51-60	Over 60
Positive	9	14	11	3	0
Neutral	2	4	4	3	1
Negative	26	39	28	7	2

3.1.4 Discussion

Looking at the qualitative data only, the insights of the interviews include the following: The forward collision warning system was perceived as important by the Chinese as well as helpful for Germany and the USA. Nonetheless, some participants in China regarded forward collision warning with a tendency to be too annoying. Probably as the complex traffic situation triggers the alarm quite often. One participant mentioned the requirement that forward collision warning should also work with pedestrians in China. The same applied to blind spot detection. Adaptive cruise control was supposed to slow traffic down, as mentioned by participants from the USA. Some Chinese participants claimed that it makes people inattentive. Lane assist systems like lane departure warning, lane keeping aid, and lane centering aid were regarded as problematic in China because of missing lane markings on the street and the poor usage of turn indicators, as this can easily trigger false alerts. The semi-automated parallel/perpendicular parking system was named helpful for beginning drivers, especially in China. Still, some participants preferred to park themselves. Traffic jam assist was regarded as too intrusive, especially by the participants from the USA.

Taking into account the study results of Lindgren et al. (2008), blind spot detection and forward collision warning were positively evaluated and regarded as useful in everyday traffic by the Chinese in their home country, as they were supposed to prevent accidents. In contrast, adaptive cruise control and lane departure warning were rather negatively evaluated. Adaptive cruise control was deemed as inappropriate for the complex Chinese traffic situation. Lane departure warning posed problems due to the lack of lane markings on many Chinese roads. Although it is difficult to come to confident conclusions due to the qualitative nature of this study, the data indicates that adaptive cruise control and the lane assist systems are seen as problematic by the Chinese, thus confirming Lindgren et al. (2008) in regard to this.

Many of the comments were actually negative. This does not necessarily mean that the systems were poorly evaluated altogether. The participants were asked to mention comments on the annoyance potential of the systems as well. An actual rating of the systems is included in the upcoming studies. Also, this was not supposed to be an expert evaluation. Only non-experts in the field of driver assistance systems participated in this study.

Looking at the quantitative analysis based on the comments, there was no significant difference between the three countries. With regard to the derived scale and the driver assistance systems under investigation, there were a comparable number of positive, negative, and neutral comments in all three countries. The data shows that at least for this qualitative approach, no differences between the countries can be found. This is contrary to the expectations, which were supported by Lindgren et al. (2008) and Marchau et al. (2001). Kyriakidis et al. (2014) and Sommer (2013) found no relevant differences between different countries in their studies and are in line with the results here. Furthermore, there were no significant differences for the other demographic variables gender and age group.

An issue of the employed sample is the fact that the sample demographics varied between the three countries, especially with regard to the age range. The Chinese were the youngest, the Americans the oldest. But this also applied to the gender distribution and the sample sizes in general. Still, the final quantitative analysis yielded no significant effect that could be traced back to the sample characteristics. The differences in the demographic variables would rather have been likely to cause effects in the data. It would be a big coincidence if older Americans reacted the same as younger Chinese people, but, for instance, young Americans different than young Chinese. Other issues, but also positive aspects pertaining to the sample characteristics, are discussed in section 4.

3.2 Subjective Evaluation of Driver Assistance Systems – Survey

3.2.1 Research Questions

The first research question asked how driver assistance systems are evaluated subjectively. It was assumed that there are differences with regard to the perceived importance and annoyance ratings. The literature review on subjective driver assistance system evaluation did not really show a clear-cut preference for any kind of driver assistance system. Taking into account the postulation by Planing (2014), the desire to exert control was found to most strongly support resistance to driver assistance systems. Thus, systems that intervene were supposed to be evaluated as less important and more annoying. This refers to adaptive cruise control, lane keeping aid, lane centering aid, and traffic jam assist in contrast to systems that are informing or warning only, such as lane departure warning, forward collision warning, and blind spot detection.

The second research question dealt with the impact of demographic factors on the subjective evaluation of driver assistance systems. The four countries with the highest number of participants, namely the USA, Germany, the United Kingdom, and Brazil, were used in order to quantitatively compare the subjective evaluations of the systems under investigation. Based on the available literature, though not clear-cut, it was assumed that the home country would have an effect on the driver assistance systems. Further demographic factors were available and could be used to analyze their impact. They include age group, gender, system experience, and yearly mileage. It was assumed that there is an impact of age group and gender. This difference might be in any direction, as there were contradicting results available in the literature. Finally, at least for adaptive cruise control, there was a sufficient number of experienced users available. It was assumed that there is a difference between experienced and unexperienced users of this system. Based on the literature, experienced users were supposed to have a more positive rating of adaptive cruise control. The yearly mileage was also supposed to have an influence. The higher it is, the less positive people evaluate the driver assistance system.

3.2.2 Method

A standardised questionnaire was distributed via an internal web survey to employees of an international automotive manufacturer in order to collect a quantitative measure on how driver assistance systems are evaluated (see Table 20 for a list of all driver assistance systems included in this study). The participants were part of a global recipient list for internal web surveys. The participation was voluntary. The questionnaire was in English. The explanations given on driver assistance systems were basically the same as outlined in section 1.2.2. The dimensions for driver assistance system evaluation were importance of and annoyance caused by the respective system. It was possible not to give an answer if participants felt that they are not able to judge one of the systems. Items were based on expert discussions. The questionnaire was pre-checked for comprehensibility by an internal group consisting of human factors experts who were asked for their feedback. Some non-experts were also asked to complete the questionnaire and provide their feedback in order to improve comprehensibility. Statistical analysis was done using SPSS version 23. Graphs were created using MS Excel 2010. The Psychometrica website (Lenhard & Lenhard, 2014) was used to calculate effect sizes according to Cohen (1988).

The following 5-point ad-hoc rating scale format was used. Participants were given the possibility to agree or disagree to the statements: “How do you evaluate this driver assistance system with regard to

…its importance in your market”

…its potential annoyance in your market”

1	2	3	4	5
strongly disagree				*strongly agree*

Table 20: Included driver assistance systems (for more details, see section 1.2.2)

- Adaptive cruise control (ACC)
- Forward collision warning (FCW)
- Lane departure warning (LDW)
- Lane keeping aid (LKA)
- Lane centering aid (LCA)
- Blind spot detection (BSD)
- Traffic jam assist (TJA)

Altogether, 3489 participants answered the survey. Taking only into account countries with at least 25 participants, there finally were 3295 remaining. Please see Table 21 for an overview. Tables 22 to 24 show the sample characteristics. The combined numbers of males and females do not always sum up to the overall sample size, as some participants did not state their gender. The same applies to the age groups. All participants had a valid driver's licence and were driving on a regular basis. As the independent variable, the home country, could not be randomly assigned to the participants in this study, the design was quasi-experimental (e.g. Bortz & Döring, 2006). The same applies to the other demographic variables. It was originally planned to also include China in the comparison regarding the home country, as it was done in Study 1. As a sufficient number of participants for the comparison was needed, only countries with at least n = 200 participants were included. Therefore, the comparison of home country took place between the USA, Germany, the United Kingdom, and Brazil.

Table 21: Number of participants per home country

Home country	***n***
Belgium	56
Germany	497
Spain	29
United Kingdom	342
Australia	186
China	44
India	51
South Africa	45
Canada	86
Mexico	92

United States	1661
Brazil	206

Table 22: Number of male and female participants

Gender	***n***
Male	2793
Female	483
Do not wish to answer	19

Table 23: Age distribution

Age	***n***
Under 31	454
31-40	732
41-50	1110
51-60	815
Over 60	162
Do not wish to answer	22

Table 24: Mileage per year

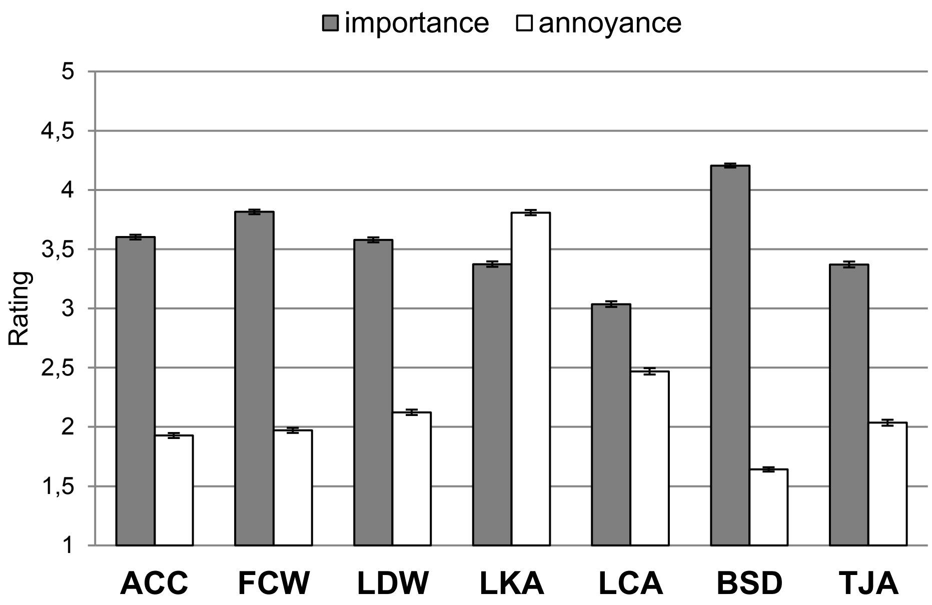
How many miles/kilometers per year do you drive?	***n***
0-5,000 miles / 0-8050 km	155
5,001-10,000 miles / 8051-16100 km	701
10,001-20,000 miles / 16101-32200 km	1562
20,001-30,000 miles / 32201-48300 km	534
30,001-40,000 miles / 48301-64400 km	192
Over 40,000 miles / over 64400 km	151

Not all variables showed a normal distribution according to the Kolmogorov-Smirnov Normality Test. Furthermore, Levene's Test for the test on equal variances showed that this precondition is not the case for all comparisons. Still, ANOVAs and other parametric statistical tests were used, as they are quite robust with regard to violated assumptions. For dependent samples, repeated measurement ANOVAs and paired *t*-tests were used. First of all, an ANOVA was conducted to check if there is a main effect in general. If yes, *t*-tests without assuming equal variances were done to check for significant differences between pairs. Adaptive cruise control was used as an example for the post hoc comparisons regarding home country. For all other demographic variables, the rating of adaptive cruise control was also used as an example driver assistance system to analyse the impact. Two-tailed *t*-tests only were done in order to have a conservative test of significance. Only those pair differences were taken into account in the discussion that were supported by a significant result. Furthermore, for the post hoc *t*-tests, a Bonferroni-Holm correction (Holm, 1979) was applied. This way the issue of α-error inflation could be minimised (e.g. Zöfel, 2003). As this was a convenience sample, and it was not possible to determine the number of participants in advance, no a priori test power calculations according to Faul et al. (2009) were done. Post hoc power calculations were not done either, as they directly depend on the calculated p-value. Low p-values correspond to high power and vice versa. Thus, the post hoc power does not change the interpretation of the data (Hoenig & Heisey, 2001).

The questionnaire used is included in the Appendix. It is a transcription, as the original was distributed as a MS SharePoint website.

3.2.3 Results

Figure 8 shows the evaluation of the driver assistance systems under investigation with regard to importance and annoyance. Altogether, the importance ratings were rather high to medium. They were especially high for blind spot detection. The main effect of driver assistance system was significant, with $F(6, 6990) = 128.04$, $p < .001$, and $\eta^2 = .10$. Thus, there was a significant difference between the subjective evaluations of different driver assistance systems' importance ratings. The effect size was medium. As altogether 21 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 21 comparisons, .05 divided by 21 is .0024. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 25 shows the *t*-test results. The *t*-tests were done to compare each pair of driver assistance systems for significance, investigating if the hypotheses postulated in section 2 are valid. Most of them were significant, also taking into account the Bonferroni-Holm correction. Notable effects with sizes that were medium to high included the differences between blind spot detection versus adaptive cruise control, lane departure warning, lane keeping aid, lane centering aid, and traffic jam assist. It also applied to the comparisons between forward collision warning and lane centering aid. This result supports the strong positive rating of blind spot detection.



Legend: ACC: adaptive cruise control; FCW: forward collision warning; LDW: lane departure warning; LKA: lane keeping aid; LCA: lane centering aid; BSD: blind spot detection; TJA: traffic jam assist

Figure 8: Evaluation of driver assistance systems with regard to importance and annoyance [Mean + Standard Error]

For the annoyance rating, there was generally a low to moderate evaluation, with the exception of the lane keeping aid system, which was regarded as rather annoying. The main effect was significant, with $F(6, 4968) = 325.24$, $p < .001$, and $\eta^2 = .28$. Thus, there was a significant difference between the driver assistance systems regarding their annoyance rating. The effect size was big. As altogether 21 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 21 comparisons, .05 divided by 21 is .0024. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 26 shows the t-test results. Most of them were significant, also taking into account the Bonferroni-Holm correction. Notable effects with sizes that were medium to high included the differences between lane keeping aid versus adaptive cruise control, forward collision warning, lane departure warning, lane centering aid, blind spot detection, and traffic jam assist. Furthermore, this included the comparison between lane centering aid and blind spot detection. This result supports the high annoyance rating caused by lane keeping aid.

Table 25: Post hoc t-tests

Adaptive cruise control versus forward collision warning	$t(2670) = 7.42$, $p < .001$, $d = 0.20$
Adaptive cruise control versus lane departure warning	$t(2590) = 1.07$, $p = .283$, $d = 0.03$
Adaptive cruise control versus lane keeping aid	$t(2453) = 6.66$, $p < .001$, $d = 0.19$
Adaptive cruise control versus lane centering aid	$t(2255) = 16.49$, $p < .001$, $d = 0.49$
Adaptive cruise control versus blind spot detection	$t(2789) = 22.26$, $p < .001$, $d = 0.60$
Adaptive cruise control versus traffic jam assist	$t(2340) = 7.30$, $p < .001$, $d = 0.21$
Forward collision warning versus lane departure warning	$t(2584) = 7.69$, $p < .001$, $d = 0.21$
Forward collision warning versus lane keeping aid	$t(2462) = 14.20$, $p < .001$, $d = 0.41$
Forward collision warning versus lane centering aid	$t(2236) = 24.65$, $p < .001$, $d = 0.74$
Forward collision warning versus blind spot detection	$t(2786) = 15.33$, $p < .001$, $d = 0.41$
Forward collision warning versus traffic jam assist	$t(2326) = 12.19$, $p < .001$, $d = 0.36$
Lane departure warning versus lane keeping aid	$t(2403) = 6.14$, $p < .001$, $d = 0.18$
Lane departure warning versus lane centering aid	$t(2179) = 16.35$, $p < .001$, $d = 0.46$
Lane departure warning versus blind spot detection	$t(2720) = 22.71$, $p < .001$, $d = 0.62$

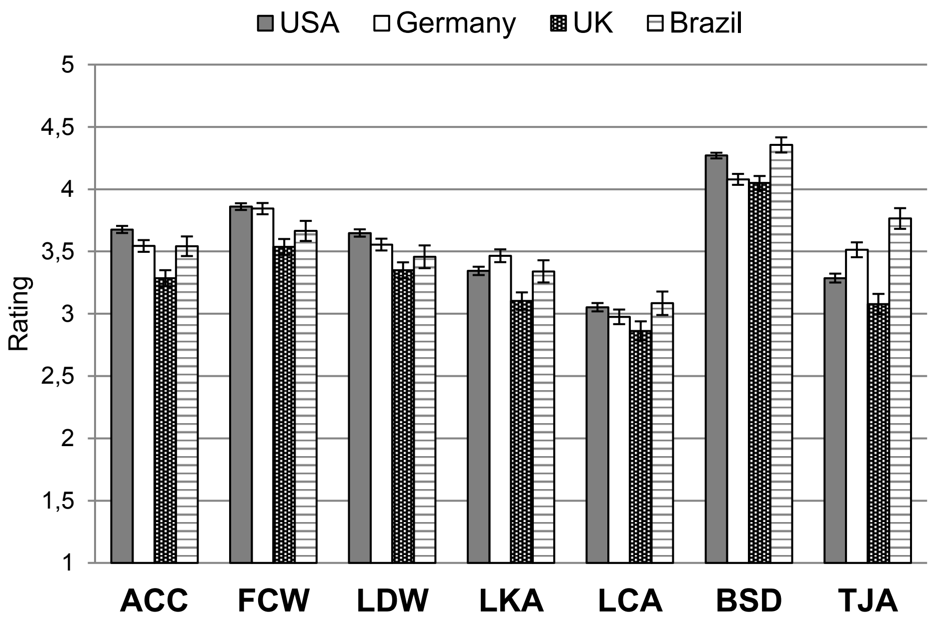
Lane departure warning versus traffic jam assist	$t(2264) = 5.72$, $p < .001$, $d = 0.17$
Lane keeping aid versus lane centering aid	$t(2080) = 8.36$, $p < .001$, $d = 0.26$
Lane keeping aid versus blind spot detection	$t(2582) = 27.94$, $p < .001$, $d = 0.78$
Lane keeping aid versus traffic jam assist	$t(2148) = 0.08$, $p = .940$, $d = 0.00$
Lane centering aid versus blind spot detection	$t(2351) = 37.93$, $p < .001$, $d = 1.11$
Lane centering aid versus traffic jam assist	$t(1972) = 8.38$, $p < .001$, $d = 0.27$
Blind spot detection versus traffic jam assist	$t(2446) = 26.06$, $p < .001$, $d = 0.75$

Table 26: Post hoc t-tests

Adaptive cruise control versus forward collision warning	$t(2376) = 1.61$, $p = .106$, $d = 0.05$
Adaptive cruise control versus lane departure warning	$t(2293) = 5.42$, $p < .001$, $d = 0.16$
Adaptive cruise control versus lane keeping aid	$t(2391) = 58.97$, $p < .001$, $d = 1.71$
Adaptive cruise control versus lane centering aid	$t(1977) = 13.75$, $p < .001$, $d = 0.44$
Adaptive cruise control versus blind spot detection	$t(2546) = 9.93$, $p < .001$, $d = 0.28$
Adaptive cruise control versus traffic jam assist	$t(2018) = 3.75$, $p < .001$, $d = 0.12$
Forward collision warning versus lane departure warning	$t(2278) = 4.60$, $p < .001$, $d = 0.14$

Forward collision warning versus lane keeping aid	$t(2390) = 55.73$, $p < .001$, $d = 1.61$
Forward collision warning versus lane centering aid	$t(1962) = 13.46$, $p < .001$, $d = 0.43$
Forward collision warning versus blind spot detection	$t(2519) = 12.02$, $p < .001$, $d = 0.34$
Forward collision warning versus traffic jam assist	$t(1999) = 1.14$, $p = .255$, $d = 0.04$
Lane departure warning versus lane keeping aid	$t(2296) = 49.63$, $p < .001$, $d = 1.47$
Lane departure warning versus lane centering aid	$t(1884) = 9.02$, $p < .001$, $d = 0.29$
Lane departure warning versus blind spot detection	$t(2438) = 15.12$, $p < .001$, $d = 0.43$
Lane departure warning versus traffic jam assist	$t(1936) = 2.38$, $p = .017$, $d = 0.08$ [adjusted critical $\alpha = .017$]
Lane keeping aid versus lane centering aid	$t(1996) = 33.72$, $p < .001$, $d = 1.07$
Lane keeping aid versus blind spot detection	$t(2540) = 73.13$, $p < .001$, $d = 2.05$
Lane keeping aid versus traffic jam assist	$t(2026) = 46.46$, $p < .001$, $d = 1.46$
Lane centering aid versus blind spot detection	$t(2120) = 23.50$, $p < .001$, $d = 0.72$
Lane centering aid versus traffic jam assist	$t(1700) = 10.58$, $p < .001$, $d = 0.36$
Blind spot detection versus traffic jam assist	$t(2137) = 11.53$, $p < .001$, $d = 0.35$

Figure 9 shows the importance ratings of all driver assistance systems with regard to the four main countries under investigation. Although there was a smaller sample size available now, the ratings for the driver assistance systems were very close to the overall sample. There seemed to be only a small impact with respect to the home country. There was a significant main effect for the impact of the driver assistance system with $F(6, 5004) = 81.27$, $p < .001$, and $\eta^2 = .09$. Thus, there was a significant difference between the subjective evaluations of different driver assistance systems' importance. The effect size was medium. This result was highly comparable to the effect discovered by the one-way ANOVA on driver assistance system importance. Thus, no further post hoc inferential statistics were done. There was a significant main effect of home country, with $F(3, 834) = 11.69$, $p < .001$, and $\eta^2 = .04$, showing a significant difference between the subjective evaluations in the countries under investigation for importance. The effect size was small. For the post hoc tests, adaptive cruise control was chosen as an example system. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 27 presents the post hoc t-tests. They showed some significant differences for adaptive cruise control. The effect sizes were small. The interaction effect of home country and driver assistance system was significant with $F(18, 5004) = 2.65$, $p < .001$, and $\eta^2 = .01$. Thus, an interaction between both factors existed, but with a small effect size. The interaction effect was disordinal. It was smaller than the effect sizes of the main effects.



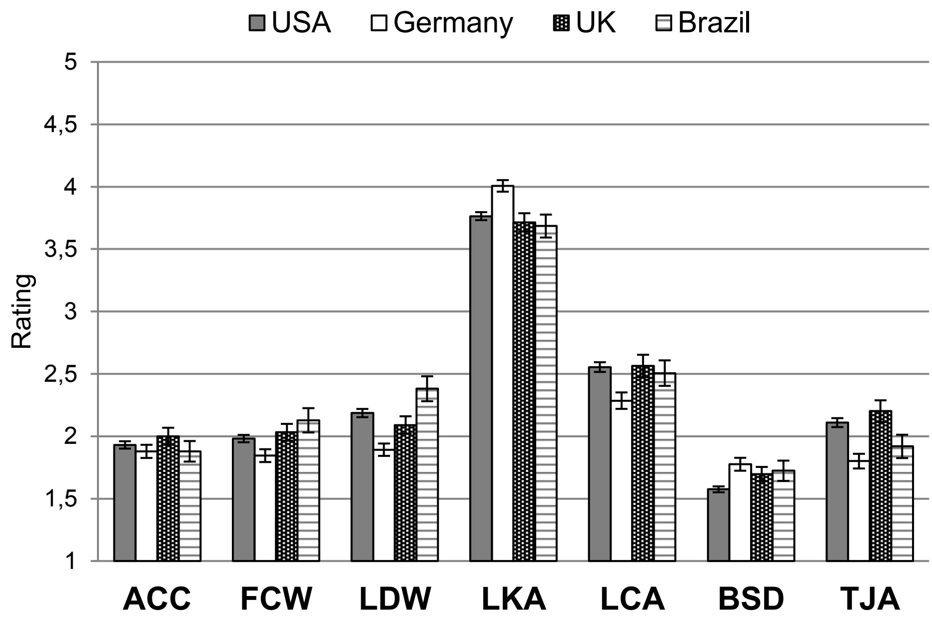
Legend: ACC: adaptive cruise control; FCW: forward collision warning; LDW: lane departure warning; LKA: lane keeping aid; LCA: lane centering aid; BSD: blind spot detection; TJA: traffic jam assist

Figure 9: Evaluation of driver assistance system importance with regard to home country [Mean + Standard Error]

Table 27: Post hoc t-tests

Brazil versus Germany	$t(330) = 0.02$, $p = .981$, $d = 0.00$
Brazil versus United Kingdom	$t(412) = 2.52$, $p = .012$, $d = 0.23$ [adjusted critical $\alpha = .013$]
Brazil versus USA	$t(240) = 1.61$, $p = .110$, $d = 0.12$
United Kingdom versus Germany	$t(601) = 3.24$, $p < .01$, $d = 0.24$ [$p = .001$]
United Kingdom versus USA	$t(430) = 5.55$, $p < .001$, $d = 0.35$
USA versus Germany	$t(825) = 2.41$, $p = .016$, $d = 0.13$ [adjusted critical $\alpha = .017$]

Figure 10 shows the annoyance ratings of all driver assistance systems with regard to the four countries under investigation. Although a smaller overall sample size was available now, the ratings for the driver assistance systems were very close to the overall sample. There seemed to be only a small impact of home country. There was a significant main effect for the driver assistance systems with $F(6, 3408) = 158.99$, $p < .001$, and $\eta^2 = .22$. Thus, there was a significant difference between the subjective evaluations of the driver assistance systems regarding annoyance. The effect size was big. This result was highly comparable with the effect discovered by the one-way ANOVA on driver assistance system annoyance. Thus, no further post hoc inferential statistics were done. There was no significant main effect of home country, with $F(3, 568) = 0.84$, $p = .474$, and $\eta^2 = .00$. The interaction effect of home country and driver assistance system was significant with $F(18, 3408) = 2.26$, $p < .01$, and $\eta^2 = .01$. Thus, an interaction existed between both factors, but only with a small effect size. The interaction effect was disordinal. Its effect size was smaller than the effect size of the significant main effect.



Legend: ACC: adaptive cruise control; FCW: forward collision warning; LDW: lane departure warning; LKA: lane keeping aid; LCA: lane centering aid; BSD: blind spot detection; TJA: traffic jam assist

Figure 10: Evaluation of driver assistance system annoyance with regard to home country [Mean + Standard Error]

Figure 11 shows the importance and annoyance ratings for a driver assistance system, comparing experienced versus unexperienced participants. As adaptive cruise control was the only system under investigation with a big subsample of experienced participants ($n = 1088$), the comparison only focused on this system. The experienced users seemed to rate the driver assistance system's importance slightly higher. The difference was significant, with $t(2138) = 6.00$, $p < .001$, and $d = 0.23$. Thus, the higher rating of the experienced participants for adaptive cruise control importance was significant, but the effect size was small. The difference for the annoyance rating was significant, with $t(2080) = 2.11$, $p < .05$, and $d = 0.08$. Thus, the slightly lower rating of the experienced participants for annoyance was also significantly different, but the effect size was meaningless and too small to be of interest.

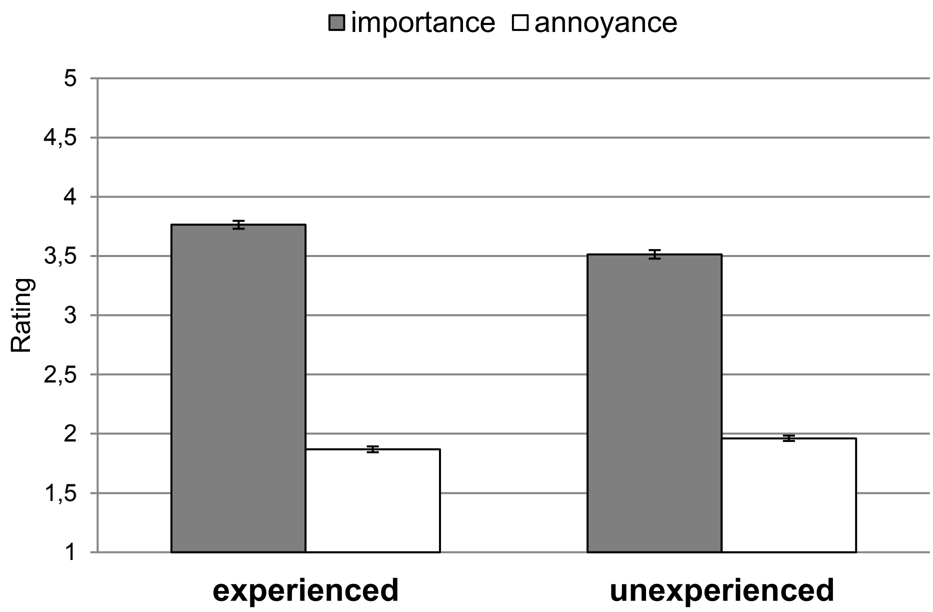


Figure 11: Evaluation of adaptive cruise control importance and annoyance with regard to system experience [Mean + Standard Error]

Figure 12 shows the importance and annoyance ratings of adaptive cruise control for males and females. Descriptively, there seemed to be no difference between the genders. There was neither a significant effect for importance ($t(591) = 1.62$, $p = .105$, $d = 0.08$) nor for annoyance ($t(548) = 0.51$, $p = .608$, $d = 0.03$). Thus, gender had no significant effect on both ratings.

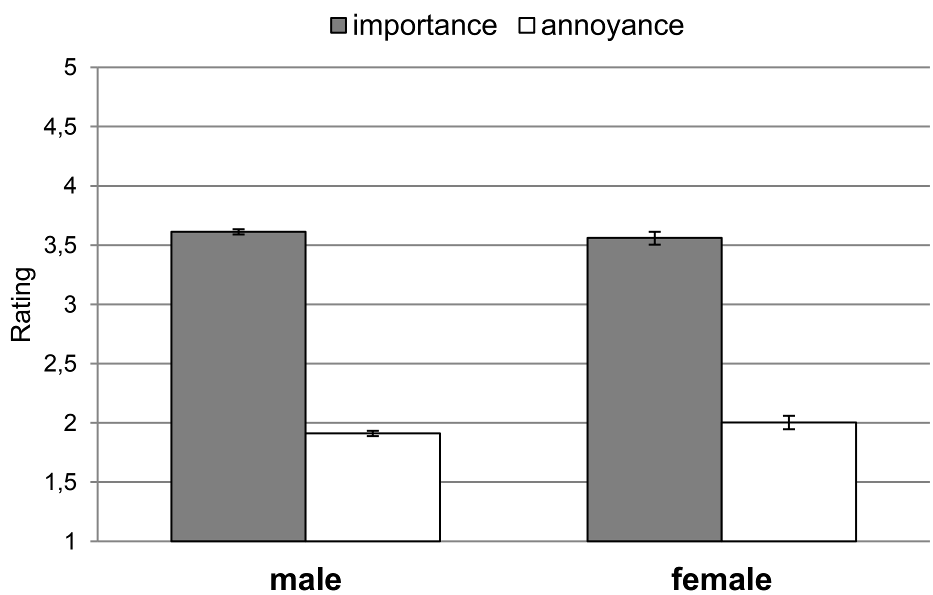


Figure 12: Evaluation of adaptive cruise control importance and annoyance with regard to gender [Mean + Standard Error]

Figure 13 shows the importance and annoyance ratings of adaptive cruise control as a function of five age groups. Descriptively, there seemed to be hardly any difference between the age groups, except for a slightly higher importance rating in the group over 60 years of age. There was neither a significant effect for importance ($F(4, 2934) = 2.27$, $p = .059$, $\eta^2 = .00$) nor for annoyance ($F(4, 2776) = 1.10$, $p = .355$, $\eta^2 = .00$). Thus, the age group had no significant effect on both ratings.

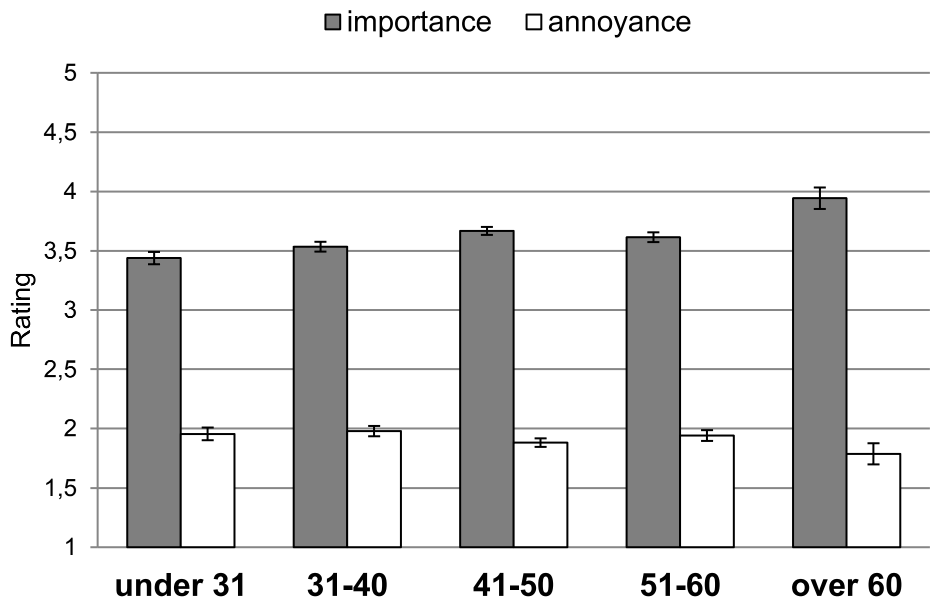


Figure 13: Evaluation of adaptive cruise control importance and annoyance with regard to age [Mean + Standard Error]

Figure 14 shows the importance and annoyance ratings of adaptive cruise control for the yearly mileage. Descriptively, there seemed to be no difference between the mileage groups. There was neither a significant effect for importance ($F(5, 2953) = 1.06$, $p = .381$, $\eta^2 = .00$) nor for annoyance ($F(5, 2792) = 0.68$, $p = .638$, $\eta^2 = .00$). Thus, the yearly mileage had no significant effect on both ratings.

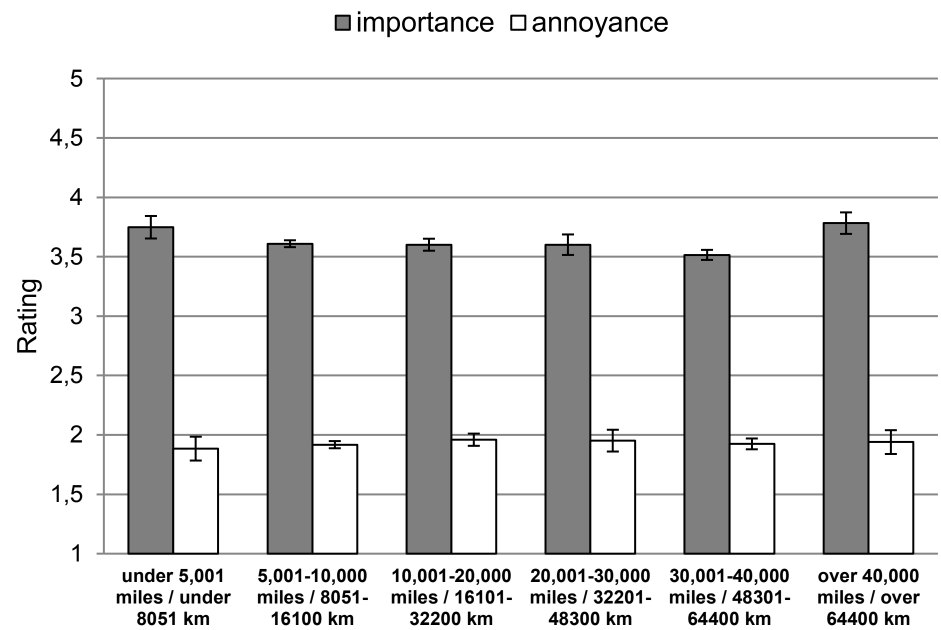


Figure 14: Evaluation of adaptive cruise control importance and annoyance with regard to mileage [Mean + Standard Error]

3.2.4 Discussion

Altogether, all presented systems were positively evaluated, especially the blind spot detection feature. Lane keeping aid was evaluated as the feature showing the highest potential for annoyance, probably because it actively interferes with lane keeping. Looking at the effects of demographic variables, there was hardly any effect of system experience on the rating, as shown for adaptive cruise control, the feature with the highest number of experienced participants. The effect of home country was small for importance and not significant for annoyance. There was no effect of gender, age, and yearly mileage on adaptive cruise control importance and annoyance. Even though lane keeping aid was rated most annoying, it was still rated as rather important.

The results indicated a high want for information and warning systems, especially blind spot detection was highly favored. This is in line with Wevers et al. (1999), Charles River Associates (1998), Mariani et al. (2000), and van Driel and van Arem (2005).

Adaptive cruise control was also positively evaluated in this study. Charles River Associates (1998) and Marchau et al. (2001) showed negative results regarding adaptive cruise control, which date back a bit and are not in line with the results of this survey. Chalmers (2001) conducted a study in which longitudinal control systems were better accepted. Blythe and Curtis (2004) and van Driel and van Arem (2005) had positive data on adaptive cruise control, which are primarily in line with this study. Piao et al. (2004) had results indicating that lane departure warning was rated much lower than adaptive cruise control. Lane departure warning was rated as well as adaptive cruise control in the survey presented here. According to Regan et al. (2002), participants liked the idea of lane departure warning. Wevers et al. (1999) demonstrated that people were indifferent to lateral support systems. They had a negative opinion of automatic interventions. Especially the high annoyance rating of lane keeping aid showed an example of this here. Mariani et al. (2000) demonstrated that there was more need for information and warnings than for driver assistance system action. This is probably also in line with how lane keeping aid was evaluated regarding annoyance. Furthermore, lane centering aid received a mediocre rating, being less important than lane keeping aid, but also less annoying. Perhaps because its intervention is not as sudden as the intervention caused by lane keeping aid. Traffic jam assist is essentially an extension of adaptive cruise control and lane keeping systems. Still, the rating was closer to adaptive cruise control. The positive evaluation of forward collision warning can possibly also be traced back to the fact that collision avoidance information was favored. This was shown by Wevers et al. (1999), Charles River Associates (1998), Mariani et al. (2000), Blythe and Curtis (2004), and van Driel and van Arem (2005). According to Planing (2014), people still desire to exert control while driving. The high importance and low annoyance ratings of blind spot detection are in line with this postulation, as this system does not actively intervene. Instead, there was a higher annoyance rating caused by lane keeping aid, which actively intervenes.

With regard to the comparison of driver assistance systems between different countries, there were differences found by Lindgren et al. (2008) and Marchau et al. (2001). This could not be confirmed for the study presented here. It might depend on the fact that other countries were compared than those being part of the survey. Lindgren et al. (2008) compared China with Sweden. Marchau et al. (2001) employed samples from Greece, Czech, Italy, Germany, the Netherlands, and Finland. Sommer's (2013) and Kyriakidis et al.'s (2014) surveys showed no differences between countries with respect to the topics covered here, being in line with the results presented. Sommer (2013) had samples from Germany, China, Japan, and the USA. Kyriakidis et al. (2014) compared 40 different countries.

Based on his research, Planing (2014) stated that prior experience with driver assistance systems improves their acceptance. Haupt et al. (2015) presented the way experience changes the perception of driver assistance systems as well. In their study, the systems were better evaluated having experience with them, which was not the case here with regard to adaptive cruise control. At least the effect size was only small. The rating of the experienced participants for the system's importance was slightly higher. Perhaps those who deem it as important are actually the ones who use it.

Gender was another factor that might have an influence on driver assistance systems' evaluation. Results from Rienstra and Rietveld (1996), Marchau et al. (2001), and

Chalmers (2001) showed a more positive rating of driver assistance systems by women compared to men. Planing (2014) came to the conclusion that women would rather buy such systems compared to the purchase interest of men. Blythe and Curtis (2004) had the opposite result: Driver assistance systems were more accepted by men. In case of a study from Piao et al. (2004), men liked adaptive cruise control best and women intelligent speed adaptation. Missel (2014), Casley et al. (2013), and Payre et al. (2014) presented results indicating a higher preference of driver assistance systems by men compared to women. Those results could not be confirmed by the data in this study. There was no difference between men and women for the subjective evaluation of adaptive cruise control. Instead, the results are in line with the studies of Haupt et al. (2015) and Mariani et al. (2000).

For older drivers, compared to younger ones, there was a low acceptance for driver assistance as reported by Czaja and Sharit (1998), Trübswetter and Bengler (2013), and Missel (2014). Planing (2014) found that the older people were, the less likely they were to buy driver assistance systems. More positive results, indicating a higher acceptance from older drivers, came from Marchau et al. (2001), Chalmers (2001), Piao et. al. (2004), Adell (2009), and Haupt et al. (2015). Those results could not be confirmed by the data in this study, as there were no differences between the age groups. Still, the age range that was gathered in the study here was probably not sufficient to really answer this research question. There were probably too many people missing in the higher age ranges of the 60+ generation.

Another factor was the influence of yearly mileage. Marchau et al. (2001) showed in their survey on driver assistance system preference a higher attractiveness of the systems for drivers with a lower mileage than for those with a higher mileage. There was no effect of this factor in the study presented here.

There were interaction effects existing with respect to the impact of both home country and driver assistance systems. The interaction effects were disordinal. Thus, the global interpretation of the main effects is problematic. Still, the effect sizes of the interactions were only small. The results have to be handled with care, but the conclusions drawn here for the hypotheses are still regarded as valid. The results have to be discussed with regard to the sample characteristics in detail in section 4.

3.3 Subjective Evaluation of Parking Driver Assistance Systems – Survey

3.3.1 Research Questions

The first research question asked how driver assistance systems are evaluated subjectively. It was assumed that there are differences with regard to the usefulness of the systems under investigation. This study could show the difference in usage frequency of different parking aids as well as the perceived usefulness of advanced parking automation systems. The literature reviews on subjective driver assistance system evaluation did not reveal preference data for any kind of system for parking. All presented parking driver assistance systems evaluated here with regard to their usefulness have a high degree of system control. Still, as they differ with regard to the actual kind of automation, differences were expected, without stating a specific hypothesis.

The second research question asked for the impact of demographic factors on the subjective evaluation of driver assistance systems. The four countries with the most participants, namely the USA, Germany, the United Kingdom, and Brazil, were used in order to quantitatively compare the subjective evaluations of the driver assistance systems under investigation. Based on the available literature, though not clear-cut and not focusing on parking assistance, it was assumed that the home country has an effect on the parking driver assistance systems' evaluation. It was specifically hypothesized in the third research question for the USA, a country with a lot of available space, to have less need for parallel parking compared to the other three countries. Based on this and the fact that parking spaces are on the average larger, it was furthermore hypothesized that advanced active parking aids are not evaluated as being as useful by US participants compared to the other three countries. Possibly the proposed effect is offset by larger cars requiring larger parking spaces.

Further demographic factors that were available and used to evaluate their impact on driver assistance systems include age group, gender, system experience, and yearly mileage. At least for semi-automated parallel/perpendicular parking, there was a sufficient number of experienced users available. It was assumed that there is a difference between experienced and unexperienced users of this system. Based on the literature, experienced users were supposed to have a higher rating of semi-automated parallel/perpendicular parking. It was expected that there is an impact of age group and gender. This difference might be in any direction, as there were contradicting results available in the literature. The yearly mileage was also supposed to have an influence. The higher it is, the less positively people were supposed to evaluate the presented systems.

3.3.2 Method

A standardised questionnaire was distributed via an internal web survey to employees of an international automotive manufacturer in order to get a quantitative measure on items evaluating the usage frequency and usefulness of parking driver assistance systems. Also, the frequency of parking behaviour patterns was asked for. The participants were part of a global recipient list for internal web surveys. The participation was voluntary. The questionnaire was in English. Items were derived based on group and internal expert discussions. Table 28 shows the included parking driver assistance systems. The explanations used were basically the same as in section 1.2.2. Up to and including semi-automated parallel/perpendicular parking, the parking driver assistance systems were already available in series production vehicles. Thus, it made sense to ask for their usage frequency. The active parking driver assistance systems, which included semi-automated parallel/perpendicular parking up to the valet parking without a driver in the car, were evaluated with regard to their perceived usefulness. Except for semi-automated parallel/perpendicular parking, they were hardly available. Table 29 lists the survey items.

Table 28: Included parking driver assistance systems (for more details, see section 1.2.2)

- Visual parking aid
- Acoustic parking aid
- Rear view camera
- Semi-automated parallel/perpendicular parking
- Fully assisted parking aid
- Remote parking aid
- Valet parking (with driver in car)
- Valet parking (without driver in car)

Table 29: Survey items

1. How often do you park your vehicle in a 7-day week? Park is defined as when you stop and physically exit the vehicle
2. How often do you park in relatively small parking spaces?
3. Please indicate the percentage of how often you park parallel and perpendicular?
4. How often do you use the visual/acoustic parking aid? It indicates the distance to adjacent vehicles via a sound signal
5. How often do you use the rear-view camera? It shows the area behind the vehicle while parking
6. How often do you use the semi-automated parallel/perpendicular parking aid? It is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel to park the vehicle. The driver has to brake and accelerate

7.	The semi-automated parallel/perpendicular parking aid is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel to park the vehicle. The driver has to brake and accelerate. How useful is it?
8.	The fully assisted parking aid is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel and actuates the brake and accelerator to park the car. The driver still remains in the vehicle during the parking manoeuvre. How useful is it?
9.	The valet parking aid feature is a function that automatically drives the vehicle from the beginning of a parking lot to one of the available parking spaces. Afterwards, the vehicle can also pull out and drive back to the entrance of the parking lot where the driver takes over again. The driver remains in the vehicle. How useful is it?
10.	Now imagine the same function, but the driver exits the vehicle before the system takes over. The vehicle drives itself from the beginning of the parking lot and back without a driver on board. Afterwards, the vehicle can also pull out and drive back to the entrance of the parking lot where the driver takes over again. How useful is it?
11.	The remote parking aid is a function that enables the driver to exit the vehicle and to start the perpendicular parking manoeuvre from outside. Pulling out from tight parking spaces is also offered with this feature. How useful is it?

Tables 30 until 32 list the ad-hoc scales used for the subjective evaluation. They also comprise the numeric code used for the respective rating scale in brackets. It was possible to not give a rating in case people did not feel as they could judge it, or in case they simply did not have a feature. The questionnaire was pre-checked for comprehensibility by an internal group consisting of human factors experts who were asked for their feedback. Some non-experts were asked to complete the questionnaire as well and provide their feedback in order to improve comprehensibility. Statistical analysis was done using SPSS version 23. Graphs were created using MS Excel 2010. The Psychometrica website (Lenhard & Lenhard, 2014) was used to calculate effect sizes according to Cohen (1988).

Table 30: Frequency rating (items 1 and 3-6)

• Over 30 times per week [6]	• 6 – 10 times per week [3]
• 21 – 30 times per week [5]	• 1 – 5 times per week [2]
• 11 – 20 times per week [4]	• Never [1]

Table 31: Frequency rating (for parking in small parking spaces only, see item 2)

• Daily [7] • 2-3 times per week [6] • Weekly [5] • Monthly [4]	• Quarterly [3] • Yearly [2] • Never [1]

Table 32: Usefulness rating (items 7-11)

• Very useful [5] • Somewhat useful [4] • Neither useful nor not useful [3]	• Not very useful [2] • Not at all useful [1]

Altogether, 2840 participants answered the survey. Taking only into account countries with at least 25 participants, finally there were 2743 remaining. Tables 33 until 36 show the sample demographics. Not all participants stated their gender, age group, or yearly mileage. All participants had a valid driver's licence and were driving on a regular basis. As the independent variable, the home country, could not be randomly assigned to the participants in this study, the design was quasi-experimental (e.g. Bortz & Döring, 2006). The same applies to the other demographic variables. The comparison between home countries took place again, as in Study 2, between Germany, the USA, the United Kingdom, and Brazil. These were the same countries as in Study 2, but with smaller sample sizes.

Table 33: Number of participants per home country

Home country	***n***
Belgium	32
Germany	537
Spain	45
United Kingdom	326
Australia	134
China	26
India	60
South Africa	27

Canada	71
Mexico	81
United States	1252
Brazil	152

Table 34: Gender distribution

Gender	***n***
Male	2283
Female	421
Do not wish to answer	39

Table 35: Age distribution

Age	***n***
Under 31	438
31-40	523
41-50	919
51-60	685
Over 60	142
Do not wish to answer	36

Table 36: Yearly mileage

How many miles/kilometers per year do you drive?	*n*
Under 3,001 miles / under 4829 km	43
3,001-10,000 miles / 4829-16094 km	507
10,001-20,000 miles / 16095-32200 km	1263
20,001-30,000 miles / 32201-48300 km	599
30,001-40,000 miles / 48301-64400 km	195
Over 40,000 miles / over 64400 km	119
Do not wish to answer	17

Figure 15 shows the frequency of parking a vehicle in a 7-day week in the employed sample. The peak was at 11-20 times per week. Only a minority parked less often.

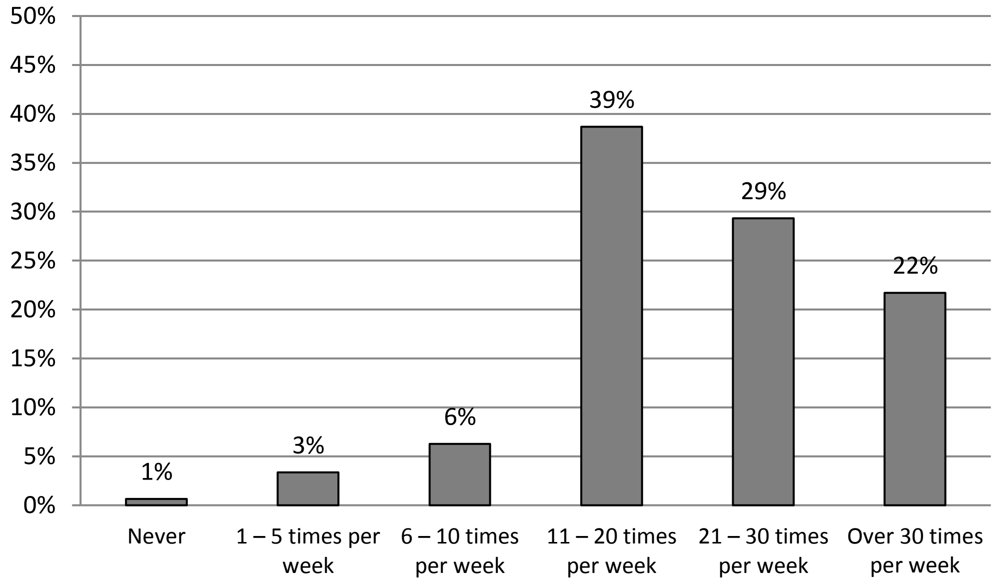


Figure 15: How often do you park your vehicle in a 7-day week? Park is defined as when you stop and physically exit the vehicle [%]

Figure 16 shows the frequency of parking in a relatively small parking space in the employed sample. "Daily" was the category chosen most often. Only a minority indicated parking in small parking spaces on an occasional basis.

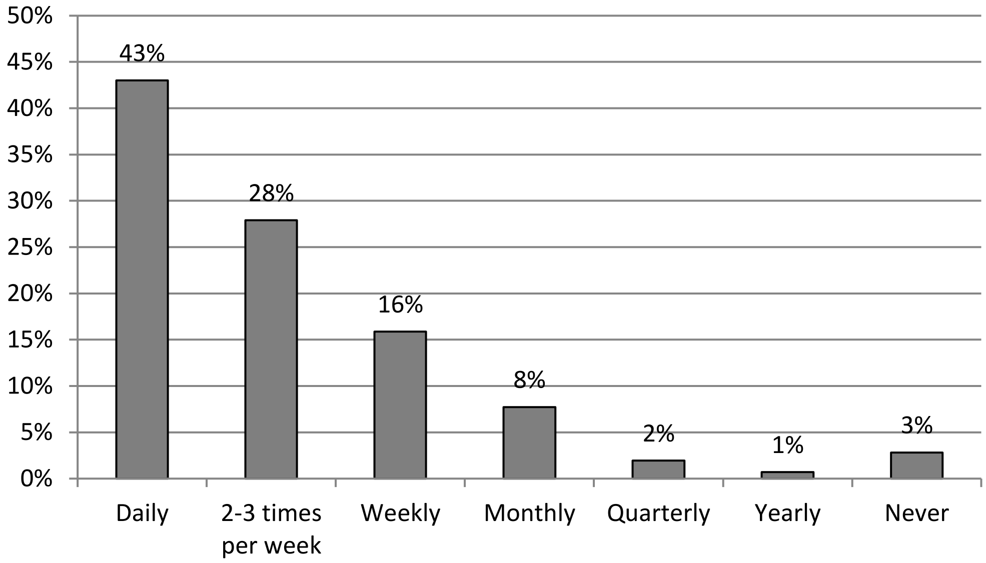


Figure 16: How often do you park in relatively small parking spaces? [%]

Figure 17 shows the frequency of parking in a parallel versus a perpendicular parking space. The answers were supposed to add up to 100% altogether. Perpendicular parking was more often the case than parallel.

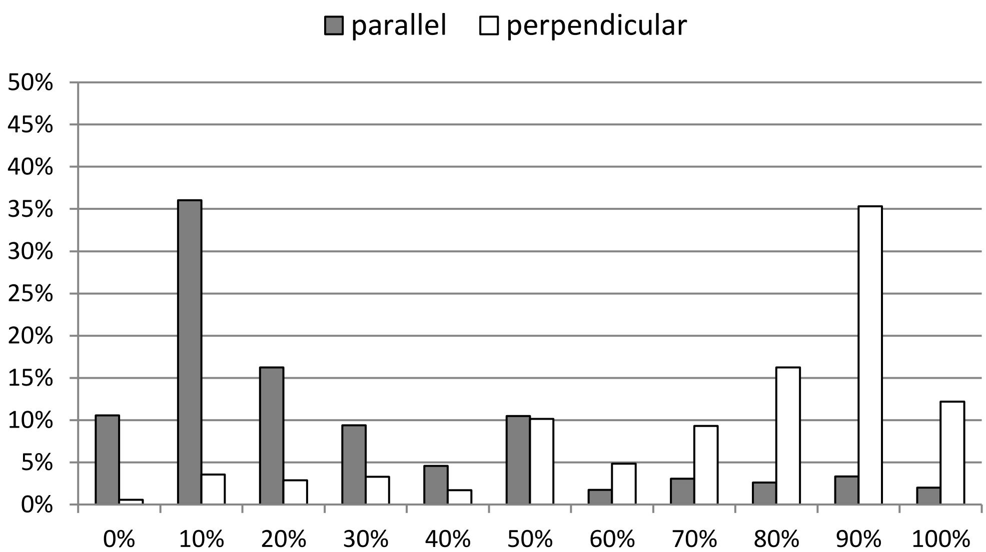


Figure 17: Parallel and perpendicular parking frequency [%]

Not all variables showed a normal distribution according to the Kolmogorov-Smirnov Normality Test. Furthermore, Levene's Test for the test on equal variances showed that this precondition was also not the case for all comparisons. Still, ANOVAs and other parametric statistical tests were used, as they are quite robust with regard to missing preconditions. For dependent samples, repeated measurement ANOVAs and paired *t*-tests were done. First of all, an ANOVA was conducted to check if there is a main effect in general. *T*-tests assuming no equal variances were done to check for significant differences between pairs. Semi-automated parallel/perpendicular parking was used as an example for the post hoc comparisons regarding home country. For all other demographic variables, also the rating of semi-automated parallel/perpendicular parking was used as an example driver assistance system to analyse the impact. Only two-tailed tests were conducted in order to have a conservative test of significance. A Bonferroni-Holm correction for the post hoc *t*-tests was applied (Holm, 1979). This way, the issue of potential α-error inflation (e.g. Zöfel, 2003) could be minimised. As this was a convenience sample, and it was not possible to determine the number of participants in advance, no a priori test power calculations according to Faul et al. (2009) were done. Post hoc power calculations were not done either, as they directly depend on the calculated *p*-value. Low *p*-values correspond to high power and vice versa. Thus, the post hoc power does not change the interpretation of the data (Hoenig & Heisey, 2001).

The questionnaire used is found in the Appendix. It is a transcription, as the original was distributed as a MS SharePoint website.

3.3.3 Results

Figure 18 shows the frequency for parking a vehicle in a 7-day week, comparing the four countries Germany, the USA, the United Kingdom, and Brazil. The ratings were rather high, thus comparable to Figure 15. The USA showed the highest rating for this item. The main effect of home country was significant with $F(3, 2263) = 50.40$, $p < .001$, and $\eta^2 = .06$, which can be considered a medium effect size. Thus, there was a significant difference between the countries with regard to the question how often people park in a 7-day week. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest *p*-value. The *p*-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 37 presents the post hoc *t*-tests. They showed significant differences between almost all comparisons. Medium effect sizes were found only for the comparisons of the USA versus Brazil and the USA versus Germany.

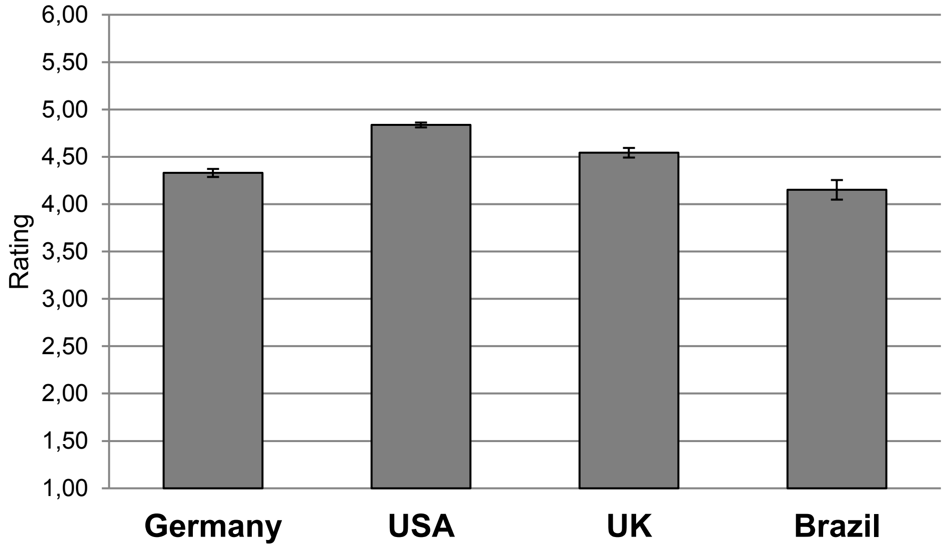


Figure 18: How often do you park your vehicle in a 7-day week? – compared by home country [Mean + Standard Error]

Table 37: Post hoc t-tests

Brazil versus Germany	$t(204) = 1.59$, $p = .112$, $d = 0.15$
Brazil versus United Kingdom	$t(226) = 3.40$, $p = .001$, $d = 0.33$ [adjusted critical $\alpha = .017$]
Brazil versus USA	$t(170) = 6.43$, $p < .001$, $d = 0.55$
United Kingdom versus Germany	$t(724) = 3.22$, $p = .001$, $d = 0.23$ [adjusted critical $\alpha = .025$]
United Kingdom versus USA	$t(505) = 5.15$, $p < .001$, $d = 0.32$
USA versus Germany	$t(947) = 10.19$, $p < .001$, $d = 0.53$

Figure 19 shows the frequency of parking in relatively small parking spaces for the four main countries. The ratings were high for all. The main effect of home country was significant with $F(3, 2263) = 29.11$, $p < .001$, and $\eta^2 = .04$, which was only a small effect size. Thus, there was a significant difference between the countries on the question how often people park in small parking spaces. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 38 shows the post hoc *t*-tests. Most of them were significant. The only medium effect size existed for the United Kingdom versus the USA.

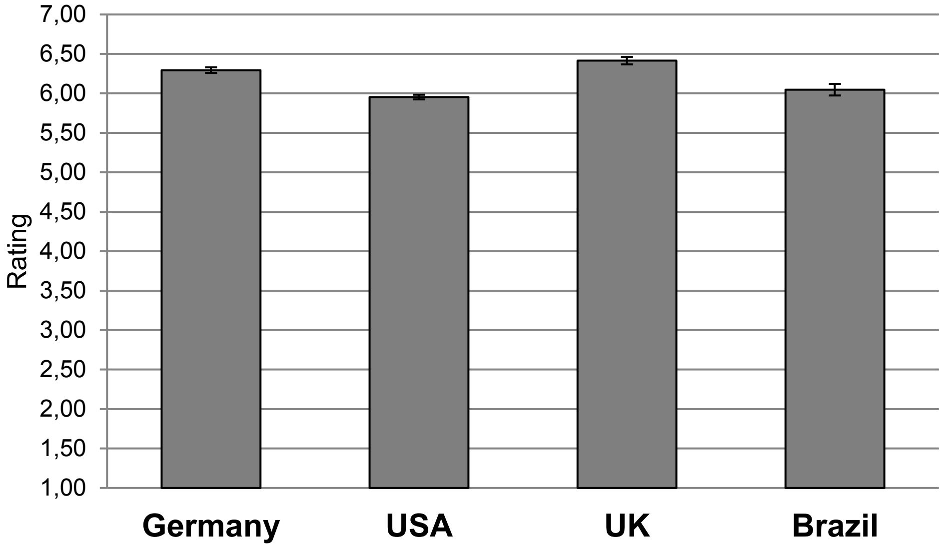


Figure 19: How often do you park in relatively small parking spaces? – compared by home country [Mean + Standard Error]

Table 38: Post hoc t-tests

Brazil versus Germany	$t(231) = 3.04, p < .01, d = 0.28$ [$p = .003$]
Brazil versus United Kingdom	$t(275) = 4.25, p < .001, d = 0.42$
Brazil versus USA	$t(202) = 1.18, p = .238, d = 0.10$
United Kingdom versus Germany	$t(692) = 2.03, p = .042, d = 0.14$ [adjusted critical $\alpha = .025$]
United Kingdom versus USA	$t(610) = 8.43, p < .001, d = 0.52$
USA versus Germany	$t(1226) = 7.30, p < .001, d = 0.38$

Figure 20 shows the frequency of parking in parallel versus perpendicular parking spaces for the four main countries. Perpendicular parking took place most often, but was far more often the case for the USA compared to the other three countries. The main effect of home country was significant with $F(3, 2263) = 147.12$, $p < .001$, and $\eta^2 = .16$, which was a big effect size. Thus, there was a significant difference on parking frequency regarding the different home countries. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 39 shows the post hoc t-tests. Most of them were significant. The only medium or high effect sizes regarded the USA versus all other countries, confirming the more prevalent perpendicular parking in this country.

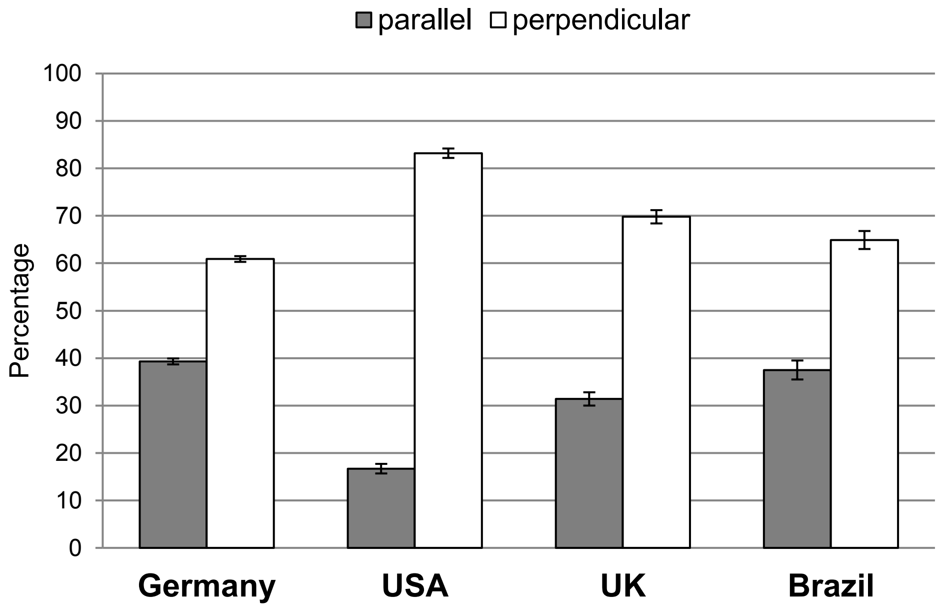
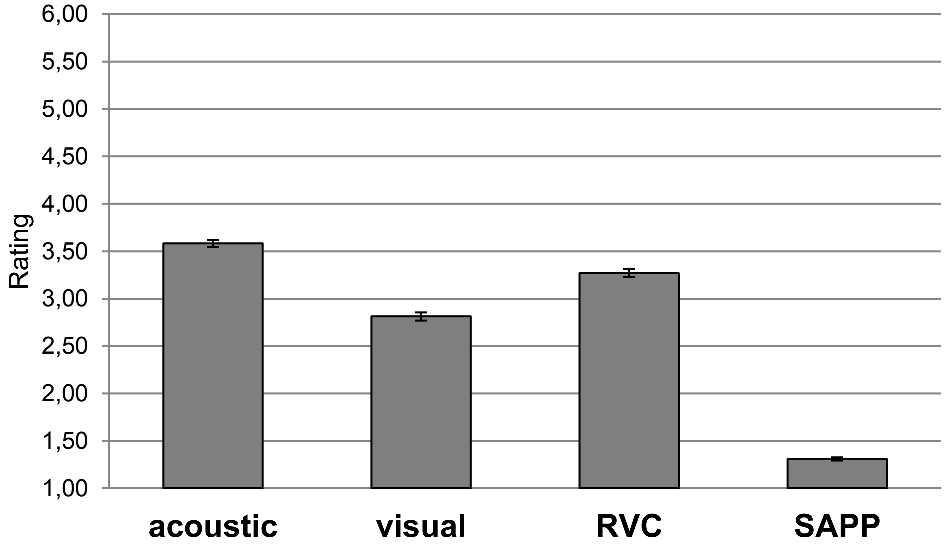


Figure 20: Parallel and perpendicular parking frequency in % – compared by home country [Mean + Standard Error]

Table 39: Post hoc t-tests

Brazil versus Germany	$t(235) = 0.82$, $p = .415$, $d = 0.08$
Brazil versus United Kingdom	$t(301) = 2.54$, $p = .012$, $d = 0.25$ [adjusted critical $\alpha = .025$]
Brazil versus USA	$t(182) = 10.03$, $p < .001$, $d = 0.86$
United Kingdom versus Germany	$t(652) = 4.64$, $p < .001$, $d = 0.33$
United Kingdom versus USA	$t(464) = 9.68$, $p < .001$, $d = 0.60$
USA versus Germany	$t(958) = 19.04$, $p < .001$, $d = 0.98$

Figure 21 shows results for the parking driver assistance system usage frequency. This only applied to people who actually had these systems available. Altogether the ratings of usage frequency were moderate, with the exception of semi-automated parallel/perpendicular parking, which was seldom used. The main effect was significant, with $F(3, 3498) = 658{,}78$, $p < .001$, and $\eta^2 = .36$, which was a big effect size. Thus, there was a significant difference between the usage frequencies of the different parking aid systems. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 40 shows the post hoc t-tests. All of them were significant. Medium to big effect sizes were found for acoustic versus visual parking aids and for semi-automated parallel/perpendicular parking versus all other parking aids. Thus, the post hoc tests confirmed the usage frequency difference between semi-automated parallel/perpendicular parking and the more often used other parking driver assistance systems.



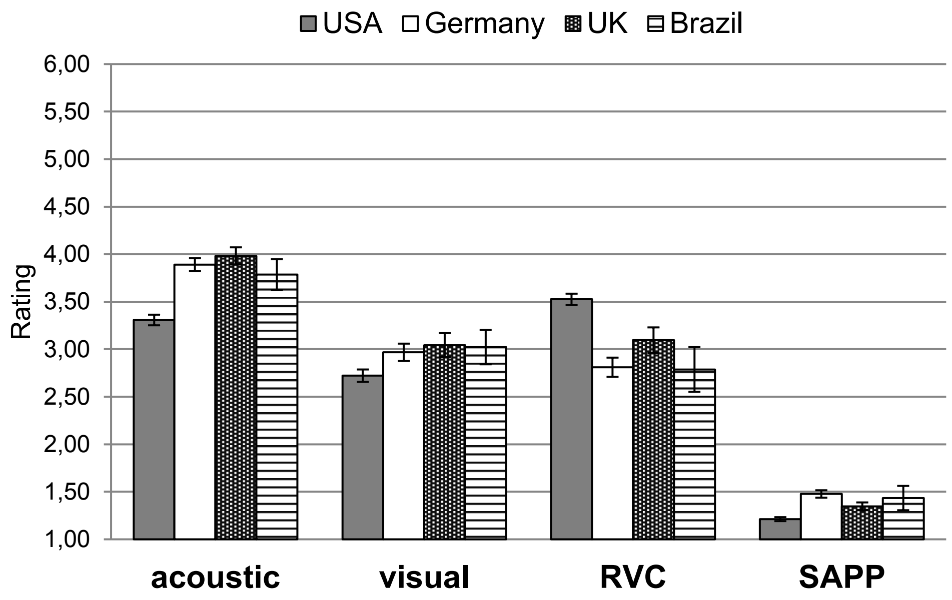
Legend: RVC: rear view camera; SAPP: semi-automated parallel/perpendicular parking

Figure 21: Parking aid usage frequency [Mean + Standard Error]

Table 40: Post hoc t-tests

Acoustic versus visual	$t(1613) = 17.45, p < .001, d = 0.61$
Acoustic versus rear view	$t(1588) = 4.24, p < .001, d = 0.15$
Acoustic versus semi-automated parallel/perpendicular parking	$t(1307) = 44.09, p < .001, d = 1.72$
Visual versus rear view camera	$t(1435) = 12.68, p < .001, d = 0.47$
Visual versus semi-automated parallel/perpendicular parking	$t(1245) = 27.57, p < .001, d = 1.10$
Rear view camera versus semi-automated parallel/perpendicular parking	$t(1220) = 34.33, p < .001, d = 1.39$

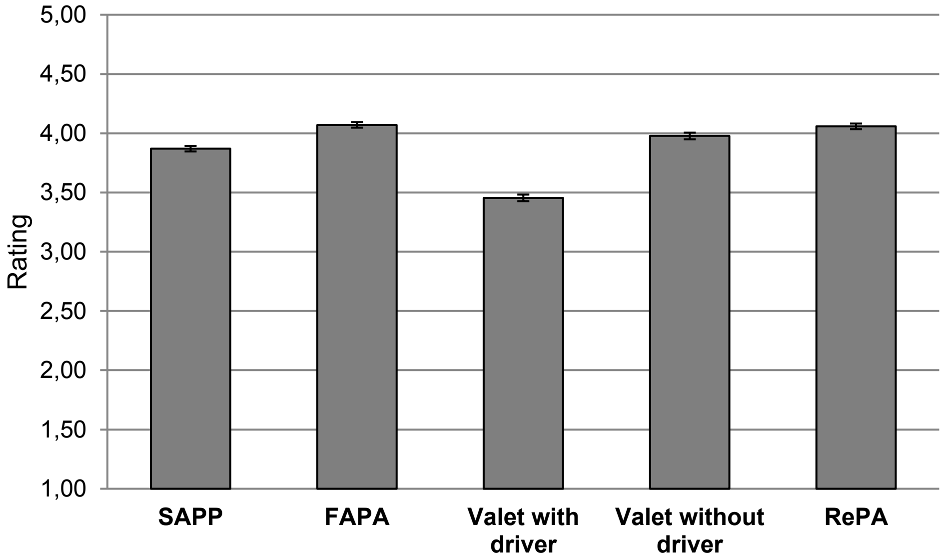
Figure 22 shows the parking driver assistance system usage frequency in the main four countries under investigation. Descriptively, despite a smaller overall sample size, the pattern of results for the evaluation of the parking driver assistance systems was comparable to the overall sample in Figure 21. The impact of home country did not look big. The main effect of driver assistance system was significant, with $F(3, 2883) = 294.05$, $p < .001$, and $\eta^2 = .23$. Thus, there was a significant difference between the usage frequencies of the parking aid systems. The effect size was big. This result was highly comparable to the effect discovered by the one-way ANOVA on parking driver assistance system usage frequency. Thus, no further post hoc inferential statistics were done. The main effect of home country was not significant, with $F(3, 961) = 0.87$, $p = .457$, and $\eta^2 = .00$. Thus, there was no influence of home country on the ratings in this case. The interaction effect between both factors was significant, with $F(9, 2883) = 14.58$, $p < .001$, and $\eta^2 = .04$, which was a small effect size. Possibly the interaction can be traced back to the fact that the rear view camera was used more often than the other parking aids by participants from the USA. The interaction effect was disordinal. Still, it was only small.



Legend: RVC: rear view camera; SAPP: semi-automated parallel/perpendicular parking

Figure 22: Parking aid usage frequency – by home country [Mean + Standard Error]

Figure 23 shows the usefulness rating of the parking driver assistance systems under investigation. Descriptively, the ratings were moderate to high. The valet parking system with the driver in the vehicle was rated least useful. The main effect was significant, with $F(4, 7680) = 196.25$, $p < .001$, and $\eta^2 = .09$. Thus, there was a significant difference between the subjective evaluations of the parking driver assistance system usefulness. The effect size was medium. As altogether 10 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 10 comparisons, .05 divided by 10 is .005. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. Table 41 shows the post hoc comparisons. Most of them were significant. Medium effect sizes were seen in the comparison between valet with driver in the vehicle versus fully assisted parking aid, remote parking aid, and valet without driver in the vehicle. This supported the observation of a less positively rated valet parking system with the driver still remaining in the car.



Legend: SAPP: semi-automated parallel/perpendicular parking; FAPA: fully assisted parking aid; RePA: remote parking aid

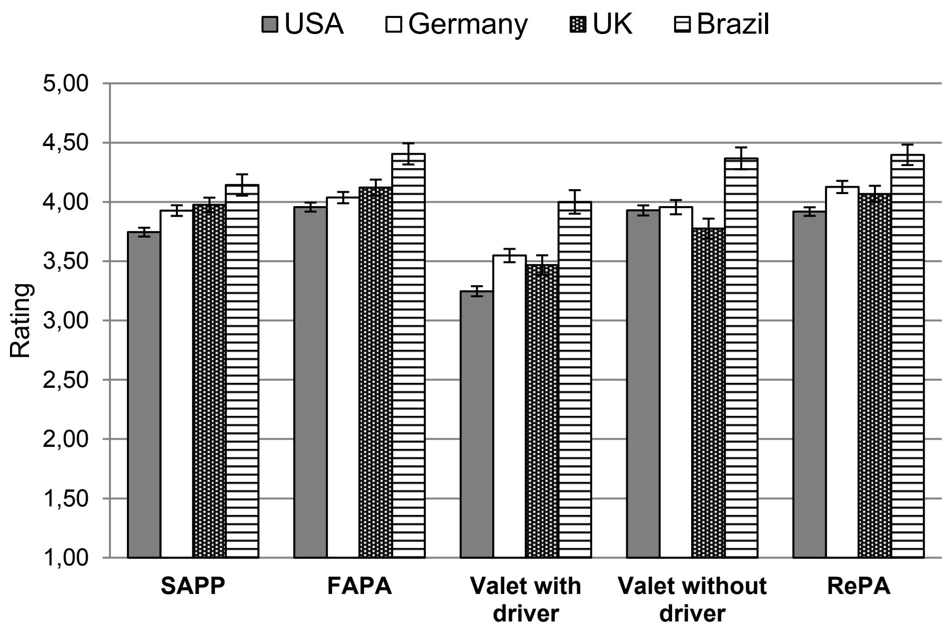
Figure 23: Evaluation of parking system usefulness [Mean + Standard Error]

Table 41: Post hoc t-tests

Semi-automated parallel/perpendicular parking versus fully assisted parking aid	$t(2139) = 11.40$, $p < .001$, $d = 0.35$
Semi-automated parallel/perpendicular parking versus valet with driver	$t(2075) = 15.02$, $p < .001$, $d = 0.47$
Semi-automated parallel/perpendicular parking versus valet without driver	$t(2077) = 4.26$, $p < .001$, $d = 0.13$
Semi-automated parallel/perpendicular parking versus remote parking aid	$t(2156) = 8.03$, $p < .001$, $d = 0.25$
Fully assisted parking aid versus valet with driver	$t(2022) = 24.44$, $p < .001$, $d = 0.77$
Fully assisted parking aid versus valet without driver	$t(2020) = 2.53$, $p = .012$, $d = 0.08$ [adjusted critical $\alpha = .025$]
Fully assisted parking aid versus remote parking aid	$t(2079) = 0.52$, $p = .602$, $d = 0.02$

Valet with driver versus valet without driver	$t(2171) = 20.30$, $p < .001$, $d = 0.62$
Valet with driver versus remote parking aid	$t(2167) = 24.32$, $p < .001$, $d = 0.74$
Valet without driver versus remote parking aid	$t(2208) = 4.42$, $p < .001$, $d = 0.13$

Figure 24 shows the usefulness ratings of the parking driver assistance systems and the impact of the main four countries. Descriptively, despite a smaller overall sample size, the pattern of results for the evaluation of the parking driver assistance systems was comparable to the overall sample in Figure 23. There did not seem to be a big influence of home country. The rating for Brazil was, on average, higher and the rating from US participants lower most of the time. The impact of driver assistance system was significant with $F(4, 7536) = 85.90$, $p < .001$, and $\eta^2 = .04$. Thus, there was a significant difference between the driver assistance systems regarding their subjective evaluation, but with a small effect size. This result was similar to the effect discovered by the one-way ANOVA on the systems' usefulness. Thus, no further post hoc inferential statistics were done. The factor home country was significant with $F(3, 1884) = 9.38$, $p < .001$, and $\eta^2 = .02$. This means that the difference between the countries regarding driver assistance system evaluation was significant. The effect had a small size. There was a significant interaction effect with $F(12, 7536) = 2.88$, $p < .01$, and $\eta^2 = .01$. This effect size was small. The interaction was disordinal. The significant main effects had slightly higher effect sizes. One driver assistance system was chosen to serve as a specific example for parking. Looking at the post hoc comparisons for the system semi-automated parallel/perpendicular parking, there were the following significant differences between the countries in Table 42. As altogether 6 post hoc tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 6 comparisons, .05 divided by 6 is .008. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. The significant differences between the USA and the other countries yielded only small effect sizes.



Legend: SAPP: semi-automated parallel/perpendicular parking; FAPA: fully assisted parking aid; RePA: remote parking aid

Figure 24: Evaluation of parking system usefulness – by home country [Mean + Standard Error]

Table 42: Post hoc t-tests

Brazil versus Germany	$t(192) = 2.15$, $p = .033$, $d = 0.22$ [adjusted critical $\alpha = .017$]
Brazil versus United Kingdom	$t(244) = 1.54$, $p = .124$, $d = 0.17$
Brazil versus USA	$t(170) = 4.09$, $p < .001$, $d = 0.39$
United Kingdom versus Germany	$t(568) = 0.64$, $p = .525$, $d = 0.05$
United Kingdom versus USA	$t(504) = 3.21$, $p = .001$, $d = 0.22$ [adjusted critical $\alpha = .010$]
USA versus Germany	$t(1128) = 3.12$, $p = .002$, $d = 0.17$ [adjusted critical $\alpha = .013$]

Figure 25 shows the rating of semi-automated parallel/perpendicular parking usefulness by users versus non-users, this means experienced versus unexperienced participants. Semi-automated parallel/perpendicular parking had a high number of experienced users ($n = 1120$). Descriptively, there was hardly any difference. There was no significant effect comparing both groups, with $t(225) = 1.42$, $p = .156$, and $d = 0.06$. Thus, the experience had no significant effect on the evaluations.

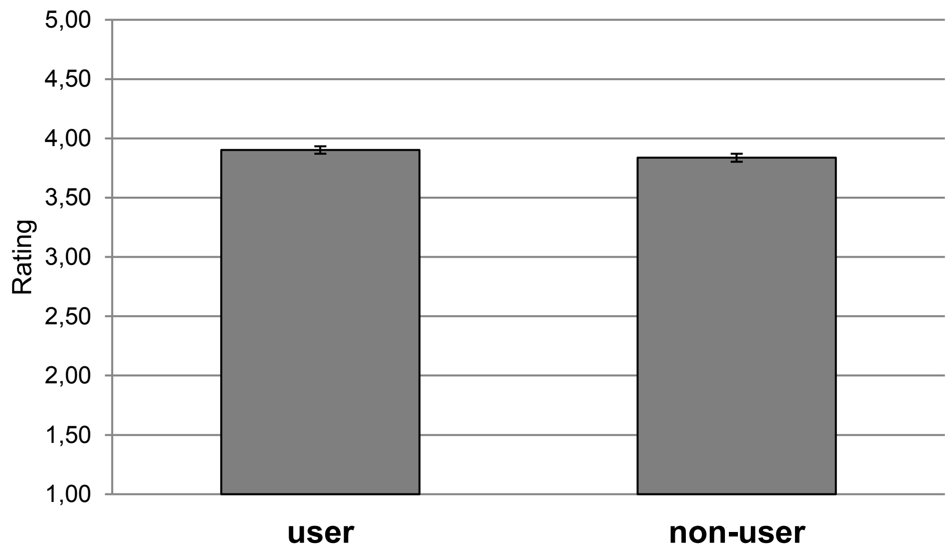


Figure 25: Evaluation of semi-automated parallel/perpendicular parking usefulness with regard to system usage [Mean + Standard Error]

Figure 26 shows the rating of semi-automated parallel/perpendicular parking usefulness comparing male and female participants. Descriptively, there was no difference. There was no significant effect comparing both groups, with $t(453) = 0.40$, $p = .693$, and $d = 0.02$. Thus, the gender had no significant effect on the evaluations.

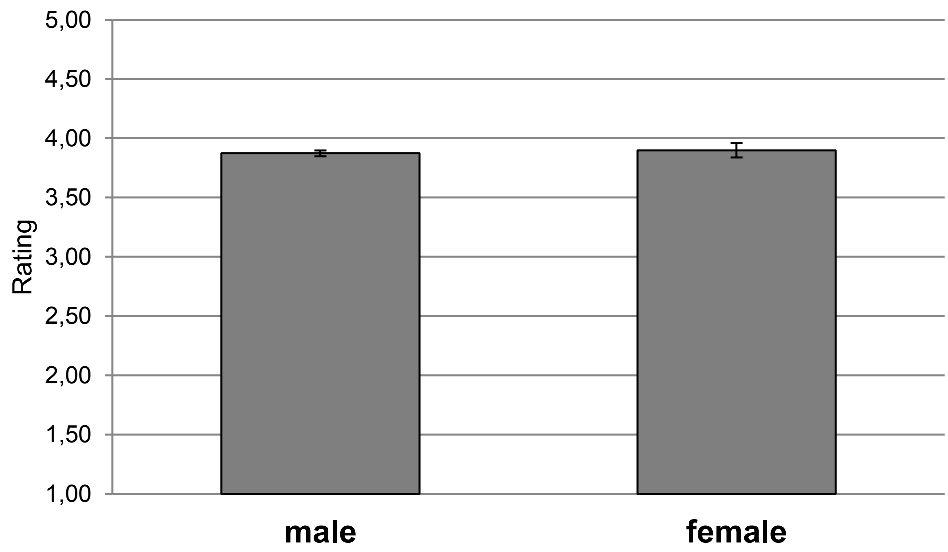


Figure 26: Evaluation of semi-automated parallel/perpendicular parking usefulness with regard to gender [Mean + Standard Error]

Figure 27 shows the rating of semi-automated parallel/perpendicular parking usefulness comparing the five different age groups. Descriptively, there was hardly any difference. There was no significant effect comparing the groups, with $F(4, 2252) = 1.60$, $p = .173$, and $\eta^2 = .00$. Thus, the age group had no significant effect on the evaluations.

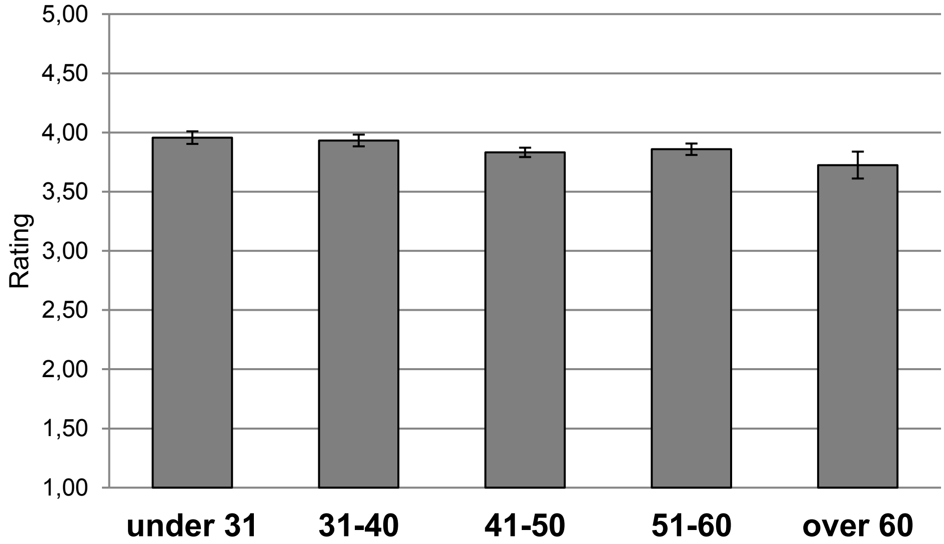


Figure 27: Evaluation of semi-automated parallel/perpendicular parking usefulness with regard to age [Mean + Standard Error]

Figure 28 shows the rating of semi-automated parallel/perpendicular parking usefulness comparing the yearly mileage. Descriptively, at least the group of people driving less than 3001 miles per year showed a higher subjective evaluation of the system compared to the other mileage groups. There was a significant effect comparing the mileage groups with $F(5, 2267) = 2.30$, $p < .05$, and $\eta^2 = .01$. Thus, there was a significant impact of yearly mileage on the evaluations. The effect size was only small.

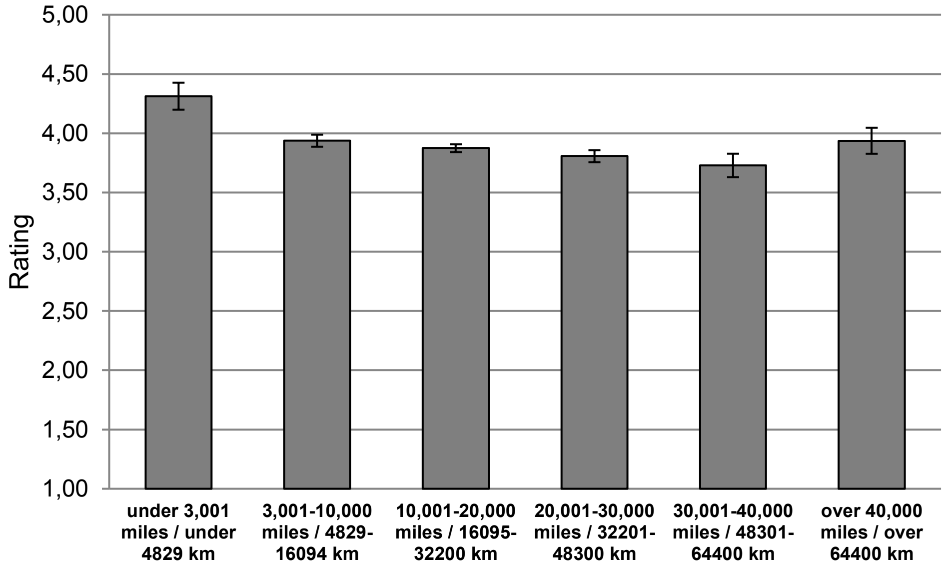


Figure 28: Evaluation of semi-automated parallel/perpendicular parking usefulness with regard to mileage [Mean + Standard Error]

3.3.4 Discussion

With regard to parking behaviour, participants from the USA parked more often in a 7-day week than participants from Brazil and Germany. This might be due to a higher usage of vehicles in the USA in general. Comparing the countries, there was only a small effect size for the question how often people park in small parking spaces. Of course, the interpretation of this item is problematic, as a small parking space was not defined. Its interpretation might vary between countries as well as individuals. There was a big effect size comparing how often people park in parallel versus perpendicular slots. This can be traced back to the USA, which has more perpendicular parking than the other countries.

Looking at the usage frequency of available parking driver assistance systems, there was a big effect, as semi-automated parallel/perpendicular parking was used less often than the other systems. Still, its usefulness was positively evaluated. Probably people appreciate semi-automated parallel/perpendicular parking, but only use it when appropriate or really needed. But there was no effect of home country on parking driver assistance system usage frequency. In general, the usefulness of parking driver assistance systems was positively evaluated, but valet parking with the driver in the car was less positively evaluated, with medium effect sizes, except against semi-automated parallel/perpendicular parking. The effect of home country on this item was only small. Comparing semi-automated parallel/perpendicular parking post hoc, there were differences between the USA and the others, but with small effect sizes. Looking at semi-automated parallel/perpendicular parking, there was no impact on the rating by demographic factors such as experience, gender, age group, and yearly mileage.

With regard to the comparison of systems between the countries, there were differences found by Lindgren et al. (2008) and Marchau et al. (2001). Although other countries and driver assistance systems were focused on, there were no meaningful differences between the countries in Study 3. Sommer's (2013) and Kyriakidis et al.'s (2014) surveys showed no differences between countries that were relevant to Study 3, being in line with the results presented here.

Planing (2014) demonstrated positive effects of prior experience on the acceptance of driver assistance systems. Also Haupt et al. (2015) pointed out that experience changed the perception of driver assistance systems. In their study, they were better evaluated with experience, which was not the case here for semi-automated parallel/perpendicular parking.

Gender was another factor that might have an influence on the evaluation of driver assistance systems. Results from Rienstra and Rietveld (1996), Marchau et al. (2001), and Chalmers (2001) showed a more positive rating of driver assistance systems by women compared to men. Planing's (2014) data indicated a higher buying interest for these systems by women. Blythe and Curtis (2004) had the opposite result: Driver assistance systems were more accepted by men. In a study from Piao et al. (2004), men liked adaptive cruise control best and women intelligent speed adaptation. Missel (2014), Casley et al. (2013), and Payre et al. (2014) presented results indicating a higher preference of driver assistance systems by men compared to women. Those results cannot be confirmed by the data of this research. There was no difference between men and women for the subjective evaluation of semi-automated parallel/perpendicular parking. Instead, the results are in line with the studies by Haupt et al. (2015) and Mariani et al. (2000). No effects for gender were found towards the driver assistance systems in both studies.

For older drivers, compared to younger ones, there was a lower acceptance, as reported by Czaja and Sharit (1998), Trübswetter and Bengler (2013), and Missel (2014). Planing (2014) reported a lower buying interest of driver assistance systems for older people. More positive results, indicating a higher acceptance on the side of the older drivers came from Marchau et al. (2001), Chalmers (2001), Piao et. al. (2004), Adell (2009), and Haupt et al. (2015). These results could not be confirmed by the data shown here. Still, the age range gathered was probably not sufficient to really answer this research question. There were probably too many people missing in the higher age ranges of the 60+ generation in the survey presented here.

Another factor was the influence of yearly mileage. Marchau et al. (2001) showed in their survey on driver assistance system preference a higher attractiveness of the systems for lower mileage drivers than for those with a higher mileage. There was no meaningful effect of this factor in the study presented here.

Interaction effects existed in regard to the impact of the home country and parking driver assistance system. The interaction effects were disordinal. Thus, the global interpretation of the main effects is problematic. Still, the effect sizes of the interactions were only small. The results have to be considered carefully, but the conclusions drawn for the hypotheses are nonetheless regarded as valid. The results are discussed with regard to the sample characteristics in detail in section 4.

3.4 Subjective Evaluation of Remote Parking Aid – Test Drive

3.4.1 Research Questions

In Studies 1 to 3, surveys of people experienced and unexperienced with respective driver assistance systems were conducted. Study 4 focused on a test vehicle equipped with a prototype remote parking aid system, tried out by unexperienced participants during a test drive. Planing (2014) showed that prior experience improved the acceptance of driver assistance systems. Haupt et al. (2015) gained results demonstrating how experienced drivers evaluated the driver assistance systems. In terms of safety, they evaluated them better than unexperienced ones. It was hypothesized that the usefulness ratings of the experienced users would reveal a more positive evaluation of the systems. Thus, it was expected that the prototype system experienced by the participants in Study 4 would be more positively evaluated than the only narratively described remote parking aid system in Study 3.

3.4.2 Method

This study was done using a prototype vehicle. The participants' task was to evaluate the acceptance and usability of a remote parking aid system. It enabled the possibility to start the engine and initiate the parking process from outside the vehicle and worked within a distance to the driver holding the key fob of circa eight meters around the vehicle. Remote parking aid use cases included parking into a perpendicular parking space (see Figure 29), parking out of a perpendicular parking space (see Figure 30), and also a so-called free drive mode (see Figure 31), which enabled the user to continuously drive the car forwards or backwards while standing outside. This can, for instance, be used to guide the vehicle through a driveway. Except for the so-called free drive mode, the system employed in this study was highly comparable to the description of the remote parking aid system investigated in Study 3. At the beginning, the system's function was explained to the participants. The study itself consisted of a fixed sequence of several parking in, parking out, and free drive manoeuvres they had to conduct on a parking lot. Four parking out and three parking in trials were done in an alternating order, finally followed by two free drive trials. The duration, on average, was one hour per participant. They evaluated the usefulness of the system at the end of each session, using the same 5-point usefulness scale as applied in Study 3. Next to an overall evaluation of the system’s usefulness, the three different use cases parking in, parking out, and the free drive mode were evaluated separately. Furthermore, at the end the whole system was evaluated on three standard instruments. Firstly, the Van Der Laan Scale (van der Laan et al., 1997) for measuring both usefulness and satisfaction was applied. Secondly, the System Usability Scale (Bangor, Kortum, & Miller, 2008) for usability as well as the NASA-TLX (Hart & Staveland, 1988) for workload were answered by the participants. The questionnaire and study design was pre-checked by an internal group consisting of human factors experts, who were asked for their feedback. Some non-experts also participated in a pre-study and provided their feedback.

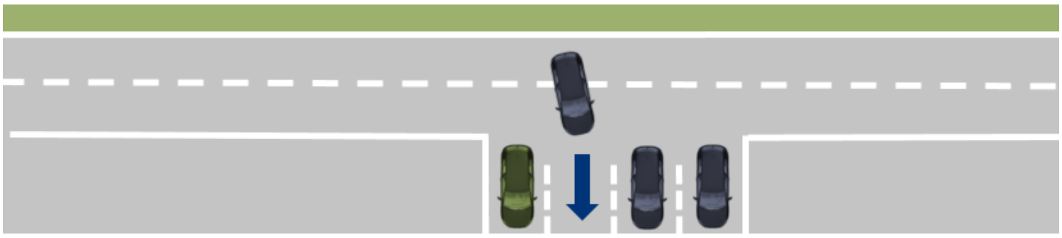


Figure 29: Parking in use case

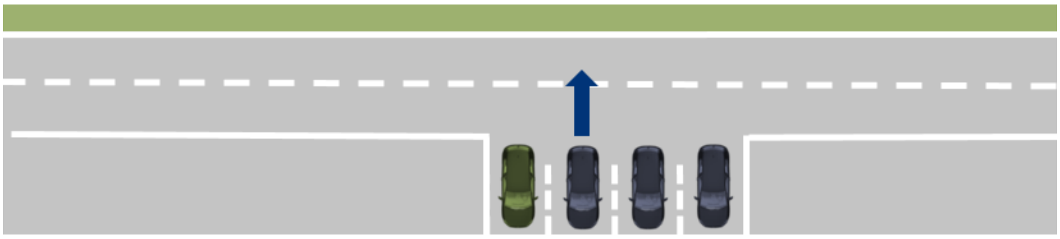


Figure 30: Parking out use case

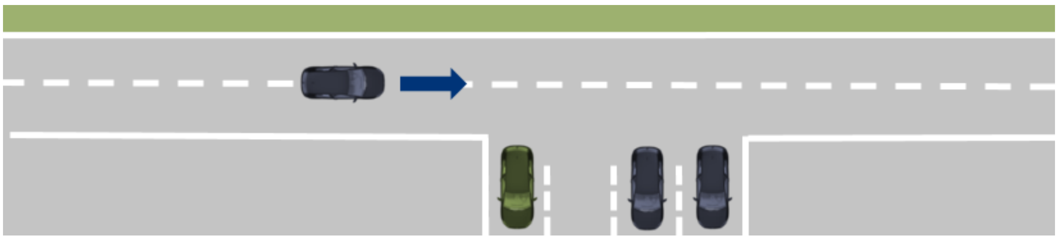


Figure 31: Free drive use case

Figure 32 shows the test vehicle, a modified Ford Kuga. Ultrasonic sensors were used for the system’s environmental perceptions. It was operated via a key fob with four buttons on the side (see Figure 33). Button [1] was used to start the engine. Button [2] was used to drive forwards. Button [3] was used to drive backwards. Button [4] was the so-called dead-man button. The dead-man button [4] had to be pressed permanently to signal the driver’s ability to monitor the situation. In case button [4] was released, the vehicle stopped immediately. To start the engine, button [4] had to be pressed permanently, while button [1] was pressed twice. While pressing button [4], button [2] could be pressed to drive forwards and button [3] could be pressed to drive backwards. A single press was sufficient for buttons [2] and [3]. The vehicle had to be placed in front of an empty parking space it was supposed to be parked in. When the parking space was detected, parking in was automatically initiated. The vehicle finally stopped inside the parking space. When parking out was detected, the vehicle stopped automatically after it had left the parking space. Otherwise, the free drive mode was initiated. One drag lasted for a maximum of ten meters. Additional drags forwards and backwards for the free drive mode were possible pressing buttons [2] and [3].

Figure 32: Remote parking aid test vehicle (Source: Ford)

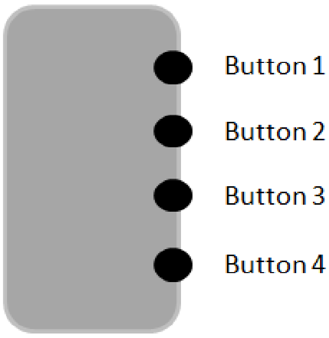


Figure 33: Key fob for remote parking aid operation

The participants were partly recruited from an international automotive manufacturer (n = 15), partly also from an external panel (n = 14). None of them was involved in the development of driver assistance systems. Altogether 29 participants took part in the study. The age ranged from 22 – 59, the average was 38 years of age. 24 males and 5 females participated. All participants had a valid driver's licence and were driving on a regular basis. The study took place at parking lots in Aachen and Cologne, Germany. It was conducted in German.

Not all variables showed a normal distribution according to the Kolmogorov-Smirnov Normality Test. Furthermore, Levene's Test for the test on equal variances showed that this precondition was also not the case for all comparisons. Still, *t*-tests were used, as they are quite robust with regard to violated assumptions. Non-equal variances were assumed for the *t*-tests. Only two-tailed *t*-tests were done in order to have a conservative test of significance. A Bonferroni-Holm correction for the post hoc *t*-tests was applied (Holm, 1979). This way, the issue of potential α-error inflation (e.g. Zöfel, 2003) could be minimised. As this was a convenience sample, and it was not possible to determine the number of participants in advance, no a priori test power calculations according to Faul et al. (2009) were done. Post hoc power calculations were not done either, as they directly depend on the calculated *p*-value. Low *p*-values correspond to high power and vice versa. Thus, the post hoc power does not change the interpretation of the data (Hoenig & Heisey, 2001).

The questionnaire used is included in the Appendix. It is a shortened and translated version of the German original.

3.4.3 Results

Table 43 shows descriptive data about the evaluation of the remote parking aid system on several standard scales. Its usefulness and satisfaction ratings on the Van Der Laan Scale were high, as well as its score on the System Usability Scale. The ratings on the NASA TLX workload scale were rather low.

Table 43: Rating scale results with scale ranges in brackets

Van der Laan Usefulness Scale	*Mean:* 0.79 *Standard error:* 0.13 [scale range: -2 to 2]
Van der Laan Satisfying Scale	*Mean:* 1.23 *Standard error:* 0.13 [scale range: -2 to 2]
System Usability Scale	*Mean:* 80 *Standard error:* 1.32 [scale range: 0 to 100]
NASA TLX	*Mean:* 31 *Standard error:* 3.55 [scale range: 0 to 100]

Figure 34 presents the evaluation of the remote parking aid system on the usefulness scale. The first bar shows the results gained from Study 3, thus the evaluation from the survey based on the description of the system given. Due to the high sample size, the standard error was very low. The other four bars present the usefulness evaluation obtained in Study 4, based on the same rating scale as in Study 3. Due to the much smaller sample size, the standard errors were relatively high. The "General" bar indicates how the remote parking aid was evaluated overall in Study 4. The three remaining bars show the usefulness of the use cases parking in, parking out, and the free drive mode. Parking in and parking out were about as well assessed as the feature in general, even a bit better. The rating was very close to the rating in the survey, for both parking in and out, as well as for the overall rating. The only much lower rating was the one for the free drive mode. Table 44 shows the significant differences according to the t-test between the rating in the survey and all ratings in the remote parking aid test drive study. As altogether 4 t-tests were performed, the critical α-level of .05 was adjusted according to the Bonferroni-Holm correction (Holm, 1979). At 4 comparisons, .05 divided by 4 is .0125. This was the critical α-level for decision about the smallest p-value. The p-values were arranged in ascending order and checked against the respective critical α-value until the first non-significant comparison was reached. The only significant difference was between the survey rating of remote parking aid and the free drive use case. The latter one was rated as significantly less useful. This comparison also yielded a big effect size.

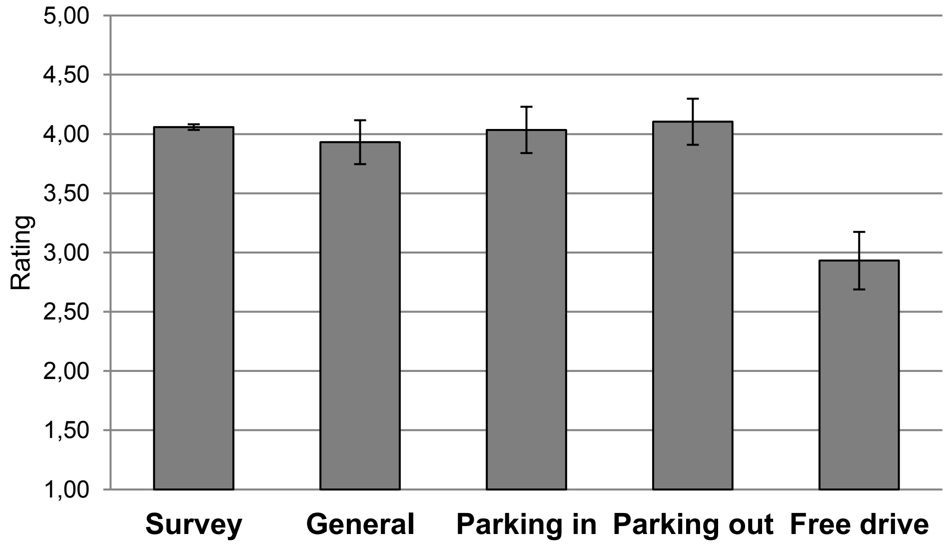


Figure 34: Evaluation of remote parking aid usefulness [Mean + Standard Error]

Table 44: T-tests

Survey versus General	$t(28) = 0.68, p = .500, d = 0.13$
Survey versus Parking in	$t(28) = 0.12, p = .904, d = 0.02$
Survey versus Parking out	$t(28) = 0.23, p = .820, d = 0.04$
Survey versus Free drive	$t(28) = 4.62, p < .001, d = 0.86$

3.4.4 Discussion

The ratings on remote parking aid usefulness were mostly rather high for the study with a prototype vehicle presented here. There was a positive evaluation on the standard scales used as well. Looking deeper into the usefulness ratings of the different use cases realized here, the overall system evaluation could primarily be attributed to parking in and parking out. The free drive use case was not that positively evaluated. Comparing the overall evaluation of the remote parking aid system as well as the rating of the use cases like parking in, parking out, and free drive with the survey results from Study 3, a clear picture emerges. There were no significant differences between the survey results and the overall evaluation of the prototype system, the parking in, and the parking out use cases. They were equally high. Only the less positively evaluated free drive use case was significantly different from the survey results, with a big effect size. It should be noted that the free drive scenario was not part of the remote parking aid system description in Study 3. Still, the rating of the system in the survey corresponded closely to its evaluation in the real drive study. As this was an experimental system not yet available on the market, no one from the sample in Study 3 could have had the chance to try it out. Thus, Study 3 was a completely theoretical evaluation of this system. Planing (2014) had data indicating an improved acceptance of the driver assistance systems after experience with them. Haupt et al. (2015) showed how experience changes the evaluation of the systems. In case of their study, people having experience with a system evaluated it higher in terms of safety than those who did not have the same kind of experience. The hypothesis based on this could not be proven, as the remote parking aid system was supposed to be better evaluated in Study 4, which is not the case. At least from this data it can be inferred that the survey's usefulness results based on a theoretical description are as valid as the results from a real drive study.

4 Final Discussion and Conclusions

First of all, we start recapitulating the studies conducted. Looking at the quantitative analysis based on the comments in Study 1, there was no significant difference between the three countries Germany, China, and the USA. With regard to the derived scale and the driver assistance systems under investigation, there were a comparable number of positive, negative, and neutral comments in all three countries. From this data, it could be derived that at least for this kind of qualitative approach, no differences between the countries under investigation exist. The driver assistance system interviews also yielded some insights on a qualitative basis. Gender and age group differences could not be found.

For Study 2, altogether, all presented systems were positively evaluated, especially the blind spot detection feature. Lane keeping aid was evaluated as the feature showing the highest potential for annoyance, probably because it actively interferes with lane keeping. Even though lane keeping aid was rated most annoying, it was still rated as rather important. Looking at the effects of demographic variables, there was hardly any effect of system experience on the ratings, as demonstrated for adaptive cruise control, the feature with the highest number of experienced participants. The effect of the factor home country was small for importance and not significant for annoyance. There was no effect of gender, age group, and yearly mileage on adaptive cruise control importance and annoyance.

Study 3 showed the following: With regard to the parking behaviour, participants from the USA parked significantly more often in a 7-day week than participants from Brazil and Germany. Probably because of a higher usage of vehicles in the USA in general. There was basically only a small effect for the question how often people park in small parking spaces, between the countries. Comparing the question how often people park in parallel versus perpendicular slots, there was a big effect size between the countries. This was a result of the USA having more perpendicular parking than the others. Regarding the usage frequency of parking driver assistance systems, there was a big effect, as semi-automated parallel/perpendicular parking was used less often than the other parking driver assistance systems. But there was no effect of home country on this item. The usefulness of parking driver assistance systems was positively evaluated in general, but valet parking with the driver staying in the car was less positively evaluated than the others, with medium effect sizes, except against semi-automated parallel/perpendicular parking. The effect of home country on this item was only small. Looking at semi-automated parallel/perpendicular parking, there was hardly any impact on the ratings that could be traced back to system experience, gender, age group, and yearly mileage.

Study 4 made it possible to compare usefulness ratings collected in a real world test to the theoretical ratings from a survey. The remote parking aid system presented was evaluated as being as useful as in the survey in Study 3. Looking at the different use cases, parking in and parking out automation were both positively evaluated. Only the free drive mode was not seen as that useful. The evaluation on the standard scales for acceptance, usability, and workload also showed a positive evaluation of the remote parking aid system in general.

The first research question tackled the topic of how driver assistance systems are evaluated subjectively. It was assumed that there are differences with regard to the perceived importance, usefulness, and annoyance of the systems described in section 1.2.2. It was specifically hypothesized for systems that intervene to be evaluated as less important and more annoying than systems issuing information or warnings only. Study 2 showed a high importance rating for the information only blind spot detection, whereas there was a high annoyance rating for the actively intervening lane keeping aid, which was still rated as rather important. This at least partially confirms the hypothesis. In case of parking assistance in Study 3, data showed that the valet parking aid, which requires the driver to stay in the car, was less appreciated. This indicates a desire for an automation enabling the driver to leave the car before the parking process starts.

The second research question asked for the impact of demographic factors on the subjective evaluation of driver assistance systems. The first three studies could be used to answer this question for the influence of home country. Contrary to the expectations, there was no meaningful effect of home country on driver assistance systems' subjective evaluation in any of the studies. This applied to the standardized ratings in Studies 2 and 3 as well as to the qualitative approach in Study 1. Further demographic factors that were available and could be used to evaluate their impact on driver assistance systems include age group, gender, and yearly mileage. Contrary to the expectations, there was basically no influence on the data, at least not for the investigated driver assistance systems adaptive cruise control and semi-automated parallel/perpendicular parking. Finally, at least for the driver assistance systems adaptive cruise control in Study 2 and semi-automated parallel/perpendicular parking in Study 3, it was possible to evaluate the effect of experienced versus unexperienced users. Contrary to the assumptions, there was no meaningful influence of this factor. Also, Study 1 showed no effect of gender and age group on the data.

The third research question referred to parking driver assistance systems in Study 3. It was assumed that the four countries differ with regard to their parking behaviour. It was hypothesized, based on observations, for the USA to have a lot of available space and thus less need for parallel parking compared to the other three countries. Based on this and the fact that parking spaces are more widespread and on average larger, it was furthermore hypothesized that advanced active parking aids are not evaluated as being as useful by US participants compared to the other three countries. Perpendicular parking did indeed take place more often in the USA compared to the other countries. This still had only a small effect on the subjective evaluation of active parking systems. They were evaluated almost equally high in all countries under investigation. Possibly the effect expected was offset by larger cars in the USA, which require larger parking spaces.

The fourth and final research question asked if the survey data gathered on a driver assistance system that has not yet been available on the market can be compared to its evaluation in a study with a prototype vehicle that was actually experienced. Based on the literature, experienced users were supposed to more positively evaluate driver assistance systems. Thus, it was hypothesized that the prototype system in Study 4 is better evaluated than the hypothetical system in Study 3. This was not the case when comparing the usefulness ratings of Studies 3 and 4 for the remote parking aid system.

Matching the results from the studies in this research work with the available data in the literature, there are on the one hand side comparable conclusions, on the other hand side contradictions. These differences could be attributed to various factors. First of all, the specifications of the systems under investigation were not the same in all cases. Driver assistance systems like, for instance, adaptive cruise control do not have the exact same properties today, but differ slightly between various automotive manufacturers. Furthermore, they have undergone changes in recent years, showing primarily a highly improved performance. Secondly, not all studies taken into account here use the same methodology, even though they are survey based. Different ways of asking questions might provoke different answer patterns. Thirdly, the participant samples employed also differ, as they are not aligned with regard to their demographic characteristics. Even though there was basically no influence of the demographics in the research work here, there might be other variables such as income or education that possibly play a role in the evaluation of driver assistance systems.

The results presented here indicate a high appreciation of information and warning systems, especially blind spot detection was highly favored. This is in line, for instance, with Wevers et al. (1999), where people revealed a preference for warning systems. Charles River Associates (1998) had collision avoidance systems favored in their study. Mariani et al. (2000) showed there was more need for information and warnings than for driver assistance system action. Blythe and Curtis (2004) discovered a preference for collision warning and prevention. Van Driel and van Arem (2005) conducted a survey with car drivers comparing their needs on driver assistance, which led to the conclusion that especially blind spot detection and downstream traffic information was favored.

Adaptive cruise control was also positively evaluated in Study 2. Charles River Associates (1998) received study results indicating adaptive cruise control had limited acceptance as it automatically controls the car. Marchau et al. (2001) showed in a European survey on driver assistance system preferences that for systems like distance keeping, speed limit adaptation, and navigational support, there was, on average, a mediocre rating of attractiveness. Both results, which are somewhat dated, are not in line with the results of this research. Also, Chalmers (2001) conducted a study in which longitudinal control systems were better accepted. Blythe and Curtis' (2004) results yielded not only a preference for collision warning and prevention, but also for adaptive cruise control and driver alertness monitoring. In van Driel and van Arem's (2005) survey, adaptive cruise control like systems were favored. Those results are primarily in line with Study 2. Piao et al. (2004) had results indicating that lane departure warning was rated much lower than adaptive cruise control. Lane departure warning was rated as well as adaptive cruise control in the survey of Study 2. According to Regan et al. (2002), participants liked the idea of lane departure warning. People were indifferent to lateral support systems, as shown by Wevers et al. (1999). They also had a negative opinion about automatic interventions. Especially the high annoyance rating of lane keeping aid shows an example of this in the survey data of Study 2. Mariani et al. (2000) concluded that there is more need for information and warnings than for driver assistance system action. This is probably also in line with the fact how lane keeping aid was evaluated regarding annoyance. People rather prefer systems that inform and warn instead of actively intervene. The intervention is regarded as annoying. Also, lane centering aid received a mediocre rating, being less important than lane keeping aid, but also less annoying. Traffic jam assist is basically an extension of adaptive cruise control and lane keeping systems. Still, the rating was closer to adaptive cruise control. The positive evaluation of forward collision warning can possibly also be traced back to the fact that collision avoidance information is favored. This was shown by Wevers et al. (1999), Charles River Associates (1998), Mariani et al. (2000), Blythe and Curtis (2004), and van Driel and van Arem (2005).

Taking into account the postulation by Planing (2014), the desire to exert control was found to most strongly support resistance to driver assistance systems. Thus, systems that intervene were supposed to be evaluated as less important and more annoying. This refers to adaptive cruise control, lane keeping aid, lane centering aid, and traffic jam assist in contrast to systems that are warning only such as lane departure warning, forward collision warning, and blind spot detection. This could at least be confirmed in Study 2 for the comparison of blind spot detection versus lane keeping aid. This might be due to the concept of self-efficacy by Bandura (1997). Active interventions lead to a low level of self-efficacy, as the driver is no longer in control anymore. This lowers the attractiveness of actions, which in turn lowers the acceptance of driver assistance systems (Arndt, 2011).

With regard to the comparison of systems between countries, differences were found by Lindgren et al. (2008) and Marchau et al. (2001). Also, the data from Hofstede (Hofstede

& Hofstede, 2004) on cultural dimensions suggests that there are differences. The home country factor certainly comprises several aspects like, for instance, infrastructure, population density, and others. But nonetheless, culture plays a big role. Still, it did not affect the subjective evaluations here in a meaningful way. Differences were found between countries in this study, but with small effect sizes only that can be regarded as meaningless. This is in line with the comparisons done by Sommer (2013) and Kyriakidis et al. (2014), who were not able to find differences between countries, at least not for driver assistance system preferences. It should be noted that other countries were compared in the literature than those being part of the studies presented here. Lindgren et al. (2008) compared China with Sweden. Marchau et al. (2001) employed samples from Greece, Czech, Italy, Germany, the Netherlands, and Finland. Sommer (2013) had samples from Germany, China, Japan, and the USA. Kyriakidis et al. (2014) did a comparison between 40 different countries.

Looking at the study done by Lindgren et al. (2008), blind spot detection and forward collision warning were positively evaluated and regarded as useful in everyday traffic by the Chinese in their home country. In contrast, adaptive cruise control and lane departure warning were rather negatively evaluated. Adaptive cruise control due to the fact that Chinese traffic was deemed as being too complex for this system. Lane departure warning was considered as problematic because many lane markings are missing on Chinese roads. Although it is difficult to come to confident conclusions due to the qualitative nature and the small sample size of Study 1, the data indicates that adaptive cruise control and the lane assist systems were seen as problematic by the Chinese, thus confirming Lindgren et al. (2008) in regard to this.

Larsson (2012), Planing (2014), and Haupt et al. (2015) showed how experience changes the perception of driver assistance systems. Planing (2014) came to the conclusion that prior experience improves the acceptance of the systems. In the study of Haupt et al. (2015), driver assistance systems were better evaluated by people having experience with them, which was not the case here for adaptive cruise control and semi-automated parallel/perpendicular parking. The same applies to the comparison of remote parking aid between Study 3 and Study 4. There was no significant difference between those who could not possibly have experience with a system only based on a prototype versus the few who had a chance to try out the prototype vehicle during a test drive in Study 4. One explanation for this might be the fact that in the studies presented here, concepts such as importance, annoyance, and usefulness were asked for. In case of the study by Haupt et al. (2015), the driver assistance systems were evaluated in terms of safety. Another possible explanation is the actual depth of experience people have with a system. It was not possible to test the actual system understanding and frequency of usage in Studies 2 and 3. Also Study 4 only made a short introduction possible. Having only participants who have used the systems extensively during a longer period of time might yield other results.

Gender is another factor that was expected to have an influence on driver assistance system evaluation. Results from Rienstra and Rietveld (1996) demonstrated how women preferred speed regulating driver assistance systems more than men did. Marchau et al. (2001) showed in a European survey on driver assistance system preferences the following: Systems like distance keeping, speed limit adaptation, and navigational support were on the average more preferred by women than by men. Chalmers (2001) demonstrated that women were rather more willing to accept help from their cars compared to men. Blythe and Curtis (2004) had the opposite result: Driver assistance systems were more accepted by men in terms that taking over control from the driver was more accepted. In a study from Piao et al. (2004), men liked adaptive cruise control best and women intelligent speed adaptation. Men deemed fully automated vehicles as more important than women did, as shown by Missel (2014). Casley et al. (2013) also showed how fully automated cars were more likely to be adopted by men compared to women. Payre et al. (2014) presented a study demonstrating that male people had a higher usage interest in fully automated driving than females. Buying interest was less than usage interest, but again higher for males compared to females. Males also had a more positive attitude towards fully automated driving than females. Planing (2014) revealed a higher buying interest of driver assistance systems for women. The results in this research did not reveal any significant differences between males and females for the ratings applied in Studies 1, 2, and 3.

Instead, the results of the studies presented here are in line with the studies of Haupt et al. (2015) and Mariani et al. (2000). Haupt et al. (2015) conducted a survey in order to evaluate safety relevant attitudes regarding driver assistance systems, also looking at gender as a factor. With regard to the systems under evaluation, there was no big difference between them in terms of safety. Mariani et al. (2000) conducted a survey where no gender differences for driver assistance systems were found.

For older drivers, compared to younger ones, it was shown that technology was less accepted and used (Czaja & Sharit, 1998). Marchau et al. (2001) presented a European survey on driver assistance system preferences with systems like distance keeping, speed limit adaptation, and navigational support. There was on the average a mediocre rating of attractiveness for the preference of driver assistance systems in vehicles. Still, results were highly depending on other variables: On the average, older drivers seemed to prefer the systems more than younger ones. Older drivers were more positive with respect to driver support systems than younger ones, as revealed by Chalmers (2001) and Piao et. al. (2004). Buying interest for driver assistance systems was higher for younger people than for older ones, as shown by Planing (2014).

Adell (2009) conducted studies demonstrating that elderly drivers had a higher satisfaction with and perceived usefulness of a speed adaptation system. Still, compared to middle aged drivers, their willingness to keep the system was lower. Trübswetter and Bengler (2013) showed in an interview study of elderly drivers on driver assistance systems that the lack of perceived usefulness was a main reason why older people did not use the systems. Older people believed fully automated cars to be less important than younger ones (Missel, 2014). Haupt et al. (2015) conducted a questionnaire study in order to evaluate safety relevant attitudes regarding driver assistance systems. Driver age had an effect, as there were bigger safety related attitudes towards the systems the older people were. Those results could not be confirmed by the data in the studies here. Still, the age range that was gathered is probably not sufficient to really answer this research question. There were probably too many people missing in the higher age ranges of the 60+ generation in the surveys presented here.

Another factor is the influence of yearly mileage. Marchau et al. (2001) showed in a survey on driver assistance system preferences how the results were highly depending on other variables: For drivers with a lower mileage, there was a higher attractiveness of the systems than for people with a higher mileage. They argue that higher mileage drivers might think of themselves as more capable. There was no meaningful impact of yearly mileage in the surveys presented here, though.

With regard to the validity of the gained data, we need to take into account that interaction effects existed looking at the impact of home country and driver assistance system. The interaction effects were disordinal. Thus, the global interpretation of the main effects is problematic. The interpretation of the effects of driver assistance systems on the data obviously depends to some extent on the home country and vice versa. Still, the effect sizes of the interactions were only small. They became significant due to the high sample sizes. Also, the effect sizes of the main effects were bigger. The results have to be handled with care, but in general the conclusions drawn for the hypotheses can be regarded as valid.

The results also have to be discussed with regard to the sample characteristics as well. As only employees of an international automotive manufacturer were part of the sample, representativity must be discussed. All studies were based on convenience samples. Another potential issue pertaining to all studies is the fact that female participants were underrepresented. This is probably due to the circumstances, as more male employees work at the departments of the international automotive manufacturer responding to the surveys. Still, the data showed no gender differences. At least for the studies presented here, this finally posed no issue. With regard to the age distribution, there were probably too many participants in the 60+ age group missing.

It is important to mention the fact that Hofstede (Hofstede & Hofstede, 2004) used a sample comprised of IBM employees only in order to derive his highly-appraised concept of cultural dimensions. People from various departments of an international automotive manufacturer responded to the surveys in this research. Such companies usually have a heterogeneous workforce from many areas and educational levels. Also, Heimgärtner (2012) employed a sample consisting of Siemens VDO employees only. In his case, it was not a survey; instead he used a software tool in order to capture quantitative data on interaction behaviour using a simulated car infotainment system. He compared English, Chinese, and German speaking people.

As the participants came from a variety of backgrounds, there is not necessarily an issue with missing representativity. In Studies 1 and 4, it was possible to fully exclude experts on driver assistance systems. The participants taking part in Study 2 and 3 were hardly related to the research and development of driver assistance systems, as these employees are only a minority of an automotive manufacturer's diverse workforce. Thus, the research results can be regarded as a subjective evaluation done by non-experts. Also, as they basically did this as part of their work, it is assumed that they strove for giving the best possible answer to the questions asked. This can form the baseline for very high data quality. The fact that a number of employees were asked to participate who regard this as part of their work is probably better than using a panel, as it is done in market research studies. In case of the latter one, the probability of self-selection to the panel is higher. A large company is probably closer to the actual population than a panel, especially if the latter one is not stratified according to the general or target population. It can also be argued that an evaluation of driver assistance as a technical system should not depend that much on a certain group of people as, for instance, the evaluation of appearance does. Thus, the results of these studies are regarded as valid, especially for the high sample sizes and quantitative data of Studies 2 and 3.

In Studies 1, 2, and 3, we dealt with many participants who did not have actual experience with the systems evaluated. Even for those who had experience, it was not possible to determine how deep this experience actually was. The comparisons for adaptive cruise control as well as for semi-automated parallel/perpendicular parking did not reveal any differences between experienced and unexperienced participants. The same applies to the comparisons for remote parking aid in Study 3 versus the prototype evaluation in Study 4. Still, these results do not take into account the question of how deep the system understanding of the participants really was, which might make a difference in case this is investigated in more detail.

The general disadvantage of a qualitative study like Study 1 is that it is hard to interpret the validity of the obtained results. Especially here the sample size was rather small. It should also be taken into consideration that most of the comments were only mentioned a few times, or once. Nonetheless, the comments uttered by the participants are valuable, as this was an open interview and the participants uttered comments on their own.

As the studies belong to the area of quasi-experiments (e.g. Bortz & Döring, 2006), it is not certain if the significant and meaningful differences can actually be attributed to the independent variables, for instance, home country or gender. There might be other, unknown extraneous variables playing a role. Of course, in this case it was not possible to randomly assign the independent variable to the participants. A potential problem is the fact that all questionnaires were in English, except in Study 4, where a German sample only participated. On the one hand side, it cannot be excluded that this might have led to misunderstandings in some cases, where participants did not speak English as a native language or were not able to understand it well enough. On the other hand side, there was no problem with regard to flawed translations to be expected.

In many cases, only a multimodal approach is successful in evaluating a driver assistance system. This research was a purely subjective evaluation. An objective evaluation, taking into account concepts such as workload, driver distraction, and situational awareness, would probably have yielded different results, if applied on the systems listed here. Various objective variables might be employed for measurements, including driving simulator data showing lane deviations, speed, distance to the lead vehicle, eye tracking behaviour, physiological data, time on task, or number of errors when operating a specific driver assistance system. Furthermore, the driver assistance systems evaluated should be extended by high and full automation systems according to the definition given by the Bundesanstalt für Strassenwesen (Gasser et al., 2012).

The conducted studies in this research work did not really yield information that can be used for the actual tuning of driver assistance systems' behaviour or adapting their human-machine interface to different regions. To do so, future driving simulator or real road tests would have to be conducted. Even simulator tests seem to be questionable in some cases, as they do not take into account the complex traffic in the real world. Future studies should especially look at the different regional requirements for the timing of warnings or the appropriateness of available system settings. As already stated by Lindgren et al. (2008), Chinese car drivers might consider cautionary warnings as too bothersome, as the traffic dynamics are different in China and they evaluate certain situations as normal that would be regarded as dangerous in Western countries. Thus, also the implementation of a double warning strategy with cautionary and imminent warnings is possibly problematic, as cautionary warnings might be issued too often. Taking these differences into account, usability and user experience can be improved. The goal is to have a human-machine interface design offering an optimal workload, high situational awareness, and low driver distraction.

Furthermore, it might prove useful to have data available for the comparison of average driver behaviour between the different countries under investigation using standardised evaluation instruments like the Wiener Fahrprobe (Risser & Brandstätter, 1985) or the Driver Behaviour Questionnaire (Reason et al., 1990). The risk or task difficulty homeostasis as discussed in section 1.3.1 is possibly also of interest, as it might differ between countries. Even though there was no meaningful impact of home country as a factor on the data here, the evaluation of driver assistance systems might in the future also depend on the tuning of the system's behaviour. For instance, how quickly people expect a driver assistance system to change lanes or how aggressive or defensive it should drive in stop and go traffic in different countries. Data on driver behaviour can thus be useful for system tuning.

Epidemiological studies regarding, for instance, accident statistics of driver assistance system equipped vehicles are also possible. Naturalistic driving studies like the 100-car study (Dingus et al., 2006, Neale et al., 2002) are something highly promising. In case of these studies, the investigation is done in a natural environment, not actively changing the conditions. The driver is monitored with cameras. Also, data from the vehicles' CAN-BUS can be captured, such as speed, acceleration, location etc. Future studies of this kind might be done in order to investigate the behaviour of people using driver assistance systems in various different countries under real environmental conditions. Field operational tests on real roads are also an option. They investigate the effect of various parameters under realistic conditions. This kind of methodology might also be applied to cross-cultural comparisons on the evaluation of driver assistance systems. It can be used to find other differences regarding driver behaviour and driver assistance system interaction in general. Furthermore, it is also possible to use data from Hofstede (Hofstede & Hofstede, 2004) or GLOBE (House et al., 2002) in order to trace back driving behaviour differences to cultural dimensions.

The studies presented here provide data on the subjective evaluation of driver assistance systems. In summary, the results of all studies form a rather clear picture: In all studies, there was no meaningful influence of demographic factors to be found. Still, as presented in Studies 2 and 3, there were differences in the subjective evaluation of driver assistance systems. In Study 2, there was a preference for blind spot detection. Lane keeping aid as a driver assistance system was regarded as annoying. Parking driver assistance systems in Study 3 were positively evaluated, but rated better when they offered the possibility for the driver to leave the car before the parking process starts, as shown by the comparison between the valet parking with and without a driver in the car. While Studies 2 and 3 were focused on quantitative survey data, Study 1 complemented this with qualitative insights. Study 4 finally presented the subjective evaluation in a real-world setting, in which the gained data closely resembled the survey data in Study 3.

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Appendix

Questionnaire Study 1

The following questionnaire asks for your open-ended assessment of several advanced driver assistance systems. After finishing the questions on demographic data, please provide your answers into the boxes presented.

Please state your home country: ______________

Please state your age: _______ years of age

Gender: ☐ male ☐ female

Adaptive Cruise Control helps you to automatically maintain a sufficient distance to the vehicle in front of you. Usually a radar sensor measures the distance to the vehicle in front, automatically breaking and accelerating, if necessary. This is an extension of the conventional Cruise Control.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Forward Collision Warning uses the same radar sensor as Adaptive Cruise Control. It does not automatically maintain the distance to the vehicle in front, but warns you if you are about to collide with the vehicle in front.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Lane Departure Warning uses a camera to monitor the lane markings on the street. In case you deviate from the street, your steering wheel will begin to vibrate to warn you. It is a warning only and will not actively take you back into the lane.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Lane Keeping Aid uses the same camera as lane departure warning to monitor the lane markings. In case you deviate from the street, your steering wheel will automatically turn slightly to the other side to get you actively back into the lane.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Lane Centering Aid uses the same camera as lane departure warning to monitor lane markings. It is a continuous, automatic support from the steering wheel to keep you within the lane.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Blind Spot Detection uses a camera to monitor the blind spot, which cannot be seen by the driver when looking into the outside mirror. In case there is an object in the blind spot, like a bicyclist or a car, the presence of this object is indicated via a flashing LED in the mirror.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Semi-automated Parking helps you to get into a parallel or perpendicular parking space without having to steer by yourself. After a parking space is found, you only have to apply the gas pedal and brake yourself. Turning the steering wheel, including any correctional moves, is done by the vehicle itself.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Traffic Jam Assist gives you the possibility to be driven by your car under special circumstances. You are driving with a speed of up to 60kph on a motorway. Then the system is able to take over accelerating, braking, and steering. You do not have to use the pedals or touch the steering wheel anymore.

What do you think about this Driver Assistance System? Especially think about your own region. Is it useful or needless? Might it be annoying for some reason? Any other comment on it?

Thanks a lot for your Participation!

Questionnaire Study 2

The following questionnaire asks for your assessment of several advanced driver assistance systems. Please provide your answers using the buttons and boxes presented.

[Explanations of each system according to the ones for Study 1 were given]

Do you have first-hand experience with **ADAPTIVE CRUISE CONTROL**?

☐ yes ☐ no

Please rate the below statement relative to **ADAPTIVE CRUISE CONTROL**.

Adaptive Cruise Control is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Adaptive Cruise Control is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **FORWARD COLLISION WARNING**?

☐ yes ☐ no

Please rate the below statement relative to **FORWARD COLLISION WARNING**.

Forward Collision Warning is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Forward Collision Warning is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **LANE DEPARTURE WARNING**?

☐ yes ☐ no

Please rate the below statement relative to **LANE DEPARTURE WARNING**.

Lane Departure Warning is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Lane Departure Warning is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **LANE KEEPING AID**?

☐ yes ☐ no

Please rate the below statement relative to **LANE KEEPING AID**.

Lane Keeping Aid is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Lane Keeping Aid is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **LANE CENTERING AID**?

☐ yes ☐ no

Please rate the below statement relative to **LANE CENTERING AID**.

Lane Centering Aid is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Lane Centering Aid is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **BLIND SPOT DETECTION**?

☐ yes ☐ no

Please rate the below statement relative to **BLIND SPOT DETECTION**.

Blind Spot Detection is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Blind Spot Detection is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Do you have first-hand experience with **TRAFFIC JAM ASSIST**?

☐ yes ☐ no

Please rate the below statement relative to **TRAFFIC JAM ASSIST**.

Traffic Jam Assist is important in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Traffic Jam Assist is annoying in my market.

1	2	3	4	5
☐	☐	☐	☐	☐
strongly disagree				strongly agree

☐ no opinion

Please indicate your age

20-30	31-40	41-50	51-60	over 60
☐	☐	☐	☐	☐

☐ do not wish to answer

Please state your gender

☐ male ☐ female

☐ do not wish to answer

How many miles/kilometres do you drive per year?

☐ 0-5,000 miles / 0-8050 km

☐ 5,001-10,000 miles / 8051-16100 km

☐ 10,001-20,000 miles / 16101-32200 km

☐ 20,001-30,000 miles / 32201-48300 km

☐ 30,001-40,000 miles / 48301-64400 km

☐ over 40,000 miles / over 64400 km

☐ do not wish to answer

Thanks a lot for your Participation!

Questionnaire Study 3

The following questionnaire asks for your assessment of your personal parking behaviour as well as of several advanced driver assistance systems related to parking. Please provide your answers using the buttons and boxes presented.

How often do you park your vehicle in a 7-day week? Park is defined as when you stop and physically exit the vehicle.

never	1-5x	6-10x	11-20x	21-30x	over 30x
☐	☐	☐	☐	☐	☐

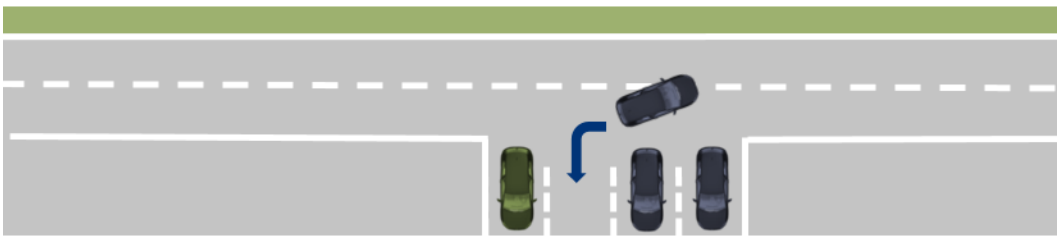
How often do you park in relatively small parking spaces?

daily	2-3x per week	weekly	monthly	quarterly	yearly	never
☐	☐	☐	☐	☐	☐	☐

Please indicate the percentage of how often you park parallel and perpendicular (YOUR RESPONSE MUST EQUAL 100%)

Parallel Parking

Perpendicular Parking



Parallel: _____ %
Perpendicular: _____ %
☐ do not wish to answer

How often per 7-day week do you use the following systems?

Acoustic parking aid - indicates the distance to adjacent vehicles via a sound signal.

never	1-5x	6-10x	11-20x	21-30x	over 30x
☐	☐	☐	☐	☐	☐

☐ do not have this feature

Visual parking aid - indicates the distance to adjacent vehicles via distance bars in a display.

never	1-5x	6-10x	11-20x	21-30x	over 30x
☐	☐	☐	☐	☐	☐

☐ do not have this feature

Rear view camera - shows the area behind the vehicle while parking.

never	1-5x	6-10x	11-20x	21-30x	over 30x
☐	☐	☐	☐	☐	☐

☐ do not have this feature

Semi-automated parking aid - is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel to park the vehicle. The driver has to brake and accelerate.

never	1-5x	6-10x	11-20x	21-30x	over 30x
☐	☐	☐	☐	☐	☐

☐ do not have this feature

How do you rate the following systems with regard to usefulness?

The **semi-automated parking aid** is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel to park the vehicle. The driver has to brake and accelerate.

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

☐ I cannot judge this feature

The **fully-assisted parking aid** is a function that detects a parking space (parallel or perpendicular) and automatically turns the steering wheel and actuates the brake and accelerator to park the car. The driver still remains in the vehicle during the parking manoeuvre.

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

☐ I cannot judge this feature

The **valet parking aid** feature is a function that automatically drives the vehicle from the beginning of a parking lot to one of the available parking spaces. Afterwards, the vehicle can also pull out and drive back to the entrance of the parking lot where the driver takes over again. The driver remains in the vehicle.

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

☐ I cannot judge this feature

Now imagine the same function, but the driver exits the vehicle before the system takes over. The vehicle drives itself from the beginning of the parking lot and back without a driver on board. Afterwards, the vehicle can also pull out and drive back to the entrance of the parking lot where the driver takes over again.

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

☐ I cannot judge this feature

The **Remote Park Aid** is a function that enables the driver to exit the vehicle and to start the perpendicular parking manoeuvre from outside. Pulling out from tight parking spaces is also offered with it.

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

☐ I cannot judge this feature

Please indicate your age

20-30	31-40	41-50	51-60	over 60
☐	☐	☐	☐	☐

☐ do not wish to answer

Please state your gender

☐ male ☐ female

☐ do not wish to answer

How many miles/kilometres do you drive per year?

☐ under 3,001 miles / under 4829 km

☐ 3,001-10,000 miles / 4829-16094 km

☐ 10,001-20,000 miles / 16095-32200 km

☐ 20,001-30,000 miles / 32201-48300 km

☐ 30,001-40,000 miles / 48301-64400 km

☐ over 40,000 miles / over 64400 km

☐ do not wish to answer

Thanks a lot for your Participation!

Questionnaire Study 4 [shortened]

The following questions asks for your assessment of the presented **Remote Parking Aid** function, including its sub functions.

Please state your age
_____ years of age

Please state your gender
☐ male ☐ female

How do you rate the following system aspects with regard to usefulness?

How useful is the **Remote Parking Aid** function altogether?

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

How useful is the parking in function?

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

How useful is the parking out function?

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

How useful is the free drive function?

not at all useful	not very useful	neither useful nor not useful	somewhat useful	very useful
☐	☐	☐	☐	☐

[NASA Task Load Index, System Usability Scale, and Van Der Laan Scale were collected as well]

Thanks a lot for your Participation!

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Erklärung zur Dissertation

Ich versichere an Eides Statt, dass die hier vorliegende Dissertation von mir selbständig und ohne unzulässige fremde Hilfe unter Beachtung der „Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf" erstellt worden ist. Die Dissertation wurde in der vorgelegten oder in ähnlicher Form noch bei keiner anderen Institution eingereicht. Ich habe bisher keine erfolglosen Promotionsversuche unternommen.

Düsseldorf, den 10.02.2017

Stefan Wolter