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Geographisches Institut, Humboldt-Universität zu Berlin

USER PERSPECTIVES ON AUTONOMOUS DRIVING

A Use-Case-Driven Study in Germany

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Preface

Autonomous driving has become a hot topic in the last few years – not only in Germany, but around the globe. In 2012, the world's largest conference on transport research and development, the Transport Research Board Annual Meeting, which takes place every January in Washington, put the topic under the spotlight for the first time with its own seminar entitled "Ready for Automated Driving." By the time of the 2016 Annual Meeting, there were already more than ten sessions on autonomous driving, and Chris Urmson from Google was the keynote speaker at the main networking event.

The interest experienced by autonomous driving has been growing equally rapidly in Germany. In 2013 Daimler Benz attracted attention with the fully automated version of its Bertha Benz Memorial Route, on which other automotive manufacturers such as Audi or BMW were soon demonstrating their own self-driving cars. Under the aegis of the German Federal Ministry of Transport, an "Automated Driving" Round Table was established; contributions from economic and social stakeholders as well as from research are incorporated in the Federal Government's "Strategy for Automated and Connected Driving." Barely a day goes by without the media reporting on autonomous driving.

Hand in hand with this trend, researchers are striving to locate the topic within the larger context of the future of mobility, thus addressing aspects that go beyond purely technical or legal matters. As those "affected" by the new technological development, ordinary people are being placed in greater focus: How is autonomous driving being received by society at large? What impact will this have on people's transport behavior? What new options and concepts appear especially interesting to the users? This study addresses these and other questions.

We are delighted that you are interested in our findings and wish you insightful and exciting reading!

Berlin, January 2016

Prof. Dr. Barbara Lenz

Head of Institute, DLR Institute of Transport Research, Berlin

About the study

Among the first larger research activities that has dealt with autonomous driving from a wider perspective was the “Villa Ladenburg” project (2012-2015). Central aspects of the project included potential future users of autonomous vehicles and possible implications for the transport system. “Villa Ladenburg” was funded by the Daimler and Benz foundation, and convened an international network of renowned experts from various disciplines. The results of this work were published in a comprehensive compendium in German in 2015 (publicly available online: http://www.springer.com/de/book/9783662458532). An English version will be available around March 2016.

Associated with the “Villa Ladenburg” project, an online survey with 1,000 respondents in Germany was conducted in April 2014. Its aim was to gather use-case-oriented mindsets concerning acceptance, mode choice, and time use related to expectations, desires, reservations, and fears concerning autonomous driving. Above all, we wanted to find out what the respondents imagine their mobility and transport behavior to be like in specific “what if…” scenarios. To what extent the respondents could actually imagine themselves in a future with autonomous vehicles is an important aspect in this early stage of technology development and implementation.

Autonomous driving, in relation to its potential types of application and potential users, implicates changes on various levels, be it transport behavior, modifications in mindsets towards the use and ownership of cars, or altered use of time while traveling, thus indicating changes in terms of future activities. An interdisciplinary approach that includes perspectives from transport and mobility research, psychology, and social sciences is required to adequately address this topic, where still little is known and many questions remain unanswered. In the survey, we therefore applied a mix of methods to deal with these uncertainties. For example, we thought open-answer options in the form of free-text boxes a suitable addition to the standardized, quantitative questions, thus giving respondents an additional opportunity for more spontaneous reactions towards autonomous driving. At the same time, we put an emphasis on different use cases representing likely application scenarios of autonomous driving.

The following results present initial, careful quantifications in a field, where many questions are still do be addressed. However, a focus on user perspectives on autonomous driving is crucial for a successful implementation of the technology into our transport system in the future.

Eva Fraedrich and Rita Cyganski

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Executive summary

What we did

Whether it will be an evolutionary development in a stepwise manner, or an initial deployment in a small area, spreading from there to a wider space: autonomous driving has the potential to change transport and mobility in the future. To address aspects in this regard, various dimensions have to be considered – an important one of them being the user perspective. With the study at hand we explored this perspective by asking 1,000 users of the transport system in Germany in April 2014 about their attitudes and mindsets towards autonomous driving.

It doing so, we introduced four different use cases on autonomous driving to the respondents to examine possible variances in perception and evaluation: Highway Pilot; Parking Pilot; Fully Automated Vehicle, which still allows a driver to take over whenever requested; and Vehicle on Demand, in the literature or the media often also referred to as “robotaxi” or “driverless car”.

What we found

Perception and evaluation: Though autonomous driving was, by the time the study was conducted, known to a majority of the respondents as well as being of interest to most of them, a general open-mindedness could not be stated. In a nutshell, it became clear that respondents still had issues imagining handing over the control of their vehicles to machines. They rather pictured themselves as surveillants than as passengers in an autonomous vehicle and only very rarely agreed to be willing to delegate everything to the computer system – assisting functions that help with parking or detecting pedestrians, on the contrary, got relatively high levels of approval.

While respondents who displayed a positive attitude towards driving a car were more interested in the topic of autonomous driving generally, this positive attitude generally did not correspond with their willingness to use an autonomous vehicle or even replace their currently preferred mode of transport.

The perception and evaluation of the four use cases that were introduced to the respondents differed, sometimes drastically, and appeared ambiguous in general. An “autonomous vehicle” – or what the interviewees recognized as one – was perceived and evaluated very much depending on their general willingness to give up driving functions. A closer look at the different use cases revealed that Parking Pilot got the

most affirmative ratings, whereas Vehicle on Demand received the least popularity – for example in relation to the willingness to use such a vehicle, or perceived benefits.

Acceptance and trust: When trying to gather verifiable statements on acceptance of autonomous driving, not only attitudes play an important role but also emotions related to the technology. Again, while Parking Pilot got the highest shares of positive affection rates, Vehicle on Demand was rated worst. For negative emotions, 'powerlessness' had the most pronounced statements.

Asked about their desires for future design and human-machine interaction, respondents revealed strong needs for control and system transparency of the autonomous vehicles. In addition, they conveyed a significant level of skepticism in relation to the reliability of autonomous driving systems.

Time use: In literature and media, autonomous driving is often related to improvements in efficient time use while traveling in a vehicle, e.g. working. However, respondents did not seem to see themselves spending time working in autonomous vehicles in the future. In fact, their idea and valuation essentially resembles current time use patterns. The perceived benefits of today's transport users for potentially altered time use are centered on window gazing, talking to companions, and relaxing.

Mode choice: A large share of respondents did not expect any impact on their mode choice if autonomous vehicles were available. Unsurprisingly, by far the biggest changes were imagined in relation to a lesser use of taxis, followed by public transport and train whereas bike and foot showed the lowest effects.

When asked for what kind of trips they would find autonomous vehicles particularly useful, Parking Pilot was rated as most beneficial specifically in an urban context, when going shopping or having luggage with them. Highway Pilot, on the contrary was deemed most positive for going on journeys and traveling for a longer time period.

Mobility related needs: The criteria that form the basis of mobility decisions for or against autonomous driving are still unknown. We therefore focused on attitudinal and emotional aspects of behavioral intentions of potential future usage. Asked whether their mobility related needs could be addressed with an autonomous vehicle – according to the different use cases – answers show high diversity for safety, independence and cost. For Vehicle on Demand, more than a third of the respondents did not see their safety needs satisfied. Twenty-six percent, however, stated that low costs would be addressed by Vehicle on Demand. In general, use cases were perceived as addressing users' needs for freedom from stress, time savings and comfort to a higher degree.

Autonomous driving for the mobility-impaired: Autonomous driving is often stated to make the life of people with mobility impairments easier. However, a vast majority of the respondents with mobility impairments rely on the car today already. Whether autonomous driving would make a significant difference, and "mobilize" more people, should be seen with caution. Respondents with mobility impairments did not show specifically affirmative attitudes towards autonomous driving. On the contrary, their refusal rates were quite high.

Use cases of autonomous driving: Specifying use cases of autonomous driving proved to be implicitly necessary and had high explanatory character. Whereas respondents seemed to be rather open-minded towards the technology, even when they were asked to replace their preferred mode of transport by a not further specified autonomous vehicle, their refusal considerably increased when specific use cases were introduced to them in the further course of the survey.

What should be on the research agenda

The study focused on attitudes and expectations towards autonomous driving in general, and also for certain specifications. We were able to show that by embedding questions in specific substantiated contexts of autonomous driving, the complexity of the answers increased. We see this result as an essential guideline of future research in two ways: examination on acceptance for autonomous driving should be geared to conceivable applications. At the same time, these applications have to be comprehensible as a true-life experience for its users. Exploring the user perspective in this regard can give inevitable impulses for the implementation of autonomous vehicles. In addition, it can give hints on appraising possible effects on the transport system that come along with a changing user behavior.

Subsequent to the study at hand we see immediate need for research in the following areas:

- → **Acceptance** of autonomous driving by specific **user groups** – particularly urban, suburban and rural population groups, car users, and public transport users, transport users that regularly or frequently travel longer distances
- → **Time use** on daily routes with conventional and autonomous vehicles
- → **Acceptance** of autonomous vehicles in relation to **new mobility concepts**
- → **Implications** of conceivable modifications in **transport behavior** for **transport demand**

These user-centered aspects could make an important and appropriate contribution in relation to the development pathway towards autonomous driving and a transport system with autonomous vehicles.

Ergebnistelegramm

Das Vorgehen

Noch ist unklar, wie der Entwicklungspfad konkret aussehen wird – sicher ist allerdings: Das autonome Fahren könnte Mobilität und Verkehr der Zukunft massiv verändern. In der Auseinandersetzung mit der Technologie des autonomen Fahrens und ihrer Umsetzung gilt es, ganz unterschiedliche Dimensionen der künftigen Entwicklung einzubeziehen – dazu gehört ganz wesentlich die Perspektive der Nutzerinnen und Nutzer. Die vorliegende Studie adressiert genau diese Perspektive: Dazu haben wir im April 2014 1.000 in Deutschland lebende Personen zu ihren Einstellungen und Erwartungen gegenüber dem autonomen Fahren befragt. Wichtig war uns herauszufinden, wie die Befragten auf konkrete Anwendungsfälle des autonomen Fahrens reagieren. Dazu haben wir vier unterschiedliche Anwendungsfälle in unserer Befragung thematisiert: einen Autobahn-Piloten, einen Park-Piloten, ein voll automatisiertes Fahrzeug mit Selbststeuerungsmöglichkeit auf Wunsch und ein sogenanntes Fahrzeug „on demand“, das in anderen Studien oder in den Medien häufig auch als „Robotaxi“ oder „Fahrerloses Fahrzeug“ bezeichnet wird.

Die Ergebnisse

Wahrnehmung und Bewertung: Obwohl die Mehrheit der Befragten angab, über Kenntnisse zum autonomen Fahren zu verfügen und auch eine Mehrheit sagte, sie würde sich für dieses Thema interessieren, zeigte sich dennoch keine generelle Offenheit gegenüber der Technik. Zusammenfassend kann gesagt werden, dass die Befragten deutliche Vorbehalte vor allem dann hatten, wenn es darum ging, die Kontrolle an das Fahrzeug zu übergeben. Die Mehrheit gab an, künftig lieber eine überwachende Funktion im Fahrzeug übernehmen zu wollen als eine reine Passagier-Funktion. Automatisierungsfunktionen, die eher ‚assistierend‘, also unterstützend, eingreifen – wie zum Beispiel Parkassistent oder Fußgängererkennung – erhielten dagegen deutlich mehr Zuspruch.

Bei der Wahrnehmung und Bewertung der vier Anwendungsfälle, die den Befragten vorgestellt wurden, ergaben sich erhebliche Unterschiede. Entscheidend bei der Bewertung des „autonomen Fahrzeugs“ – was auch immer die Befragten sich darunter konkret vorstellten – war vor allem die generelle Bereitschaft, die komplette Fahraufgabe an das Fahrzeug abzugeben. Vergleicht man die vier Anwendungsfälle – zum Beispiel hinsichtlich der Nutzungsbereitschaft – dann zeigt sich, dass der Park-Pilot insgesamt die größte, das Fahrzeug „on demand“ hingegen die geringste Zustimmung bekam.

Insgesamt waren Befragte mit positiver Einstellung zum Auto mehr am Thema autonomes Fahren interessiert. Allerdings schlug sich das nicht in einer besonders hohen Bereitschaft zur Nutzung eines autonomen Fahrzeugs nieder.

Akzeptanz und Vertrauen: In Hinblick auf die Akzeptanz des autonomen Fahrens waren in unserer Befragung nicht nur Einstellungen relevant, sondern auch Emotionen, die die Befragten gegenüber der Technik empfanden. Auch hier erhielt der Park-Pilot die höchste Zustimmung, während das Fahrzeug „on demand" am schlechtesten bewertet wurde. Das insgesamt am stärksten hervorgehobene negative Gefühl gegenüber dem autonomen Fahren war „Machtlosigkeit".

Entsprechend äußerten die Befragten einen hohen Bedarf an Kontrolle und Transparenz hinsichtlich der vom autonomen Fahrzeug ausgeführten Aktionen. Darüber hinaus wurde auch der Zuverlässigkeit von autonomen Fahrzeugen generell eine hohe Skepsis entgegengebracht.

Zeitnutzung: In der wissenschaftlichen Literatur, aber auch in den Medien wird das autonome Fahren häufig mit einer effektiven und effizienten Nutzung der Unterwegszeit in Verbindung gebracht, so z.B. durch die Möglichkeit, während dieser Zeit zu arbeiten. Für die überwiegende Mehrheit der Befragten war die Vorstellung allerdings wenig attraktiv, die gewonnene Zeit künftig mit Arbeit zu füllen. Vielmehr ähnelte ihre Erwartung an die Nutzung der künftig verfügbaren Unterwegszeit in hohem Maße dem, was sie auch heute tun, wenn sie unterwegs sind. So waren die wichtigsten von den Befragten genannten Aktivitäten bei der Fahrt mit dem autonomen Fahrzeug das Aus-dem-Fenster-schauen, die Unterhaltung mit anderen Personen im Fahrzeug und das Entspannen.

Verkehrsmittelwahl: Ein hoher Anteil der Befragten ging nicht davon aus, dass sich ihre Verkehrsmittelwahl durch das autonome Fahren grundlegend ändern würde. Wenig überraschend wurde der größte Einfluss in Richtung einer rückläufigen Nutzung eines Taxis angenommen, gefolgt von geringerer Nutzung des öffentlichen Nah- und Fernverkehrs. Wenig Veränderung erwarteten die Befragten hingegen im Hinblick auf die Nutzung des Fahrrads und das Zurücklegen von Wegen zu Fuß.

Bei der Frage nach der Nützlichkeit von autonomem Fahren für spezifische Wege wurde der Park-Pilot am stärksten positiv eingeschätzt, ganz besonders für Situationen im urbanen Umfeld, bei denen man eine größere Menge an „Transportgütern" mit sich führt oder beim Einkaufen allgemein. Der Autobahn-Pilot erhielt die stärkste Zustimmung dort, wo es sich um längere und länger andauernde Fahrten handelt.

Mobilitätsbedürfnisse: Es gibt derzeit erst wenige Erkenntnisse darüber, auf welchen Einflussfaktoren die „Entscheidung" für oder gegen autonomes Fahren beruhen. Betrachtet man einstellungs- und emotionsabhängige Einflüsse auf die Bewertung von autonomem Fahren, dann zeigen sich Einschätzungen, die je nach Anwendungsfall sehr unterschiedlich sind; dies gilt insbesondere im Hinblick auf Sicherheit, Unabhängigkeit und Kosten. So gab über ein Drittel der Befragten an, ihr Sicherheitsbedürfnis werde mit einem Fahrzeug „on demand" nicht ausreichend befriedigt – wohingegen wiederum fast ein Drittel sagte, dass vor allem der Aspekt niedriger Kosten durch ein solches Fahrzeug adressiert werde. Die wichtigsten

positiven Zuschreibungen erhielt das autonome Fahren über alle Anwendungsfälle hinweg bezüglich der Eigenschaften „stressfrei“, „zeitsparend“ und „komfortabel“.

Autonomes Fahren für Menschen mit Mobilitätseinschränkungen: Immer wieder wird hervorgehoben, autonomes Fahren könne das Leben von Menschen mit Mobilitätseinschränkungen einfacher machen. Unsere Befragung macht jedoch auch deutlich, dass sich bereits heute ein großer Teil der Menschen mit Mobilitätseinschränkungen im Alltag des Autos bedient. Ob also das autonome Fahren für diese Menschen einen grundlegenden Zugewinn ermöglicht und sie „mobilisiert“, ist mit Bedacht in das Kalkül aufzunehmen. Interessant ist, dass Menschen mit Mobilitätseinschränkungen das autonome Fahren nicht positiver als andere bewertet haben. Ganz im Gegenteil – das Ausmaß an Ablehnung war sogar vergleichsweise hoch.

Anwendungsfälle für autonomes Fahren: Unsere Untersuchung zeigt, dass sich die Spezifizierung von Anwendungsfällen als ausgesprochen bedeutend erweist und in hohem Maße zur Erklärung von Einstellungen und Erwartungen zum autonomen Fahren beiträgt. Besonders auffällig war, dass bei den Befragten mit der beispielgebenden Einführung von Anwendungsfällen die Bewertungen ablehnender, vor allem aber auch sehr viel differenzierter wurden.

Forschungsbedarf „Nutzerperspektive“

Der Fokus der vorliegenden Studie lag auf Einstellungen und Erwartungen an das autonome Fahren im Allgemeinen und in spezifischen Ausprägungen. Dabei konnten wir zeigen, dass mit der Einbettung der Fragen in spezifische konkretisierte Kontexte von autonomem Fahren die Differenziertheit der Antworten zunimmt. Diese Erfahrung sollte eine wesentliche Leitlinie in der weiteren Forschung werden. Dies gilt in zweierlei Richtungen: Arbeiten zur Akzeptanz von autonomem Fahren müssen sich stärker an absehbaren Anwendungen dieser Technologie orientieren; gleichzeitig müssen Anwendungen zum autonomen Fahren konkret erfahrbar werden. Damit kann die Erforschung der Nutzerperspektive die notwendigen Impulse geben für die Implementierung des autonomen Fahrens, aber auch für die Abschätzung der Wirkungen, die von einem sich wandelnden Nutzerverhalten auf das Verkehrssystem ausgehen.

In Fortführung der vorliegenden Studie sehen wir dabei folgenden unmittelbaren Forschungsbedarf:

- → **Akzeptanz** von autonomem Fahren durch **spezifische Nutzergruppen**, insbesondere urbane, suburbane und ländliche Bevölkerung, Autonutzer/innen und Nutzer/innen des Öffentlichen Verkehrs, Personen mit vergleichsweise häufigen längeren Wegen im Fernverkehr

- → **Zeitverwendung** bei Alltagswegen beim konventionellen und autonomen Unterwegssein

→ **Akzeptanz** autonomer Fahrzeuge im Kontext **neuer Mobilitätskonzepte**

→ **Auswirkungen** der absehbaren Veränderungen im **Verkehrsverhalten** auf die **Verkehrsnachfrage**.

Diese auf die Nutzerinnen und Nutzer zielenden Themen werden einen wichtigen zielorientierten und sachgerechten Beitrag auf dem Entwicklungspfad hin zum autonomen Fahren und zu einem Verkehrssystem mit autonomen Fahrzeugen leisten.

1 Introduction and scope of the study

The implementation of autonomous road vehicles into the transport system is envisioned in the not-too-distant future, although there are remaining uncertainties concerning various aspects, e.g. technological, regulatory, etc. (see Gasser et al. 2012). The topic is currently receiving attention in many fields, be it media, transport research, futures research, policy making, or transport planning.

Autonomous driving, also often labelled as “driverless”, “self-driving”, or “fully automated driving”, and referring to level 4 and 5 systems as defined by the VDA (German Association of the Automotive Industry)[1], see Figure 1, is often considered to have radical implications on future transport systems: it is supposed to reduce crashes or even eliminate them completely, it may have significant impact on traffic flow, reduce emissions, etc. (cf. Friedrich 2015, Hönle 2015, Litman 2015, Winkle 2015, Burns 2013, Fagnant & Kockelman 2013).

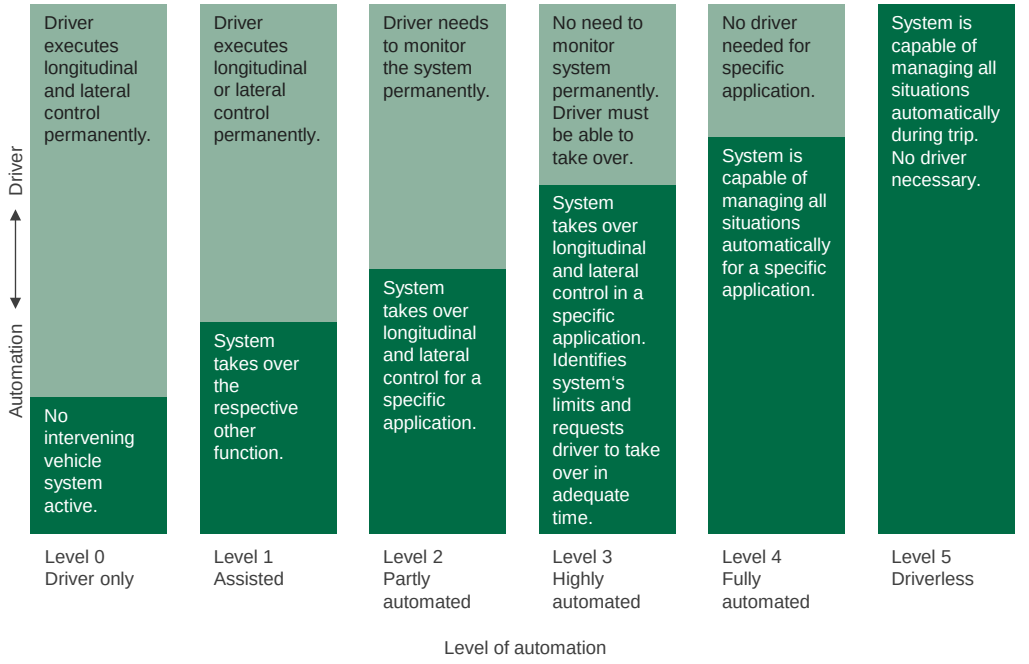


Figure 1: Levels of automation, as defined by the VDA (2015, translated, modified by the authors)

Autonomous driving is also likely to have a highly significant impact on future users as well as road vehicle usage. Changes in mode choice behavior, time valuation and a rise in productivity while traveling are currently being discussed in this regard (cf. Fagnant & Kockelman 2015, Silberg et al. 2012). However, the lack of empirical examination and the comprehension of important aspects about the usage context, constraints and perceived benefits, especially on the future users’ side, make predictions as well as planning difficult. While the general set-up (i.e. technological,

[1] There are various definitions on autonomous driving for different countries that are similar in most aspects but vary in others, see for example the SAE J3016 Information Report (2014).

regulatory, etc.) remains essential before autonomous vehicles can be implemented into the transport system in the first place, someday in the near or distant future, acceptance of possible future users, what they perceive as benefits of the technology, and potential changes and disruptions in their travel behavior will all play a major role, too. For actors in industry, politics, transport planning, consumer research, and science, it is therefore important to examine potential users and the type of impacts the technology might have on their behavior, thus likely influencing the transport system in a broad sense.

Recent empirical work has usually focused on general attitudinal and acceptance issues, experiences with driver assistance systems, desired assistance or convenience functions of cars (cf. Continental 2015, 2013). The studies rarely account for differentiation of the possible heterogeneous variants of the technology, e.g. specific applications, and are not aimed at providing insights on behavioral changes or prospective application situations. When talking about the “human factors”, reference is usually made to psychological aspects of individuals in interaction with automated driving systems while setting aside users, usage and the transport system in a more systemic approach.

In addition, examining autonomous driving in relation to users and usage is problematic per se: neither broad knowledge nor actual experience of the technology can be assumed to-date and respondents, when asked, simply do not have accurate notions of what the technology can and cannot do.

The scope of the study at hand is to focus on how autonomous driving may impact future users’ behavior (in prospective application situations), and how today’s users of the transport system perceive and evaluate the future technology. Given the above-mentioned challenge of the lack of user knowledge and user experience with autonomous vehicles, we integrated quantitative as well as qualitative aspects to adequately address respondents’ opinions on the topic. Furthermore, we distinguished specific use cases of autonomous driving to explore whether they could have different outcomes. Despite remaining uncertainties, this approach enables a more comprehensive understanding of transport user attitudes towards the technology and gives valuable hints on influencing parameters as well as their possible development over time. Further details on the study design are presented in section Approach.

1.1 Recent trends of autonomous driving in Germany

Autonomous driving as a topic entered the broader public debate in Germany only recently (approximately 3 years or so), which can be seen in a huge amount of media reports of all kinds (cf. Hänsch-Petersen 2016, Hucko 2015, Maier-Borst 2015), policy, research and planning strategy platforms (cf. Gasser et al. 2015), as well as legal and industry developments (cf. Gasser et al. 2012, Daimler 2013). The inclusion of transport user perspectives into the debate, though, has been underexposed to-date. Only a few studies and position papers explicitly addressing potential future users of autonomous driving have been published so far (cf. Cyganski et al. 2015, Fraedrich & Lenz 2014).

A variety of reports that are more user oriented[2], some containing empirical data, originate from consulting companies and market research – these, however, display a rather heterogeneous picture of user attitudes towards autonomous driving. Some identify a general openness of their respondents towards the technology (BITKOM 2015; AutoScout24 2014, 2012) while others see still skeptical attitudes and low receptivity (cf. Puls Marktforschung GmbH 2015; Ernst & Young 2013). Certainly, studies like these could give interesting and valuable insights into the current trends and developments of a technology – but a common limitation can be seen in the general lack of knowledge of and experience with autonomous driving. It is often quite ambiguous what respondents of the above-mentioned studies mean when they reveal their attitudes towards autonomous driving: the 'concept' of autonomous driving is very likely to be not well-known or understood in different ways – which then explains the heterogeneity of the study results.

A multi-disciplinary joint German-US project called "Villa Ladenburg", funded by the Daimler and Benz Foundation, dealt with ethical, social, legal, psychological and transport-related aspects of autonomous driving, giving a comprehensive view of the topic (Maurer et al. 2015)[3]. Some of the examinations within the project also contained user perspectives on autonomous driving. Fraedrich & Lenz (2014) looked at acceptance of the technology with the help of qualitative research methods and found ambivalent and complex attitudes of transport users with no clear for or against the technology. And Woisetschläger (2015) revealed that there already exists a substantial market segment of users potentially willing to buy an autonomous vehicle although noticeable acceptance issues still remain.

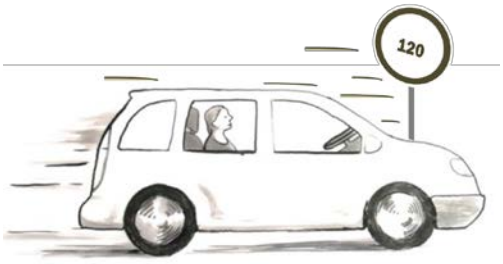
The study at hand was also part of the Villa Ladenburg project. Here, specific use cases were identified to "describe typical usage scenarios for autonomous driving" (Wachenfeld et al. 2016: forthcoming). Although the selection is not exhaustive, the four use cases represent proxies of fully automated applications that cover the range of autonomous driving functions from those that can be 'switched on' whenever requested to vehicles where no human driver is allowed anymore (i.e. a so-called "Vehicle on Demand"). The decision to distinguish the different use cases of autonomous driving presented in the subsequent section when conducting the survey was made to explicitly address different impacts that could come along with them regarding user perception and evaluation, as well as time use while traveling and changes in travel behavior.

[2] The following remarks concentrate on Germany only but can be quite easily transferred to other western countries.

[3] The results from the project were published in German in a monograph in 2015. A translation of the book in English will be available as of March 2016. In the following, we will refer to the German version whenever mentioning results from the project.

1.2 Use cases of autonomous driving

The following section briefly describes the use cases that were applied in the survey. For an extensive version, please see Wachenfeld et al. (2015). Also, a short overview is given on possible implications for future transport behavior, the transport system as well as potential spatial transformations to illustrate potentials as well as challenges of the use cases from a systemic point of view – more information on that is provided, for example, by Cyganski (2015), Heinrichs (2015), and Levinson & Krizek (2015).



Use case 1: Highway Pilot

"On interstates or interstate-like expressways the driving task can be transferred to the vehicle. During that time, the driver does not have to monitor traffic or driving and can pursue other activities." [4]

The main benefits for the users is supposed to be the relief of tasks that are often regarded as stressful (monotonous driving over longer time periods, traffic jams or road work scenarios with exhausting braking and acceleration tasks) (cf. Continental 2013) and the possibility of spending time in a different way – one that is potentially perceived as more worthwhile.

Whereas today public transport usage mostly offers the possibility of spending time actively while traveling, a future with Highway Pilot could have significant impacts on the use of cars on long distances, offering the same advantages as trains without having to share the space with other, unknown, passengers.

Use case 2: Parking Pilot

"After all passengers got out, the vehicle can drive autonomously to a pre-defined parking spot and return from there, too."

The possibility to get out of the vehicle at a desired destination and let the vehicle park itself could significantly help to ease time and parking pressure that especially occur in areas where space for private parking is limited, cost-intensive and also frequently combined with long walking-distances to and from parking locations. The function would facilitate transporting children and cargo, and make the use of cars easier for people with mobility constraints.

[4] The quotations of the four use cases are identical to the descriptions as presented to the respondents in the survey.

Parking search traffic could be minimized substantially with positive effects on inner-city traffic and reduction of travel-time. Then again, additional trips could originate from empty tours of vehicles, thus leading to more traffic and potentially counterbalancing the before-mentioned effect. This use case could also lead to significant changes in car ownership rates as such vehicles could be privately owned, but might as well be owned by a carsharing provider or similar business model (Wachenfeld et al. 2015).

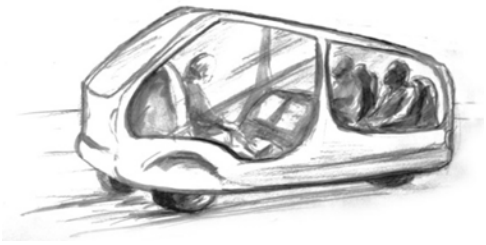
Use case 3: Fully Automated Vehicle

"On demand, the driving can be transferred to the vehicle. During that time, the driver does not have to monitor traffic or driving and can pursue other activities."

From an individual perspective, increased safety, and travel-time spent in worthwhile ways might be perceived benefits of this use case. This could especially apply for commuters, who could spend their onboard time more productively or more meaningfully.

Impacts on the transport system and on land use could be tremendous. If travel-time is perceived more positively, people could tend to accept longer commuting distances, live in the suburbs, or in more remote, rural areas, while working in the city (Cyganski 2015, Heinrichs 2015).

Moreover, decreasing inhibition thresholds for inexperienced, insecure or elderly drivers could lead to an increase in car use and ownership rates as well as to a decline in the use of public transport modes (cf. Fagnant & Kockelman 2013; Brookhuis et al. 2001) depending, however, on regulations on requirements for drivers' licenses, which makes it difficult overall to predict the developments.



Use case 4: Vehicle on Demand

"A Vehicle on Demand is a motor vehicle that can transport its passengers without any driver. Humans cannot drive manually; therefore, such a vehicle does not have a steering wheel or pedals anymore."

Vehicle on Demand could provide seamless use of transport means, therefore likely increasing multimodal travel behavior. At the same time, however, it could serve as a rival to public transport, increasing VMT and car use dramatically (see Fagnant & Kockelman 2013; Willumsen 2013).

This use case implies large-scale changes in the user experience as well as in travel behavior and in the overall transport system as it allows for individual and flexible mobility. Vehicle on Demand is expected to bring car ownership rates down drastically and lead to tremendous increase in carsharing with significant impacts on land use, e.g. in inner-city areas, where parking space could be freed for alternative use as well as to transform individual and public transport systems as we currently know them (cf. Fraedrich et al. 2015c, Litman 2014; Silberg et al. 2012),.

2 Approach

Within the Villa Ladenburg comprehensive research project, a study on the potential impact of autonomous driving was conducted in April 2014 via an online market research panel with respondents aged 18 and over. The survey differentiated between the use cases of autonomous driving described above and focused on attitudes and anticipated uses of the respondents.

The sample consisted of 1,000 completed questionnaires and was stratified by gender, age, income and education in order to be nearly representative for the German population aged 18 or above.

A first section of the questionnaire included information on the sociodemographics of the participants, their level of knowledge and interest in the topic of autonomous driving as well as their previous use of driver assistance systems. Subsequently, the current use of and attitudes towards the available transport modes were collected. Additionally, the respondents were interviewed on their usual time use when traveling by car, long-distance train and public transport.

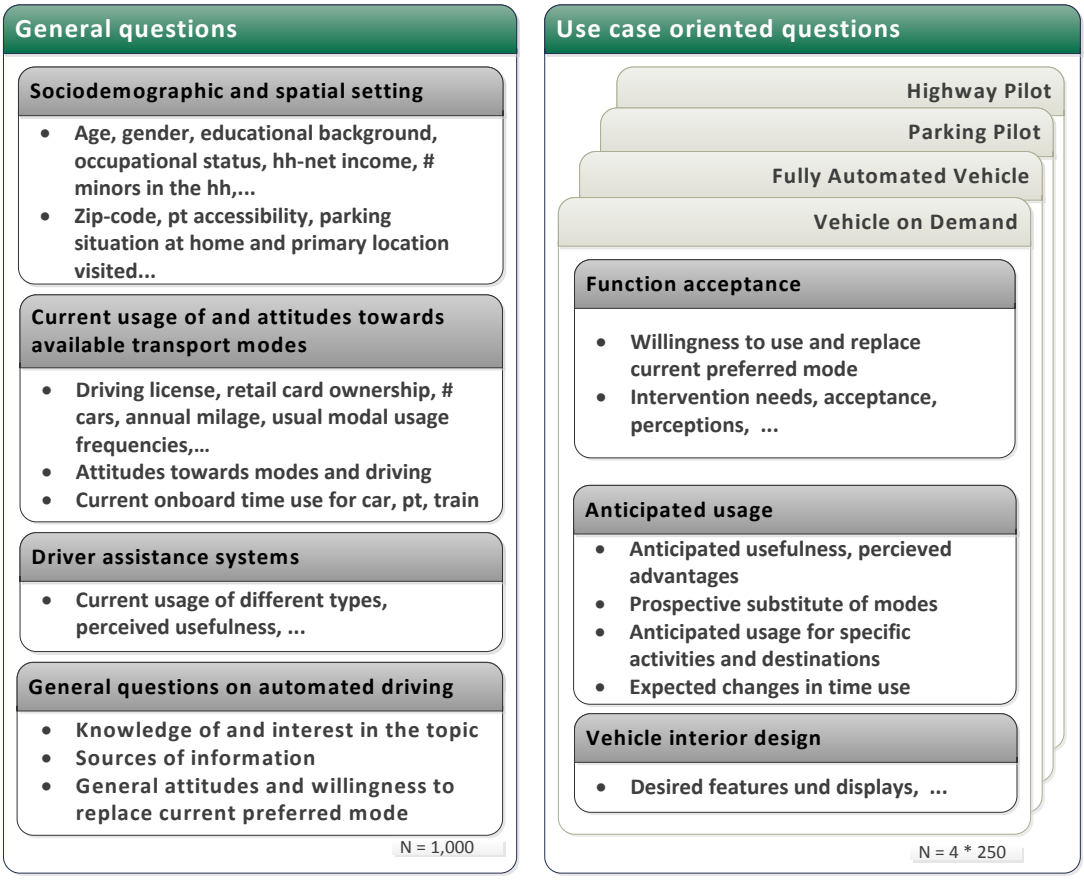


Figure 2: Design of the study

In the second part of the survey, participants were asked detailed questions on one randomly selected use case. Hereby, 250 interviews were obtained for each use case. As illustrated in Figure 1, use case oriented questions addressed anticipated use and deployment purposes, prospective substitute transport modes, perceived usefulness and expected changes in time use. Furthermore, attitudes towards the described

vehicle, the respective need for intervention, and different aspects of design requirements were also asked about.

For all the figures presented in the following sections of the report, you will find a more or less literal translation of the original German survey question in a text field next to the figure. For further detailed information, the questionnaire can be obtained in German language on request. Contact information is provided at the end of the publication.

Table 1 contains an overview of the sociodemographic characteristics of respondents and the sample structure as well as information on their current transport behavior. The key indicators presented in the table were compared to the corresponding shares in the Mobility in Germany 2008 survey, known as MiD 2008, in order to check for representativeness. This well-known und very frequently used national travel survey is commissioned by the Federal Ministry of Transport and Digital Infrastructure (BMVI), and conducted on a regular basis. The latest, the 2008-wave, contains detailed information on the travel behavior of over 60,000 persons in around 26,000 households and is therefore a good base for reference. Details on the survey can be found in infas & DLR (2010).

In our survey, slightly over half of the 1,000 respondents were female, and in comparison to the actual age distribution of the German population reported in the MiD, our sample contains slightly more single living people, with a lower educational level, whereas the age structure is comparable (infas & DLR 2010: 78). Clear differences in the samples can be seen in the structure of household sizes. With a share of 17 % of single- and 48 % of two-person households, household sizes are considerably smaller than in the MiD, where the corresponding shares amount to 4 % and 26 % respectively.

Based on the post code provided by the respondents, the type of settlement structure of their place of residence was determined. We used the so called “Siedlungsstruktureller Kreistyp” classification provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), which is based on total population as well as population density measures[5]. In our sample, about a third of the respondents were living in major cities, an additional 40 % in urban characterized counties – a share a bit higher than in the MiD.

Our share of 90 % of the respondents holding a driver’s license for a car is one of the important indicators for judging whether the sample contains a reasonable share of general or even regular car users. Our sample corresponds well with the findings of MiD 2008 – there, 88 % of respondents aged 18 or above report holding such a license (infas & DLR 2010: 70). The number of households without any car in our sample is a little bit lower than in the MiD (13 % vs. 18 %).

With respect to the usual transport mode usage, our sample is rather similar to the patterns found in MiD. There, daily car usage rates amount to 54 %, almost identical with our samples usage. At the same time, low intensity cars users are overrepresented

[5] For details, please refer to http://www.bbsr.bund.de/BBSR/DE/Raumbeobachtung/ Raumabgrenzungen/Kreistypen4/ kreistypen.html?nn=443270.

in our sample, with 17 % using the car less than monthly as a driver compared to 8 % in MiD. The shares of respondents using public transport on at least a weekly basis are very similar in our survey and in MiD, at 24 % of our and 23 % respectively, as is also the case for low intensity users (59 % vs. 61 %). Also identical is the share of respondents stating they use a non-local train at least once per month (7 %), with our sample showing a clearly lower share of (almost) non-users (47 % vs. 64 %).

Annual reported mileage or kilometers as a driver seems to be reasonably or a little low, with around 50 % percent of the respondents stating they drive 10,000 km per year at most. Those driving at most 5,000 km per year might be overrepresented, though, as data released by market research institute DAT indicates (Motortalk 2015). Unfortunately, comparison of our sample with the MiD is not applicable, due to their car-based mileage reporting. Also, MiD does not contain perception- or attitude-oriented questions, thus a base for comparison is lacking here as well.

Most of the analysis we present in the following sections are based on so-called ‘closed questions’ with given answering options. Indicated percentages are usually rounded, and any deviations in the column sums you might find are due to rounding effects. In the figures and tables presented, you will see two sample sizes frequently occurring. A sample size of 1,000 – corresponding to the number of all respondents – refers to questions presented to all participants. A sample size of 250 indicates use-case-specific questions with a consequently smaller group of respondents. In sections 3 and 6, two exceptions to this rule can be found: the analysis of what driving function respondents would be willing to give up was confined to those stating they are regular drivers, resulting in 824 cases. Also, the figures referring to participants with stated mobility impairments are naturally based on a smaller sample size.

Varying sample sizes also occur for a second reason in section 3, where we present results stemming from the qualitative analysis of the answers given to the open questions we asked. In order to explore what respondents currently associate with autonomous driving, they were asked to declare in their own words what they understand by the term “autonomous vehicle,” in general and in terms of the use cases. Participants were given one free-text box for their answers on the general term and up to fifteen boxes for the use cases. The answers given were first summarized and categorized by hand and then allotted specific connotations. As a result of the different number of respondents, but especially due to the varying number of given answers, the number of statements we were able to process vary strongly, ranging between 531 and 1,236. Details on the approach used for the qualitative analysis can be found in Fraedrich & Lenz (2015b).

Most of the closed questions asked in the survey with given answering options followed an ordinal, Likert scale answering scheme. The Likert scale is a psychometric scale and commonly used to measure the level of agreement of a respondent to a given statement (see e.g. Friedrichs 1990: 175). Most of the scales used in the survey have 6 answering options, the most common one being an agreement format (Strongly

disagree/ Disagree/ Slightly disagree/ Slightly agree/ Agree/ Strongly agree [6]). Especially when it comes to the current and anticipated time use, you will find 4-option schemes (Never/ Sometimes/ Often/ Always) prevailing.

Table 1: Sociodemographic and transport behavioral characteristics of the data set

Attribute	***Level***	***Percent***
Gender	*female*	*56 %*
Age (years)	*18-29*	*9 %*
	30 - 49	*34 %*
	50 - 64	*32 %*
	65+	*26 %*
Children under 18 in the HH	*no*	*76 %*
Household size	*1 person*	*17 %*
	2 persons	*48 %*
	3+ persons	*36 %*
Highest educational level = High school degree	*yes*	*30 %*
Highest professional qualification = University degree	*yes*	*18 %*
Occupational status	*full-time (>= 35 h/w)*	*32 %*
	part-time (18-<35 h/w)	*13 %*
	other	*55 %*
Household net income (Euro)	*< 900*	*7 %*
	900-<1,500	*18 %*
	1,500->2,000	*15 %*
	2,000 - < 2,600	*14 %*
	2,600 - < 3,600	*19 %*
	3,600+	*28 %*
BBSR type of settlement structure of place of residence	*Major city (100,000+ pop.)*	*33 %*
	County with denser pop. + urban character	*41 %*
	Rural county with signs of densification	*16 %*
	Sparsely populated rural county	*10 %*

[6] For sake of better understanding, we are using the scale terminology most common in English instead of a literal translation of the German answer option originally provided in the survey. As a consequence, slight semantic shifts might occur in some cases. A juxtaposition of the German and English scales is provided in the Appendix.

Driving license	*yes*	*90 %*
Rail card	*Yes*	*9 %*
Number of cars in the household	*0*	*13 %*
	1	*52 %*
	2	*29 %*
	3+	*7 %*
Annual car mileage as driver (km)	*< = 5,000 km (8,050 mi)*	*17 %*
	5,001 – 10,000 km (8,050 – 16,100 mi)	*32 %*
	10,001 – 15,000 km (16,100 – 24,150 mi)	*28 %*
	15,001 – 20,000 km (24,150 – 32,200 mi)	*12 %*
	+20,000 km (32,200 mi)	*12 %*
Usual car usage (driver)	*(almost) daily*	*55 %*
	1-3 days a week	*23 %*
	1-3 days a month	*5 %*
	less than monthly	*5 %*
	(almost) never	*12 %*
Usual car usage (passenger)	*(almost) daily*	*6 %*
	1-3 days a week	*25 %*
	1-3 days a month	*23 %*
	less than monthly	*28 %*
	(almost) never	*18 %*
Usual public transport (PT) usage	*(almost) daily*	*14 %*
	1-3 days a week	*10 %*
	1-3 days a month	*18 %*
	less than monthly	*30 %*
	(almost) never	*29 %*
Usual train usage (>=100 km)	*(almost) daily*	*0 %*
	1-3 days a week	*1 %*
	1-3 days a month	*6 %*
	less than monthly	*46 %*
	(almost) never	*47 %*

For sake of clarity and readability of the figures, you will find that we limited the range of answering options depicted in some cases. This applies either for the middle range answers (Slightly agree / Slightly disagree, Quite important / Quite unimportant) indicating no clear position of the respondent, or when the figure concentrates on either side of the answering scale. For instance, Figure 14,

depicting the importance of mobility related needs for the everyday life of the respondents, is an example where we refrained from depicting the middle ranges.

Figure 6, showing the sources of information on autonomous driving, only presents the shares of the respondents' answers with affirmative connotation.

For enhanced readability of the figures, we also sometimes treated the ordinal scales as quasi-metric and worked with the averages of the responses given rather than depicting a 6-part column. You will find this kind of figures primarily when comparing different use cases, for instance in Figure 22, which shows the perceived usefulness for different kind of trips. When building the average in these cases, affirmative answers are counted positively; disagreeing or negative answers are counted with negative sign. Accordingly, in the case of a 6-level Likert scale, answers are accounted for as (-)1 up to (-)3 depending on the level of (dis)agreement.

Generally, variables used in the analysis are directly derived from the questions we asked in the survey. There is, however, one prominent exception: in the tables presented for the correlation results (see Table 3, Table 4, and Table 5), we included results for a variable called "DAS user". In the survey, respondents were asked whether and how often they used a number of different driving assistance functions (e.g. cruise control, lane keeping assist, emergency brake assist). The Boolean variable DAS user was generated on basis of these answers: we hereby defined a DAS user as a respondent using at least three different driving assistant functions at least frequently.

In most of the sections, we present results from tests checking for existence and strength of correlation between variables, e.g. acceptance-related items and sociodemographic items. Methods used vary depending on the variable scales. For the test of significance, we used Pearson's chi-squared test for combinations of ordinal and nominal variable scales. In the more common case of two ordinal variables, Spearman's rank correlation coefficient test (Spearman's Rho) was used. In the following, correlations are indicated as statistically significant when exhibiting values of 0.05 or lower, for values of 0.01 and lower, the term highly statistically significant is used. When the results indicated a statistically significant correlation, the measure of association was determined next. For the combination of ordinal variables, Spearman's Rho was used again; for the combination of nominal and ordinal variable scales, Cramer's V was calculated. Both measures indicate the strength and the direction of the association of the variables. When checking whether differences in the answering patterns displayed for different use cases showed statistical significance, we used single-factor analysis of variance (ANOVA) methods, thus treating the ordinal scales as quasi-metric (see for instance, Brosius (2011) for details on the statistical methods.

While details on the significance and strength of correlation are kept short in the text, Table 3 and Table 4 in section Autonomous driving and mobility and Table 5 in section Conclusions provide an in-depth overview of the findings. Depending on the p-value derived from testing, correlations are marked following conventions with a single * when exhibiting values from 0.05 to 0.01, with ** for values between 0.01 and 0.001, and with *** for values lower than 0.001. In case no correlation was found, the table indicates this by displaying the cell in a very light grey. For those cases where we found statistically significant correlations, the table indicates further the strength of correlation

using color coding from light grey to blue. The categories used correspond with Brosius (2011: 523). A light grey indicating a very weak correlation, ranges from above 0 to 0.2, the second follows up to 0.4 (weak correlation). We use the term medium correlation when the p-value ranges between 0.4 and 0.6. Strong correlation is indicated with a dark green for values between 0.6 and 0.8. When correlation results were (highly) significant but only had a very weak measure of association, we did not further comment on the effect in the following. While statistically relevant, these results did not seem to be relevant with regard to contents. An example: the number of children proved to be highly statistically relevant in relation to the stated willingness to use and autonomous vehicle (with a p-value lower than 0.001, thus in the Table 5 marked with ***). However, the strength of the correlation was only very weak (lower than 0.2), indicated by the grey color, and meaning that the means of the answers given did barely differ between the groups.

3 Autonomous driving – a topic worth noting?

Briefly


Interest in the topic of autonomous driving in general can be described as remarkable but not overwhelming – only 21 % stated having a high interest in autonomous driving.


The technology still seems far from well-known to the broad mass: 44 % claimed to have no knowledge on autonomous driving at all and a notable portion of respondents did not seem to be aware of the functionality of autonomous vehicles in terms of their future role. Unsurprisingly, the no. 1 source of information is mass media.


A large majority of respondents (62 %) preferred to be assisted by an autonomous vehicle rather than to be replaced: driver assistance functions that help detect pedestrians, stabilize the vehicle, park or change gears are favored to those that guide the vehicle, steer, or brake. Consequently, two-thirds picture themselves as surveillant rather than as passenger in the car of the future.


In their own words, respondents described and valuated various use cases of autonomous driving quite differently: Fully Automated Vehicle was rated more positively than Vehicle on Demand – and overall, more respondents could not really picture what Vehicle on Demand even is.

3.1 Interest, knowledge, and sources of information

By the time the survey was conducted, autonomous driving had already undergone a notable transition from a subject only to be found in professional journals to one that had been introduced to a wider public via various media reports (see Munsch 2014, Hägler 2013, Sokolow 2013). Along with this shift came a broader debate that also manifests in rising interest among the respondents of the study. Fifty-seven percent claimed to have interest in the topic in general, see Figure 3.

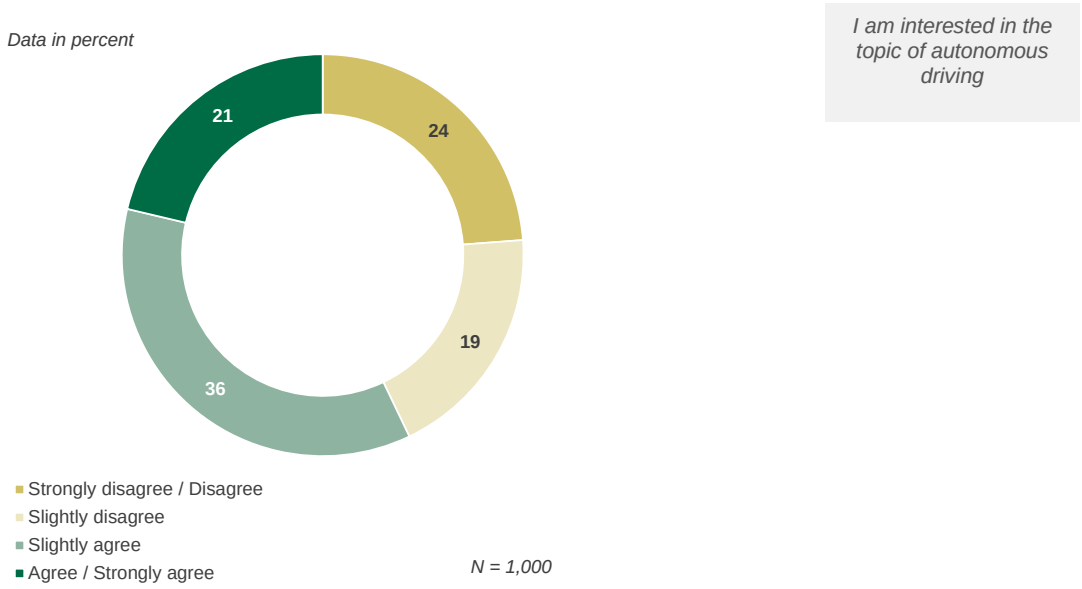


Figure 3: Interest in the topic of autonomous driving

Respondents who declared themselves interested in autonomous driving were significantly more willing to hand over driving functions such as speed regulation, parking, braking, steering, gear changing, pedestrian detection, vehicle stabilization, and the complete vehicle guidance to a computer system – although the strength of the correlation was only weak.

While there is no or only very weak correlation with interest in the topic and sociodemographic aspects – neither gender nor age, income, children in the household, educational background, etc. mattered – interest in the topic corresponded well and positively with knowledge on autonomous driving, see Figure 4.

Overall, a distinct level of knowledge of the topic appeared relatively infrequently at the time the survey was conducted. Almost half of the respondents (44 %) stated they had no knowledge at all. Fifty-one percent declared they had at least heard of or read about it. However, only a very low number (5 %) of all respondents declared that they feel well acquainted, very knowledgeable or even as experts in the topic, see Figure 5.

Interest in and level of knowledge of autonomous driving

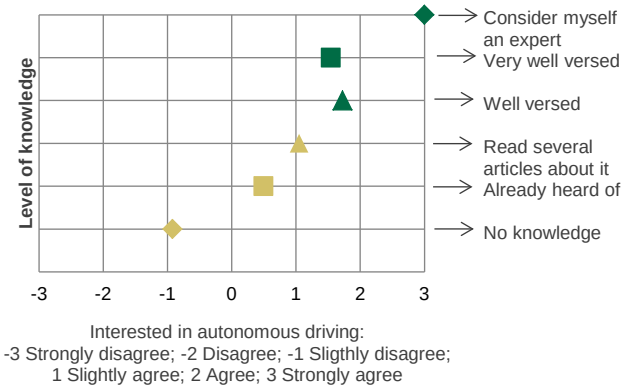


Figure 4: Interest in autonomous driving in relation to level of knowledge on the topic

When asked about their sources of references on the topic (multiple answers were possible), 77 % stated they obtained their information from the mass media, almost two-thirds (65 %) said they turned to experts (defined as dealers and service providers in the questionnaire), 56 % talked to friends or colleagues, and 27 % seeked exchange on social media platforms, see

How would you rate your personal knowledge of autonomous driving?

Figure 6.

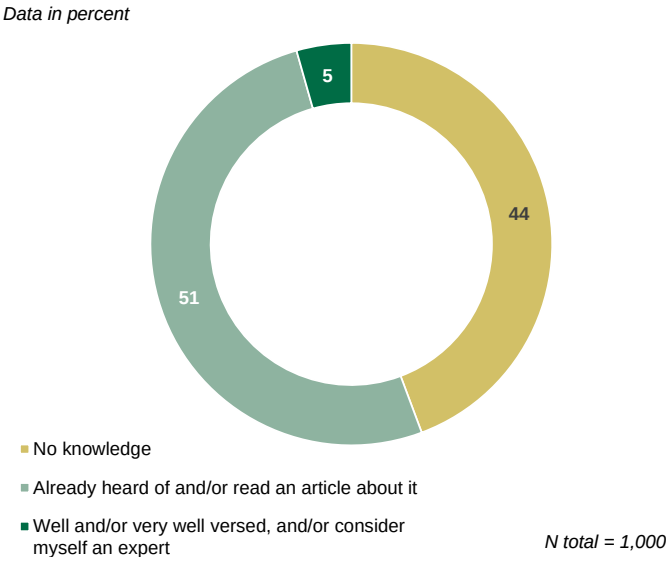


Figure 5: Self-assessment of knowledge on autonomous driving

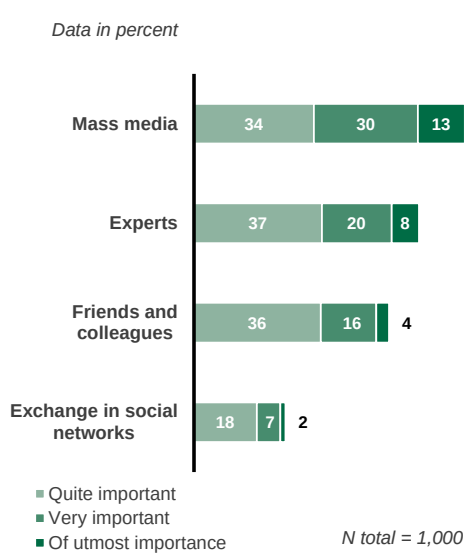


Figure 6: Sources of information on autonomous driving

3.2 Ready to hand over?

Riding in an autonomous vehicle, on the one hand, means to be liberated from the task of driving. On the other, it also means to be willing to hand over control to a machine / computer system. A vast majority of the respondents (62 %), however, would not want to hand over the complete vehicle operation. It seems that they prefer to be assisted rather than to be replaced. The results thus show that functions operating on a relatively 'low' level of intervention (e.g. park assist, gear changing assist, pedestrian detection assist) are preferred to ones potentially perceived as too invasive. Figure 7 shows that respondents did not want to transfer driving functions such as braking, steering or guiding the vehicle to a machine. The preferences match another result where almost two-thirds stated they would favor seeing themselves in the role of a supervisor (64 %) rather than in the role of a passenger when driving in an autonomous vehicle, see Figure 8.

These results are not surprising considering the fact that there has not as yet been any real-life user experience with autonomous vehicles, possibly making it difficult for potential users to imagine a fully automated car functioning safely and reliably.

Which functions or operations would you like to delegate to driver assistance systems?

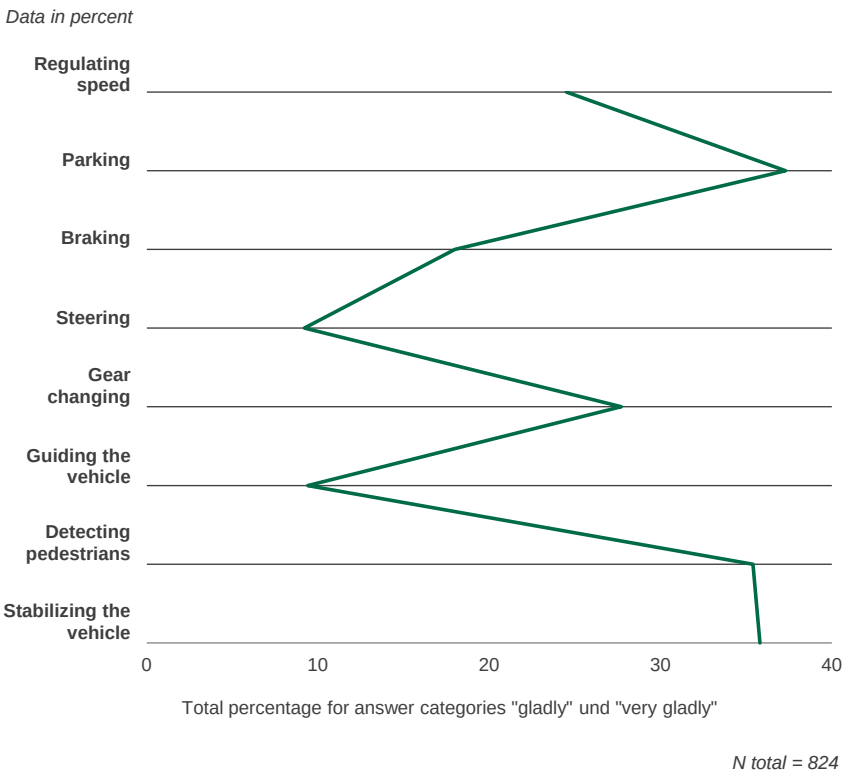


Figure 7: Stated willingness to give up driving functions (filter applied: regular car users)

Again, the item did not correspond, or only very weakly corresponded with sociodemographic variables. We found, however, a significant correlation with car-related behavior and attitudes. Respondents were more likely to state they prefer the role of a surveillant to that of a passenger when they fulfilled the following criteria: they had a driver's license, used an automobile in everyday life, declared that driving a car meant relaxation and felt safe and protected, needed the private space of an automobile, enjoyed applying their driving skills, and resisted transferring steering and complete vehicle guidance to a machine (see Figure 9).

Please indicate via the scroll bar what role you would prefer in an autonomous vehicle.

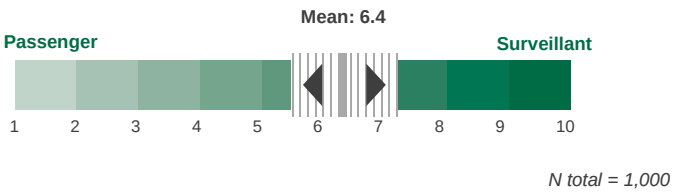


Figure 8: Stated role of the future driver

Preferred role in an autonomous vehicle and willingness to give up the guidance of the vehicle

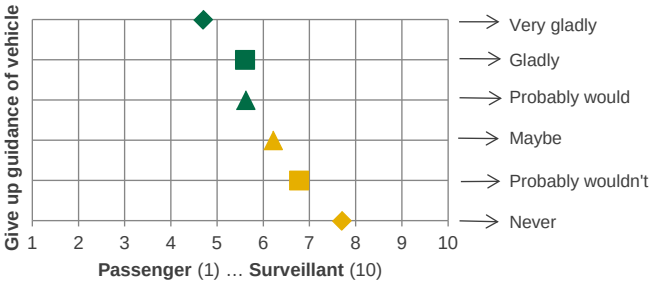


Figure 9: Correlation between the preferred future role in an autonomous vehicle and the willingness to give up the complete guidance of the vehicle

3.3 Connotations of autonomous driving, and autonomous vehicles

To explore what they currently associate with the technology, the respondents were asked to explain in their own words what "autonomous driving" is. These comments are interesting on the one hand because they reveal the level of knowledge on autonomous driving. On the other, they also shed light on sometimes apparent, sometimes latent valuations and meanings that people attribute to the technology.

The free-text answers were categorized and analyzed in terms of the respondents' perception of future drivers' roles in autonomous vehicles. This gives a more precise understanding of how they currently perceive the technology and has to be seen in relation to their attitudes and valuations regarding the technology.

As described in section Introduction and scope of the study, an autonomous vehicle is technically defined as a system where (in a specific use case or in every traffic situation) no human input is necessary to execute the driving task (level 4 and 5, VDA – German Association of the Automotive Industry). However, the results show that this understanding was not familiar to all of the respondents, see Figure 10. Of the 531 statements[7], 43 % clearly displayed a comprehension of autonomous driving as defined in the VDA description – they identified their future role as passengers or bystanders, whereas the vehicle autonomously does everything it needs to get from point A to point B. On the other hand, 25 % of the respondents saw themselves only partly supported in the driving function by the computer systems – meaning that they also implied being engaged themselves in driving functions in one way or another or having to take over whenever the system requests them to. A very small proportion of 2 % had the notion that autonomous driving means some sort of remote- or externally-controlled function and 31 % of the statements had no (or no recognizable) reference to the role of a

[7] Of all 1,000 entries (one text field per respondent), 469 had to be labeled as 'invalid' – information thus obtained that did not make sense in connection to the survey question at all (e.g. "xxx", "…").

human in an autonomous vehicle – this could mean that they had no idea at all what autonomous driving is, that they confused it with something else (e.g. carsharing) or that it did not become clear what they really referred to.

Role of driver in an autonomous vehicle (free text analysis)

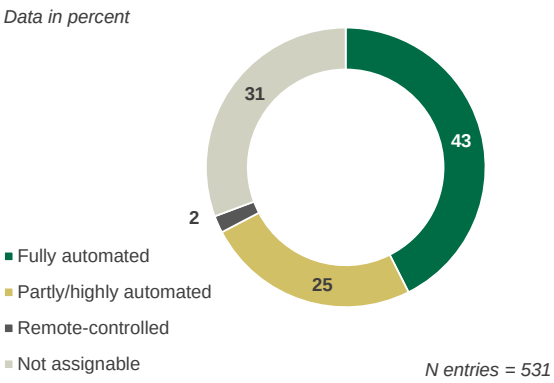


Figure 10: Intended roles of drivers in autonomous vehicles, assigned via free text box

In the further course of the study, the respondents were requested to state in their own words, in fifteen free-text boxes, what they understand by the term “autonomous vehicle” in relation to the specific use case they were randomly assigned to. The short descriptions, provided in section Introduction and scope of the study, served as a basis here. The following analysis refers to the answers of those respondents who had been allocated the Fully Automated Vehicle and Vehicle on Demand use cases.

The answers of the 250 respondents were summarized and categorized by hand and then allotted specific connotations. For Fully Automated Vehicle, there was a total of 3,750 entries; of these, 2,587 (69 %) were invalid for various reasons, similar to the ones mentioned in footnote 7 and probably also due to the fact that the structure of the online questionnaire forced the respondents to fill in text in every of the fifteen boxes – obviously, some had no say in this regard. For Vehicle on Demand, 2,512 of the 3,750 entries (67 %) were unusable. Figure 11 shows the distribution of statements with various connotations: positive, ambiguous, negative or without connotation – the invalid entries have already been taken out at this point and the percentages refer to the remaining statements.

While just under half of the statements for Fully Automated Vehicle have a positive connotation, the same can only be said for 38 % of statements applied to Vehicle on Demand. In terms of negative connotations, a similar portion (36 % and 40 %) could be allotted to the two use cases. A small portion of the perceptions (5 % and 4 % respectively) were ambiguous, i.e. they could not clearly be connoted as positive or negative. Whereas only 9 % of the statements for Fully Automated Vehicle where without connotation, this percentage rose up to 18 % for Vehicle on Demand – the next section describes what this means specifically.

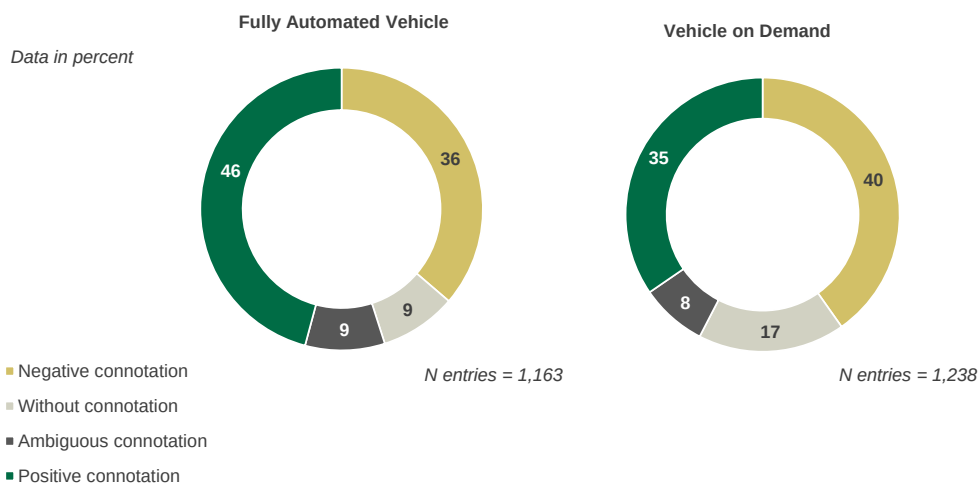


Figure 11: Connotations for Fully Automated Vehicle, and for Vehicle on Demand

Overall, the characteristics that the respondents attributed, independently of one another, to each of the two scenarios were relatively similar. Many answer categories are both equivalent in their meaning and similar in their percentage distribution. However, the results also demonstrate that Vehicle on Demand was subject to the greatest number of negative and fewest positive assessments. The word clouds (see Figure 12 and Figure 13) graphically display the (paraphrased and summarized) statements in relation to the frequency of their occurrence for both use cases. In comparison to Fully Automated Vehicle, not only is Vehicle on Demand described with more negative statements but the attributes also seem to be more emotionally connoted, see below. Moreover, as can be shown in the number of answers attributing “no idea”, fewer respondents had any conception of what precisely is meant by this kind of ‘car’.

The answer categories “expensive” and “luxury”, however, which are specifically attributed to Fully Automated Vehicle, indicate that these are still strongly linked to the idea of individual, private ownership as can be found in the privately owned and used automobile. Vehicle on Demand, on the other hand, is compared to other transport modes only to a very small degree or not at all, thus suggesting that the respondents had difficulties of linking this specific use case to any existing transport mode.

N entries = 1,163

Figure 12: Characteristics ascribed to Fully Automated Vehicle, paraphrased, reduced, and generalized

N entries = 1,238

Figure 13: Characteristics ascribed to Vehicle on Demand, paraphrased, reduced, and generalized

The summarized and categorized attributes given for both use cases can be seen in percentaged overview in Table 2 for the top five (respectively four, or three) attributes in every category – for a more detailed explanation of the results, see Fraedrich & Lenz (2015b). In general, the attributes ascribed to either one of the use cases were quite similar, and many were equivalent in both meaning and percentage distribution. In the following, we will therefore only refer to differences where they could be found.

Notable differences in the ambiguous category could be found in the fact that 8 % of the statements given for Fully Automated Vehicle referred to “luxury” – a label that is not once mentioned in relation to Vehicle on Demand. Similar results could be found in the negative category: “expensive” (15 %) ranked on the second position and is not

represented at all among the top five for Vehicle on Demand. As mentioned above, “no idea” was a statement very much linked to Vehicle on Demand, for 50 % of all attributes in the category without connotation were allotted here. In contrary, only 20 % of all statements in this category could be related to Fully Automated Vehicle.

In the negative category, Vehicle on Demand seemed to be associated with very strong emotional descriptions: a quarter of all negative statements comprise “scary” (10 %), “dangerous” (7 %), “weird” (6 %), and “terrible” (2 %) – the latter three not being displayed in the table. These emotionally connoted attributes can hardly be found for Fully Automated Vehicle. “Weird” is mentioned in 11 % of the statements, whereas “dangerous” and “terrible” are only mentioned in 3 % respectively 1 % of the entries (the latter two are not shown in the table).

Table 2: Characteristics ascribed to Fully Automated Vehicle and Vehicle on Demand

Fully Automated Vehicle (FAV) N entries = 1,163			**Vehicle on Demand** (VOD) N entries = 1,238		
Valuation	**#**	**%**	**Valuation**	**#**	**%**
Top 5 positive valuations (N total FAV = 535, N total VOD = 428)					
Comfortable	90	17%	Useful	66	15%
Good	64	13%	Comfortable	59	14%
Safe	62	11%	Relaxing	59	14%
Relaxing	53	10%	Modern	53	12%
Modern	53	10%	Safe	43	10%
Top 5 negative valuations (N total FAV = 422, N total VOD = 498)					
Not for me	68	16%	Not for me	82	16%
Expensive	65	15%	Technology-dependent	58	12%
Unnecessary	52	12%	Unnecessary	57	11%
Uncanny	46	11%	Scary	52	10%
Unsafe	46	11%	Unsafe	49	10%
Top 4 (3) ambiguous valuations (N total FAV = 106, N total VOD = 97)					
The future	51	48%	The future	40	41%
Utopian	24	23%	Utopian	39	40%
Needs getting used to	23	22%	Needs getting used to	18	19%
Luxury	8	8%	/	/	/
Top 3 without connotation (N total FAV = 102, N total VOD = 215)					
Autonomous	29	29%	No idea	109	51%
No idea	20	20%	Autonomous	48	22%
Statement not clear	18	18%	Statement not clear	34	16%

4 Autonomous driving and mobility

Briefly

Asked whether their mobility related needs could be addressed with an autonomous vehicle – according to the different use cases – answers show high diversity for safety, independence and cost. For Vehicle on Demand, more than a third of the respondents did not see their safety needs satisfied. Use cases were seen as addressing users' needs for freedom from stress, time savings and comfort to a higher degree.

Respondents' willingness to hand over a driving or control function to a machine correlated with the mobility related needs that were perceived as being addressed by an autonomous vehicle. Strongest effects concentrated on the combinations freedom from stress, safety and comfort on one side and complete vehicle guidance, steering and pedestrian detection on the other.

While people displaying a positive attitude towards driving seemed to be more prone to be interested in the topic generally, this attitude generally did not correspond with their willingness to use such a vehicle or even replace their currently preferred mode.

With autonomous vehicles at hand, respondents expect by far the biggest changes with respect to their taxi usage, followed by public transport and train usage. While a large share of respondents did not expect any impact on their mode choice, expected effects are lowest for bike and foot.

When respondents were asked for what kind of trips they would find autonomous vehicles particularly useful, the answering patterns for Vehicle on Demand and Fully Automated Vehicle show clear similarities in most cases. Fully Automated Vehicle was at the same time consistently perceived as being more useful than Vehicle on Demand for all trip types - including in an urban context. For trips in the city and with shopping and luggage haulage, Parking Pilot is seen as helpful while Highway Pilot is deemed most positive on longer trips and journeys.

4.1 What needs do autonomous vehicles address?

Mobility, although sometimes a need in itself, mostly serves to satisfy specific needs which cannot be met exclusively at one place (e.g. home). Thus, an additional requirement to move arises from these needs. There exists a variety of needs, from primary needs (e.g. the need to get in social contact with other people), functional ones (e.g. the need to get groceries at a supermarket) to more emotional, psychological, or social needs (e.g. the need to act environmentally responsibly, the need to feel independent). Choices for or against using specific modes of transport relate to such needs. In empirical decision research and related to transport behavior, the focus on instrumental, symbolic and affective functions when choosing a transport mode has widely prevailed (see e.g. Steg 2005).

At the same time, mode choice behavior and mobility related needs are not stable categories but rather subject to constant change – be it on an individual level, thus related to cognitions and emotions, or on a societal level, thus embedded in social dynamics and societal change. Mobility decisions are an assemblage of rational and irrational, conscious and unconscious aspects, of learned behavior, and approved, long-lasting routines (see, for example, Scheiner & Holz-Rau 2007, Schwanen et al. 2012, Cyganski 2015, Bühler 2001). The exact strength of influence of a single criterion or a set of criteria leading to individual mobility choices in everyday life is hardly to be determined. Due to problems in measurement, quantification and isolation of many of the effects, mobility behavior research therefore often uses proxies that are thought to indirectly represent these influences. In contrast with standard economic models, these psychometric approaches use psychological constructs to understand the underlying motives and needs of travel behavior, according to theories from social sciences and psychology (e.g., Anable & Gatersleben 2005, Verplanken et al. 2008).Understandably, the criteria that form the basis of mobility decisions for or against autonomous driving are still unknown. In this study, we therefore focused on attitudinal and emotional aspects of behavioral intentions of future use and purchase of autonomous vehicles. Theoretically the work is grounded in social psychology and cognitive science as well as empirically on our previous work exploring the influence of beliefs, affects and needs on decision processes in the context of innovation adoption (cf. Wolf et al. 2015).

In the following, we mainly conducted univariate analyses, thus restricting the explanatory power of mobility related needs in conjunction with autonomous driving. Nonetheless, the results give first hints as to how these needs relate to potentially new transport modes such as autonomous vehicles and are therefore important to determine the possible impacts on future transport behavior. Assessing needs in relation to autonomous driving allows respondents' perception and evaluation towards the technology more accurately to be linked with their attitudes, not only on a cognitive but also on a conative level.

In the questionnaire, respondents were first asked to rate the importance of nine specific needs in relation to their everyday mobility and transport mode choice. Figure 14 shows the results in a positive-negative bar diagram while omitting the indecisive answer categories "slightly agree" and "slightly disagree".

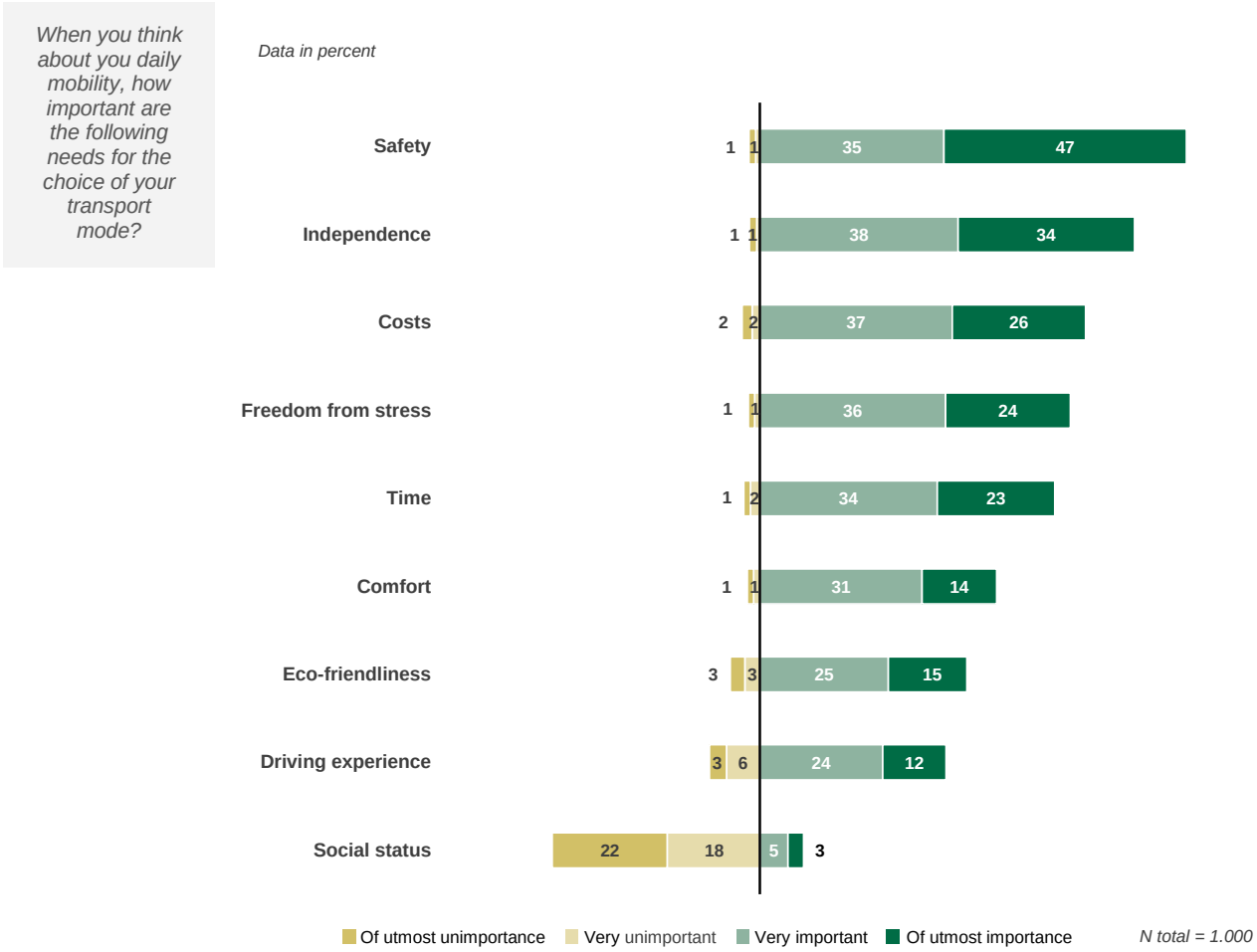


Figure 14: Importance of needs for respondents' everyday transport mode choice

More than four fifth (82 %) of all respondents rated safety as being the most important aspect when fulfilling their daily mobility; 72 % thought independence, 63 % costs, 60 % freedom from stress, 57 % time, and almost half (45 %) comfort as being very important or of utmost importance to them when choosing their individual transport mode. Eco-friendliness (40 %), and driving experience (36 %) got lower shares in these answer categories. When it comes to social status as a mobility need, only a very small share of the respondents awarded it relevancy, and 40 % even stated it to be very unimportant or of utmost unimportance to them – an answering pattern that coincides with findings from other studies (see e.g. Fisher & Katz 2000).

When testing the answering patterns for univariate correlation with respondents' characteristics, attitudes towards different transport modes, usual mobility behavior, and usage of driving assistance functions, hardly any or only very weak correlations were generally to be found. Noticeable exceptions were weak correlations for the importance of independence on one side, and regular car usage, the frequency of car usage as well as the frequency of public transport usage on the other. Also, weak correlations were identified for the importance of freedom from stress with the willingness to hand over parking or pedestrian detection to an autonomous system. The

following Table 3 provides an overview of the correlations tested for and the results both with respect to statistical significance and strength of effects.

Figure 15 illustrates the above-mentioned differences in answering patterns for the case of the importance of independence with discrimination between respondents who stated they use the car for their daily mobility and those who did not. When respondents stated independence to be of utmost importance, the likelihood of them being also regular car users increased noticeably.

Car use in daily life and importance of independence

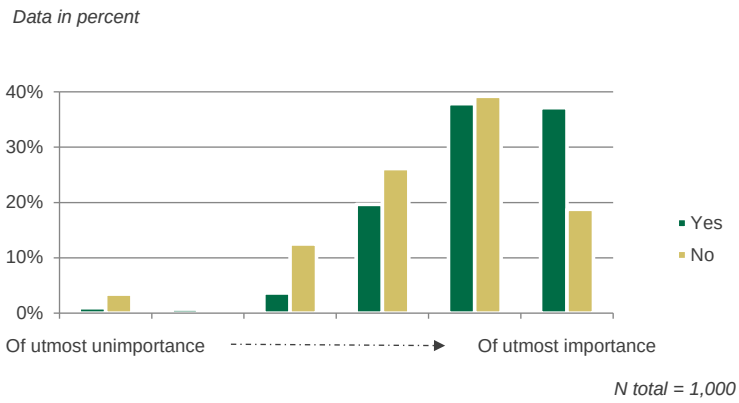


Figure 15: Stated importance of independence when choosing a transport mode for regular and non-regular car users

The question of what mobility related needs are addressed when using different transport modes was taken up again in the further course of the survey. For the specific use cases assigned to the respondents, we asked how this kind of autonomous vehicle would satisfy their individual needs. Figure 16 and Figure 17 show the corresponding answers with the shares for the two indecisive answering categories (“Slightly agree”, “Slightly disagree”) omitted. Also, answering patterns are not illustrated for the items eco-friendliness, driving experience and social status as they were reported as being of comparatively minor importance when choosing modes (see Figure 14).

When respondents were asked to relate their mobility related needs to an autonomous vehicle as a transport means, first thing to notice is the heterogeneous perception displayed in Figure 16 and Figure 17. Especially with respect to safety, independence and cost aspects associated with usage of autonomous vehicles, the prospective users’ answers display a rather balanced pattern: the share of people who felt these needs addressed are rather comparable with those who did not.

Table 3: Does the importance of needs addressed when choosing a transport mode correlate with respondents' characteristics and mobility behavior? Overview of results for correlation testing [8]

		Mobility needs								
Topic	***Variable***	**Independence**	**Freedom f. stress**	**Comfort**	**Costs**	**Eco friendliness**	**Safety**	**Social status**	**Driving experience**	**Time**
Socio-demographics	Gender	*	**			***	***			***
	Age					***	***			***
	Qualification				**		*			
	Educational background				**	**	*	*	***	
	Mobility impairment							*		
	Employment status	*				**	***		*	
	Income			**	***	***			*	*
	Children		*							
Mobility behavior	Driver's license	***			*	*		**		
	Car use	***		**	***	***			*	
	Kilometers traveled/year	**		**					**	***
	DAS user	*		***				***	**	
Willingness to give up driving functions	Speed regulation		***	*	**	***	**			
	Parking	***	***	***	*	*	***			
	Braking		***	**	*	***	*			
	Steering		***			**				
	Gear changing		***	**						
	Vehicle guidance (complete)		***	*		**		**		
	Pedestrian detection	**	***	***	***	***	***			**
	Vehicle stabilization	***	***	***		*	***			***
Transport mode choice	Car (driver)	***		***	***	**	*		***	***
	Car (passenger)			*						**
	Bicycle	*	*			*	**			
	Public transport	***		**	***	*			***	
	Train (longer distances)	***							***	
	Ride sharing	*		*			**			
	Car sharing									

		Not significant
((*))	0 < r < (-)0.2	Very weak correlation
((*))	(-)0.2 < r < (-)0.4	Weak correlation
((*))	(-)0.4 < r < (-)0.6	Medium correlation
((*))	(-)0.6 < r < (-)0.8	Strong correlation
((*))	(-)0.8 < r < (-)1	Very strong correlation
((*))	r = (-)1	Perfect correlation

DAS user: Driver assistance system user (Boolean variable)

[8] Please note that, while the number of stars refers to the strength of the significance of the correlation (* = 0.05-0.01, ** = 0.01-0.001, *** = > 0.001), the coloring scheme (from grey to blue, see legend) reveals the strength of the correlation. We did not highlight correlations lower 0.2 (very weak correlation) in our results. See section Approach for further details on this.

As safety aspects are very prominently discussed when looking at possible advantages that come along with the introduction of autonomous vehicles, the diverse perception of potential safety increase is noticeable. This holds especially true for the case of Vehicle on Demand, which more of a third of the respondents (35 %) did not see as satisfying their safety needs. At the same time, Vehicle on Demand is considered to have positive effects on mobility costs from the largest share of respondents compared with all the other use cases. Here, 26 % of those interviewed saw their needs addressed or strongly addressed. For freedom from stress, time savings and comfort, the satisfaction of the needs associated with using the prospective type of an autonomous vehicle displayed a more positive picture. This is particularly the case for Parking Pilot: 44 % of the respondents stated that such a vehicle would address their need for freedom from stress, 39 % saw advantages with respect to time savings, and 43 % felt their desire for comfort addressed. The over-average positive perception of Parking Pilot matches very well with the overall high acceptance rates for this use case, see section Acceptance and trust as well as perceived benefits for specific purposes, see Figure 22 below.

Figure 16: How safety, independence, and costs as needs are met with different use cases of autonomous driving

For each of the needs in relation to autonomous driving, correlations of the answering patterns with the respondents' characteristics and mobility behavior were tested for. Generally, no or only weak correlation was to be found with these attributes as well as with respondents' usage patterns with respect to transport modes and driving

assistant functions. Table 4 shows details for all correlations checked for as well as the few exceptions to this general finding. Four aspects might be worth highlighting: First, most correlations could – if at all – be found for usually only one or two of the use cases. Second, Vehicle on Demand was most often amongst those use cases – frequently also displaying the highest statistical significance and strength of correlation. Third, the regularly used transport modes, especially the usage of mass transportation, proved slightly more often to be correlated with the mobility related needs people see addressed by autonomous vehicles. Again, this is especially the case for Vehicle on Demand where frequent usage of public transport and bike is in several cases positively correlated with the mobility related needs people see addressed – most noticeably comfort and freedom from stress but also safety and time. Noticeable also is the lack of any correlation of the needs people saw addressed with how frequently they drove a car. And fourth, out of the socio-demographic variables we tested for correlation with the mobility related needs, gender was the only variable displaying more than once at least weak correlation – especially for the Vehicle on Demand use case. Here, e.g., male respondents saw their safety and stress level significantly more positively addressed by this use case than women did.

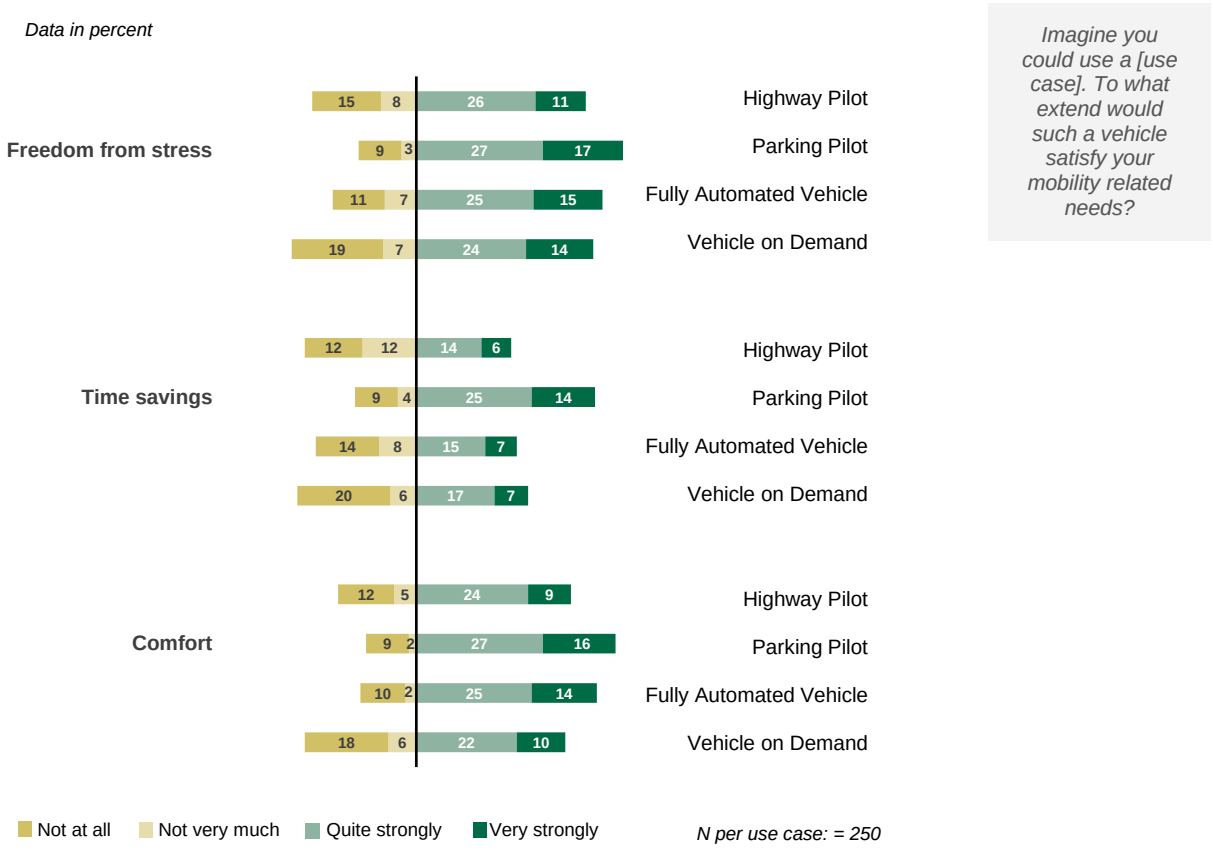


Figure 17: How comfort, freedom from stress, and time savings as needs are met with different use cases of autonomous driving

At the same time, the table shows quite impressively that respondents' willingness to hand over a driving or control function to a machine correlated with the mobility related

needs that were seen as being addressed by an autonomous vehicle. Lower values of significance and strength of the effect concentrated on the way people saw their request for low costs addressed by such vehicles, whereas the strongest effects of this correlation concentrated on freedom from stress, safety and comfort. Most noticeable is the strong interrelation between the willingness to hand over the complete vehicle guidance and the perceived addressing of the respondents' needs.

Table 4: Do the needs respondents see addressed by autonomous vehicles correlate with their characteristics and mobility behavior? Overview of results for correlation testing[9]

		Mobility needs																					
		Independence				Freedom from stress				Comfort				Costs				Safety				Time			
Topic	*Variable*	HP	PP	FAV	VOD	HP	PP	FAV	VOD	HP	PP	FAV	VOD	HP	PP	FAV	VOD	HP	PP	FAV	VOD	HP	PP	FAV	VOD
Socio-demographics	Gender				*			*	**			**	*								**				
	Age																						*		
	Qualification																								
	Educational background					*				*			**			*				*			*		*
	Mobility impairment																				*				
	Employment status		*															**	*		*				
	Income									*	*							*			**				
	Children	*	*				*			*															
Mobility behavior	Driver's license																				*				
	Car use																								
	Kilometers traveled/year																								
	DAS user									*							*		**			*			**
Willingness to give up driving functions	Speed regulation	***	***	***	***	***	***	**	***	***	***	*	***	***	**	*	***	***	***	***	***	***	***	***	***
	Parking	***	***	***	***	***	***	***	***	***	***	***	***	**	*	***	***	***	***	***	***	***	***	***	***
	Braking	***	***	***	***	***	***	***	***	***	***	***	***	***	**	***	***	***	***	***	***	***	***	***	***
	Steering	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
	Gear changing	***	***	**	***	***	***	**	***	***	***	*	***	*	**		***	***	**	**	***	***	***	*	***
	Vehicle guidance (complete)	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
	Pedestrian detection	***	***	***	***	***	***	***	***	***	***	***	***	***	*	*	***	***	***	***	***	***	***	***	***
	Vehicle stabilization	***	***	***	***	***	***	***	***	***	***	***	***	***	**	**	***	***	***	***	***	**	***	***	***
Transport mode choice	Car (driver)																								
	Car (passenger)		**								*	**											**		
	Bicycle				*				***				***				**				*				
	Public transport				**				**				**				*				*		*	*	**
	Train (longer distances)			**	*	**		**	**	*		*	*			**				**	***			***	
	Ride sharing						*				*						*		*						*
	Car sharing				*																				

		Not significant	**AV** Autonomous vehicle, without specification
((*))	0 < r < (-)0.2	Very weak correlation	**HO** Highway Pilot
((*))	(-)0.2 < r < (-)0.4	Weak correlation	**PP** Parking Pilot
((*))	(-)0.4 < r < (-)0.6	Medium correlation	**FAV** Fully Automated Vehicle
((*))	(-)0.6 < r < (-)0.8	Strong correlation	**VOD** Vehicle on Demand
((*))	(-)0.8 < r < (-)1	Very strong correlation	
((*))	r = (-)1	Perfect correlation	**DAS user:** Driver assistance system user (Boolean variable)

[9] Please note that, while the number of stars refers to the strength of the significance of the correlation (* = 0.05-0.01, ** = 0.01-0.001, *** = > 0.001), the coloring scheme (from grey to blue, see legend) reveals the strength of the correlation. We did not highlight correlations lower 0.2 (very weak correlation) in our results. See section Approach for further details on this.

4.2 Do people's general attitudes towards the car correspond with their attitudes towards autonomous vehicles?

How people perceive their current usage of the car is one important aspect in the debate of whether they might or might not be eager to embrace the new technology. One might assume that especially people who see the car foremost as a pragmatic means of transport might be inclined to welcome the assistance that autonomous vehicles offer. At the same time, one might expect to find a stronger reluctance to hand over control and steering among those who state they actively enjoy driving their car (see e.g. Fraedrich & Lenz 2014). As the questionnaire contained a variety of items related to the respondents' attitudes towards the car as well as public transport, we tested for correlations between these attitudes and the interest in autonomous vehicles as well as the willingness to use autonomous vehicles.

Figure 19 shows general attitudes of the respondents towards the car compared with attitudes that they exhibited towards public transport. The answer patterns display significant differences in the attitudes towards the two alternative modes. Overall, the car was rated as more attractive in terms of freedom, flexibility, relaxation, comfort, cost-efficiency, safety, fun, privacy, and time savings. Foremost, car usage was associated with freedom (with 83 % of the respondents agreeing with the statement with varying rigor), comfort (88 %) and minimizing time spent for mobility (88 %). These shares appear especially high when compared with the substantial negative answering shares obtained for public transport.

At the same time, car driving itself is also perceived positively by a large proportion of the regular car users: when asked whether they would enjoy driving a car, 81 % of the respondents agreed or strongly agreed.

Figure 18 also shows the answers for a second question aiming directly at the activity of driving and the perceived individual expertise in driving. Agreement rates are similar but a little lower when asked whether respondents were enjoying exercising their driving skills.

As mentioned above, time savings, freedom from stress and comfort were needs that a substantial share of respondents saw as being addressed by autonomous vehicles (see Figure 17). Thus, we tested whether the current perception of the car with respect to stressfulness, comfort, time savings, and safety correlated with respondents' attitudes towards autonomous vehicles. Additionally, the items aiming at the perception of driving as a joyful activity and enjoying to exercise one's driving skills were used for correlation testing with three subsequent variables: willingness to use an autonomous vehicle, willingness to replace the currently preferred transport mode by one of the use cases, and respondents' interest in autonomous driving. Interviewees' interest in the topic proved to be highly significantly correlated with perceiving the car as comfortable as well as enjoying driving and displaying one's own driving expertise – even though the strength of the effect was only weak (see Table 4). Thus, while people who displayed a positive attitude towards driving seemed to be

more likely to be interested in the topic, this attitude generally did not seem to correspond with their willingness to use such a vehicle or even replace their currently preferred mode with such a vehicle: no correlation was found when testing these combinations. Willingness to use autonomous vehicles or replace other transport modes is taken up with more detail in section Acceptance and trust.

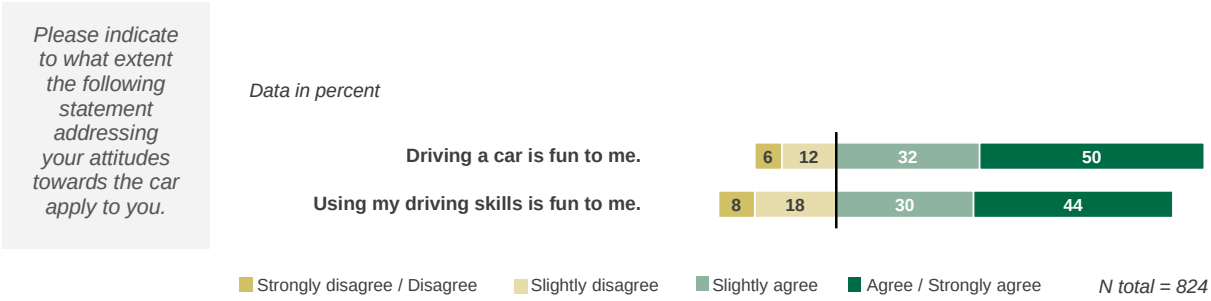


Figure 18: Stated attitudes towards using a car

4.3 Are changes in mode choice ahead?

A key question within transport research related to autonomous driving is how the technology could affect mobility behavior and the use of other transport modes in the future (see, e.g., Litmann 2015). The use of autonomous vehicles will very likely depend on specific benefits and fields of application – see section Introduction and scope of the study for further explanation on possible application fields for the different use cases – and could therefore have varying impacts on the use of individual or public transport modes (Cyganski 2015). More recently, a growing number of studies have been directing attention towards this question, mainly from transport modeling points of view (see, e.g., OECD/ITF & CPB 2015; Fagnant & Kockelmann 2013). Still, user perspectives, as well as a differentiation of use cases and application fields of autonomous driving are rarely taken into account.

Please indicate to what extent the following statement addressing your attitudes towards the car apply to you.

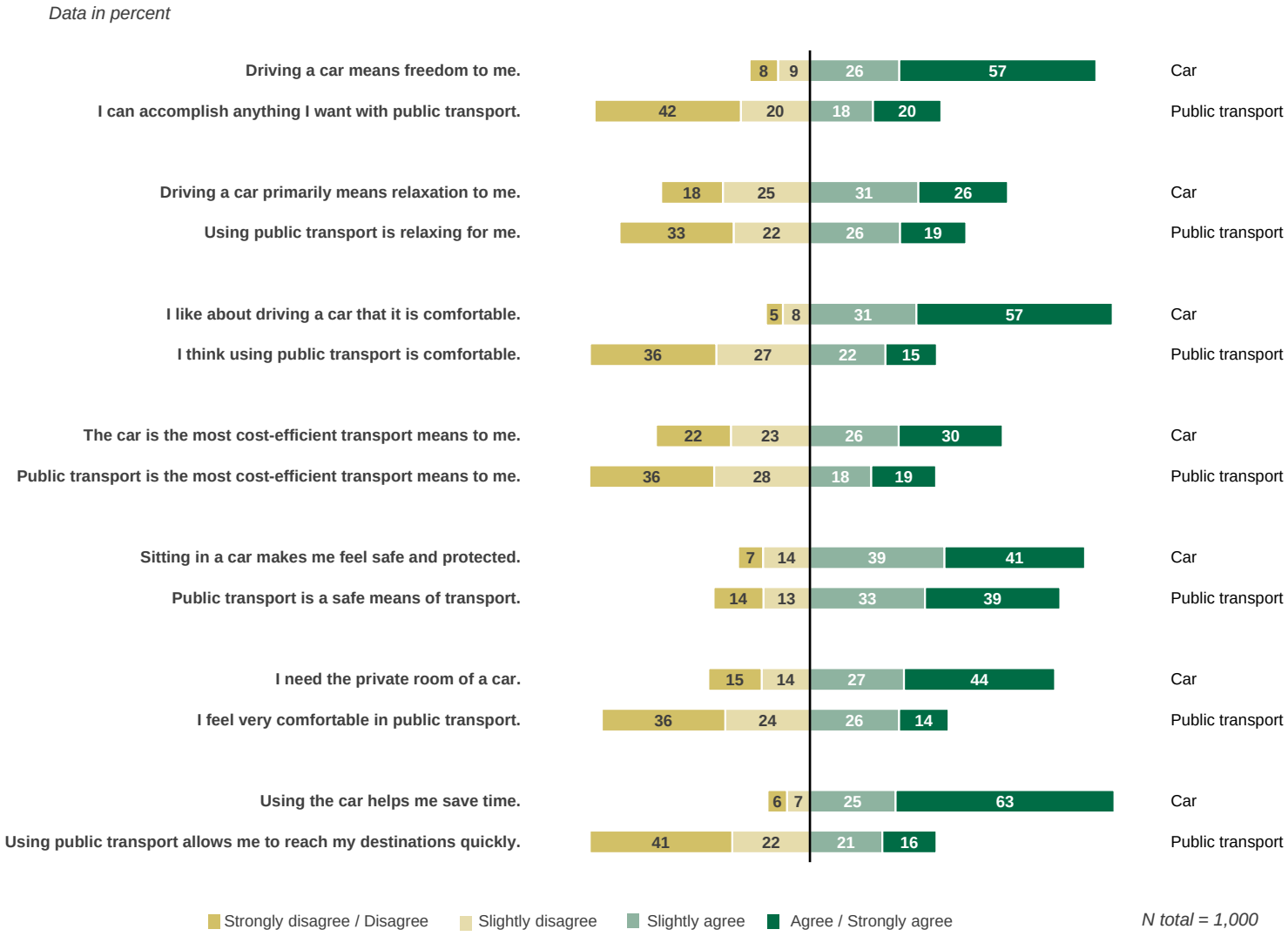


Figure 19: Stated attitudes towards transport modes (car and public transport)

In the study, we wanted to get a first glimpse at what possible implications autonomous vehicles might have on respondents' every day mobility behavior. First and foremost, our interest lay in the impact respondents were expecting the vehicles to have on their everyday mode choice. Rather than asking how often they would use the vehicles presented in the use cases, we asked respondents how they would anticipate their usage of currently available modes changing. The modes presented included public transport, foot or bike, and train. Figure 20 shows the results in a line diagram where the answers were averaged. Answering options provided ranged from "far less often" (-2) to "far more often" (+2). In the figure, a value of 0 indicates that on average, respondents would anticipate no change in usage of the mode concerned, whereas the lower the average value of responses gets, the more respondents anticipate using this mode less frequently. As before, results are presented separately for the use cases. It has to be noted though, that differences in answering patterns between the use cases were statistically insignificant for all other modes.

Looking at this aggregate illustration, obviously the biggest declines in usage are anticipated for the taxi: for all use cases, using a taxi is expected to become less common with the availability of autonomous vehicles. It is also noticeable that Parking Pilot provoked the strongest associations of switching – particularly from taxi use, with its very low mean value of -0.78. It seems possible that interviewees associated the use case with the option of the car driving itself home when not needed even though the use case description did not explicitly mention this type of function.

How do you think such a vehicle would affect your transport mode choice?

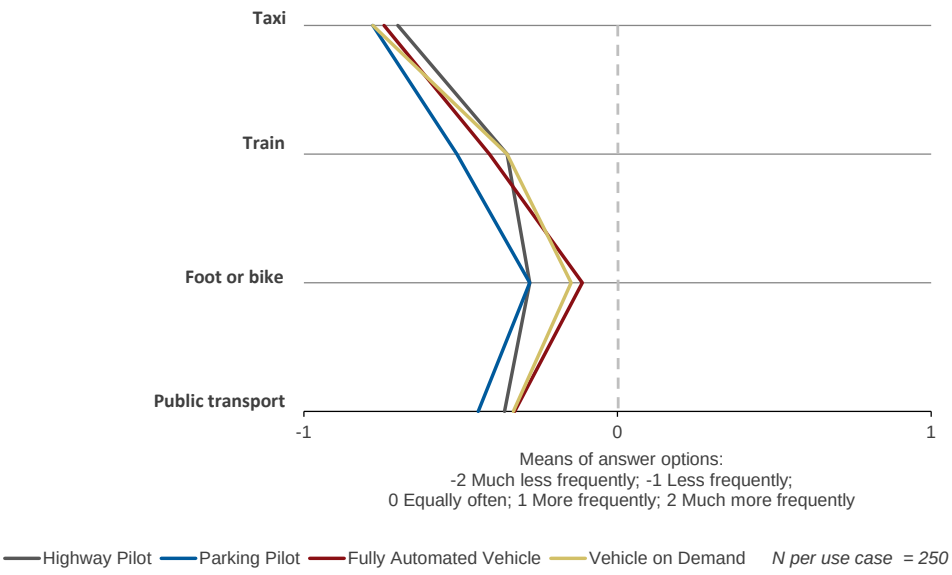


Figure 20: Anticipated mode choice in a world with autonomous vehicles (means of answers)

Figure 21 complements the aggregate picture with more detail. Noticeable is the high share of answers where respondents do not anticipate great changes in their transport behavior – resulting in the low mean seen in the figure before. The anticipated impact is especially low for walking and biking.

Almost half of the respondents (49 %) expect to be using taxi services less often than currently. Substantial decreases in usage are also expected for public transport and

train. The increase in usage stated consistently but with varying degree for all modes might be interpreted to some extend as refusal to use autonomous vehicles.

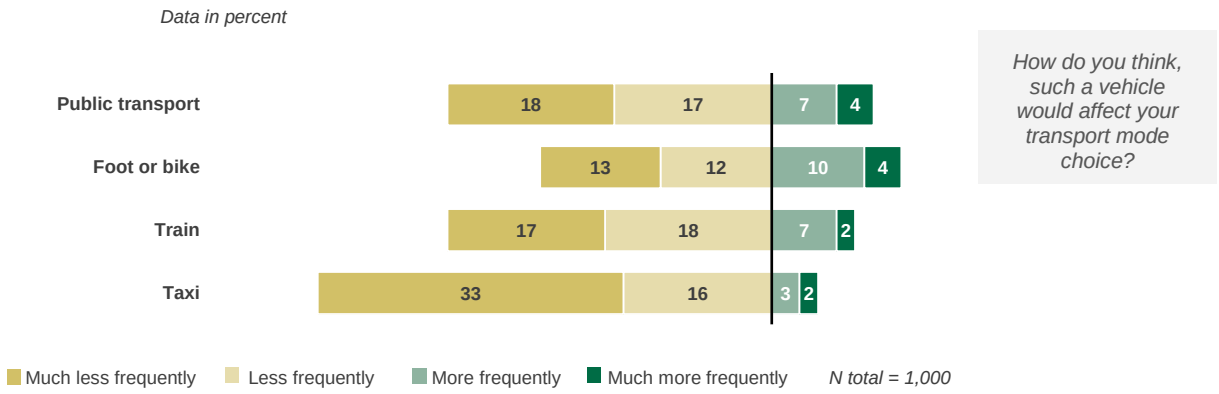


Figure 21: Anticipated mode choice in a world with autonomous vehicles (detailed results)

4.4 For what kind of trips are autonomous vehicles perceived as beneficial?

In the course of the survey, respondents were also asked for what kind of trips they would consider the use case assigned to them to be particularly useful. Questions asked addressed the trip purpose as well as the context of the trip, the spatial setting and the trip duration. Figure 22 shows the means of answers given for the trip characteristics asked for – as usually differentiated by use case. Differences in answering patterns between use cases proved as statistically highly significant – thus indicating clearly varying perception of the use cases by the respondents. Escorting trips form the only exception – here, differences in the means of answers given proved statistically insignificant. Answering options ranged from -3 (not helpful at all) to 3 (totally helpful). Hence, the mean values of the answers are again with few exceptions relatively low, stemming not least from the large share of answers in the middle range. On average over all use cases, 40 % of the respondents stated they found the vehicles somewhat or somewhat unhelpful. Least number of indecisive answers was given for the usage of Highway Pilot on long distance trips whereas especially high numbers of answers in this category were allotted to Fully Automated Vehicle for escorting trips, shopping trips and trips with company or luggage.

Following the outlines of the answers in the figure, the answering patterns for Vehicle on Demand and Fully Automated Vehicle show clear similarities in most cases, while Highway Pilot and especially Parking Pilot display distinct patterns. Parking Pilot is viewed as particularly helpful in urban contexts and for transporting items – be it luggage or shopping goods. Forty-two percent of the respondents declared they find it very or totally helpful in urban setting; for shopping and luggage haulage, the shares amount to 37 % and 36 % respectively. Consequently, approval rates are lowest for cross-country trips with 71 % of respondents not finding it helpful in varying degrees. A contrasting pattern can be found for Highway Pilot, which was deemed on average

least useful in the prior-mentioned settings. Instead, 64 % of respondents perceived this use case as helpful on long distance trips. Further, answering means were relatively high for traveling or going on journeys, trips with company, and cross-country drives with 58 % of answers indicating helpfulness in the first case and 48 % for both the others. Long distance trips, longer journeys and cross country trips are – In descending order – also the trip types most stated as being very or totally helpful for Fully Automated Vehicle and Vehicle on Demand.

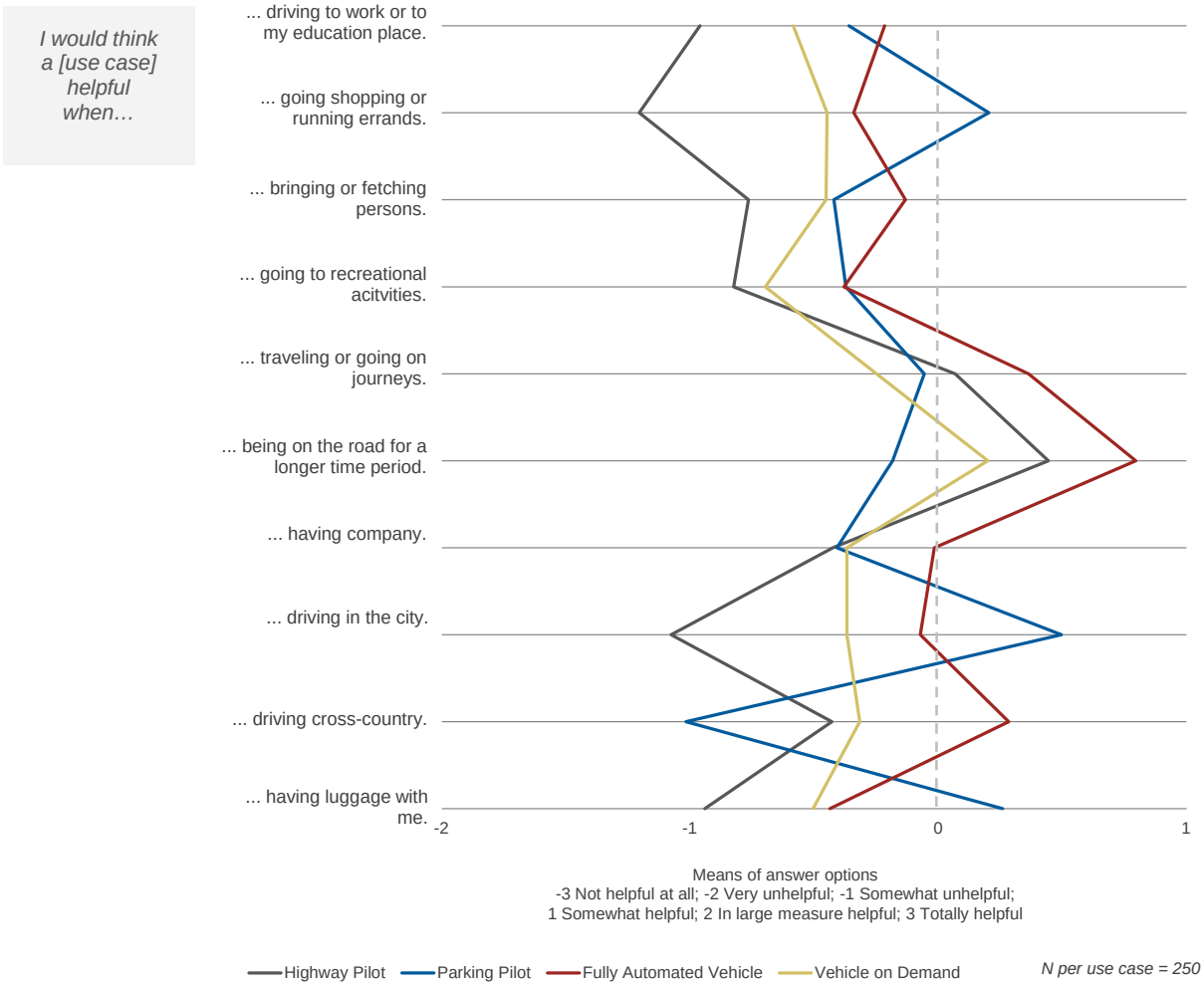


Figure 22: Perceived usefulness of autonomous vehicles by trip characteristics (differentiated by use cases)

Noteworthy is foremost the comparatively very high mean of 0.8 for being on long trips with Fully Automated Vehicle, resulting from 72 % of the respondents indicating they consider this helpful. For Vehicle on Demand, the respective shares amount to 61 %. Interestingly, not only for cross-country trips, but also for all other trip types including those in an urban context, mean answering values are consistently higher for Fully Automated Vehicle than for Vehicle on Demand. In large part, this can be attributed to a high share of respondents considering this type of autonomous vehicle not at all helpful – regardless of the trip context. Thus, the answers probably might be seen as

indicator of a generally skeptical position towards this use case, as we found this effect for several other items evaluated as well (see e.g. section Acceptance and trust).

Statistically significant differences can be shown with respect to sociodemographic attributes of the respondents for some of the use case-trip type combinations (Cyganski 2015). Noteworthy findings include male respondents exhibiting statistically significantly higher answering means for all trip purposes when confronted with Vehicle on Demand. The same holds true for the case for work and long-distance trips using Highway Pilot. Also, answers given for Parking Pilot differ significantly depending on household size and the presence of children on long-distance and urban trips.

5 Time use

Briefly

The assumption that people are eager to spend their time productively in an autonomous vehicle has to be considered with caution: the perceived benefits of today's transport users for potentially altered time use are centered on window gazing, talking to companions, and relaxing.

By the time the survey was conducted, listening to music, talking to passengers and enjoying both the trip and the landscape were activities people were engaged in most often while driving. The latter was also the most prominent activity on train and public transport rides. Working while traveling, in current time use, played only a very minor role.

Parking Pilot might not have been linked to autonomous driving specifically but was seen foremost in the context of easing parking search and enhancing the safety of the car while being parked.

In the discussion of the prospective benefits that autonomous vehicles may provide, the possibility of an altered time use is one of the most prominent issues (see amongst others Cyganski et al. 2015; Munsch 2014; Schulz 2014; Sokolow 2013; Silberg et al. 2012). Usually, the introduction of autonomous vehicles is associated with an increase in productivity or comfort during the onboard time, thus leading to a more positive – or less negative– valuation of the time spent on the road. In particular, morning commutes, currently perceived as particularly unpleasant and stressful (Tatje 2014, Kahnemann & Krueger 2006), could change in their perception tremendously, as formerly "dead time" (Gardner & Abraham 2007: 190) might be used differently. However, empirical examination has not yet been carried out and the assumed benefits are speculative to date. This lack in systematic empirical examination leaves it unclear how travelers might perceive and valuate the new time use options that come along with autonomous driving – or if they actually would change their time-spending behavior at all.

5.1 Current time use patterns

To address various aspects of how people spend 'mobility time', the survey contained questions on current as well as anticipated future time use while traveling. First, the respondents were asked in which activities they were generally engaged while traveling by car, local public transport, or train, the latter being defined, as in the prior sections, as interregional train for distances of 100 km or above.

Figure 23 presents the results for the activities conducted today while traveling in the different transport modes. Naturally and not surprisingly, focusing on the ride and the route is the main activity reported while driving a car. Driving is often accompanied by listening to music or chatting with other passengers: around 80 % of the car drivers stated they often or always listen to music, the corresponding shares for chatting amount to about two-thirds (62 %). Also, more than half (56 %) of the respondents reported always or often enjoying the ride and the scenery. Already now, the car is used at least sometimes as mobile office by 7 % of the car drivers – potentially by means of making phone calls, for example[10]. However, over 90 % stated never to work while driving a car. Social networking, such as using the phone, mailing or sending text messages, was similarly uncommon with over 80 % of the survey participants reporting never doing it.

[10] Focus group discussions that were conducted within the Villa Ladenburg project (Fraedrich & Lenz 2015b) as well as a project on the impacts of autonomous driving on mobility (funded by ifmo – results will be published in a report as of mid-2016) revealed that work-related activities car drivers are performing, are versatile; they range from writing e-mails, change clothes / getting dressed for a business meeting (including putting on make-up), taking notes while talking on the phone, to making coffee (!).

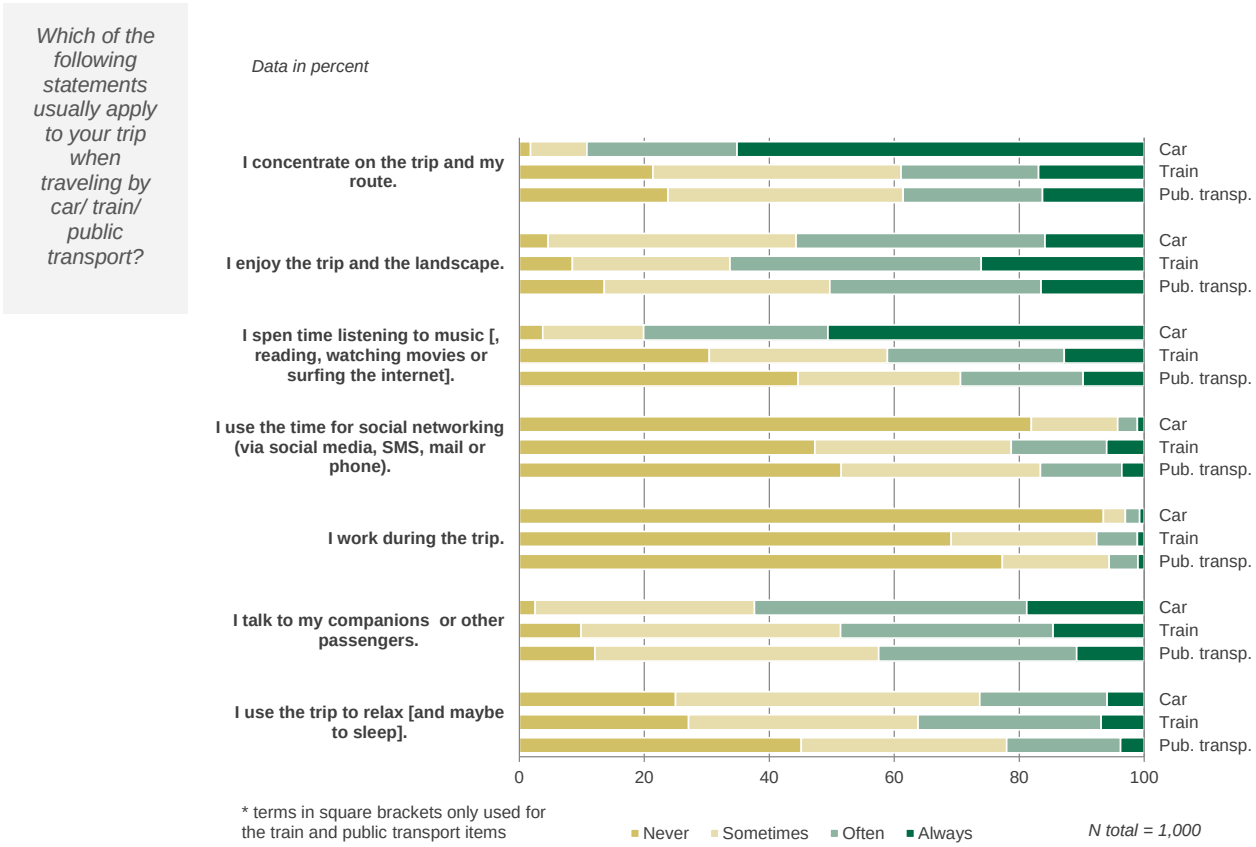


Figure 23: Today's time use when traveling by car, train, or public transport

By far the most mentioned activity pursued often or always in public transport and long-distance trains is enjoying the landscape and the journey (50 % for public transport, 66 % on trains), closely followed by conversations with fellow travelers (43 % and 49 %). Two-thirds of the train users report frequently or always enjoying the view, for public transport users this share is down to 50 %. Almost half of the train users reported always or often conversing. Generally, our findings seem very in line with those reported by Lyons et al. (2007). In their study on the activities conducted by British rail users, window gazing was also – especially on short trips – the most mentioned activity on train trips.

Listening to music, reading or relaxing is another oft-mentioned activity, especially on train trips. Interestingly high are the shares of people stating they often or always concentrate on the trip – in both variants of mass transportation by almost 40 %. The low share of our survey respondents stating that they use the time for social networking purposes is also noticeable.

When contemplating the potential for productive time use, the low share of people that actually currently work while riding on trains or in public transport is remarkable: 77 % of respondents say they never work during public transport trips. On long-distance train trips, this share is down to 69 %, contrasted by 6 % of the interviewees often or always working on the go. Sociodemographic factors had a statistically significant effect on the answers – especially the variables gender, income, education level, household size, and the presence of children in the household (see Cyganski et al.

2015 for details). Generally, our findings correspond well with the work of Gardner and Abraham, who reported that "[…] participants tended to neglect the potential for journey time to be used productively […]" on commuting activities (2007: 190).

5.2 Riding in an autonomous vehicle: anticipated time use

In the course of the survey, respondents were then asked what advantages they would perceive in using a vehicle from one of the four use cases. Answering options were given parallel to the ones provided for current time use – except for answers for the Parking Pilot use case. Figure 24 shows the results for Highway Pilot, Fully Automated Vehicle, and Vehicle on Demand. For sake of reading ease, the figure contains the means of answers for each of the items. For further reference on the exact percentages in the different answering categories, please refer to Cyganski et al. (2015), which contains the corresponding six-item bar chart.

Variance analysis (ANOVA) shows that the differences in answering patterns between the uses cases are significant for social networking and highly significant for all other answering options. An exception is the opportunity to talk – here, no statistically significant differences exist between the three use cases. Not only the figure but also a pairwise comparison of the averages following Scheffé [11] clearly indicates that Highway Pilot was often perceived differently by the interviewees than the other use cases. Generally, the distinctive answering patterns stress once again the importance of differentiating the precise usage context when looking at autonomous vehicles' potential implications.

The particular advantages most respondents could agree with were the enhanced possibility of enjoying the trip and the landscape as well as the chance of talking to fellow travelers. In both cases, about a third stated they considered this in large measure or strongly an advantage of the corresponding autonomous vehicle type. Shares of respondents agreeing were here as for all other answering options slightly higher for Vehicle on Demand than for the other two cases while those for Highway Pilot were lower – a fact that can also be identified in Figure 24. Relaxing and sleeping options were other activities that a high share of respondents mentioned positively. For Vehicle on Demand, 30 % of the respondents reported seeing this in large measure or absolutely as an advantage, this share being slightly smaller for Fully Automated Vehicle and even increasingly smaller for Highway Pilot. It should be mentioned, though, that the shares of respondents who disagree or strongly disagree with the statements were almost as high for Vehicle on Demand or even significantly higher for the other two use cases – resulting in the low means seen in Figure 24.

[11] See e.g. Brosius (2011) for details on the Scheffé's method.

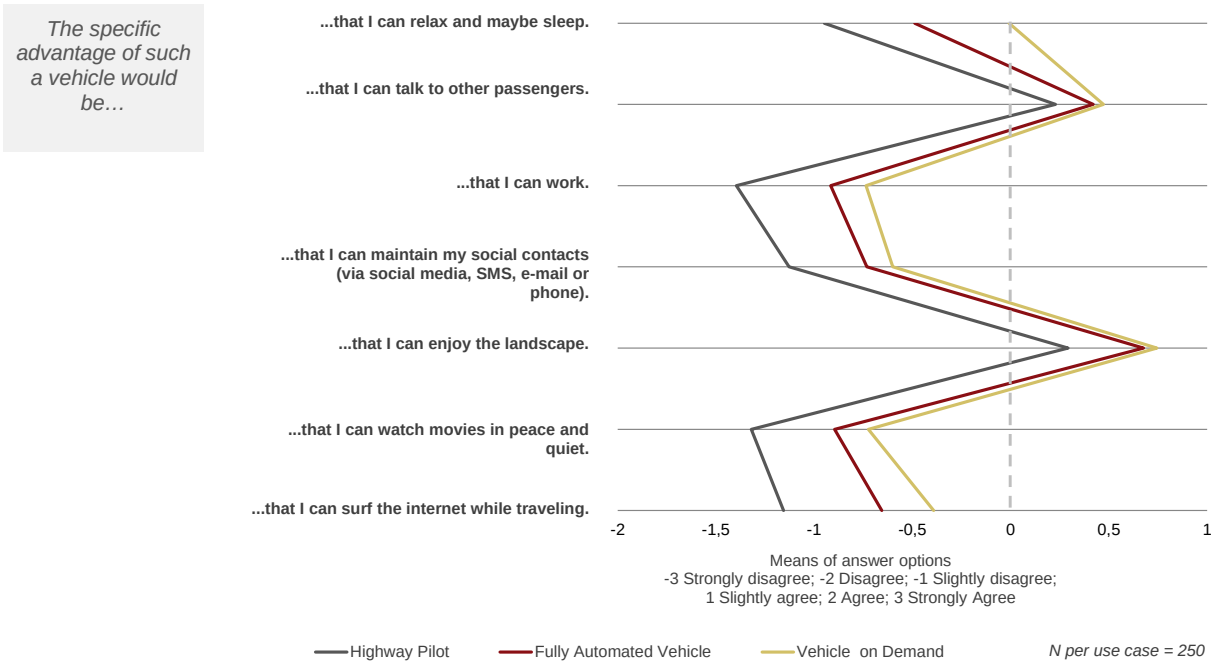


Figure 24: Perceived benefits or anticipated time use for autonomous vehicles (for the use cases Highway Pilot, Fully Automated Vehicle, and Vehicle on Demand)

It is worth noting that a large proportion of respondents did not expect to use their time in an autonomous car by activities like surfing the internet, watching movies or social networking. The range of disagreement went up to 51 % for the case of watching movies in Highway Pilot. While using Vehicle on Demand 21 % welcomed the option to surf the internet, but still 34 % thought they would not engage in this activity even though they are no longer active for driving.

Working enjoyed the least reception among all options of activities to be done while traveling in a self-driving car. When asked if they perceive the option to work as an advantage of autonomous driving the highest disagreement (52 %) came for the case of Highway Pilot; for Vehicle on Demand the corresponding rate was 30 %. At the same time, 17 % of participants felt that working while traveling in a Vehicle on Demand would be a good option for them. For Fully Automated Vehicle, the corresponding share amounted to 13 %.

With the little attraction the possibility of working in the car seemed to hold for the users interviewed, our findings clearly differ from the results of a German survey conducted by Autoscout24 (2012). Here, almost a third of the respondents wished for the opportunity to use their car as a mobile office.

The notion of wasted, unproductive time being turned into (economically) valuable time is one of the most dominant arguments in the debate on autonomous driving. In Cyganski et al. 2015, we therefore used an ordered probit model (see e.g. Green 2002) to further identify the factors influencing the decision to work in an autonomous car for the three use cases in question. We found current time use to be an important predictor of the perception and evaluation of the option to work while traveling whereas sociodemographics showed only minor importance: the more frequently

respondents spent time working – especially in public transportation but also in long-distance trains – the more likely they were to consider working possibilities as an advantage of autonomous vehicles. On the other hand, the more people spent their time enjoying the landscape on longer trips today, the less likely they were to imagine spending their time working in the future. Generally, the findings for the use cases Highway Pilot, Fully Automated Vehicle and Vehicle on Demand lead us to conclude: "Overall, advantages of automated vehicles were predominately identified for those activities already favored in today's conventional cars. Not having to concentrate on the driving procedure is welcomed as a possibility for having more time or less distraction, especially for window gazing and talking." (Cyganski et al. 2015: 10) The only minor share of respondents that explicitly declared working while traveling to be a benefit of autonomous vehicles clearly shows that any assumption of people being eager to spend their travel time 'productively' while traveling has to be regarded with caution. Instead, the similarities between the current stated and anticipated future time use patterns we found go in line with research demonstrating that people consider time spent at current activities adequately invested, thus perceiving that "[t]ime in the car […] is not necessarily time that is lost" (Kent 2014: 104). Time spent on travel might just as well be perceived positively and meaningful (Lyons et al. 2013; Mokhtarian & Salomon 2001), as "a gift rather than a burden" (Jain & Lyons 2008: 81).

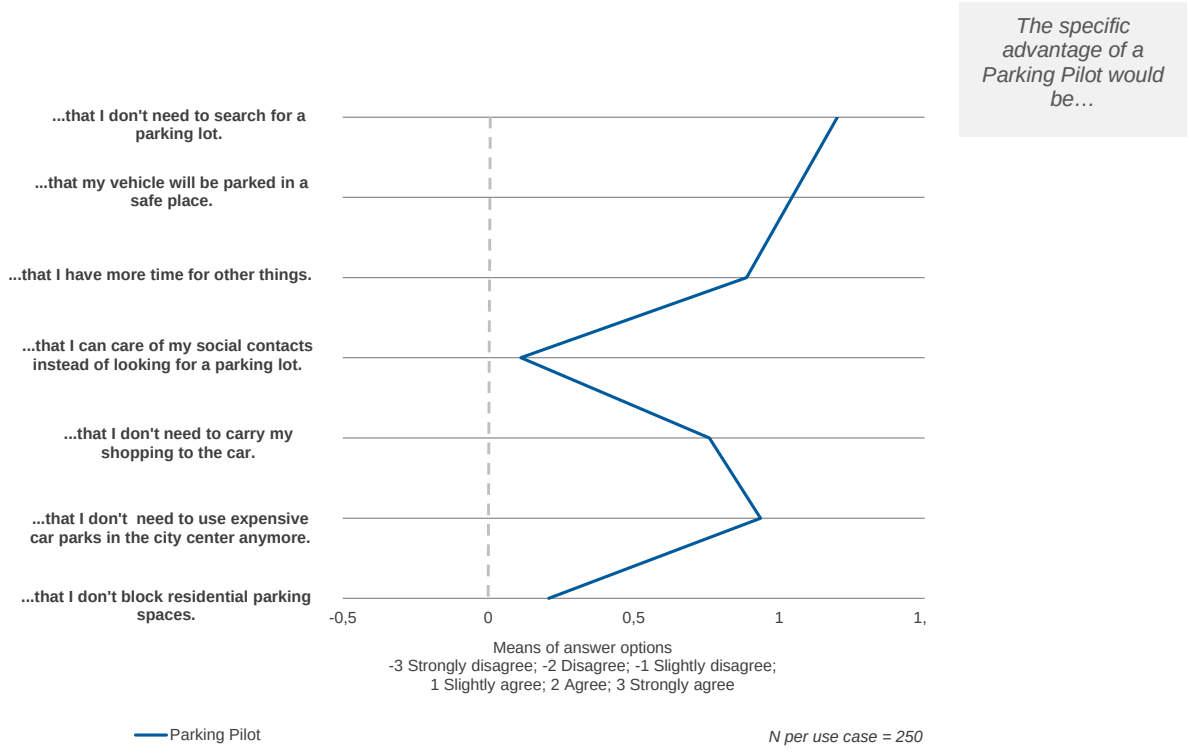


Figure 25: Perceived benefits for the Parking Pilot use case

The Parking Pilot use case implies a generally different scope of application. Thus, the answering categories for the question addressing the perceived benefits of such a vehicle were adapted accordingly. As can be seen in Figure 25, the answering options were aiming not primarily on the onboard time but were targeting the access and egress part of the trip, the trip and parking context as well as alternative engagements. Again, the figure shows the means of the answers given. First thing to

notice is the relatively high means of answering options compared with those obtained for the other use cases. Specific advantages of a vehicle with Parking Pilot are seen foremost in the most evident answering option: not needing to search for a parking lot. Fifty-four percent of the respondents agreed on seeing this in large measure or absolutely as an advantage. The option of parking the car at a safer spot is the answering option with the second-highest mean value and a share of 46 % of respondents saw this absolutely or in large measure as advantage. Saving money on parking fees, having more time for other errands and not having to carry the shopping to the car also got positive evaluation: in all three cases, the shares of respondents having agreed in large measure or absolutely summed up to around 43 %.

The by far least favorable assessed answering options were those of devoting time to social contacts instead of searching for a parking lot and for not blocking parking space for residential parking necessities. Generally, the shares of undetermined answering options chosen were for all potential advantages provided relatively high.

6 Autonomous driving: a solution for the mobility-impaired?

Briefly

Mobility-impaired respondents in our study indicated that they already use the car in their daily lives a lot. Thus, the additional share of those who would truly benefit from autonomous driving because they are not able to use a car today might be lower than expected.

Respondents with mobility impairments did not show specifically affirmative attitudes towards autonomous driving. On the contrary, their refusal rates were quite high.

The study only considered a few aspects related to mobility-impaired transport users and autonomous driving. Further examination should therefore deepen insights into this highly heterogeneous group and their mobility needs in the future to be able to obtain valid results in relation to autonomous driving.

One very substantial and prominent argument in the debate on the benefits of autonomous driving is that it would help impaired people to maintain their individual mobility in an easy, flexible and unprecedented way (Chapman 2012; Silberg et al. 2012; Bradshaw-Martin & Easton 2014). Autonomous driving – so runs the assumption – could help all those who suffer from physical infirmities. In the discourse, these are often associated with the elderly.

To address the user perspectives, it is necessary to take a closer look at today's mobility of impaired people: In what way do they travel? What transport modes do they use? Do they have any 'typical' characteristics? What are their mobility needs? How do they differ from people without impairments? And how do they perceive and evaluate autonomous driving? How do they think the technology might be specifically useful to them (or not)?

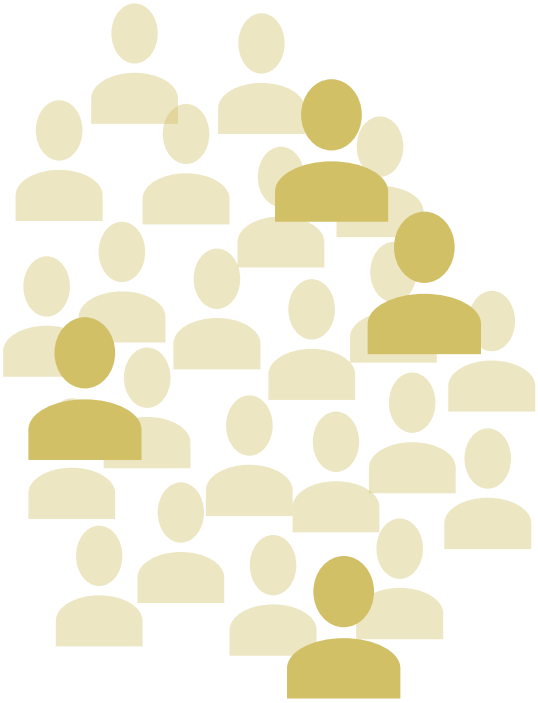
In our survey, 189 out of 1,000 respondents declared they were mobility-impaired. This number did not correspond specifically well with the results of the NTS Mobility in Germany (MiD) 2008 study (infas & DLR, 2010: 85). There, only 9.4 % of the respondents stated they were mobility-impaired because of a health restriction (authors' own analysis, based on MiD data). While differences in the characteristics of the respondents in comparison to MiD were already talked about in section Approach, some additional discrepancies might also be due to the fact that we used a market research panel to recruit respondents. An overview of the sociodemographic and car related characteristics for the group of mobility-impaired respondents from our sample is given in Figure 26.

In comparison to respondents without mobility restrictions, both driver's license possession rates and car use in daily life showed significant but only weak correlations: whereas 80 % of the mobility-impaired stated they had a driver's license, respondents without mobility impairments have a 90 % possession rate. And while 85 % of the respondents without mobility impairments stated to use a car in their daily lives, 74 % of all mobility-impaired respondents reported using to do that.

These results indicate that already today mobility-impaired people are coming back to the car to be on the move and/or to satisfy their mobility needs. So much so that one might assume that the automobile in general is the transport means most suitable for people with disabilities – in contrast to other transport means such as foot, bike or even public transport which, for example, provide mobility hurdles, especially for those who have walking disabilities: Forty-one percent of all respondents with health restrictions in the MiD survey stated to suffer from this kind of restriction (infas & DLR 2010: 85).

When asked whether they can imagine maintaining their daily lives without a car, or whether they can do what they want to by public transport alone, the results did not show statistically significant correlations for neither group – i.e. respondents with and without mobility impairment. When looking at respondents who indicated using the car in their daily lives, the share of those stating they might stop using the car is in general rather high: 45 % of the respondents agreed or strongly agreed they would be able to do that. Only 20 %, on the other hand, declared that public transport is a means suitable or very suitable to maintain everything.

Mobility-impaired respondents



19% labeled themselves as affected by a physical or health restriction that limits their mobility.

80% possess a driver‘s license and 74% stated they use a car in their daily lives.

Elderly mobility-impaired respondents stated they use the car more often than younger ones.

Mobility-impaired users are older, have lower income, and tend to be unemployed or in part-time employment more often.

Figure 26: Key figures and findings for mobility-impaired respondents in the study

With autonomous driving, it is often postulated, mobility-impaired transport users might be individually mobile in just the same way as ‘healthy’ transport users. However, the share of people among the mobility-impaired that would benefit from the technology because they are not able to drive a car today might be smaller than expected. The results show that ‘mobility impairment’ does not necessarily mean that people are not allowed to drive at all (see above). It might just mean that they have problems getting on the bus because of an artificial hip joint, for example. Results from MiD showed that visual impairments, on the contrary, that might actually prevent transport users from using a car, thus making an autonomous vehicle a truly beneficial transport mode, ‘only’ accounted for 8 % of all health restrictions (infas & DLR 2010: 85).

In addition, assuming that the technology will be quite expensive by then, the likelihood decreases even more that a high share of impaired could be among the earlier groups to purchase and/or use an autonomous vehicle: people who suffer from mobility impairments tended to be unemployed or in part-time employment and with lower income significantly more often than the non-impaired in our survey.

6.1 Do mobility-impaired transport users have a specific interest in cars that drive themselves?

As autonomous driving seems to address specific challenges that mobility-impaired transport users have, one could assume that this group shows significantly more positive attitudes towards the technology.

However, neither interest in the topic, the willingness to use an autonomous vehicle, nor the willingness to replace the currently preferred means of transport with an autonomous vehicle accounted for any significant differences. Surprisingly though, an above-average level of mobility-impaired respondents could not imagine using an autonomous vehicle, or replacing it with another transport mode. The results in Figure 27 show that (in this example for Vehicle on Demand) mobility-impaired respondents expressed a higher refusal towards Vehicle on Demand, with 63 % stating that they would not be willing to use it at all – whereas 'only' 44 % of the respondents without mobility impairment could agree with that statement. These results already indicate that there might not be an overwhelming reaction towards autonomous vehicles on the part of the mobility-impaired in general – due to low case numbers however, we were not able to check on possible correlations here.

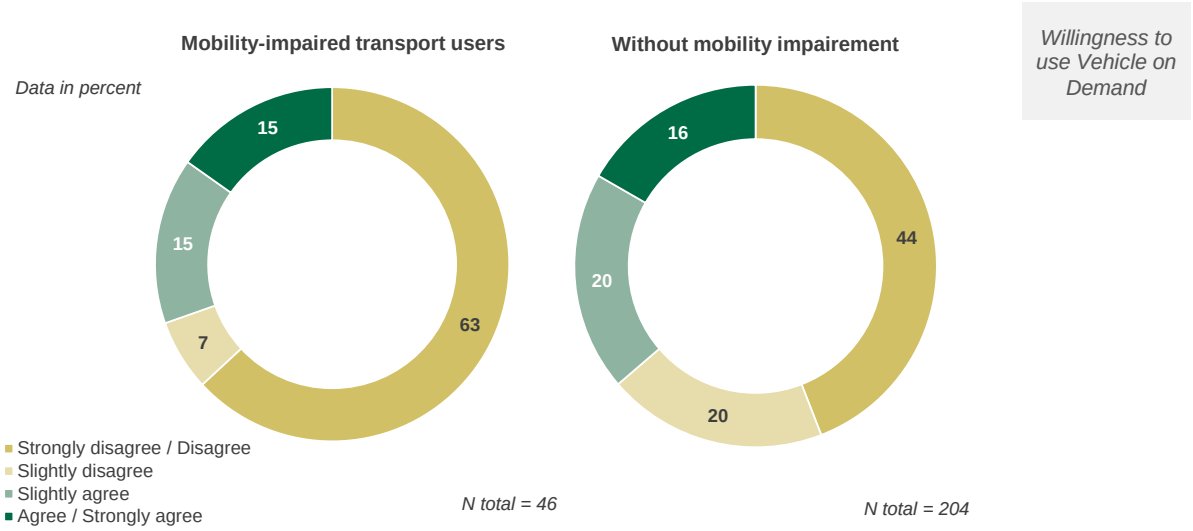


Figure 27: Willingness to use Vehicle on Demand by mobility-impaired transport users compared to non-impaired transport users

6.2 Autonomous driving – individual door-to-door mobility for all?

Autonomous driving could, among other benefits, lead to better inclusion of mobility-impaired transport users (that are not able or allowed to drive a car today) by providing cost-efficient, flexible ‘on-demand’ access to individual motor car traffic that does not require a conventional driver’s license. Among a variety of advanced autonomous driving functions that execute navigation as well as longitudinal and lateral control of the vehicle, a variety of ‘special features’ for autonomous vehicles beyond that are conceivable – e.g. medical and emergency monitoring – that meet specific needs of the mobility-impaired.

Certainly, a whole series of questions in this relation is currently unanswered, among them, for example, whether legal driving requirements have to be amended to enable people that are currently not allowed to drive a car could use an autonomous vehicle, or whether only level 5 systems (VDA 2015) could be given approval for people without conventional driver’s licenses. At present, it is hardly foreseeable when (or if) humans in autonomous vehicles will be let off the hook completely.

Altogether, the assumption that the mobility-impaired could greatly benefit from autonomous driving has to be considered in a more differentiated way in future. The mobility-impaired do not form a homogeneous group with specific needs and requirements. In fact, different impairments in different age groups, living environments, social classes, etc. require different solutions to meet the mobility needs of these transport users – certainly not only technological ones.

7 Acceptance and trust

Briefly

Overall, respondents were not overwhelmingly open-minded towards autonomous driving in general. A closer look at the different use cases, however, revealed that Parking Pilot gets the most affirmative ratings, whereas Vehicle on Demand receives the least popularity.

Specifying use cases of autonomous driving proved to be implicitly necessary. Whereas respondents seemed to be rather open-minded towards the technology, even when they were asked to replace their preferred mode of transport by an autonomous vehicle in the first place, their refusal considerably increased when specific use cases were introduced to them.

When trying to gather verifiable statements on acceptance of autonomous driving, not only attitudes play an important role but also emotions related to the technology. Comparable to the other results, again, Parking Pilot got the highest shares of positive affection. For negative emotions, ‘powerlessness’ had the most pronounced statements – and overall, Vehicle on Demand was rated worst.

When asked about their desires for design and human-machine interaction in a future autonomous vehicle, respondents revealed strong needs for control and system transparency of the autonomous vehicles. In addition, they conveyed a significant level of skepticism in relation to the reliability of autonomous driving systems.

A public debate on autonomous driving in terms of possibilities, benefits, and challenges that might come along with the technology has barely begun. Besides a broader discussion on a societal level, such a debate should also include individual user perspectives on autonomous driving, addressing aspects of acceptance and thus asking to which extent individuals (potential future users of autonomous vehicles as well as transport users in general) could be willing to use such vehicles, or how they currently view autonomous driving (see Fraedrich & Lenz 2015a).

7.1 Are people willing to use an autonomous vehicle?

To gain insights into aspects of acceptance towards autonomous driving, surveys typically record whether their respondents are willing to use an autonomous vehicle (see, e.g., Autoscout24 2015). However, the results sometimes differ quite significantly from each other. As already mentioned above, these differences could be ascribed to the fact that autonomous driving is labeled in diverse ways. On the other hand, the results rarely point towards the challenge that a general understanding about autonomous driving, a "general consensus", so to say, does not exist to date, thus making it difficult to assess attitudes and valuations at all – for more details on this topic, see section Autonomous driving – a topic worth noting? as well as Fraedrich and Lenz (2014).

Although we could not solve the problem that today's users of the transport system do not have any real life experience with autonomous vehicles and sometimes only a very marginal knowledge, the discrimination into specific use cases facilitated a more differentiated view of how the technology is evaluated by the respondents[12].

In the second part of the survey, where the 1,000 respondents were randomly distributed to one of the four use cases, they were asked whether they could imagine using this kind of autonomous vehicle. The results for the corresponding cases of Highway Pilot, Parking Pilot, Fully Automated Vehicle or Vehicle on Demand are illustrated in Figure 28. Whereas Parking Pilot got relatively high approval rates – 53 % declared their general willingness and 25 % assigned high approval rates – Vehicle on Demand was seen with the greatest skepticism: about two thirds (65 %) of the respondents showed slight to total unwillingness to use such a vehicle. Answering patterns for Highway Pilot and Fully Automated Vehicle showed strong similarities and range in between the two above-mentioned cases. Again, these results match well with others where a Parking Pilot seemed to more directly address specific mobility related needs, for example, see section Autonomous driving and mobility.

[12] The different use case groups were tested for correlations regarding sociodemographic aspects as well level of knowledge on autonomous driving. No significant correlations were to be found in this regard.

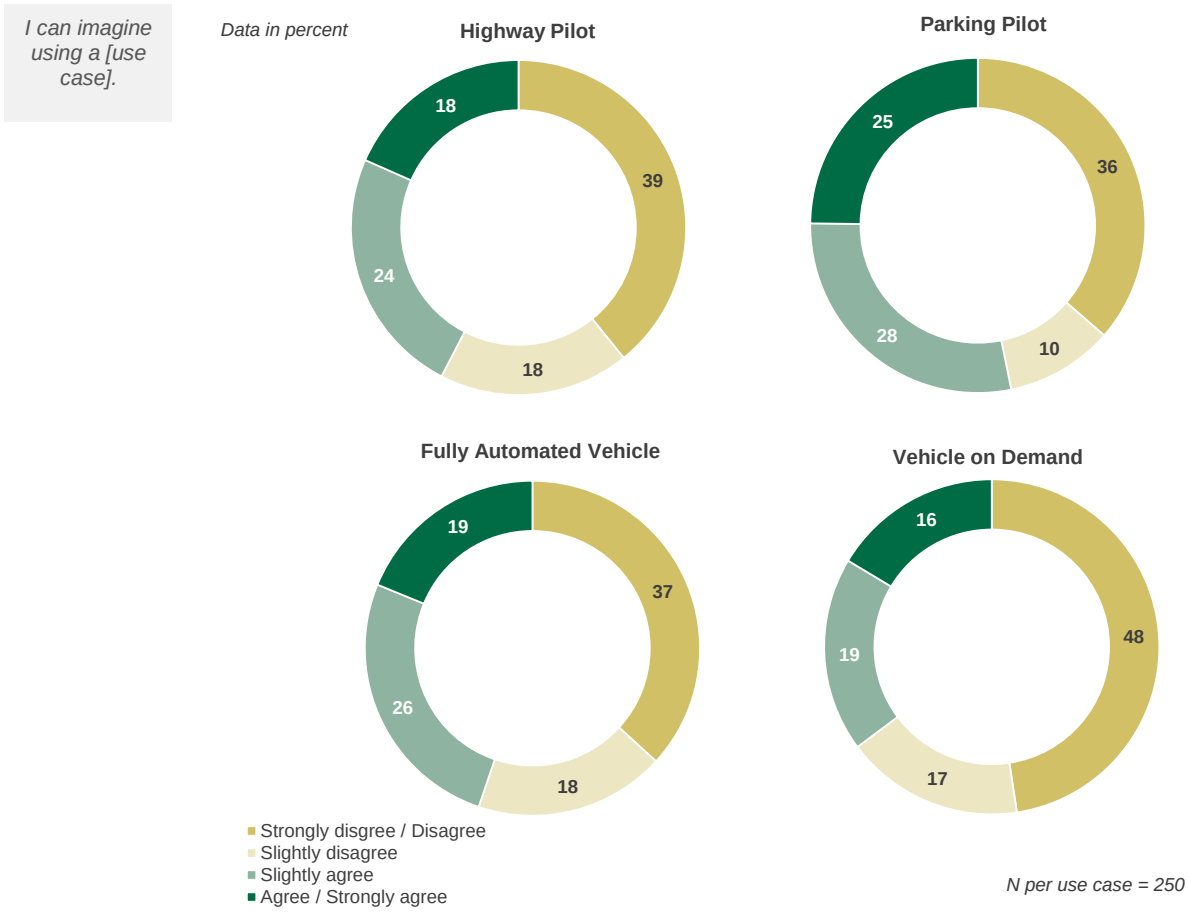


Figure 28: Willingness to use an autonomous vehicle for different use cases

As outlined above, sociodemographic aspects, actual mobility behavior, attitudes towards the car, and needs hardly played any significant role to explain the willingness to use an autonomous vehicle – with only a few notable exceptions, see below. In contrast to this the stated willingness to give up specific driving functions and operations to a machine did very well. Respondents who were willing to delegate speed regulation, parking, braking, steering, gear changing, vehicle guidance, pedestrian detection, and vehicle stabilization were also more likely to agree on the potential option to use an autonomous vehicle.[13]

When correlated with sociodemographic aspects, the willingness to use an autonomous vehicle only showed significant results in a few cells, and the strength of the correlations was mostly non-existent – see Table 5 in section Conclusion for a graphical overview on this. Among all the use cases, a few notable exceptions for Vehicle on Demand could give interesting hints on how autonomous driving is perceived and evaluated specifically. Being male, having a higher educational

[13] For detailed results on the correlations, their levels of significance, and the strength of correlation values, see Conclusions, Table 5.

background, a higher income, and living in a larger household showed significant influence on the willingness to use Vehicle on Demand. Combined, these aspects seem to correspond well with rather ‘typical’ characteristics of the so-called ‘early adopters’ of (mobility) technologies (for the example of electric vehicles, see Frenzel et al. 2015; Peters and Hoffmann 2011; for the example of carsharing, see Kawgan-Kagan 2015). This points towards the assumption that Vehicle on Demand – potentially more than the other use cases introduced in the survey – is seen as some kind of tech gadget, thus requiring the tech-savvy users, at least in the first instance. However, in this examination, only univariate analyses were conducted; multivariate analysis could give further information about the interrelations here.

7.2 And what about their willingness to replace transport modes?

A question in the first section of the survey – before the sample was evenly distributed to the four use cases (Highway Pilot, Parking Pilot, Fully Automated Vehicle, and Vehicle on Demand) – addressed the general willingness of respondents to replace their currently preferred mode of transport with an autonomous vehicle, which at this time was not further specified. In a later section of the survey, the respondents were confronted with the question again – this time in relation to a specific use case.

Figure 29 highlights the large share of respondents having answered quite indifferently (“slightly agree”, and “slightly disagree”) for both the general as well as specific questions asked in grey color. In the case of an autonomous vehicle that was not specified further, this share amounts to almost 60 %. When autonomous driving was introduced as a specific use case, however, the shares of indifference declined in favor of significantly increasing shares of reluctance to exchange the preferred mode of transport – whereas approval rates barely changed. In the case of Vehicle on Demand, negative answers accounted for 54 % of all answers – on the contrary, only 27 % rejected the notion to replace their preferred means of transport with a ‘general’ autonomous vehicle. In comparison to the answers given for the item ‘willingness to use an autonomous vehicle’, the answers for the item ‘willingness to replace the preferred means of transport’ are noticeably less positive.

In summary, and throughout all use cases, it becomes clear that specifically a rejecting and therefore skeptical attitude towards autonomous driving increased when it was made more explicit what is meant by such a vehicle.

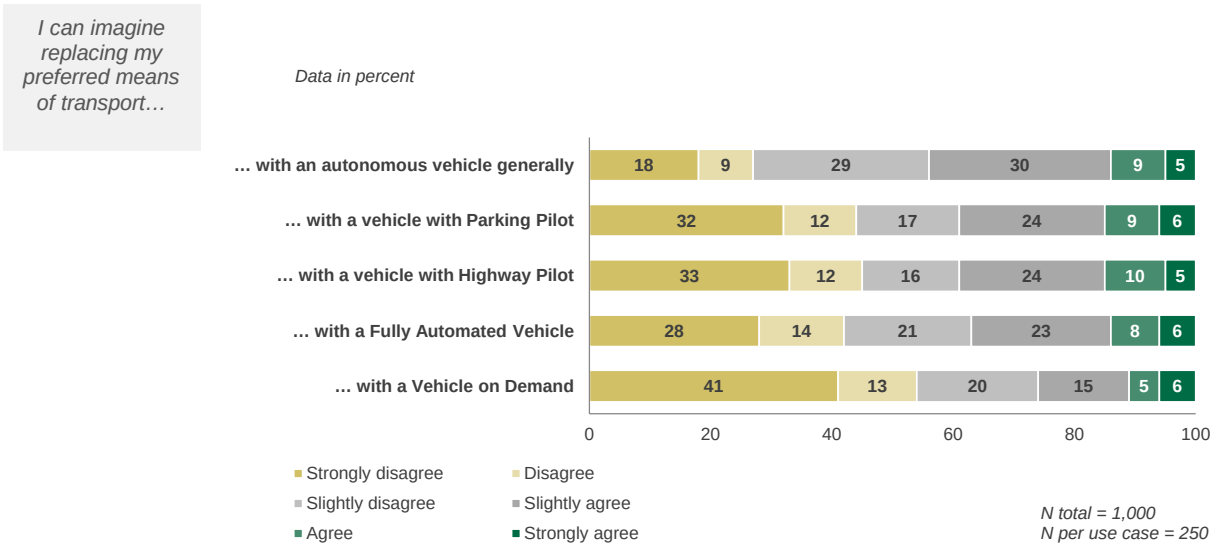


Figure 29: Willingness to replace the currently preferred means of transport with an autonomous vehicle, for different use cases

Comparable to the statements on the potential willingness to use an autonomous vehicle, the stated disposition to hand over manual driving functions to a machine not only accounted for very high significances throughout all use cases but also showed the strongest correlations for this item (although only weak and medium correlations were to be found in the most cells), see Table 5 in section Conclusions for an overview. For Parking Pilot, the existence of children in a household and the household size showed significant influence on approval. Although the strengths of correlation is weak this could be interpreted as a hint for a specific user group that might have a special interest in a vehicle with autonomous parking function: if they had to carry children and/or transport a large amount of groceries, for example, not having to search for a parking space and being dropped off at the destination could be perceived as a relief. Children in the household, however, showed significant correlations also for Fully Automated Vehicle and Vehicle on Demand. Moreover, gender proved to be highly significant for Vehicle on Demand. In relation to transport needs (see section Autonomous driving and mobility), respondents that declared comfort to be of high relevance to them were also statistically significantly more likely to state being willing to replace the currently preferred means of transport with an autonomous vehicle – but the strength of correlation was only very weak.

7.3 How do people assess use cases of autonomous driving?

In general, assessments and valuation of autonomous driving were not overwhelmingly positive: Figure 30 shows the results for questions addressing the perception of autonomous vehicles. Their summed percentage values lie in a range between 15 and 45. Again, Parking Pilot was assessed more positively than Highway Pilot, Fully Automated Vehicle, or Vehicle on Demand. Thirty-three percent of the respondents stated that Parking Pilot would be a helpful and useful system, 34 %

thought it to be fun to use such a system, and 28 % could imagine relying on Parking Pilot in their everyday mobility. Rather high approval rates (34 %) were given for the statement that Parking Pilot would only require little attention and control – though this is not surprising, as respondents were briefed that the autonomous driving mode would operate without any human inside the vehicle.

Vehicle on Demand, on the contrary, got the least approval throughout most of the items: 45 % of the respondents indicated a general skepticism towards this use case, whereas only 22 % thought it would be a reliable system, 25 % could imagine it to be helpful or useful, and only 18 % agreed or strongly agreed with the statement that they would be willing to hand over the driving task to the system.

Interestingly, Fully Automated Vehicle got the lowest rates of approval in terms of the idea that using such a vehicle could be fun – only 24 % agreed or strongly agreed with that – although they were told that such a use case would offer the possibility to hand over the driving task whenever *they* wanted.

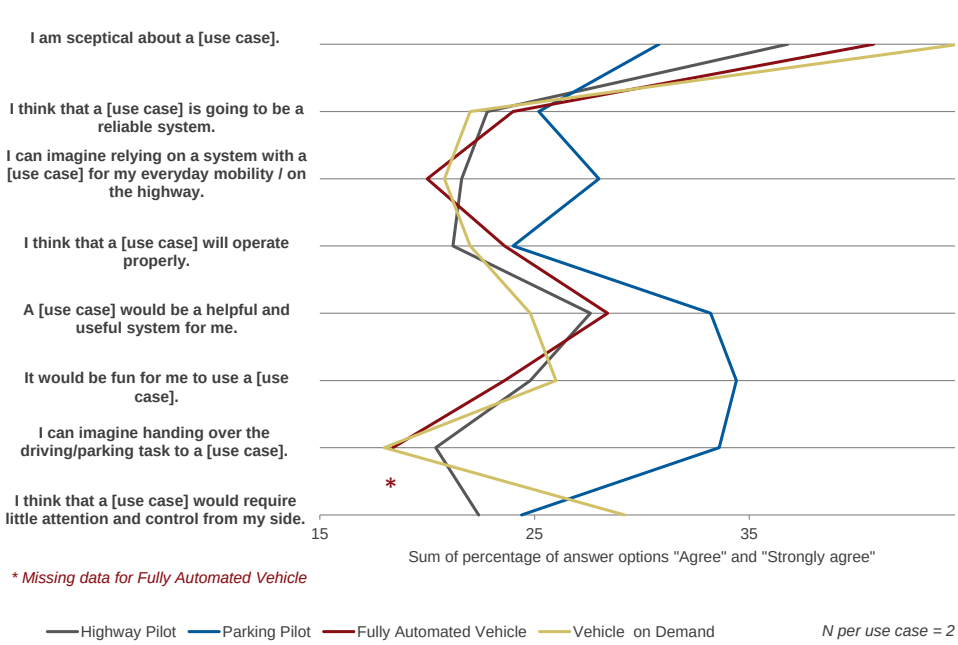


Figure 30: Attitudes towards different use cases of autonomous driving

7.4 What emotional responses do people exhibit towards use cases of autonomous driving?

Theoretical and empirical research suggests that trust and the intention to use technological innovations such as autonomous vehicles depend on certain attitudes and emotions of users. According to social-psychological frameworks, adoption behavior results from intentions that are a function of attitudes associated with an

object (see Fishbein & Ajzen 2010; 1975). Attitudes in turn are based on users' related beliefs and feelings. People's cognitive beliefs towards familiar choice options are built on factual information about and earlier experiences with objects. However, in the case of unfamiliar technological innovations where earlier experiences are not available yet, people tend to base their attitudes more on emotional responses (e.g., Lee et al. 2005). Thus, perceived affects towards autonomous vehicles offer added explanatory and predictive value for the overall attitudes and future behavioral intentions.

In addition to the cognitive beliefs towards autonomous vehicles described above, affective attitude components were measured with an affective judgment scale. The scale consisted of four items measuring positive emotions (i.e., joy, hope, satisfaction and relaxation) and six items measuring negative emotions (i.e., fear, aversion, anger, stress, concern, and powerlessness). Respondents were asked to indicate to what degree they experienced each of the emotions when imagining themselves using an autonomous vehicle described in the respective use case.

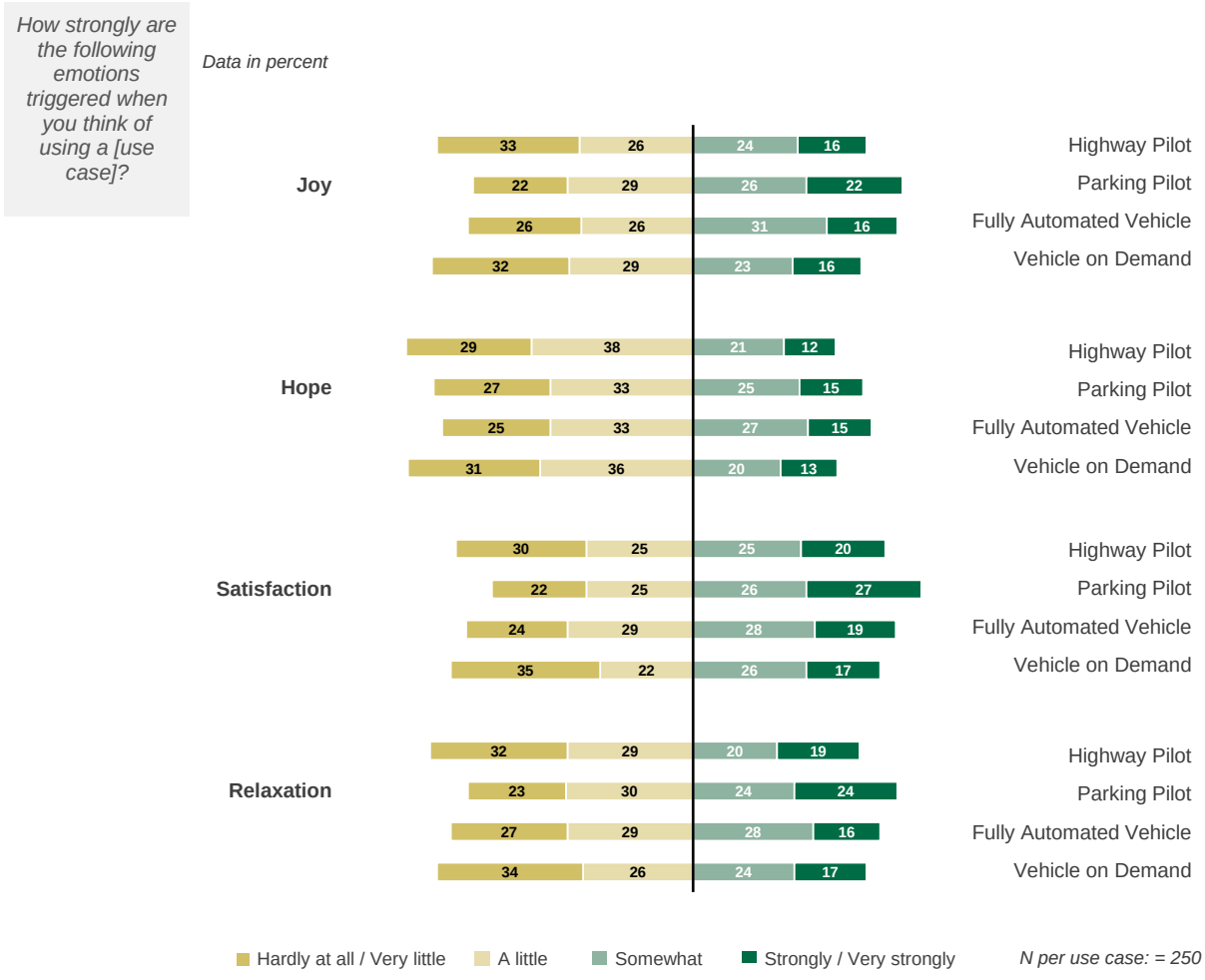


Figure 31: Positive emotional responses towards different use cases of autonomous driving

The results shown in Figure 31 confirm the tendencies found in the cognitive attitude components toward autonomous vehicles. The strongest positive emotions, i.e., satisfaction, relaxation and joy, were associated with the Parking Pilot use case and on a lower level with Fully Automated Vehicle. The majority of respondents in the Vehicle on Demand and Highway Pilot scenarios did not experience positive emotions when imagining the use of these vehicles. The most notable differences were found across all positive emotions between Parking Pilot and Vehicle on Demand, most pronounced for the emotion joy (48 % vs. 39 %).

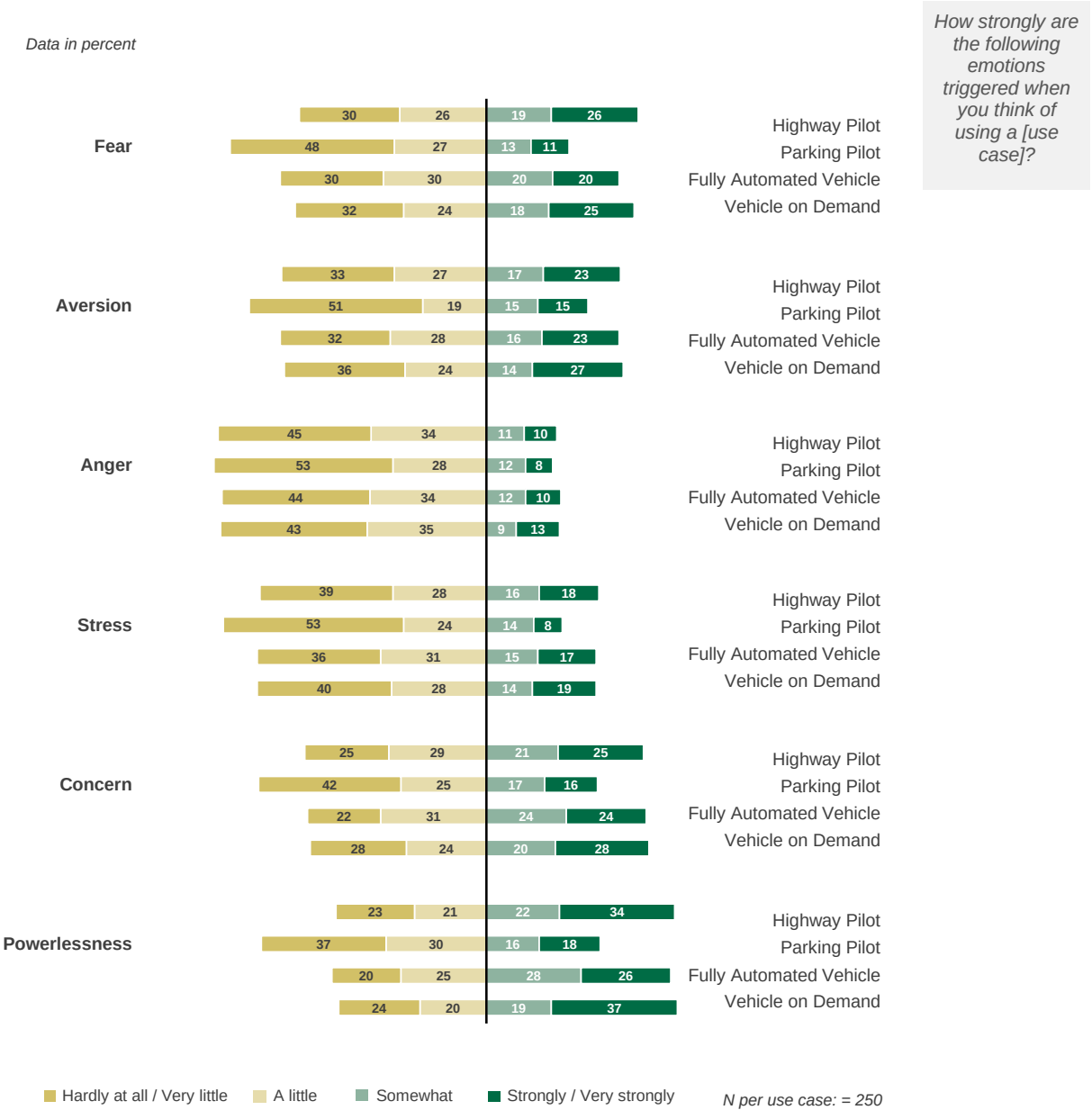


Figure 32: Negative emotional responses towards use cases of autonomous driving

The experienced negative emotions towards the examined use cases of autonomous vehicles show an inverse response pattern (Figure 32). Respondents imagining the

use of Parking Pilot reported significantly less negative emotional reactions compared to the other use cases. Highway Pilot, Fully Automated Vehicle and Vehicle on Demand, however, evoke mainly negative affective responses while powerlessness was the most strongly perceived emotion for these use cases.

Overall, the differences between Parking Pilot and the three other scenarios of autonomous driving are more prominent for negative emotions. Interestingly, although Fully Automated Vehicle generates more negative feelings similar to Highway Pilot and Vehicle on Demand, respondents also link relative strong positive emotions such as hope and joy to this scenario.

7.5 What are favored options for intervention and control?

Affects and emotions play an important role in the context of human-automation interaction. Substantial evidence demonstrates that trust influences reliance on automation and depends on how well the capabilities and the design of the automation meet the expectations and needs of (potential) users (Lee & See 2004). Thus, to gain a deeper understanding of factors affecting trust and willingness to use autonomous vehicles, respondents were asked to indicate their agreement or disagreement with a series of items pertaining to different aspects of interaction with the vehicle in their respective use case. Since the capabilities of the autonomous vehicles differ, in part substantially, items were adapted to the specific characteristics of the respective use case.

The responses across all scenarios provided strong support for needs for control and system transparency of the autonomous vehicles. The majority of the people wanted to be constantly informed about route planning and change as well as the current traffic situation. They predominantly expected an adaptive automation satisfying their individual priorities, driving styles and mobility related needs. The low levels of trust for Highway Pilot, Fully Automated Vehicle and Vehicle on Demand displayed in Figure 33 could be interpreted this way: these use cases seemed to elicit a desire for control and respondents felt the need to focus their attention towards traffic including an automated system detecting the attention allocation of the passengers and the need to remain in the traditional upright seating position. Moreover, for the use case Parking Pilot, high flexibility via smartphone control regarding parking location and pickup characteristics was expected by most of the respondents.

Figure 33: Desired control and system capabilities of different use cases of autonomous driving

8 Conclusions

Distinguishing between four use cases of autonomous driving served as the methodological basis of the study. The confrontation with these specific use cases brought extremely diverse perceptions and evaluations to light. For one thing, we were able to demonstrate the difference between how the topic is generally assessed and how the specific use cases are perceived. For another, it is ever clearer how specifying the situation concretely allows respondents to better assess the benefits, and also the drawbacks they perceive, of road vehicle automation.

An important finding, in light of this, is that interest and positive attitudes towards autonomous driving are not automatically equitable with the desire to drive an autonomous vehicle. This divergence of attitudes and intended behavior makes it essential to examine and consider respondents' expectations, desires, reservations, and fears in greater detail. The present study was able to achieve this thanks to its particular approach. The aim was not so much to go into the general acceptance of autonomous driving on the basis of attitudes and evaluations, but rather to test, by means of the survey and its use cases, how respondents would expect to personally react and behave in view of specific new mobility options. To this end, the standardized survey was supplemented by so-called reconstructive procedures: through the analysis of free-text boxes, in which the respondents could address the topics in their own words, subjective ascriptions of autonomous driving were recorded, which made specific attributions more visible. In the following we would like to highlight particular findings of our study and the resulting conclusions.

1. Parking Pilot has great potential to become a "gateway" to autonomous driving.

In several places in the survey, we saw that Parking Pilot is widely accepted. This rests largely on the particular benefit seen as coming with this vehicle-automation function: less stress, less time spent parking, more comfort. As a result, this use case in particular would, in respondents' eyes, contribute greatly to making driving more attractive for them. It is thus hardly surprising that Parking Pilot was assessed most positively in comparison with the other three use cases. It is notable that the driverless movement of the vehicle when parking was met with an above-average level of trust. Automated parking of the vehicle is viewed as especially safe – unease and doubts are especially infrequent for Parking Pilot. The respondents may possibly expect to have a high level of control of over the Parking Pilot function via a "surveillance" system, e.g. from a smartphone while, at the same time, they might feel safe because they are not subject to the vehicle's control in this process. The transparency of the process and its clear-to-see usefulness makes it likely that Parking Pilot will be an important initiator on the road to automated driving.

2. Highway Pilot, at least from users' point of view, does not appears to be a potential pathfinder for autonomous driving.

In view of its immediate technical feasibility, Highway Pilot will in all likelihood be the "inevitable" next step on the path to autonomous driving. In its foreseen application – journeys lengthy in both time and distance – Highway Pilot is actually seen as helpful by a large share of the respondents. Expectations of filling time gained via automation with alternative activities, even merely conversing with others in the vehicle, are

particularly low compared to other use cases, however. It is possibly understood as more of a support than an autonomous system, an assumption backed up by the rather limited trust Highway Pilot enjoys. Its acceptance thus only increases when it comes to particular usage scenarios. There is a notably high level of willingness to replace currently preferred transport modes among respondents who have high demands for time-saving. Respondents who already use driver-assist systems are also noticeably willing to use Highway Pilot, see Table 5.

3. Fully Automated Vehicle is the luxury limousine of tomorrow.

The respondents view Fully Automated Vehicle and Vehicle on Demand as being very similar in many respects. That the idea of being on the road in a self-driving car is actually catching on can be seen in the high degree of approval of filling freed-up time with alternative activities. Fully Automated Vehicle is seen as particularly useful for longer trips, even more so than Highway Pilot. At the same time, it is notable that respondents only explicitly raised the issue of expected costs in the case of Fully Automated Vehicle, as the free-text boxes vividly show. This type of vehicle is clearly seen as a kind of extension of current premium-class vehicles, whose driver-assists technology is already highly sophisticated. In any case, only a third of respondents would change to such a vehicle, and there was considerable skepticism about the its technical reliability. Beyond this, the expected fun factor for Fully Automated Vehicle proved to be especially low, and the willingness to trust oneself to such a system in their daily mobility is lower than for all other use cases.

4. Vehicle on Demand (still) appears very far off, in every sense.

The user evaluations of Vehicle on Demand, as well as the “no-idea” comments lead one to suspect that the characteristics of autonomous driving in the sense of a fully self-driving car are currently still very far removed from concrete ideas of a vehicle that moves through traffic with no driver input. This is accompanied by especially pronounced doubts as to the safety of such a vehicle, even when its comfort, usefulness and potential cost benefits are stressed. In the current debate, Vehicle on Demand has been discussed explicitly as a future mobility concept primarily addressing daily mobility in an urban setting. However, the study’s respondents did not think of it as being particularly useful in this context.

Overall, the negative assessment of Vehicle on Demand may show that people tend to feel more “exposed” to its potential risks and dangers than is the case with other use cases. Vehicle on Demand is the use case in which direct, driver-initiated “steering” is no longer an option. The difficulty of actually imagining oneself using this system is apparently connected with fears of the new technology, ultimately leading to a comparably high level of rejection.

5. In people’s heads, autonomous driving hardly appears to have “arrived.”

Overall, this study shows that acceptance is most strongly impacted by respondents’ present level of interest in, and knowledge of, autonomous driving, as well as their willingness to surrender specific driving functions – especially total control of the vehicle – to a machine, see Table 5. Whenever interest, knowledge, and such willingness are present, there is also a peak in respondents’ positive mindsets and

evaluations vis-à-vis autonomous driving. In contrast, aspects that are thought to typically impact strongly on attitudes and behavior, such as socio-demographics, have little to no explanatory potential in our study.

Further, the respondents currently expect barely any impact on their personal mobility behavior. These findings lead us to conclude that the topic of “autonomous driving,” in the eyes of its potential users, has not arrived in quite the way the boom in media coverage might lead us to believe. This underlines all the more the need for further research directed at people and their expectations, or fears, of the technology. This is how the ultimate destination of autonomous driving can be reached with society’s consent.

Table 5: Correlations for interest on autonomous driving, willingness to replace the currently preferred means of transport, and willingness to use an autonomous vehicle[14]

		Interest	Willingness to replace					Willingness to use			
Topic	***Variable***	AV	AV	HP	PP	FAV	VOD	HP	PP	FAV	VOD
Socio-demographics	Gender	*					***				***
	Age								**		
	Qualification	**	**								
	Educational background	***	**	*				*			**
	Mobility impairment										
	Employment status										
	Income	**	***				**		*		***
	Household size	***	***		**		**		**		**
	# of cars in the hh	**	**		**				*		
	District type		*			*					*
	Children	**	***		*	*	*				
Mobility behavior	Driver's license	***	***								
	Car use	***	***		*	*				*	
	Kilometers traveled/year	***	*	*				*			*
	Car use frequency (driver)	**			*	*					
	Car use frequency (pass.)		**						*	*	
	DAS user	***	***	**				*			**
Interest & knowledge	Level of knowledge	***	***	***	***		***	***	***	*	***
	Interest		***	***	***	***	***	***	***	***	***
Willingness to give up driving functions	Speed regulation	***	***	***	***	***	***	***	***	***	***
	Parking	***	***	***	***	***	***	***	***	***	***
	Braking	***	***	***	***	***	***	***	***	***	***
	Steering	***	***	***	***	***	***	***	***	***	***
	Gear changing	***	***	***	**	***	***	***	***	***	***
	Vehicle guidance (complete)	***	***	***	***	***	***	***	***	***	***
	Pedestrian detection	***	***	***	***	***	***	***	***	***	***
	Vehicle stabilization	***	***	***	***	***	***	***	***	***	***
Attitudes towards the car	Driving: relaxing										*
	Driving: exercising skills	***									
	Driving: comfortable	***				*				*	
	Driving: joyful	***									
	Driving: safe & protected						*				*
Mobility needs	Comfort	**	**	*	**	*		*			
	Freedom from stress	***	***	**				*			
	Driving experience	**									
	Safety	**	**								
	Time	*	*	***				**			

		Not significant
((*))	0 < r < (-)0.2	Very weak correlation
((*))	(-)0.2 < r < (-)0.4	Weak correlation
((*))	(-)0.4 < r < (-)0.6	Medium correlation
((*))	(-)0.6 < r < (-)0.8	Strong correlation
((*))	(-)0.8 < r < (-)1	Very strong correlation
((*))	r = (-)1	Perfect correlation

AV	Autonomous vehicle, without specification
HO	Highway Pilot
PP	Parking Pilot
FAV	Fully Automated Vehicle
VOD	Vehicle on Demand

DAS user: Driver assistance system user (Boolean variable)

[14] Please note that, while the number of stars refers to the strength of the significance of the correlation (* = 0.05-0.01, ** = 0.01-0.001, *** = > 0.001), the coloring scheme (from grey to blue, see legend) reveals the strength of the correlation. We did not highlight correlations lower 0.2 (very weak correlation) in our results. See section Approach for further details on this.

List of references

Anable, Jillian and Birgitta Gatersleben (2005): All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes, in: *Transportation Research Part A: Policy and Practice,* 39 (2–3), pp. 163–181.

Autoscout24 GmbH (2015): Unser Auto von morgen 2015. Einschätzungen, Wünsche, Visionen, [online] http://ww2.autoscout24.de/de_autoscout24_-_the_cars_we_want_tomorrow.pdf [January 22 2016].

Autoscout24 GmbH (2014): Unser Auto von morgen 2013/14. Was wünschen sich die Europäer vom Auto von morgen?, [online] http://about.autoscout24.com/de-de/au-press/2013_as24_studie_auto_v_morgen.pdf [January 22, 2016].

Autoscout24 GmbH (2012): Unser Auto von morgen: Studie zu den Wünschen der Europäer an das Auto von morgen, [online] http://about.autoscout24.com/de-de/au-press/2012_as24_studie_auto_v_morgen_en.pdf [January 22, 2016].

Bradshaw-Martin, Heather and Catherine Easton (2014): Autonomous or 'driverless' cars and disability: a legal and ethical analysis,in: *European Journal of Current Legal Issues*, 20 (3), pp. 1-15.

Brookhuis, Karel A., Dick de Waard and Wiel H. Janssen (2001): Behavioural impacts of Advanced Driver Assistance Systems – an overview. Special Issue: Implementation Issues of Advanced Driver Assistance Systems, in: *European Journal of Transport and Infrastructure Research*, Vol. 3, pp. 245-254.

Brosius, Felix (2011): *SPSS 19*, Heidelberg: MITP-Verlags GmbH & Co. KG.

Buehler, Ralph (2011): Determinants of transport mode choice: a comparison of Germany and the USA, in: *Journal of Transport Geography*, 19, pp. 644–657.

Bundesverband Informationswirtschaft, Telekommunikation und Neue Medien e.V. (BITKOM) (2015): Jeder dritte Deutsche ist offen für selbstfahrende Autos, [online] https://www.bitkom.org/Presse/Presseinformation/Jeder-dritte-Deutsche-ist-offen-fuer-selbstfahrende-Autos.html [January 22, 2016].

Burns, Lawrence D. (2013): Sustainable mobility: A vision of our transport future, in: *Nature* 497, pp. 181-182.

Chapman, Laura (2012): What Do Self-Driving Vehicles Mean for Disabled Travelers. [online] http://www.disabled-world.com/disability/transport/autonomous-vehicles.php [January 22, 2016].

Continental (2015): It's Mine. Yes To Mobility. Insight and Outlook. 2015 Continental Mobility Study, [online] http://report.conti-online.com/pages/service/download/docs/mobility_study_2015_en.pdf [January 22, 2016].

Continental (2013): Continental Mobility Study 2013, [online] http://www.continentalcorporation.com/www/download/pressportal_com_en/themes/ini

tiatives/channel_mobility_study_en/ov_mobility_study2013_en/download_channel/pres_mobility_study_en.pdf [January 22, 2016].

Cyganski, Rita (2015): Autonome Fahrzeuge und autonomes Fahren aus Sicht der Nachfragemodellierung, in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 241-263.

Cyganski, Rita, Eva Fraedrich and Barbara Lenz (2015): Travel-time valuation for automated driving: A use-case-driven study, in: *Proceedings of the 94th Annual Meeting of the TRB.* 94th Annual Meeting of the Transportation Research Board, January 11-15 2015, Washington, USA.

Daimler (2013): Pionierleistung: Autonome Langstreckenfahrt im Überland- und Stadtverkehr: Mercedes-Benz S-Klasse INTELLIGENT DRIVE fährt autonom auf den Spuren von Bertha Benz, [online] https://media.daimler.com/dcmedia/0-921-614307-49-1629819-1-0-0-1630016-0-0-0-0-0-1-0-0-0-0-0.html [January 22, 2016].

Ernst & Young GmbH (2013): Autonomes Fahren – die Zukunft des PKW-Marktes?, [online] http://www.ey.com/Publication/vwLUAssets/EY_Studie_-_Autonomes_Fahren_-_die_Zukunft_des_Pkw-Marktes/$FILE/EY-Autopilot-2013-Praesentation.pdf. [January 22, 2016].

Fagnant, Daniel J. and Kara Kockelman (2013): Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations, Washington D.C.: Eno Center for Transportation.

Feierabend Online Dienste für Senioren AG (2013): Fahrassistenzsysteme für ältere Autofahrer: zwischen Wunsch und Wirklichkeit. Feierabend Studie zur IAA 2013, [online] http://www.5-sterne-redner.de/fileadmin/download/pdf/Rednermappen/Wild_Studie_Fahrassistenzsysteme_Senioren.pdf [January 22, 2016].

Fishbein, Martin and Icek Ajzen (2010): Predicting and changing behavior: The reasoned action approach, New York: Psychology Press (Taylor & Francis).

Fishbein, Martin and Icek Ajzen (1975): Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research, Reading, MA: Addison-Wesley.

Fisher, Robert J. and James E. Katz (2000): Social Desirability Bias and the Validity of Self-Reported Values, in: *Psychology & Marketing*, 17 (2), pp. 105-120.

Fraedrich, Eva and Barbara Lenz (2015a): Gesellschaftliche und individuelle Akzeptanz des autonomen Fahrens, in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 639-660.

Fraedrich, Eva and Barbara Lenz (2015b): Vom (Mit-)Fahren: autonomes Fahren und Autonutzung, in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann

Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 687-708.

Fraedrich, Eva, Barbara Lenz and Sven Beiker (2015c): Transition pathways to fully automated driving and its implications for the sociotechnical system of automobility, in: *European Journal of Futures Research,* 3 (11), pp. 1-11.

Fraedrich, Eva and Barbara Lenz (2014): Automated Driving – Individual and Societal Aspects, in: *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2416 (2), pp. 64-72.

Frenzel, Ina, Julia Jarass, Stefan Trommer and Barbara Lenz (2015): Erstnutzer von Elektrofahrzeugen in Deutschland. Nutzerprofile, Anschaffung, Fahrzeugnutzung, 2nd ed., Berlin: German Aerospace Center.

Friedrich, Bernhard (2015): Verkehrliche Wirkung autonomer Fahrzeuge, in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 331-350.

Friedrichs, Jürgen (1990): Methoden empirischer Sozialforschung, 14th ed., Opladen: Westdeutscher Verlag.

Gardner, Benjamin and Charles Abraham (2007): What drives car use? A grounded theory analysis of commuters' reasons for driving, in: *Transportation Research Part F: Traffic Psychology and Behaviour*, 10 (3), pp. 187-200.

Gasser Tom, Eike A. Schmidt, Klaus Bengler et al. (2015): Bericht zum Forschungsbedarf. Runder Tisch Automatisiertes Fahren – AG Forschung, [online] http://www.bmvi.de/SharedDocs/DE/Anlage/Digitales/bericht-zum-forschungsbedarf-runder-tisch-automatisiertes-fahren.pdf?__blob=publicationFile [January 22, 2016].

Gasser, Tom, Clemens Arzt, Mihiar Ayoubi et al. (2012): Rechtsfolgen zunehmender Fahrzeugautomatisierung. Gemeinsamer Schlussbericht der Projektgruppe, in: *Berichte der Bundesanstalt für Straßenwesen. Fahrzeugtechnik*, Heft F 83. Bremerhaven.

Greene, W. H. (2002): Econometric Analysis. 5th Edition, New Jersey: Prentice Hall.

Hägler, Max (2013): Kutschen ohne Kutscher. [online] http://www.sueddeutsche.de/auto/autonomes-fahren-kutschen-ohne-kutscher-1.1767575 [January 22, 2016].

Hänsch-Petersen, Lars (2016): So kommt das autonome Fahren, [online] http://www.autobild.de/artikel/autonomes-fahren-was-erlaubt-ist-und-was-nicht-7191393.html [January 22, 2016].

Heinrichs, Dirk (2015): Autonomes Fahren und Stadtstruktur. in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 219-239.

Hönle, Stephan (2015): Connected & Automated Driving. ERTRAC 2015 Annual Conference, [online] http://www.ertrac.org/uploads/documents_publications/2015 %20Conference %20presentations/Bosch.pdf [January 22, 2016].

Hucko, Margret (2015): Verkehrsplanung: “Selbstfahrende Autos sind eine Chance für die Stadt“, [online] http://www.spiegel.de/auto/aktuell/autonomes-fahren-chance-fuer-die-stadt-a-997393.html [January 22, 2016].

Institut für angewandte Sozialwissenschaft GmbH (infas), Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) (2010): Mobilität in Deutschland (MiD) 2008 [online] http://www.mobilitaet-in-deutschland.de/pdf/MiD2008_Abschlussbericht_I.pdf [January 22, 2016].

Jain, Juliet and Glenn Lyons (2008): The gift of travel time, in: *The Journal of Transport Geography*, 16 (2), pp. 81-89.

Kahneman, Daniel and Alan B. Krueger (2006): Developments in the Measurement of Subjective Well-Being, in: *Journal of Economic Perspectives*, 20 (1), pp. 3–24.

Kawgan-Kagan, Ines (2015): Early adopters of carsharing with and without BEVs with respect to gender preferences, in: *European Transport Research Review*, 7 (33), pp. 1-11.

Kent, Jennifer L. (2014): Driving to save time or saving time to drive? The enduring appeal of the private car, in: *Transportation Research Part A: Policy and Practice*, 65, pp. 103-115.

Lee, Chul-Joo, Dietram A. Scheufele and Bruce V. Lewenstein (2005): Public attitudes toward emerging technologies. Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology, in: *Science Communication*, 27 (2), 240–267.

Lee, John D. and Katrina A. See (2004): Trust in Automation: Designing for Appropriate Reliance, in: *Human Factors*, 46 (1), pp. 50–80.

Levinson, David M. and Kevin J. Krizek (2015): The End of Traffic and the Future of Transport, Kindle Editions.

Litman, Todd (2014): Ready or waiting?, in: *Traffic Technology International*, pp. 37-42.

Litman, Todd (2015): Autonomous Vehicle Implementation Predictions Implications for Transport Planning, vtpi, [online] http://www.vtpi.org/avip.pdf, [January 22, 2016].

Lyons, Glenn, Juliet Jain, Yusak Susilo and Stephan Atkins (2013): Comparing Rail Passengers’ Travel Time Use in Great Britain Between 2004 and 2010, in: *Mobilities*, 8 (4), pp. 560-579.

Lyons, Glenn, Juliet Jain and David Holley (2007): The use of travel time by rail passengers in Great Britain, in: *Transportation Research Part A: Policy and Practice*, 41 (1), pp. 107-120.

Maier-Borst, Haluka (2015): Autohersteller wagen Experimente, [online] http://www.deutschlandfunk.de/autonomes-fahren-autohersteller-wagen-experimente.676.de.html?dram:article_id=335076 [January 22, 2016].

Maurer, Markus, J. Christian Gerdes, Barbara Lenz and Hermann Winner (2015), Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte, Berlin: Springer.

Mokhtarian, Patricia L. and Ilan Salomon (2001): How derived is the demand for travel? Some conceptual and measurement considerations, in: *Transportation Research Part A: Policy and Practice*, 35 (8), pp. 695-719.

Motortalk (2015): Männer fahren weiter als Frauen, noch [online] http://www.motor-talk.de/news/maenner-fahren-weiter-als-frauen-noch-t5230478.html, [January 22, 2016].

Munsch, Elfriede (2014) Autonomes Fahren: Platz sparen mit dem Bordcomputer [online] http://www.zeit.de/mobilitaet/2014-05/autonomes-fahren-feldversuch-schweden [January 22, 2016].

OECD/ITF & CPB (2015): Urban Mobility System Upgrade. How shared self-driving cars could change city traffic, [online] http://www.internationaltransportforum.org/Pub/pdf/15CPB_Self-drivingcars.pdf, [January 22, 2016].

Peters, Anja and Jana Hoffmann (2011): Nutzerakzeptanz von Elektromobilität. Eine empirische Studie zu attraktiven Nutzungsvarianten, Fahrzeugkonzepten und Geschäftsmodellen aus Sicht potentieller Nutzer, Ergebnisbericht aus dem Projekt Fraunhofer Systemforschung Elektromobilität FSEM am Fraunhofer ISI Karlsruhe.

Puls Marktforschung GmbH (2015): Autonomes Fahren „Guck mal – freihändig“ , [online] http://www.puls-marktforschung.de/images/926/2015-06-puls-studie-autonomes-fahren-auszug.pdf, [January 22, 2016].

Society of Automotive Engineers (SAE) (2014): Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. Surface Vehicle Information Report.

Scheiner, Joachim and Christian Holz-Rau (2007): Travel mode choice: affected by objective or subjective determinants?, in: *Transportation*, 34 (4), pp. 487–511.

Schulz, T.(2014): Google-Auto: Unterwegs im selbstfahrenden Auto. Spiegel Online, May 2014. http://www.spiegel.de/auto/aktuell/google-auto-unterwegs-im-selbstfahrenden-auto-a-969532.html, [January 22, 2016].

Schwanen, Tim, David Banister and Jillian Anable (2012): Rethinking habits and their role in behaviour change: the case of low-carbon mobility, in: *Journal of Transport Geography*, 24, 522–532.

Silberg, Gary, Mitch Manassa, Kevin Everhart, Deepak Subramanian, Michael Corley, Hugh Fraser and Vivek Sinha (2013): Self-Driving Cars: Are We Ready? KPMG, [online] https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-are-we-ready.pdf [January 22, 2016].

Silberg, Gary, Richard Wallace, Gary Matuszak, Jos Plessers, Chris Brower, Deepak Subramanian (2012): Self-driving cars: The next revolution. KPMG and Center for Automotive Research, [online] https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-next-revolution.pdf, [January 22, 2016].

Sokolow, Andrej (2013): Autonome Autos: Autobranche vs. Google, [online] http://m.heise.de/newsticker/meldung/Autonome-Autos-Autobranche-vs-Google-2072050.html [January 22, 2016].

Steg, Linda (2005): Car use: lust and must. Instrumental, symbolic and affective motives for car use, in: *Transportation Research Part A: Policy and Practice*, 39 (2-3), pp. 147–162.

Tatje, Claas (2014): Arbeitsweg: Die Pendlerrepublik [online] http://www.zeit.de/2014/22/mobilitaet-pendler-arbeitsweg, [January 22, 2016].

Verplanken, B., I. Walker, A. Davis, M. Jurasek (2008): Context change and travel mode choice: combining the habit discontinuity and self-activation hypotheses, in: *Journal of Environmental Psychology,* 28 (2), 121–127.

VDA (German Association of the Automotive Industry) (2015): Stufen des automatisierten Fahrens, [online] https://www.vda.de/de/themen/innovation-und-technik/automatisiertes-fahren/automatisiertes-fahren.html [January 22, 2016].

Willumsen, Luis G. (2013): Forecasting the Impact of Self-Driving-Cars. What to do about them in our models and forecasts. Presented at Citilab Asia User Conference, Karon, Thailand, Nov. 5, 2013.

Woisetschläger, David M. (2015): Marktauswirkungen des automatisierten Fahrens, in: Markus Maurer, J. Christian Gerdes, Barbara Lenz and Hermann Winner (eds.), *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, Berlin: Springer, pp. 709-732.

Wolf, Ingo, Tobias Schröder, Jochen Neumann and Gerhard de Haan (2015): Changing minds about electric cars: An empirically grounded agent-based modeling approach, in: *Technological Forecasting & Social Change*, pp. 269-285.

Appendix

German scales, and their English equivalents

German scale	English scale
Trifft überhaupt nicht zu Trifft überwiegend nicht zu Trifft eher nicht zu Trifft eher zu Trifft überwiegend zu Trifft voll und ganz zu	Stongly disagree Disagree Slightly disagree Slightly agree Agree Strongly agree
Viel seltener Viel häufiger	Far less often Far more often
Überhaupt nicht hilfreich Überwiegend nicht hilfreich Eher nicht hilfreich Eher hilfreich Überwiegend hilfreich Voll und ganz hilfreich	Not helpful at all Very unhelpful Somewhat unhelpful Somewhat helpful In large measure helpful Totally helpful
Äußerst unwichtig Sehr unwichtig Eher unwichtig Eher wichtig Sehr wichtig Äußerst wichtig	Of utmost unimportance Very unimportant Quite important Quite unimportant Very important Of utmost importance
Keinesfalls Eher nicht Vielleicht Eher ja Gerne Sehr gerne	Under no circumstances Probably not Maybe Probably yes Gladly Very gladly
Überhaupt nicht Überwiegend nicht Überwiegend ja Voll und ganz	Not at all Not very much Quite strongly Very strongly
Viel seltener Seltener Gleich häufig Häufiger Viel häufiger	Much less frequently Less frequently Equally often More frequently Much more frequently
Nie Manchmal Häufig Immer	Never Sometimes Often Always
Äußerst gering Gering Eher gering Eher stark Stark Äußerst stark	Hardly at all Very little A little Somewhat Strongly Very strongly

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