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Users' resistance towards radical innovations: The case of the self-driving car

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ABSTRACT

In this paper we unpack and examine attitudes and potential barriers of end-users towards the self-driving car. We explore whether drivers have (mental) barriers and/or show resistance towards the self-driving car and, given such barriers and resistance are identified, investigate the main underlying reasons. Further, we suggest potential strategic implications for automotive companies and avenues to overcome, or at least mitigate, drivers' barriers. The paper contributes to a better understanding of end-users' opinions on radical innovations such as the self-driving car and strives to add value by linking scientific insights from both psychology as well as innovation literature. Only a limited number of studies so far have dealt with the potential barriers of users towards the self-driving car; therefore, it is our intent to provide first empirical evidence to trigger further research and foster a broader discussion on this relevant topic.

1. Introduction

The automotive industry is currently undergoing a potentially revolutionary change that could not only affect how vehicles are built but also reshape the design of roads and cities as well as the interaction between humans and machines (Silberg et al., 2012). The advent of self-driving cars could eliminate the driver from the driving equation, having the potential to substantially improve safety, time and fuel efficiency as well as mobility in general (Beiker, 2012; Douma & Palodichuk, 2012; Silberg et al., 2012). The introduction of such a radically new technology is surrounded by a high degree of uncertainty (Van Geenhuizen & Nijkamp, 2003) and possibly not all stakeholders would welcome the change. As a result, the wide-spread acceptance and hence adoption of this new technology is far from certain and will thus be analyzed comprehensively in this paper.

Prior studies did not commonly focus on the users' attitudes towards self-driving cars in terms of judging perceived benefits and concerns, instead they either had a more narrow focus or consulted experts instead of the public. Most importantly, however, no study derived and empirically tested strategic implications aiming to overcome identified barriers of drivers. Bekiaris, Petica, and Brookhuis (1997) were among the first covering the prospect of "automatic driving" as they termed it. They investigated user needs and users' acceptance of technology that could assist impaired drivers and found that users value driver assistance systems that provide warning functions, but show a clear rejection of automated driving. Recent studies show a more positive attitude of users towards self-driving technology; nevertheless, considerable resistance remains (Kyriakidis, Happee, & De Winter, 2014). For example, Begg (2014) conducted a study consisting of 3500 London

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transport professionals asking whether, and, if yes, when they expect autonomous vehicles to materialize. The more sophisticated the level of automation, the more skeptical people have been. In addition, Epprecht, von Wirth, Stünzi, and Blumer (2014) interviewed experts in Switzerland asking them to provide a list of critical factors affecting the acceptability of future transportation systems. Subsequently, they developed various scenarios with different levels of newness. By judging the acceptance of these scenarios, they found that Swiss users have valued the most radical scenario the least favorable despite various potential advantages over the incremental alternatives. The first online study involving drivers was carried out by Schoettle and Sivak (2014) who focused their study on people from Australia, China, India, Japan, the U.S. and the U.K. They found that the majority of respondents were familiar with the new concept of self-driving vehicles and have a positive general opinion of them. People have been found to have high expectations regarding the potential benefits of the technology (fewer crashes and better fuel economy being the most promising ones while less congestion and short travel times have been perceived to be the least likely to occur). Respondents have also indicated severe concerns about riding in driverless cars without a steering wheel, about safety issues related to errors in the system or equipment, and about self-driving technology not driving as well as humans. In contrast, people have neither feared to have high need for learning with self-driving cars, nor a lack of data privacy. While respondents have predominantly desired to have such technology in their vehicles, most of them have not been willing to pay extra. Finally, also Kyriakidis et al. (2014) employed an online survey about the public opinion of self-driving cars but focused primarily on the respondents' opinion of when self-driving car would materialize. Results show that nearly 70% of respondents have believed that autonomous cars would reach a market share of 50% by 2050. They have also found a higher openness towards self-drive technology in emerging markets, while, across all countries studied, people have been especially concerned about the threat of hacking as well as about legal issues still to be addressed, followed by safety and privacy concerns.

Given that it will be the end-consumers (the actual drivers) who will eventually decide whether self-driving cars will successfully materialize on the mass market (Van Geenhuizen & Nijkamp, 2003), the lack of wider empirical evidence for the user perspective forms the rationale for our research. A product development process over-relying on the input of technicians alone tends to show a lack of market orientation (Epprecht et al., 2014; Renn & Zwick, 1997) as these processes have a tendency of focusing solely on making the product as sophisticated as possible. Whether the consumer wants these features, and is thus willing to pay for them, is sometimes neglected. Beiker (2012, p. 1149) notes that *"besides the technology aspects of this field, questions regarding consumer acceptance (. . .) remain*". Consequently, this paper aims to fill the prevalent research gap and to derive promising strategic implications for automotive companies.

The idea of the self-driving car fits well to the notion of innovation coined by Schumpeter, who described innovation as a destructive process that challenges current best practices by superseding existing products or processes with new ones; a process famously termed "creative destruction". Hauschildt (2004, p. 22ff) declares the level of radicalness "new for mankind" a "rare border case", which holds true for the self-driving car, since it is new for mankind and has the potential to disrupt the worldwide mobility regime. In this context, it is very probable that the self-driving car will meet considerable resistance (Douma & Palodichuk, 2012). User resistance to change has been found to be a crucial cause for many implementation problems (Jiang, Muhanna, & Klein, 2000). The assumption that a possibly disruptive innovation such as the self-driving car could lead to major resistance on behalf of the public is based on the fact that people regularly react with caution and wariness to 'new things' and 'change' or, in extreme cases, even fight them (Goldenberg, Lehmann, & Mazursky, 2001; Kemp, Schot, & Hoogma, 1998). A prime example of this is the advent of the automobile itself that, in its early days, was confronted with bans and seen as an "unruly intruder" (Böhm, Jones, Land, & Paterson, 2006; Norton, 2008). Morison (1966) notes that there is a human instinct to protect oneself and, especially, to protect one's familiar way of life. The extreme form of this fear being termed 'neophobia': the *"extreme or irrational fear or dislike of anything new, novel, or unfamiliar*" (The Oxford Dictionary, 2015). Regarding the desired level of automation, Khan, Bacchus, and Erwin (2012, p. 88) hypothesize that *"it is likely that a significant percentage of drivers may not be comfortable with full autonomous driving.*" People might experience driving to be *"adventurous, thrilling and pleasurable*" (Steg, 2005, p. 148). Mokhtarian and Salomon (2001, p. 695) argue that travel *"is not only derived demand*", but may be *"desired for its own sake*". It is assumed to be challenging to convince those 'pleasure drivers' to hand over the driving task to technology. While self-driving cars might post significant advantages for many segments of the population, driving enthusiasts might not be among the people adopting this new technology. Those who are driving cars *"for pleasure or for the thrill of controlling a powerful machine, may not want to use autonomous vehicles*" and *"passively being driven around by an autonomous vehicle just does not fit the active mastery and in-control-at-all-times superhero image.*" (Glancy, 2012, p. 1184). Similarly, analyzing reasons why people do not use public transportation, Böhm et al. (2006, p. 4) make a distinction between "moving" and "being moved", highlighting the latter as "dependent". This poses the question whether self-driving cars could be seen as providing the ultimate level of autonomy, as people are free to engage in any activity once relieved from the task of driving or, psychologically, making people dependent on technology. Further, as people regularly view their cars as source of power and similar attributes, *"it is uncertain whether this close identification of personal autonomy with a person's vehicle may be different with regard to use of autonomous vehicles*" (Glancy, 2012, p. 1188). Other users might resist self-driving technology not because they value the driving task but because they simply do not trust *"a machine making decisions for them*" (Rupp & King, 2010, p. 3). There are also privacy issues: Song, Qu, Blumm, and Barabási (2010) have found that by tracking peoples' daily driving, predictability of where those people will go in the future can be maximized up to 93%. Given that self-driving cars could be tracked steadily involving *"vehicle location, as well as information about where the user wanted to go, did go, and what the user could have seen along the way*" (Beiker, 2012; Glancy, 2012, p. 1179f; Khan et al., 2012; Silberg et al., 2012), could lead people to believe that the self-driving car would be

the next step towards higher surveillance and might thus resist to ride in such tracked vehicles. Another potential cause for barriers towards self-driving technology is the risk of a "misbehaving computer system" (Douma & Palodichuk, 2012, p. 1164). With autonomous vehicles, criminals or terrorists might be able to hack into and use their cars for illegal purposes such as drug trafficking or, even worse, terroristic attacks (Douma & Palodichuk, 2012). Further, the unavoidable rate of failure (or crashes), no matter how small, could foster initial mistrust, especially as people tend to underestimate the safety of technology while putting excessive trust in human capabilities like their own driving skills (Moore & Lu, 2011; Reimer, 2014; Rupp & King, 2010).

Causes for barriers and resistance can be categorized into three perspectives (Jiang et al., 2000). The "people-oriented" perspective argues that resistance is created by user-internal factors such as gender, age or cultural background. The "system-oriented" perspective states that technological features such as user interface, reliability or design are the origin of resistance. Finally, the "interaction" perspective reasons that resistance is developed by the interaction between users and the technology and its magnitude is varying in different settings and differently among users. Both "over-trust" as well as "under-trust" may be problematic as overly trusting the automation might result in automation misuse whereby users rely too heavily on the automation and fail to override the system when necessary, while not trusting the automation enough, may lead to automation disuse, foregoing improved performance potential (Lee & See, 2004; Merritt, Heimbaugh, LaChapell, & Lee, 2012; Rudin-Brown & Parker, 2004). Frey and Frank (2001) imply that people see what they want to see; social cognition being an active process with the aim to harmonize newly obtained information with, put simply, one's own image of the world. Therefore, prior experiences and prejudices strongly influence which information is 'saved' in our brain and how it is interpreted. This could lead to the question of whether people with automated features already existing in their current cars might have less negative prejudices towards self-driving technology.

While a number of insights have been gained, there is still insufficient knowledge (and mixed results) about which barriers (and to which magnitude) are the strongest, which advantages of self-driving cars are seen as the most pronounced ones, or, most importantly, which strategic implications obtained results should trigger. Further, there has not been an empirical comparison between the acceptance of self-driving cars operated in a car-sharing scheme and those owned by individuals, and there is also no clear indication yet of how a self-driving car should be designed to have the highest probability of acceptance in the marketplace. This study provides first empirical evidence to address those issues.

2. Methods

2.1. Research design

The theoretical underpinning of the study's content and scope was informed by the seminal insights on the role of acceptance and behavioral adaptation as presented in Rudin-Brown and Jamson (2013), and on drivers acceptance of new technology in Regan, Horberry, and Stevens (2014), as well as on behavioral adaptation and acceptance related to intelligent vehicles by Martens and Jenssen (2012). It is hence presumed that, from the viewpoint of driver psychology, unintended and even negative behavioral adaptation might arise as a consequence to changes in the drivers' environment and to challenges towards the driver's traditional role.

As the current state of scientific research about self-driving cars is still in its infancy, an explorative study was decided for. This approach was chosen following the reasoning of Krogh, Rossi-Lamastra, and Haeflinger (2012) on how to deal with phenomenological research in its "embryonic stage". The rationale for employing an explorative study was therefore to pose useful questions, to gather data, to generate first evidence, to provide relevant insights, and to foster further research inside and outside the focal concept.

For this purpose, a non-probability convenience sampling method was applied that leveraged the researchers' broad networks. Although convenience sampling means that the sample is not representative, it was a viable opportunity to reach out to the crucial audience and to enable the collection of relevant data forming first evidence. This should inform further research, especially when a more mature stage of insights on the subject is reached, and a variety of descriptive research designs can be applied. As the subject matter rested with the general public, participation rights were granted to all people in the driving age while there was also no strict geographical scope in order to reach as many different people as possible, allowing for comprehensive first indications of drivers' attitudes towards self-driving cars not only applying to certain regions.

2.2. Data collection

Data were collected over a two-week time frame in July 2015 using a quantitative self-completion online questionnaire. This method was chosen for several reasons. For one thing, assessed information was widely available among the public. For another, given the study's international scope, an online approach made it easier to reach people across borders, and by not requiring an interviewer to be present, it reduced both potential bias and corresponding cost and time. Finally, a questionnaire was preferred over other methods such as experiments as Zikmund, Babin, Carr, and Griffin (2012) noted that *"attitudes are latent constructs and because of this, they are not directly observable*".

The questionnaire was compiled based on insights by Corbetta (2003), Kallus (2010) and Porst (2011). It was designed using the survey platform *typeform.com*. Prior to publication, it was pre-tested according to guidelines by Brace (2008) and Saunders, Lewis, and Thornhill (2011) involving people representing a broad range of the variables age, gender, education levels, and exposure to the English language.

After successful testing, participants were reached by sending out emails and private messages on social media including both a personalized invitational letter built on Peterson (2000) as well as a direct link to the online questionnaire. It shall be noted that the invitation letter explicitly stated self-driving cars as the topic of the study, potentially resulting in both a response as well as a non-response bias that have to be taken into account when analyzing results in Section 3. On the cover page of the questionnaire, respondents were assured of anonymity and confidentiality. 460 people in the researchers' networks were contacted together with using a university mailing list while also allowing people to forward the invitation. Consequently, no explicit response rate can be calculated. Given the study's explorative character and the mentioned "embryonic stage" of evidence for this phenomenon, reaching a large number of respondents was prioritized.

2.3. Measures

2.3.1. Attitudes towards self-driving cars

Participants' existing knowledge about and attitudes towards self-driving cars were assessed. Emphasis was additionally placed on differentiating between types of self-driving cars distinguished by the degree of the possibility to gain control over the driving task manually and whether participants had diverging attitudes depending on whether to merely ride in a self-driving car compared to personally buying one.

Respondents were confronted with a set of rating questions containing one-dimensional, even, numerical Likert scales made up of six points ranging from 'I strongly disagree' (1) to 'I strongly agree' (6). There were two exceptions. First, to allow for a 'neutral' opinion, the statement "Thinking of self-driving cars, your current overall thoughts can be considered as..." was combined with a 5-point scale ranging from 'Very negative' (1) to 'Very positive' (5). Second, an open question was included asking for participants' willingness to pay for self-driving cars in order not to constrain answers to certain ranges.

2.3.2. Potential benefits and concerns

After this initial assessment of attitudes towards self-driving cars, participants were further asked to rate their agreement with statements reflecting presumed benefits and concerns accompanying the hypothetical use of self-driving cars by using the same six-point Likert scale. Besides gathering data on participants' attitudes towards these statements that were derived from a thorough literature analysis, an open-ended question was included that aimed to collect potentially existing but not yet registered additional concerns.

2.3.3. Strategic implications

Beyond the scope of existing scientific knowledge, the study aimed to gather first indications concerning promising actions that could be undertaken by enterprises developing self-driving cars to overcome identified concerns of drivers. Again, study participants had to indicate their agreement using the six-point Likert scale and were subsequently given the option to state any additional actions they considered promising.

2.3.4. Personal car use and demographics

In the final part of the questionnaire, participants were asked how often they drove a car over the past year presented with the answering options '(Nearly) never', 'Occasionally', 'Frequently', and '(Nearly) every day'. Respondents also had to classify the degree of automation in their present car according to 'I have no car', 'I have a car (nearly) without any automated features', 'I have a car with features of a limited automation level such as anti-lock braking system (ABS) or sensors measuring distances to objects (parking assistance)', and 'I have a car with advanced automated features assisting me in regular driving tasks such as lane assistance or automated parking'. Additionally, information was drawn concerning whether participants were living in urban (above 100,000 people) or rural areas (below 100,000). Also respondents' age ('30 or younger', '31–59', '60 or older'), gender, and the country of origin was assessed. The complete questionnaire can be found in Appendix A.

3. Results

3.1. Participants' profile

In total, 489 complete and unique responses from 33 countries were recorded, whereby a predominant majority was coming from Austria (366 respondents, 75%). In total, 271 of the respondents were male (55%) while 218 were female (45%). With regards to age, young people were over-represented. While 321 respondents were '30 or younger' (66%), 129 participants were '31–59' (26%), and 39 people were '60 or older' (8%). Sufficiently high absolute numbers per age group nevertheless allowed for first indications about the link between age and the participants' attitudes towards self-driving cars. Concerning participants' center of living, 360 respondents (74%) indicated to live in urban areas, while 129 (26%) lived in

rural areas. Further, the majority of participants used a car either '(nearly) every day' (38%) or 'frequently' (31%). However, also 'occasional' drivers (21%) and people '(nearly) never' using a car (10%) were represented in sufficiently high numbers. Finally, with regards to the automation level of participants' cars, respondents owning a car with limited automation (47%) clearly outnumbered other categories (Fig. 1) reflecting the situation on streets today.

3.2. Attitudes towards self-driving cars

Overall, knowledge about the existence of self-driving cars was widespread with less than five percent of participants having never heard of self-driving cars prior to the study. Again, one has to keep in mind the sample being skewed towards university-educated, tech-savvy people. At the same time, with a mean of 3.58 (S.D. = 1.37), the level of knowledge tended to be limited. In general, people thought rather positively about self-driving cars (Mean = 3.50, S.D. = 1.03).[1] Female respondents had a significantly less positive attitude than men (p 0.002%[2]), urban residents tended to be more open than rural citizens (p 5.0%), and the older the participants, the more wary they were (p 0.07%). Regarding frequency of car use, effects were not significant with p-values ranging from seven to nine percent. Notwithstanding, the more often respondents made use of their cars, the less positive their attitudes towards self-driving cars and both people with no car as well as those with a car possessing high automation levels showed a modestly more positive attitude towards self-driving vehicles than those owning a vehicle with none or limited automation (Fig. 2). Finally, there was a significant positive trend between existing knowledge about self-driving cars and peoples' attitudes towards them. For those who 'never heard of self-driving cars', the mean evaluation was 3.13, whereas for the group of respondents indicating 'I have a good understanding' the mean was 4.40; p 0.00000005%).

Confronting respondents with the statement 'The idea of a driverless car is tempting.' resulted in broad agreement (Mean = 4.31, S.D. = 1.51). Again, young people valued driverless cars considerably more than did old people (Mean = 4.43 compared to Mean = 3.67; p 0.04%) and males were more open than females (Mean = 4.47 compared to Mean = 4.08; p 0.09%). Subsequently, respondents were asked whether they would also be willing to ride in a self-driving vehicle and later also whether they would consider buying one. While riding yielded very similar results (Mean = 4.20, S.D. = 1.59), the buying option was considerably less attractive for many (Mean = 3.54, S.D. = 1.74). Correspondingly, 30% of participants were not even willing to pay anything extra for self-driving cars compared to their current budget for cars. A notable exception being participants without a car at their disposal; the only sub-group showing a mode unequal to zero (Mode = 5000). The low willingness to invest a considerable sum of money was also reflected in the result that a car-sharing scheme operated by self-driving cars received greater acceptance (Mean = 3.71, S.D. = 1.69) than the previous statement 'I would be willing to own or lease a self-driving car.'

The sections' final questions concerned peoples' need for control over the vehicle. While the statement 'I would have no concerns riding in a self-driving vehicle without a steering wheel.' resulted in a very low mean of 2.84 (S.D. = 1.49), the possibility to take over control in cases of emergency raised the agreement considerably (Mean = 4.44, S.D. = 1.36) and, with high significance, even further to a mean of 5.00 (S.D. = 1.28) when presented with the option to take over control whenever wanted.

3.3. Potential benefits and concerns

Fig. 3 contains the assessed potential benefits of self-driving cars starting with the one showing the highest mean across respondents. 'A self-driving car could solve the transport problems of older or disabled people.' showed the highest agreement (Mean = 4.71, S.D. = 1.41), while it is interesting to note that young people were more optimistic than old people themselves (Mean = 4.38 compared to Mean = 3.64; p 2.4%). The second most valued benefit was the possibility to engage in other things than driving. However, while young people would highly value the corresponding increase in efficiency (Mean = 4.74), the segment '60 or older' showed a mean of merely 3.31 (p 0.00004%). Interestingly, while especially commuters should benefit given the amount of time they spend in their cars, agreement deteriorated the more people used their cars ('(Nearly) never': Mean = 4.89; '(Nearly) every day': Mean = 4.33; p 1.75%). On the other end of the scale, respondents across segments did not perceive self-driving cars to give them social recognition (Mean = 2.54, S.D. = 1.55) nor did they trust them to yield shorter travel times (Mean = 3.20, S.D. = 1.60).

Despite the rather high assigned value to potential benefits, respondents showed an even higher degree of concern towards self-driving cars. All ten statements yielded means higher than 3.0 while seven even yielded means higher than 4.0 (Fig. 4). With a mean of 4.51, legal issues were the leading cause of concern, closely followed by the concern of possible attacks from hackers. The most apparent result, however, is the prevalent lack of trust across all sub-groups in the functioning of the technology. While both people driving cars with advanced automated features and young drivers tend to have a less pronounced level of concern, differences were not significant. On the other end of the scale, respondents' least concerns were a threat of job losses accompanying the introduction of self-driving cars (Mean = 3.23, S.D. = 1.74) and the risk that self-driving cars might not drive as well as human drivers do (Mean = 3.01, S.D. = 1.58).

[1] Note, as indicated in Section 2.3.1, this question was combined with a scale of 5 instead of 6 points.

[2] For the purpose of this paper, a confidence level of 5% has been set to assess significance of results. Further, all statements are based on the underlying preconditions "on average, ceteris paribus".

Socio-demographic and car use characteristics	N	%
Gender		
Men	271	55
Women	218	45
Age		
30 or younger	321	66
31 - 59	129	26
60 or older	39	8
Center of living		
Urban	360	74
Rural	129	26
Frequency of car use		
(Nearly) never	47	10
Occasionally	104	21
Frequently	152	31
(Nearly) every day	186	38
Level of automation in present car		
No car	140	29
(Nearly) no automation	76	16
Limited automation	229	47
Advanced automation	44	9

Fig. 1. Distribution of study participants by socio-demographic and car use characteristics.

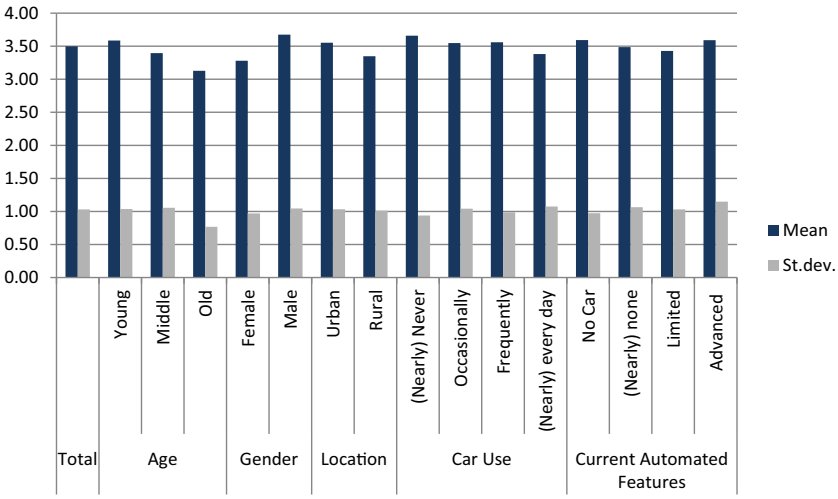

Fig. 2. Attitudes towards self-driving cars across sub-groups.

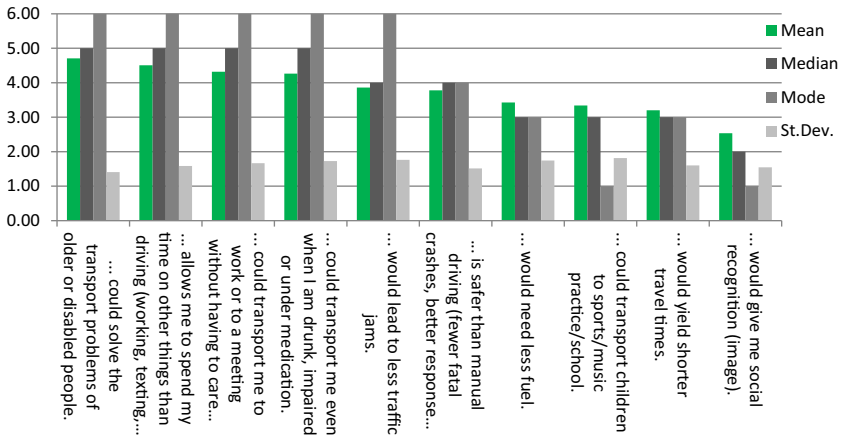

Fig. 3. Potential benefits of self-driving cars ranked according to participants' agreement.

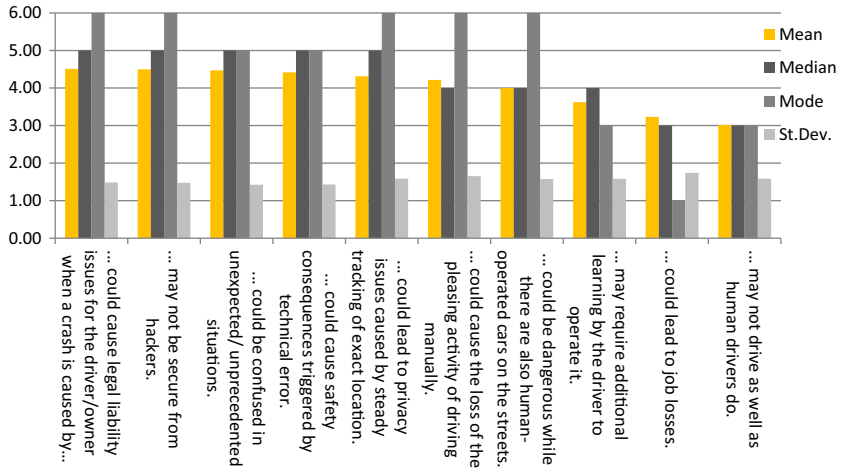

Fig. 4. Potential concerns about self-driving cars ranked according to participants' agreement.

In addition, a number of further concerns not included in the closed questions of the questionnaire were obtained and subsequently categorized. Most concerns were subsumed under 'Dependence on machines', followed by concerns relating to 'Missing infrastructure' and 'Ethical considerations'. A complete list of mentioned statements can be found in Appendix B.

3.4. Strategic implications

Of the ten presented strategic implications (Fig. 5), 'The driver should have the possibility to take over control whenever wanted.' was identified as the most effective option to increase trust towards self-driving cars (Mean = 5.20), whereby participants aged '60 or older' (Mean = 5.38, S.D. = 0.99) and female respondents (Mean = 5.47, S.D. = 1.03) showed the highest agreement. The second most valued action was to offer free test rides. While there was broad consensus among participants, those (nearly) never using a car valued free test rides the most (Mean = 5.23; '(Nearly) every day': Mean = 4.85; p 3.6%). Respondents across all sub-groups also indicated to wish for comprehensive information in the showroom, with drivers possessing cars with 'advanced automated features' showing a somewhat lower rate of agreement.

In contrast, the three options rated the least promising showed considerably lower means (and modes of 1 instead of 6 as for all other actions), which represented a clear cut in which actions were deemed to be effective. The majority of participants did not favor tax incentives to promote the sale of self-driving cars. Neither did they want self-driving cars to occupy special lanes nor did participants want to be actively involved in the development of driverless cars. Finally, participants were asked to provide additional actions they deemed to be effective to overcome their concerns towards self-driving cars. Comments ranged from 'Harmonizing legal systems across borders' to ideas on 'Pricing' and 'Design'; a complete list can be found in Appendix B.

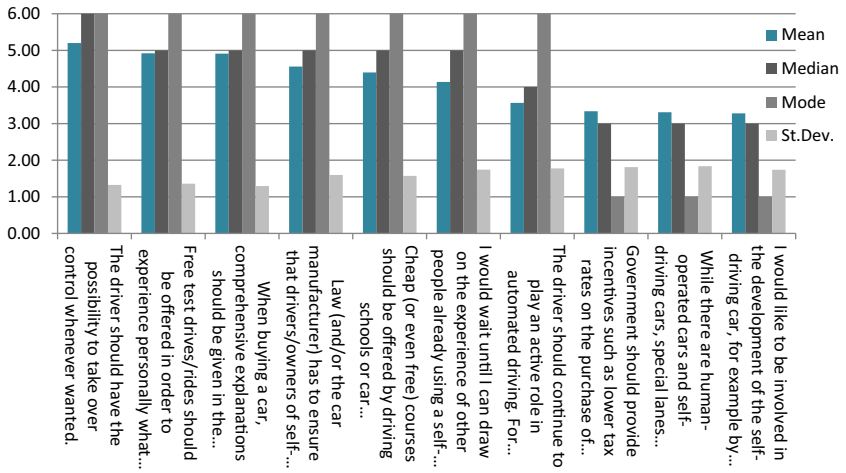

Fig. 5. Potentially promising strategic implications to overcome concerns towards self-driving cars ranked according to participants' agreement.

4. Discussion

While studies, news articles, and automotive companies frequently present self-driving cars as 'the future of mobility', this study found considerable concerns among car drivers towards this radical innovation. According to various studies, once a person has doubts about the safety or the benefits of a technology, the person tends to avoid using it (Reimer, 2014; Frey & Frank, 2001; Rudin-Brown & Parker, 2004). In this section, obtained results are thus not only discussed but also directly linked to actions that could overcome these identified concerns.

It stands out that only 2% of respondents indicated they felt 'very negative' about self-driving cars, which showed a considerably lower level of concern compared to the study by Kyriakidis et al. (2014). Part of this result might be attributable to the overrepresented young, university-educated and computer-savvy segment in the sample and a high share of people being interested in automated vehicles triggered by mentioning the topic of the study in the invitation letter. Notwithstanding, there were considerable differences between sub-groups with older respondents to be more worried about self-driving cars than younger respondents, females to have more concerns than males, and rural respondents to value self-driving cars less than urban participants. These findings are in line with studies by Giffi, Vitale, Drew, Gangula, and Schmith (2014) as well as Silberg et al. (2012), who also found males, younger persons and urban residents to have less mental barriers. The latter possibly results from urban residents being more regularly exposed to the negative externalities of cars such as congestion or a lack of parking spots, consequently being more open for promising alternatives (Mitchell, Borroni-Bird, & Burns, 2010). Surprisingly, people who used a car more often tended to be less open. While Calo (2015) expected regular commuters to derive the most benefits from self-driving cars given the amount of time they 'lose' while driving, the obtained finding could be the resulting fear of too radical a change in the regular car users' daily routine. The sub-group of regular drivers most likely consisted of a higher percentage of 'pleasure drivers' who valued the driving task itself more than possible benefits stemming from handing over control to technology. Correspondingly, and across all sub-groups, the most pronounced desire of respondents was to have the possibility to manually take over control of the driving task whenever wanted, which entails the necessity to keep the steering wheel. It is thus seen as crucial to include an overriding function in the initial versions of self-driving cars. Drivers should be enabled to decide on demand when to switch to self-driving mode. The possibility to *"drive the enjoyable drives which may add excitement and a sense of freedom*" (Rupp & King, 2010, p. 8) together with the option to resume control in situations when the driver does not trust the technology.

Regarding car use, both people without a car and those with a car having advanced automated features, showed a more positive attitude towards self-driving vehicles than respondents who owned a vehicle with none or limited automation. Interestingly, people currently not possessing a car thus might have viewed self-drive technology as an opportunity to again (or even for the first time) participate in car traffic, while people who had experienced well-functioning automated features in their present cars might have had a higher acceptance due to their higher level of trust in the technology. In contrast, people with limited or no automation in their current vehicles could have tended to be more wary given their unfamiliarity with advanced automation technology. Another interpretation being that the latter group may have a stronger connection to the act of driving itself. A similar result was obtained when assessing perceived safety benefits of self-driving cars. Infrequent drivers trusted the technology more than did regular drivers. Having less practice, they might have trusted the 'system' more than their own driving skills and thus felt safer with a self-driving car (the same was found to be true for elderly people, which might be attributed to cognitive shortcomings related to age). In addition, people already using advanced automated features attributed higher safety benefits to automation than people without such features in their cars.

Analyzing participants' concerns across driving frequencies categories yielded similar results. The most severe concern involving the car and the technology itself was the fear of possible attacks by hackers. The increased amount of technology led participants across all analyzed sub-sets to have concerns about system safety; the only segment with a comparatively lower concern being people already using advanced automated features. Further safety concerns, namely possible confusion of technology in unprecedented situations and the fear of technical errors, again yielded the result that people already using advanced automated features had less concerns regarding technical issues in general. This leads to the conclusion that prior experience with automated features could raise drivers' trust in automation. A step-by-step advancement of "driver assistance" systems together with a widespread inclusion of such features in today's cars could thus steadily grow peoples' trust in automation. One such feature that could already be included in cars today is the automated parking assistant that allows the car to look for an appropriate parking spot itself. This benefit of not having to find a parking spot anymore was highly valued by respondents (especially urban citizens) and might thus meet considerable demand.

There was a high awareness of self-driving cars among respondents, which was surprising given Schoettle and Sivak's finding in 2014 of up to 43% of respondents to be unfamiliar with self-driving cars. The substantial awareness increase in a period of one year most likely reflected the recent regular news coverage and the pace of the technology's development. Notwithstanding, the before mentioned invitation letter might have influenced the result as well. Nevertheless, also Schoettle & Sivak's sample consisted of an overrepresented segment with academic background (40% and above, depending on the country) and a large share of people below the age of 30 (up to 46%), increasing the comparability due to similar biases. Further, having chosen an online questionnaire also entailed the possibility to have reached an unproportional number of tech-savvy people. However, the level of knowledge was still found to be highly limited. It stood out that the more participants knew about self-driving cars, the more positive their attitude towards these vehicles tended to be. Thus, a lack of knowledge about the functioning of the product will most certainly lead to non-adoption (Frey & Frank, 2001). Consequently, educating people about the functions of the technology, about involved benefits for the driver, and also about existing limitations of the technology are identified to be paramount for a successful introduction of self-driving cars to the market. How people should be educated involves multiple channels. It has been found that people would highly value information given to them in the showroom. In addition, free courses hosted by car developers or institutions such as driving schools would most likely be accepted, while the latter channel appeared to be especially promising for convincing women and older people of the benefits of the new technology.

Despite the finding that participants were predominantly fascinated with the idea of a driverless car and would also be willing to ride in such a vehicle, 30% of respondents were not willing to spend anything extra when buying such a car. This result was in accordance with Schoettle and Sivak (2014) who even found a majority of respondents to be unwilling to invest additional money on top of their current budget for cars. Together with the finding that people do not perceive self-driving cars to be a status symbol (Böhm et al. (2006) note that handing over control to a machine was widely viewed as non-independent and even weak), this leads to the conclusion that while there could be a small market niche for luxurious fully self-driving cars (3.5% of respondents indicated they would pay €30,000 extra or more), the majority of the public seems not yet ready to buy self-driving cars. However, this could be changed by offering free test-drives to enable people to experience first-hand what riding a self-driving car is like. Given presented findings, offering people to participate in such test-drives would most likely be met with excitement. Similarly, participants' identified openness towards car-sharing schemes could be leveraged by equipping a fleet with features that offer the possibility for the driver to engage in automated driving. This way, people would not have to invest a large sum of money to buy a self-driving car right away but could gradually build up trust by using these shared self-driving cars first.

Finally, it was found that people did have additional concerns that were not analyzed in literature to date. The most pronounced of which was the general rejection of increasing reliance on machines. Some respondents viewed handing over control to machines as both a frightening as well as a generally rejectable action involving *"the surrender of individual human choice and independence*". On a less extreme note, however, these concerns raised additional questions, especially for legislation. Should people be obliged to have driver licenses when operating a self-driving car? How should novice drivers be trained given the only time they might take over the driving task is in emergency situations? This might lead to a "learned incompetence" (Douma & Palodichuk, 2012). Consequently, should it be decided that indeed people need a driving license, it might not be possible to materialize one of the major potential benefits of self-driving cars, namely the possibility to solve the mobility problems of the elderly or people with disabilities (or children).

To sum up the proposed actions to overcome peoples' concerns by making use of the Rogers' criteria (Rogers, 1995), the higher the relative advantage (benefits have to be accurately perceived, which could be ensured by educating people), the higher the compatibility (including a steering wheel together with a disengage button), the higher the trialability (offered test-drives), the higher the observability (early adopters and car-sharing fleets), and the lower the complexity (stepwise introduction of features of increased automation), the higher the probability of wide-spread adoption of the innovation.

4.1. Limitations

Despite every effort to obtain reliable results, certain limitations of this study have to be noted. Most importantly, the study had an explorative character gathering first evidence in a presently largely undeveloped field rather than claiming to draw final conclusions. Thus, one has to be aware of potential bias resulting from the used convenience sample. The group of respondents was made up predominantly by Austrians and people below the age of 30. Having identified young people to

be, on average, more open towards self-driving cars than their older counterparts, the arithmetic means of openness could tend to be higher, whereas levels of concern could tend to be lower, than if studying the actual entire population. In addition, university-educated, computer literate, and potentially even people having been interested in self-driving cars prior to the study were overrepresented, resulting in further increased means of openness. Independent of the chosen method, while assessing attitudes and trust, an incomplete understanding of influencing factors may have been obtained as people regularly do not understand why they experience a certain level of trust (Merritt et al., 2012). Using a self-administered online questionnaire implied potential bias on its own. Despite every effort to minimize this risk, participants might have misunderstood certain statements. It can neither be judged how much thought participants put into their answers while the researchers' expectations which questions are deemed to be important to include could also result in missing information. Notwithstanding, this risk was minimized by including open questions allowing participants to state additional remarks concerning the topic.

We want to emphasize that the icons provided in the survey using the platform *typeform.com* are not ideal. Even supposing that the "thumbs-up" gesture and the "lightning bolt" as well as the "neutrality" sign are universally understood, their representations could still be subliminally leading the respondents to assumptions that could be avoided entirely by omitting them. In retrospect, we realize that this is not optimal, hence we strongly recommend to make the survey design completely neutral and symmetric in future uses of those questions.

Finally, as this study tackled a topic that will materialize in the future, people are judging their potential future decisions (e.g. whether to buy a self-driving car and how much to invest) based on their current knowledge and experience. Thus, there could be a chance that certain reasons for resistance identified could change over time and might thus need an update once the first self-driving cars are actually ready for the market.

4.2. Conclusion

First evidence derived from obtained results points to the conclusion that the hypothesized psychological barrier of car drivers towards self-driving cars does indeed exist. People were found to be reluctant to hand over control over their cars to technology, the most distinct objections stemming from safety concerns caused by the fear of potential attacks by hackers and system malfunction. It stands out that considerable differences with regards to the magnitude of respondents' concerns have been identified across sub-groups with young people, men, urban citizens, and people already driving cars with advanced automated features showing the highest openness towards self-driving cars.

Epprecht et al. (2014, p. 38) note that "as long as user mindsets are focused on contemporary transportation modes, the introduction of new innovative transportation seems to be a Herculean task." This study thus additionally investigated which actions companies developing self-driving cars could engage into overcome these present barriers. While a number of promising strategic implications have been derived, spinning off already developed self-driving features by gradually implementing them in manually-operated cars on a large scale is seen as the most promising opportunity to both increase safety in car transportation already today and to accustom drivers to self-drive technology, thereby increasing the probability of successful market introduction of self-driving cars tomorrow.

Appendices A and B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.trf.2016.10.013.

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