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How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups

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ABSTRACT

Current research on willingness to use automated cars indicates differences between men and women, with the latter group showing lower usage intentions. This study aims at providing a first explanation of this effect. Research from other fields suggests that affective reactions might be able to explain behavioral intentions and responses towards technology, and that these affects vary depending on age levels. By examining a sample of 1603 participants representative for Germany (in terms of biological sex, age, and education) we found evidence that affective responses towards automotive cars (i.e., anxiety and pleasure) explain (i.e., mediate) the effect of biological sex on willingness to use them. Moreover, we found that these emotional processes vary as a function of respondent age in such a way that the differential effect of sex on anxiety (but not on pleasure) was more pronounced among relatively young respondents and decreased with participants' age. Our results suggest that addressing anxiety-related responses towards automated cars (e.g., by providing safety-related information) and accentuating especially the pleasurable effects of automated cars (e.g., via advertising) reduce differences between men and women. Addressing the anxiety-related effects in order to reduce sex differences in usage intentions seems to be less relevant for older target groups, whereas promoting the pleasurable responses is equally important across age groups.

1. Introduction and motivation

It is expected that the introduction of automated cars will have profound effects on society and environment. Until today, it is unclear whether society will rather benefit or suffer from them. Although it is argued that 93% of vehicle accidents are human performance errors, which can be reduced by implementing assisting technology (U.S. Department of Transportation, 2008) it raises the question, whether assisting technologies should decide about life or death in critical situations, such as: saving a pedestrians by sacrificing the driver? (Bonnefon et al., 2016). This dilemma might increase the conflicts of law between producers of the technology and society. Moreover, it is argued that autonomous cabs can reduce travel costs, because they need no driver (Burns et al., 2013), which could help people or cities with lower financial funds. However,

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on the other side, autonomous cabs, buses or trucks might also cause a shift in the labor force because human drivers could get obsolete in the distant future. Automated cars might also contribute to the mobility of older drivers by assisting especially elderly people or people with disabilities to enhance their individual mobility and thus their participation in society (Fagnant and Kockelman, 2015). However, this in turn can also lead to an increase in traffic density due to higher usage rates.

Furthermore, it is expected that autonomous cabs reduce greenhouse gas emissions, which contributes to a better CO_2 mobility performance in comparison to traditional cars (Greenblatt and Saxena, 2015). However, if autonomous cabs are driving around all the day without any break it is likely that there is an increase in energy consumption, whose amount cannot be estimated yet (Wadud et al., 2016).

In sum, automated cars can help to improve current societal and environmental mobility problems such as high levels of CO_2 emissions, accidents, and travel costs. However, the implementation of automated cars is likely to have adverse side effects such as the loss of workplaces and higher traffic density. Given the tremendous efforts to put people away from cars to other means of transport such as trains or bicycles, which compared to automated cars can be more eco-friendly and sometimes healthier for the individual, one might argue that it seems contradictory to promote new technological concepts, which might tempt people to intensify car usage. To clarify, our claim is not to argue that implementing automated cars is the panacea in transportation. Rather we argue that it might be superior to traditional cars, and hence should be supported compared to using conventional cars. Implementing automated cars should not reduce societal and political approaches to promote cycling, walking or using public transport.

To facilitate the implementation of automated cars, it is necessary to reach early public acceptance among early adopters, which, can be understood as people who are the most likely early buyers of a new technology (Bansal et al., 2016; Plötz et al., 2014). However, research on automated cars has already indicated that population subgroups of society systematically differ in their willingness to use automated cars. The two dominant biological sexes show consistent differences in terms of their willingness to use automated cars. Men usually report higher tendencies to use automated cars. Addressing this difference and trying to explain it might help to foster the implementation of automated cars within society.

We argue that one approach to explain gender differences in terms of willingness to use automated cars is to examine people's affective reactions towards these cars. For example, findings from research on electric vehicles has shown that affective reactions influence the intention to use them (Moons and De Pelsmacker, 2012). Interestingly, correlational results by Kyriakidis et al. (2015) indicate that women in comparison to men associate higher levels of worry regarding automated cars. These differences in affective responses have, so far, never been used to explain attitudinal differences between the two dominant sexes in terms of automated cars. We argue that using this approach might help to explain (and consequently: to overcome) these sex differences.

While examining the role of affective responses in order to explain differences between the two biological sexes, we extend our analysis by also taking into account another important demographic variable, which has been shown to also influence people's automated car adoption intention: the chronological age of the evaluating person. As research on information technology, which is highly prevalent in autonomous cars, has shown, older women tend to be more anxious towards them than younger women (Czaja et al., 2006).

To sum up, previous research has found sex differences in the willingness to use automated cars, but did not provide any examination of variables potentially explaining this difference. However, examining the variables underlying this sex difference is a necessary step in order to address and mitigate this difference, which seems reasonable in order to promote societal acceptance of automated cars. Our research is the first to examine explanatory variables which might account for differences between sexes in their intention to use automated cars. We argue that affective responses towards automated cars might serve as variables explaining the sex difference regarding the use of automated cars.

Furthermore, when examining affective responses as explaining variables we take positive as well as negative affective responses into account at the same time. This approach provides first answers of the questions whether both affective valences, positive as well as negative, are simultaneously operative and if so to what extent. Should interventions be based on both, fostering pleasure and reducing anxiety towards automated vehicles? Our research will provide a first answer of the relative importance of accentuating positive aspects or mitigating negative connotations of automated cars.

Finally, previous research has not yet looked at the role of chronological age as a variable influencing these effects. Addressing age seems particularly important when examining people's affective reactions towards automated cars. Existing research has started to examine the direct effects of age in intentions to use automated cars, but failed to address whether this variable influences the effects of other variables (in this case: biological sex) on intentions to use automated cars. Therefore, we examine the potentially moderating effects of age on the effects of biological sex. By doing so, our findings will provide some first answers on how interventions might be adapted to different age groups. Do emotions become less relevant as explanatory variables as age increases? If so, target-group specific interventions should be adapted accordingly.

2. Background and existing literature

This section summarizes current empirical evidence in public opinion surveys about the adoption of automated cars, which have found connections between biological sex and the willingness to use them. Furthermore, this section includes studies, which have considered affective reactions towards automated cars.

First evidence about sex differences were mentioned by a study of Ernst and Young (2013), which conducted a survey of 1000 respondents in Germany. They provided descriptive results, which begin to show that men could easier imagine to use

automated cars then women. A study from Schoettle and Sivak (2014), which examined the acceptance towards automated cars in the U.S. ($N = 501$), U.K. ($N = 527$), and Australia ($N = 505$) found correlative support that men compared to women could easier imagine to automated cars. Subsequently, Payre et al. (2014) examined the willingness to use automated cars among an unrepresentative French sample ($N = 421$) and found predictive evidence that men in comparison to women were more likely to use them. Recently, findings from Kyriakidis et al. (2015) and Bansal et al. (2016), which have focused on other behavioral aspects, i.e., the willingness to pay, found that men compared to women, were willing to pay more for automated cars. In sum, research on automated cars has shown that biological sexes quite systematically differ in their willingness to use them. Note that these findings did not provide any empirical examination of the reasons underlying this difference between the two sexes.

Interestingly, further differences between biological sexes towards automated cars were found regarding their affective reactions. For example, the results by Kyriakidis et al. (2015) indicate that women tend to worry more about issues related to automated cars than men. Such findings raise the question whether differences in the experience of affective reactions between sexes might explain differences in their willingness to use automated cars, which so far, was not examined in existing research.

When focusing on the role of demographics on adoption intentions towards automated cars another variable beside biological sex was found to be important: chronological age. For example, Payre et al. (2014) found that as age increases the intention to use automated cars decreases. The same difference was observed by Schoettle and Sivak (2014) who found that younger people in comparison to older people were more interested using self-driving technology. Further support for age differences in the behavior towards automated cars were found by Kyriakidis et al. (2015) and Bansal et al. (2016), who showed that younger people in comparison to older people are willing to pay more for them. These direct effects of chronological age on the willingness to adopt automated cars indicate that chronological age might be an important variable when examining behavioral tendencies towards them. Previous research on automated cars did not address age as a variable influencing the effects of other variables on attitudes towards automated cars.

To sum up, current research has indicated sex differences in the willingness to adopt automated cars, but did not provide any explanation for this difference. Therefore, we introduce variables which might be able to explain this difference. Research has found sex differences regarding affective reactions towards automated cars but not examined their potential role as explanatory variable for the effect of sex on the willingness to use. We address this gap by examining the potential relevance of affective responses as variables explaining differences in biological sex. Additionally, it remains unclear whether the influence of positive, negative or both affective reactions explain the sex difference towards the willingness to use automated cars and if so to what extent. Does the sex difference towards automated cars exist because men are more positively stimulated by them than women or do women feel more anxious about them? To address this unanswered question we simultaneously introducing positive and negative affective responses towards automated cars as mediators. Furthermore, current research has not considered the role of chronological age when examining the effect of biological sex on affective reactions. Thus, we, for the first time, examine if sex differences on the willingness to use automated cars through affective reactions might vary with participants' age.

The research model in Fig. 1 describes our assumption that sexes differ in their willingness to use automated cars (H1). Furthermore, it describes the extension of existing research by arguing that biological sexes differ in their emotional experience towards automated cars (H2a, H2b), which causes the difference in their willingness to use them (H3a, H3b). Hereby, we differentiate between positive and negative affective responses. Moreover, it includes our assumption that sex differences due to affective reactions towards the willingness to use automated cars depend on participants' age (H4).

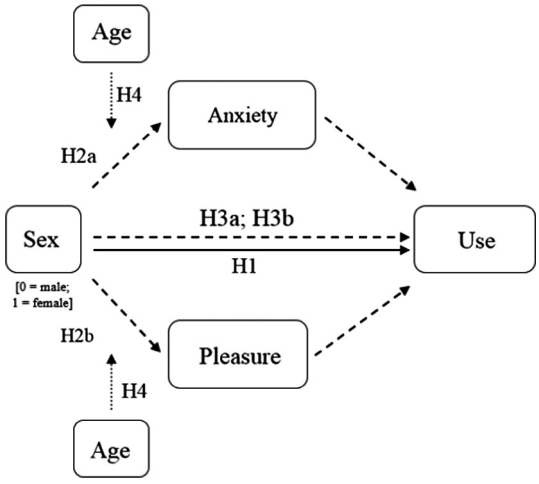

Fig. 1. The conceptual moderated mediation model. *Note*. Dashed lines indicate our extension of current findings between biological sex differences towards the willingness to use automated cars.

3. Method

3.1. Procedure

An online questionnaire was distributed between February and November 2014 through social media channels and two different survey providers in Germany. Using a web-based method to gather public opinions, has been found to be a reliable tool in social research for quantitative research (Weigold et al., 2013). In general, Internet samples are relatively diverse with respect to socioeconomic status or demographics (Gosling et al., 2004). Given our balanced sample in terms of age, sex, and education we aimed to reduce potential biases of Internet samples such as lower rates of Internet access from people with lower education.

Participants were informed that the aim of the questionnaire is to figure out how people assess and evaluate future technologies. The questionnaire consisted of several parts; the analyses in this report are limited to the first two sections of the survey. In the first part participants had to answer questions regarding their demographics as well as psychographics. In the second part, participants read three vignettes in a row for different levels of automated cars (i.e., partially-automated, highly-automated, fully-automated; see Appendix B). Each vignette described the primary functions of each level of automation derived from the definitions by the American national highway traffic safety administration (level 2–4) (NHTSA, 2013) and the German federal highway research (level 3–5) (BASt, 2012). Thereby, the level of automation describes the technical ability of the technology in accordance to its maturity. For example, NHTSA (2013) classifies the automated car level 2 as a level, where two primary control functions, such as steering and accelerating are controlled by the car. The same institution characterizes an automated car level 3 by the same means, where the driver additionally only needs to be available for occasional interventions. The final level 4 automation definition from the NHTSA (2013) describes a vehicle, where the driver no longer has to be available for interventions anymore. Rather the only input the vehicle needed is the final destination.

Thus, each vignette exemplified the objective levels of automation based on the currently accepted definitions. After each vignette, participants had to indicate their emotions as well as their willingness to use (different levels) of automated cars.

3.2. Sample

A sample of 1603 people (51.3% females) with an average age of $M = 48.51$ years ($SD = 15.64$) took part in our study. Most people had a lower (i.e., less than 10th grade, primary school; 39.3%), followed by an intermediate (i.e., till 10th grade, secondary school I; 31.7%), and higher (i.e., above 10th grade, secondary school II; 29%) educational degree. Approximately 59% of the participants were employed. A total of 86.5% were in possession of a driver license and 73.9% were in possession of a car. To achieve a German representative sample in terms of age, sex, and education we calculated corresponding cell sizes by analyzing data from the German Federal Statistical Office (FSO, 2012) (see Appendix C) and provided the resulting cell size requirements to the data collectors in order to achieve representativeness. The corresponding cell sizes are calculated based on a combination of six different age classes, paired with the number of biological sexes within this age class and their educational background in the German population. As the data providers over-delivered the number of respondents for each cell, which led to a bias in the representativeness of our sample, we had to randomly remove 303 cases prior to analyses in order to avoid skewed cell sizes of specific population subgroups that would not be in line with the general population.

3.3. Analytical procedures

Data analyses were performed by using the PROCESS macro by Hayes (2012) for SPSS. The macro uses regression-based analyses and is able to combine continuous independent and mediator variables with a dichotomous dependent variable. For continuous variables, PROCESS estimates outcomes by ordinary least square (OLS) estimation, while for binary variables PROCESS estimates outcomes by logistic regression estimation. Hence, the effect of sex on emotional appraisal (i.e., a-path) as well as the effect of age on the association between sex and emotional appraisal (i.e., moderation) were examined by OLS. The effect of sex on usage (i.e., c-path) as well as the effect of emotional appraisal on willingness to use (i.e., b-path) were conducted by logistic regression estimation.

Furthermore, in all our analyses we included vignette dummies, and source of data dummies as covariates to control for their confounding influence. In our model, the willingness to use served as the dependent variable, whereas biological sex served as the independent variable. The affective reactions were entered as the potential mediators. To examine the function of people's age and sex on the experience of emotion, age was included as a moderator between sex and anxiety as well as pleasure.

3.4. Measures

Anxiety towards (different levels of) automated cars is operationalized analog to Venkatesh (2000), where anxiety can be seen as an "individual's apprehension, or even fear, when she/he is faced with the possibility of using" (p. 349) a technology such as automated cars. To distinguish between positive and negative emotions, each affective response was measured by a single-item question on a 7 point Likert scale. To indicate the anticipated pleasure towards (different levels of) automated cars, participants were asked: 'How much pleasure would driving such a car provide for you?' Prospected levels of anxiety

were captured by asking participants: 'How frightening would such a car be for you?' Pleasure labels were anchored with '0 = almost no pleasure' and '6 = very much pleasure', while for anxiety the anchors were '0 = not scary at all' and '6 = very scary'. Subsequently, the behavioral intention towards (different levels of) automated cars was acquired by asking: "Were you willing to use such a car today?" Participants could then indicate their willingness on a binary scale (i.e., '0 = no' vs. 1 = 'yes'). Sex was indicated by checking a box were '0 = male' vs. '1 = female'.

4. Results

Our results obtained were calculated in a single model (see Fig. 3 for final results). The findings presented in the result section were presented separately to facilitate readability and confirmability. Correlations between our variables used can be found in Table 1.

4.1. Main effects

To test hypotheses H1–H2b we used a regression-based approach where sex was entered as the predictor variable and willingness to use served as criterion. Age, education, vignette dummies, and source of data dummies were included as covariates. As expected, the results showed that it is more likely that automated cars will be used by men (B = −0.45, OR = 0.64, $p < 0.001$, 95% CI: −0.57 to −0.34), which confirms hypothesis H1. Additionally, higher levels of anxiety were more likely for females ($\beta = 0.23$, $p < 0.001$, 95% CI: 0.17–0.28), whereas higher levels of pleasure were more likely for men ($\beta = -0.17$, $p < 0.001$, 95% CI: −0.23 to −0.11), which supported our Hypotheses H2a and H2b. Moreover, as age increases, people showed lower levels of pleasure ($\beta = -0.05$, $p < 0.001$, 95% CI: −0.09 to −0.02) but not anxiety ($\beta = -0.01$, $p = 0.73$, 95% CI: −0.04 to 0.03).

4.2. Multiple mediation analysis

To examine whether anxiety and pleasure mediate the influence of sex on willingness to use (i.e., hypotheses H3a and H3b), we performed a regression-based mediation analysis based on the PROCESS macro for SPSS (model 4; 5000 bootstrap samples) by Hayes (2012). The model 4 in the PROCESS syntax is able to calculate a regression-based mediation analysis, with one dependent as well as independent variable, covariates, and multiple mediators simultaneously. A detailed formula can be found in Hayes (Hayes, 2013, p. 127). In our analysis sex served as the predictor and willingness to use as the criterion (age, education, vignette and source of data dummies were again included in the model as covariates in order to control for their influence). Pleasure and anxiety served as the putative mediating variables. The original effect of sex on willingness to use (c path, B = −0.45, OR = 0.64, $p < 0.001$, 95% CI: −0.57 to −0.34) was reduced (but still significant) when anxiety and pleasure were entered into the model (c' path, B = −0.29, OR = 0.74, $p < 0.001$, 95% CI: −0.45 to −0.13) indicating a mediating effect of pleasure and anxiety. Confirming our Hypotheses H3a and H3b, anxiety and pleasure were able to partially explain the effect of sex on willingness to use (point estimate of indirect effect of anxiety: −0.16, 95% CI: −0.20 to −0.12; and pleasure −0.33, 95% CI: −0.43 to −0.21). When comparing the indirect effects of sex on willingness to use through anxiety and pleasure, we observed that the specific indirect effect through pleasure is larger than the specific indirect effect through anxiety (point estimate = 0.17, OR = 1.19, 95% CI: 0.06–0.27).

4.3. Moderation analysis

To test the moderating effects of age on the association between sex and the appraisal (i.e., Hypothesis H4) of emotions we evaluated the PROCESS output (model 1; 5000 bootstrap samples) by Hayes (2012) in order to assess whether the effects of sex on anxiety and pleasure varied as a function of age. The model 1 in the PROCESS syntax is able to calculate a regression-based moderation analysis by automatically creating a product term out of the dependent and the moderator variable. A detailed formula can be found in Hayes (2013, p. 214). In our analysis sex served as the predictor while anxiety and pleasure served alternately as the criterion (sex, education, source of data, and vignette dummies were again included in the model as covariates in order to control for their influence). Age was entered as the moderating variable. Results partly confirmed our hypotheses: We observed a significant moderation effect for the interaction term of sex and age on anxiety ($\beta = -0.08$, $p < 0.01$ (95% CI: −0.14 to −0.02), but not for the effect of the interaction term of sex and age on pleasure ($\beta = 0.05$, $p = 0.09$, 95% CI: −0.01 to 0.11). As recommended by Aiken and West (1991), follow-up analyses examined the strength of sex at low levels of age (i.e., 1 SD below the mean), moderate levels of age (i.e., at the mean of age), and at high levels of age (i.e., 1 SD above the mean) on anxiety. Interestingly, age influenced the effect of sex on anxiety perceptions for low ($\beta = 0.30$, $p < 0.001$, 95% CI: 0.23–0.38), moderate ($\beta = 0.22$, $p < 0.001$, 95% CI: 0.17–0.28), and high levels (1 SD above the mean) ($\beta = 0.15$, $p < 0.01$, 95% CI: 0.06–0.23) of age and therefore partially supported our hypothesis H4. Fig. 2 shows the details of the interaction, indicating that sex differences in the perception of automated cars are more pronounced between young men (vs. young women) but decline as age increases. The smallest difference in the evaluation of anxiety between sexes was found between old men (vs. old women).

Table 1
Means, standard deviations, skewness, kurtosis, and correlations among variables.

	M	*SD*	*SK*	*KU*	Range	(1)	(2)	(3)	(4)	(5)
(1) Age	48.51	15.63	−0.18	−1.00	15–87	(–)	0.02	0.00	−0.05**	0.06**
(2) Sex	1.51	0.50	−0.05	−1.99		0.02	(–)	0.12**	−0.09**	0.12**
(3) Anxiety	3.89	2.04	0.04	−1.26	1–7	0.00	0.12**	(–)	−0.31**	0.35**
(4) Pleasure	3.56	2.09	0.20	−1.29	1–7	−0.06**	−0.09**	−0.31**	(–)	0.67**
(5) Willingness to Use	1.48	0.50	0.07	−1.99	1–2	−0.07**	−0.12**	−0.35**	0.67**	(–)

Note. ** $p < .01$, *M* = Mean, *SD* = Standard Deviation; *SK* = Skewness, *KU* = Kurtosis, code for sex 1 = male, 2 = female, *N* = 1603. Since most skewness and kurtosis values are within the range of −1.00 and +1.00 suggested by Muthén and Kaplan (1985) parametric analyses seem justified. Pearson correlation above main diagonal and Spearman correlation below main diagonal.

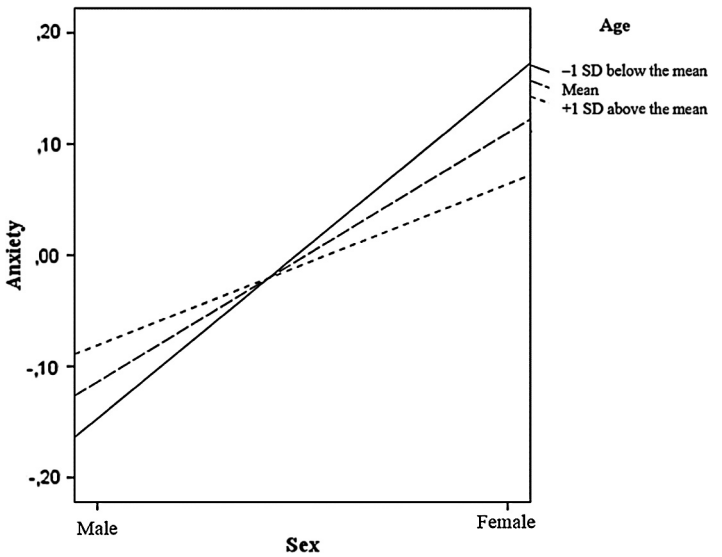

Fig. 2. Illustrating the moderation of sex on anxiety with different levels of age. *Note*. Standardized values were used for analysis.

4.4. Exploratory analyses: moderated mediation

Our simple mediation analysis provided evidence of a negative indirect effect of sex on willingness to use through anxiety as well as a positive indirect effect of sex on willingness to use through pleasure. Moreover the moderation analysis indicates that the effect of sex on emotional appraisal (i.e., anxiety) depends on the evaluators' age. Combining these with the findings, it seems obvious that the indirect effect of sex on willingness to use through anxiety depends on levels of age. To test for a moderated mediation (i.e., Hypothesis H5) we, again, used PROCESS (model 7; 5000 bootstrap samples). This model combines the aforementioned models (i.e., model 4, model 1) into a single model. The model 7 in the PROCESS syntax is able to calculate a moderated mediation analysis. A detailed formula can be found in Hayes (2013, p. 338). In our analysis, sex was entered as the predictor and willingness to use as the criterion. Age served as the moderator variable, while anxiety and pleasure served as mediating variables. Again, education, vignette dummies, and source of data dummies were included as covariates. And indeed, the index test of moderated mediation, which is "a test of linear moderated mediation in path analysis based on an interval estimate of the parameter of a function linking the indirect effect to values of a moderator" (Hayes, 2015, p. 1), did not include zero and hence indicated a significant effect of sex on willingness to use through anxiety for different levels of age (95% CI: 0.02–0.09). The point estimates and confidence intervals can be found in Table 2. As indicated, the indirect effect of sex on willingness to use through anxiety was negative for people with relatively low (i.e., −1 SD mean; −0.21, 95% CI: −0.27 to −0.15) moderate (i.e., mean; −0.16, 95% CI: −0.20 to −0.11) and high levels of age (i.e., +1 SD mean; −0.10, 95% CI: −0.16 to −0.04). Thus, the indirect effect via anxiety decreased as respondent age increased, which supported our Hypothesis H5.

Fig. 3 shows the final results of our model. As reported women were more likely to associate anxiety and not pleasure with automated cars, whereas the effect was reverse for men. Additionally, the model shows that higher levels of anxiety lead to lower, whereas higher levels of pleasure lead to a higher willingness to use automated cars. Moreover, it shows that the difference in the association of emotions towards automated cars, partially accounts for the observed sex difference in the willingness to use automated cars. Moreover, the model shows that respondents' age was able to moderate the mediation effect of anxiety but not pleasure between sex and the willingness to use automated cars (see Table 3).

Table 2
Conditional indirect effect of sex on willingness to use through anxiety at values of age.

	Age	Anxiety	
		Point estimate	95% Bias-corrected bootstrap confidence interval
Low	−1.00	−0.21	−0.27 to −0.15
Moderate	0.00	−0.16	−0.20 to −0.12
High	+1.00	−0.10	−0.16 to −0.05

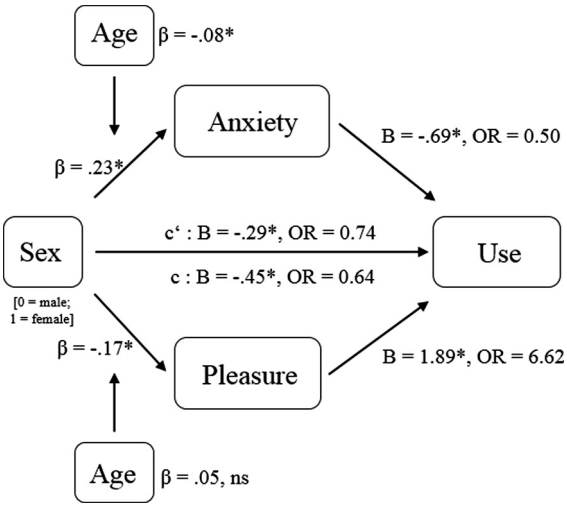

Fig. 3. Final result of the moderated mediation model. *Note.* * $p < 0.05$; β = standardized regression coefficient; B = maximum-likelihood based logistic regression coefficients; OR = Odds Ratio; c = effect of sex on the willingness to use without controlling for anxiety and pleasure; c′ = effect of sex on the willingness to use when controlling for anxiety and pleasure.

Table 3
Status of postulated hypotheses.

Hypotheses	Status
H1: Men in comparison to women will show a higher level of willingness to use automated cars	✓
H2a: Men are more likely to associate positive emotions towards automated cars than women	✓
H2b: Women are more likely to associate negative emotions towards automated cars than men	✓
H3a: The effect of gender on the willingness to use automated cars is mediated through positive emotions	✓
H3b: The effect of gender on the willingness to use automated cars is mediated through negative emotions	✓
H4: With increasing age, men compared to women, exhibit lower levels of emotional intensity towards automated cars	✓ (partially: only for anxiety)
H5: The indirect effect of gender on willingness to use trough emotions is greater for low levels of chronological age	✓ (partially: only for anxiety)

5. Discussion

In this section, we present our overall findings and discuss to what extent they provide an answer why biological sexes differ in their willingness to use automated cars and how they do. We start by answering the question why biological sexes differ in their willingness to use automated cars. With our multiple mediation analysis we show that the difference between sexes towards the willingness to use automated cars could be partially explained by the affective reaction towards them. Thus, we were for the first time able to show, why biological sexes differ in their willingness to use automated cars: The reason for this difference lies in both, positive as well as negative affective responses towards automated cars. In particular we found that here was a higher likelihood that men anticipate pleasure and not anxiety, which in turn was for both sexes associated with a higher willingness to use automated cars. Conversely, it was more likely that women anticipate anxiety and not pleasure, which in turn was associated for both sexes with a lower willingness to use automated cars. Thus, the biological sex difference on the willingness to use automated cars occurs, because women do not just feel less pleasure towards automated cars, they additionally feel more anxious towards them. Conversely, men do not just feel more pleasure towards automated cars, they additionally feel less anxious towards them. These results obtained extend existing research on

automated cars and might be transferred to explain sex differences in various areas of technology. Thus, our research might contribute to go beyond mere automated car research.

Additionally, by employing a moderated mediation we provided first evidence on whether the indirect effect of sex on willingness to use automated cars through anxiety and pleasure varies with levels of chronological age (for a similar approach see: Bekk et al. (2016)). This provides an answer to the question how biological sexes differ in their willingness to use automated cars. Thereby, the indirect effect of sex on willingness to use automated cars through pleasure, did not vary with participants' age, indicating that pleasure seems equally important for all age groups. However, the indirect effect of sex and willingness to use through anxiety did vary for different levels of age. Thus, the negative effect of anxiety on willingness to use depends on levels of the moderator. With increasing levels of chronological age, the effect of sex on willingness to use through anxiety was reduced due to a decreased magnitude in the difference of anxiety perceptions between sexes. Thereby, the indirect effect of sex on willingness to use through anxiety was strongest for young women and old men, slightly decreased for middle-aged men and women, and was least strong for young men and old women. These effects answered the question whether the effect of sex on affective reactions towards automated cars varies as a function of the chronological age of a person.

Noteworthy, the pattern regarding the differences of sexes on the perception of anxiety dependent on chronological age was somehow contrary to our expectations. We assumed that sex differences on the perception of anxiety are more pronounced between elderly men and women rather than between young men and women. This finding may be due the fact that life experience rather than natural aging processes determinates the appraisal of negative effect (Thomsen et al., 2005). Because men are more frequently involved in traumatic traffic events during their lifetime, such as the severity and frequency of accidents, than women (Al-Balbissi, 2003), their experience of negative emotions is solely higher. This experience could manifest itself in the late adulthood and be influenced by higher safety concerns of elderly towards technology in general (Mitzner et al., 2010).

6. Conclusion

6.1. Research contributions

Our study extends the current state of research by providing three contributions which, so far have not been addressed, but help to explain existing findings:

- We differentiate between the explanatory variance of positive and negative affect when controlling for each other on the willingness to use automated cars.
- We show that affective reactions can explain sex differences in the willingness to use automated cars: the two biological sexes in terms of positive as well as negative affects and these affects, in turn, explain willingness to use automated cars.
- We provide evidence that the effect of sex on affective reactions towards automated cars varies as a function of the chronological age of a person.

6.2. Implications for practice and policy

Our study provided insights for the question why biological sexes differ in their willingness to use automated cars. In particular, we found that especially emotions have different importance for each sex when thinking about the willingness to use automated cars. Albeit, men are more likely to adopt automated cars in general, their willingness to do so is primarily enhanced by highlighting positive emotions, which in turn should be fostered by simultaneously avoiding to elicit feelings of anxiety. With regard to women, their willingness to use automated cars can be enhanced by reducing negative emotions and in the same way by stimulating positive emotions. Thus, policy or marketing campaigns should be tailored to successfully reduce sex differences in the intention to use automated cars, which in turn can increase the number of adopters. To foster positive emotions in men, policy or automaker campaigns should target them by activating status motives when promoting automated cars (Steg, 2005). For example, they can advertise with slogans like: "Be the first adopter". To evoke positive emotions in women, policy campaigns could highlight that automated cars provide comfort in terms of protection, such as feeling safe, due to the fact that for women, feelings of security when using means of transportation seem more important than for men (Gardner and Abraham, 2007). To reach a broad mass, policy campaigns should try to induce these different emotional images about automated cars through communication channels like TV, newspaper, and internet. This would be a more convenient approach, due to the fact that evoking emotions only requires minimal stimulus material, like pictures, and emotions are inducible (Murphy and Zajonc, 1993).

Further measures to avoid feelings of anxiety for both sexes could be the implementation of emergency buttons, which allow the disruption of the automation mode. Policymakers could, additionally, think about promoting end-user trainings especially tailored for women. It was found that this measure enhances self-efficacy beliefs, which in turn reduce feelings of anxiety (Bandura, 1988; Venkatesh, 2000). Moreover, given the moderating effect of age on the effect of sex on willingness to use through anxiety, which leads to a more pronounced sex difference between young men and women, programs such as end-user trainings should especially target young women.

6.3. Implications for theory

In terms of theory, authors who focused on the acceptance of technology and have considered emotions as potential drivers of adoption (e.g., Venkatesh, 2000) should consider moderation effects of chronological age on the association between sex and emotional appraisal. Frequently used theoretical models like the technological acceptance model (Davis, 1989) or the unified theory of acceptance and use of technology (Venkatesh et al., 2003) could add incremental predictive validity to their models by considering both valences of emotions, positive and negative (see also Welpe et al. (2012)), and the interplay between age and sex towards the effects of these emotions.

Moreover, we provide evidence that negative emotions do not necessarily have the same impact on behavioral consequences for sexes at all levels of age. Instead, albeit their negative valence, the appraisal of emotions varies with sex depending on respondents' chronological age. Given the mixed results of sex differences towards technology as age increases, it seems mandatory to extend previous findings on the acceptance of technology to figure out if the negative effect of other discrete emotions such as anger or fear are influenced by participants' age.

Additionally, focusing on automated cars in special, object-specific perceptions regarding their perceived risks might account for sex differences towards the willingness to use them. Women were found to associate higher risks with motorized vehicles than men (Flynn et al., 1994), which in turn reduced their adoption intentions (Featherman and Pavlou, 2003). Hence, future research should take into account subjective risk perceptions towards automated cars such as dread to examine their potential mediating effects on the effect of sex on usage intentions through risk. On the person side, as previous research has indicated, someone's own risk taking behavior can influence the behavior towards technology (cf. Parasuraman, 2000) and thus should be considered in further research on automated cars.

6.4. Limitations and outlook

Our effects observed are limited by the fact that only the notion of Western Europe people have been captured. People from Western Europe have shown to put weight on different values than for instance parts in the United States like affective autonomy or hierarchy (Schwartz, 2006). However, values play a role in the adoption for technology adoption (Leidner and Kayworth, 2006). Given the fact that automated cars determine the functions of the car and hence are highly autonomous, people from other nations like the US, might put a different weight on the emotional appraisal towards them. Furthermore, although, we found that emotions can reduce biological sex differences towards the willingness to use automated cars, we were not able to fully explain these differences. Thus, further research should examine the influence of other discrete emotions, which have been found to differ between sexes such as contentment or sadness (cf. Brebner, 2003).

Appendix A. Measurement

English version	German version
Anxiety	
How frightening would such a car for you?	Wie beängstigend wäre ein solches Auto für Sie?
Pleasure	
How much pleasure would driving such a car provide for you?	Wieviel Freude würde es Ihnen bereiten, ein solches Auto zu fahren?
Willingness to use	
Were you willing to use such a car today?	Wären Sie bereit, heute ein solches Fahrzeug zu nutzen?

Appendix B. Vignette

English version	German version
Partially automated	
Imagine your car is able to park by itself. You do not need to accelerate, brake or steer the wheel. Your car drives autonomous in the city, the countryside, or the highway and holds the distance to the car in front of you as well as the lane automatically. Your car needs time to react (e.g., stop to standstill) towards sudden obstacles (e.g., reeving car, mobile road works). It recognizes traffic	Stellen Sie sich vor, dass Ihr Auto selbstständig einparkt ohne das Sie Gas, Bremse oder Lenkrad bedienen müssen. Ihr Auto fährt selbstständig in der Stadt, auf der Landstraße oder der Autobahn und hält dabei den Abstand zum Vordermann sowie die Fahrspur. Ihr Auto benötigt Zeit um auf plötzliche Hindernisse (z.B. einscherendes Auto, Wanderbaustelle) zu reagieren (z.B. bis zum

Appendix B (*continued*)

English version	German version
signs (e.g., speed limit) and is able to adopt the speed respectively (beyond national borders). However, you have to permanently observe the drive. Your car is not able to change the line (e.g., due to an obstacle) autonomously. Your car is not able to detect changes on the road (e.g., snow, aquaplaning) and to adopt the speed. You can always take control of the system (e.g., break or steer) whether the car is going to make a mistake. During the whole time you are capable to take control of the car. You can turn off the system (e.g., on/off switch) if you do not want to use it	Stillstand bremsen). Es erkennt Verkehrszeichen (z.B. Ges chwindigkeitsbeschränkung) und kann die Geschwindigkeit entsprechend anpassen (über Ländergrenzen hinweg). Sie müssen jedoch permanent das Fahrgeschehen überwachen. Ihr Auto kann keinen Fahrstreifenwechsel (z.B. bei einem Hindernis) selbstständig vornehmen. Ihr Auto ist nicht in der Lage Veränderungen der Fahrbahn (z.B. Schnee, Aquaplaning) zu erkennen und die Geschwindigkeit an diese anzupassen. Sie können eingreifen (z.B. durch Bremsen oder Lenken), wenn das Auto einen Fehler macht. Sie bleiben daher die ganze Zeit über in der Lage, wieder die Fahrzeugführung zu übernehmen. Sie können das System ausschalten (z.B. mit einem Ein/Aus Taster), wenn Sie es nicht benutzen möchten
Highly automated Imagine your car is able to do everything that a partially-automated car can do. However, now, it can autonomous react towards sudden obstacles (e.g., reeving car, mobile road works). Moreover, now, it detects changes on the road (e.g., snow, aquaplaning). Now, it is possible for you for a short time to turn away from the driving (e.g., to phone, write an email, to read) until your car informs you to take over the control. If you do not take over the control and a collision could occur, the car autonomously brakes until it stands still. Your car is still not able to change the lane by itself. During the whole time you are capable to take control of the car (e.g., break or steer). You can turn off the system (e.g., on/off switch) if you do not want to use it	Stellen Sie sich nun vor, Ihr Auto kann alles was ein teilautomatisiertes Auto kann. Jedoch kann es zudem eigenständig sofort auf plötzliche Hindernisse (z.B. einscherendes Auto, Wanderbaustelle) reagieren. Darüber hinaus erkennt es Veränderungen der Fahrbahn (z.B. Schnee, Aquaplaning). Es ist Ihnen jetzt möglich sich für einen kürzeren Zeitraum (z.B. Telefonieren, email Schreiben, Lesen) vom Verkehrsgeschehen abzuwenden, bis ihr Auto Sie darauf aufmerksam macht, wieder selbst die Steuerung zu übernehmen. Sollten Sie nicht reagieren und eine Kollision bevorstehen, bremst das Auto selbstständig, wenn nötig, bis zum Stillstand ab. Ihr Auto kann jedoch weiterhin nicht selbständig den Fahrsteifen wechseln. Sie können weiterhin eingreifen (z.B. durch Bremsen oder Lenken), wenn das Auto einen Fehler macht. Sie bleiben die ganze Zeit über in der Lage, wieder die Fahrzeugführung zu übernehmen. Sie können das System ausschalten (z.B. mit einem Ein/Aus Taster), wenn Sie es nicht benutzen möchten
Fully automated Imagine your car is able to do everything that a highly-automated car can do. However, now, it additionally is able to autonomous change lanes (by slow as well as by high speed) and to break in critical situations – and if necessary to drive to the emergency lane. Your car recognizes if your physical condition is impaired (e.g., heart attack, stroke) and takes over the steerage (accelerates/breaks and steers). In the same time the car is able to transmit an emergency call. Now it is possible for you to turn away from the drive for a longer period of time (e.g., sleep, watch TV). During the whole time you are capable to take control of the car (e.g., break or steer). You can turn off the system (e.g., on/off switch) if you do not want to use it	Stellen Sie sich nun vor, Ihr Auto kann alles, was ein hochautonomes Auto kann. Jedoch kann es zusätzlich eigenständig Fahrstreifen wechseln (bei niedriger als auch bei hoher Geschwindigkeit) und in Gefahrensituationen bis zum Stillstand bremsen und - wenn möglich - auf den Seitenstreifen fahren. Ihr Auto erkennt zusätzlich, wenn Sie körperlich beeinträchtigt sind (z.B. Herzinfarkt, Schlaganfall) und übernimmt weiterhin für Sie die Steuerung des Autos (Gas geben/Bremsen und Lenkung). Zeitgleich setzt es einen Notruf ab. Sie können sich jetzt über einen längeren Zeitraum (z.B. Schlafen, Fernsehen) vom Verkehrsgeschehen abwenden. Sie können eingreifen (z.B. durch Bremsen oder Lenken), wenn das Auto einen Fehler macht. Sie bleiben daher die ganze Zeit über in der Lage, wieder die Fahrzeugführung zu übernehmen. Sie können das System ausschalten (z.B. mit einem Ein/Aus Taster), wenn Sie es nicht benutzen möchten

Appendix C. Characteristics of the sample

	Sample						German population					
	Total		Male		Female		Total		Male		Female	
	N	%	*N*	%	*N*	%	*N*[a]	%	*N*[a]	%	*N*[a]	%
Age groups												
<20 years	31	1.9	17	1.0	14	0.9	1630	2.4	871	1.27	759	1.11
20–29 years	231	14.4	114	7.1	117	7.3	9732	14.2	4961	7.2	4771	7.0
30–39 years	232	14.5	117	7.3	115	7.2	9783	14.3	4935	7.2	4848	7.1
40–49 years	317	19.8	159	9.9	158	9.9	13505	19.7	6882	10.0	6623	9.7
50–59 years	278	17.4	139	8.7	139	8.7	11808	17.3	5843	8.5	5965	8.7
>60 years	514	32.1	235	14.7	279	17.4	19536	32.2	9817	14.3	12194	17.9
Education												
Low[b]	630	39.3	306	19.1	324	20.2	25860	37.7	12567	18.4	13293	19.3
Intermediate[c]	508	31.7	230	14.3	278	17.4	20500	29.9	9232	13.5	11268	16.4
High[d]	465	29.0	245	15.3	220	13.7	18956	27.7	10049	14.7	8907	13.0
Working status												
Employed	745	46.8	378	23.8	367	23.0						
Self-employed	119	7.5	66	4.2	53	3.3						
Student	138	8.7	70	4.4	68	4.3						
Homemaker	100	6.3	10	0.6	90	5.7						
Unemployed	69	4.3	33	2.0	36	2.3						
Retired	420	26.4	217	13.6	203	12.8						
Car ownership												
Yes	1185	73.9	604	37.7	581	36.2						
No	418	26.1	177	11.0	241	15.1						
Driver license												
Yes	1387	86.5	694	43.3	693	43.2						
No	216	13.5	87	5.5	129	8.0						

Note.
[a] In thousand.
[b] Secondary school until 9th grade [German: Hauptschule].
[c] Includes polytechnic secondary school and secondary school until 10th grade [German: Polytechnische Oberschule and Realschule].
[d] Includes secondary school above 10th grade [German: Fachhochschulreife and Hochschulreife].

References

Aiken, L.S., West, S.G., 1991. Multiple Regression: Testing and Interpreting Interactions. Sage, Thousand Oaks, CA.
Al-Balbissi, A.H., 2003. Role of gender in road accidents. Traffic Injury Prevent. 4 (1), 64–73.
Bandura, A., 1988. Self-efficacy conception of anxiety. Anxiety Res. 1 (2), 77–98.
Bansal, P., Kockelman, K.M., Singh, A., 2016. Assessing public opinions of and interest in new vehicle technologies: an Austin perspective. Transp. Res. Part C: Emerg. Technol. 67, 1–14.
BASt., 2012. Rechtsfolgen zunehmender Fahrzeugautomatisierung [Legal consequences of increasing vehicle automation]. Retrieved from <http://www.bast.de/DE/Publikationen/Foko/Downloads/2012-11.pdf?__blob=publicationFile>.
Bekk, M., Spörrle, M., Landes, M., Moser, K., 2016. Traits grow important with increasing age: Customer age, brand personality and loyalty. J. Bus. Econ.. Advance online publication. http://dx.doi.org/10.1007/s11573-016-0834-4.
Bonnefon, J.-F., Shariff, A., Rahwan, I., 2016. The social dilemma of autonomous vehicles. Science 352 (6293), 1573–1576.
Brebner, J., 2003. Gender and emotions. Personality Individ. Differ. 34 (3), 387–394.
Burns, L.D., Jordan, W.C., Scarborough, B.A., 2013. Transforming Personal Mobility. The Earth Institute.
Czaja, S.J., Charness, N., Fisk, A.D., Hertzog, C., Nair, S.N., Rogers, W.A., Sharit, J., 2006. Factors predicting the use of technology: findings from the center for research and education on aging and technology enhancement (CREATE). Psychol. Aging 21 (2), 333–352.
Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quart. 13 (3), 319–340.
EY, 2013. Autonomes Fahren – die Zukunft des Pkw-Marktes?, pp. 1–14.
Fagnant, D.J., Kockelman, K., 2015. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. Transp. Res. Part A: Policy Pract. 77, 167–181.
Featherman, M.S., Pavlou, P.A., 2003. Predicting e-services adoption: a perceived risk facets perspective. Int. J. Hum. Comput. Stud. 59 (4), 451–474.
Flynn, J., Slovic, P., Mertz, C.K., 1994. Gender, race, and perception of environmental health risks. Risk Anal. 14 (6), 1101–1108.
FSO, 2012. Bildungsstand der Bevölkerung - 2012. Federal Statistical Office, Wiesbaden. Retrieved from <https://www.destatis.de/DE/Publikationen/Thematisch/BildungForschungKultur/AlteAusgaben/BildungsstandBevoelkerungAlt.html>.
Gardner, B., Abraham, C., 2007. What drives car use? A grounded theory analysis of commuters' reasons for driving. Transp. Res. Part F: Traffic Psychol. Behav. 10 (3), 187–200.

Greenblatt, J.B., Saxena, S., 2015. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. Nat. Clim. Change. http://dx.doi.org/10.1038/nclimate2685.
Hayes, A.F., 2012. PROCESS: A Versatile Computational Tool for Observed Variable Mediation, Moderation, and Conditional Process Modeling.
Hayes, A.F., 2013. Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-based Approach. Guilford Press, NY, New York.
Hayes, A.F., 2015. An index and test of linear moderated mediation. Multivar Behav Res 50, 1–22.
Kyriakidis, M., Happee, R., De Winter, J., 2015. Public opinion on automated driving: results of an international questionnaire among 5,000 respondents. Transp. Res. Part F: Traffic Psychol. Behav. 32, 127–140.
Leidner, D.E., Kayworth, T., 2006. A review of culture in information systems research: toward a theory of information technology culture conflict. MIS Quart. 30 (2), 357–399.
Mitzner, T.L., Boron, J.B., Fausset, C.B., Adams, A.E., Charness, N., Czaja, S.J., Sharit, J., 2010. Older adults talk technology: technology usage and attitudes. Comput. Hum. Behav. 26 (6), 1710–1721.
Moons, I., De Pelsmacker, P., 2012. Emotions as determinants of electric car usage intention. J. Market. Manage. 28 (3–4), 195–237.
Murphy, S.T., Zajonc, R.B., 1993. Affect, cognition, and awareness: affective priming with optimal and suboptimal stimulus exposures. J. Pers. Soc. Psychol. 64 (5), 723–739.
Muthén, B., Kaplan, D., 1985. A comparison of some methodologies for the factor analysis of non-normal Likert variables. Brit J Math Stat Psy 38 (2), 171–189.
NHTSA, 2013. U.S. Department of Transportation Releases Policy on Automated Vehicle Development. <http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development> (retrieved 01.04.2013).
Parasuraman, A., 2000. Technology readiness index (TRI) a multiple-item scale to measure readiness to embrace new technologies. J. Serv. Res. 2 (4), 307–320.
Payre, W., Cestac, J., Delhomme, P., 2014. Intention to use a fully automated car: attitudes and a priori acceptability. Transp. Res. Part F: Traffic Psychol. Behav. 27, 252–263.
Plötz, P., Schneider, U., Globisch, J., Dütschke, E., 2014. Who will buy electric vehicles? Identifying early adopters in Germany. Transp. Res. Part A: Policy Pract. 67, 96–109.
Schoettle, B., Sivak, M., 2014. A Survey of Public Opinion about Autonomous and Self-driving Vehicles in the US, the UK, and Australia. Retrieved from <http://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf?sequence=1&isAllowed=y>.
Schwartz, S.H., 2006. A theory of cultural value orientations: explication and applications. Int. Stud. Sociol. Soc. Anthropol. 104, 137–182.
Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use. Transp. Res. Part A: Policy Pract. 39 (2), 147–162.
Thomsen, D.K., Mehlsen, M.Y., Viidik, A., Sommerlund, B., Zachariae, R., 2005. Age and gender differences in negative affect—is there a role for emotion regulation? Person. Indiv. Differ. 38 (8), 1935–1946.
U.S. Department of Transportation, N.H.T.S.A., 2008. National Motor Vehicle Crash Causation Survey: Report to Congress. DOT HS 811, 059.
Venkatesh, V., 2000. Determinants of perceived ease of use: integrating control, intrinsic motivation, and emotion into the technology acceptance model. Inf. Syst. Res. 11 (4), 342–365.
Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003. User acceptance of information technology: toward a unified view. MIS Quart. 27 (3), 425–478.
Wadud, Z., MacKenzie, D., Leiby, P., 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. Transp. Res. Part A: Policy Pract. 86, 1–18.
Weigold, A., Weigold, I.K., Russell, E.J., 2013. Examination of the equivalence of self-report survey-based paper-and-pencil and internet data collection methods. Psychol Methods 18 (1), 53–70.
Welpe, I.M., Spörrle, M., Grichnik, D., Michl, T., Audretsch, D.B., 2012. Emotions and opportunities: The interplay of opportunity evaluation, fear, joy, and anger as antecedent of entrepreneurial exploitation. Entrep. Theory Pract. 36 (1), 69–96.