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Investigating the Factors Influencing the Acceptance of Fully Autonomous Cars

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Once thought of as a product of science fiction, self-driving cars are discussed today as an unavoidable means towards improving transportation systems. In fact, many car manufacturers have announced their plans to deploy highly autonomous cars as soon as 2020; according to the Society of Automotive Engineers (SAE) these vehicles are capable of reacting "even if the human driver does not respond appropriately to the request to intervene (SAE level 4)". There is however a long way to go before fully autonomous cars (SAE level 5) - where pedals and steering wheels are forgone and limitations to driving during severe weather or in unmapped areas are surmounted - are produced. Herein, the overall aim is to study the drivers and inhibitors of autonomous cars' acceptance across cultures with a special focus on the different risks that might deter consumers from using highly and/or fully autonomous cars. After an extensive reviewing of previous works, a research model based on UTAUT2 was developed and accordingly an online survey was conducted in the US and in Germany; 313 valid answers were collected and analyzed. The findings presented here have serious implications both on the academic field as well as the industry, especially in regards to the roles that risks, culture and gender play in the acceptance of fully autonomous cars.

Keywords: Fully Autonomous Cars; Technology Acceptance Models; PLS SEM

1 Introduction

According to the World Health Organization (WHO), car accidents rank within the top causes of death of people worldwide and rank first if we only consider young people aged 15 to 29 (WHO, 2015); In 94% of the cases, the fault did not lie with the vehicle but with the human drivers, be it drunkenness, drowsiness or distraction (NHTSA, 2015); Sadly, even though the price paid every year is too high, the number of casualties is expected to rise as a result to more people embracing car ownership (Lipson and Kurman, 2016).

Supporters of a rapid adoption and quick mainstreaming of autonomous cars believe that their benefits far outweigh their disadvantages; these beliefs are far from baseless as many facts seem to support them; for instance, according to the Eno Center for Transportation (Eno), if 90% of the driven cars in the USA were autonomous "the number of driving related deaths would fall from 32400 per year to 11300" (Eno, 2013); Other major benefits of autonomous cars are their convenience, ease of use and the freedom they offer to consumers, especially to the old, disabled and those incapable of driving.

However, benefits of autonomous cars notwithstanding, they are far from being perfect or at the very least they present many issues that make it hard for consumers to accept them wholeheartedly. In fact many are reluctant to use them for a multitude of reasons; some do not trust them to be safe, secure or private, others avoid them because of social pressure and some consumers have trouble accepting them simply because they love driving.

In order to have a deep understanding of the drivers and inhibitors governing the consumers' attitudes towards autonomous cars' acceptance, we investigated the main probable drivers; the proposed research model comprises constructs from UTAUT2 as well as other relevant constructs that are rooted in the literature and strongly relevant to the context of this research.

2 Theoretical Background and Hypotheses

Technology acceptance models have been around since the early days of information system research, their aim –unchanging over the years- is to investigate the factors influencing the adoption of a technology or its rejection; Several such models emerged over time: TRA (1975), TPB (1985), TAM (1989) and UTAUT (2003) to mention some of them (Venkatesh et al., 2003). UTAUT2, an extended version of UTAUT proposed by Venkatesh in 2012, presents a fitting basis for our present research; some of its constructs, pertaining to usefulness (Performance Expectancy), ease of use (Effort Expectancy), social pressure (Social influence) and enjoyment (Hedonic Motivation), should play a major role considering the nature of the present research (Venkatesh, Thong and Xu, 2012). Certainly, the next step is to adapt the theory to the current context; Hong et al (2014) clearly defined the approaches for the contextualization of a theory (Hong et al., 2014); the first level of this process is to add or remove core constructs; Next, contextual factors such as antecedents are incorporated in the model. Following these guidelines we assimilated some key constructs –rooted in the literature- into the model (see figure 1); these constructs are Desirability of Control (DEC) defined as "the fear of losing control over the vehicle" (Planing, 2014), Perceived Convenience (PC) which is "the level of convenience toward time, place and execution that one feels when driving an autonomous car" (Hsu and Chang, 2013), Personal Innovativeness in IT (PIIT) defined as an "individual trait reflecting a willingness to try out any new technology" (Agarwal and Prasad, 1998) and the Intention to Prefer an autonomous car over a conventional car (IP). The hypotheses regarding the influence of the previously mentioned constructs on the Behavioral Intention (BI), i.e. the intention of the consumer to use fully autonomous cars, are the following:

H1: PIIT has a positive influence on BI

H1: DEC has a negative influence on BI

H3: HM has a positive influence on BI

H4: PE has a positive influence on BI

H5: EE has a positive influence on BI

H6: SI has a positive influence on BI

H7: PC has a positive influence on BI

H8: BI has a positive influence on IP

Additionally, risks are expected to play a major role inhibiting the acceptance of autonomous cars. we singled out five relevant types of risks, these risks are (1) Privacy Risk (PRIV) linked to a "possible loss of privacy as a result of a voluntary or surreptitious information disclosure to the autonomous car" (Dinev and Hart, 2006; Liao, Liu and Chen, 2011), (2) Performance Risk (PERR) associated with "The

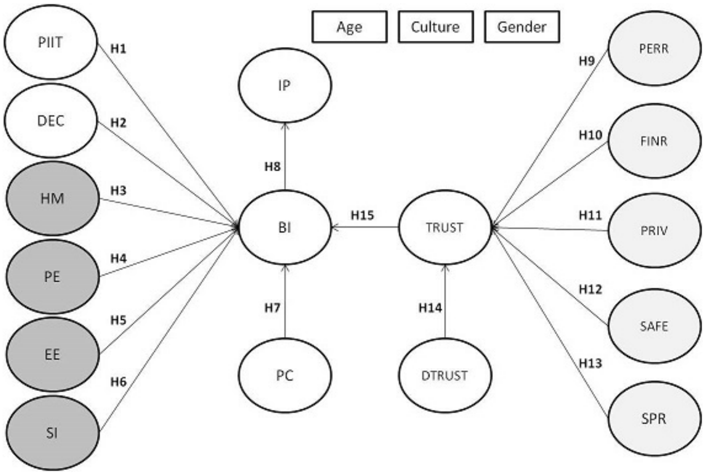

Figure 1: Proposed research model

possibility of the autonomous car malfunctioning and not performing as it was designed and advertised and therefore failing to deliver the desired benefits." (Grewal, Gotlieb and Marmorstein, 1994), (3) Safety Risk (SAFE) which is the risk of the user's safety being endangered through his use of an autonomous car, (4) Financial Risk (FINR) pertaining to "the potential monetary outlay associated with the initial purchase price as well as the subsequent maintenance cost of autonomous cars" and finally (5) Socio-psychological Risk (SPR) defined as the "Potential loss of status in one's social group as a result of using fully autonomous cars, looking foolish or untrendy and risking to lower the consumer's self image" (Kim, Lee and Jung, 2005). Understanding the influence risks have on trust is a major point in this research as it will not only show which risks are relevant but also which ones have more impact. Trust (TRUST) is defined by Mayer et al. (2011) as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the truster, irrespective of the ability to monitor or control that other party". We believe the disposition of a person to trust might also play a role in him/her trusting autonomous cars, hence the DTRUST construct, defined as "how a person sees himself/herself in regards to his/her interactions with other people"(Srivastava, Singh and Srivastava, 2013).

The hypotheses pertaining to trust are the following:

H9: PERR has a negative influence on TRUST

H10: FINR has a negative influence on TRUST

H11: PRIV has a negative influence on TRUST

H12: SAFE has a negative influence on TRUST

H13: SPR has negative influence on TRUST

H14: DTRUST has a positive influence on TRUST

H15: TRUST has a positive influence on BI

3 Methodology

3.1 Sample Description

An online study was conducted in Germany and the USA to collect the necessary data for the present study. The questionnaire was designed following the well-established principles for survey design by Dillman, Tortora and Bowker (1998). The survey took approximately 10 minutes to complete and was accessible for three weeks starting from May 31st, 2017.

313 participants answered the survey of which 160 reside in the USA and 153 in Germany. The survey was designed in a way that participants had to answer all questions before they were able to submit the questionnaire.

Age distribution shows the mean age of the respondents to be 35; it also shows 41.9% of them to be male and 58.1% to be female (see table 1).

The majority of the participants have an annual income inferior to €50.000. 95.5% of the respondents have had some experience driving cars and 84.3% of them currently own one.

Table 1: Participant demographics

Variable	Category	Freq	In%	Mode
Gender	Male	131	41.9	Female
	Female	182	58.1	
Age	Younger than 35	175	55,9	29
	35 and older	138	44.1	
Education	8th grade or less	2	0.6	Graduated from college, graduate or post-graduate school
	Some high school (Grade 9-11)	14	4.5	
	Graduated from high school	81	25.9	
	1-3 years of college/university	74	23.6	
	Graduate or postgraduate	138	44.1	
	No answer	1	0.3	
Annual Income	Less than €50.000	157	50.2	Less than €50.000
	€50.000 to €100.000	88	28.1	
	€100.000 to €150.000	14	4.5	
	€150.000 and more	3	1	
	I would rather not say	51	16.3	
Car Owner- ship	Yes	264	84.3	Yes
	No	49	15.7	
Driving Experience	Yes	299	95.5	Yes
	No	14	4.5	

3.2 Data Analysis

For the purpose of data analysis, we opted for the PLS SEM approach. PLS SEM also known as PLS Path Modeling presents a good choice when the purpose of the study is prediction rather than confirmation and when the analyzed samples are small (Reinartz, Haenlein and Henseler, 2009). There are two parts to PLS SEM; the first part is where the measurement (outer) model is assessed to determine its reliability and validity. The structural (inner) model assessment is performed in the second part of the analysis, the aim of which is to determine the significance of the paths and R^2 values (Anderson and Gerbing, 1988). For the purpose of this analysis SmartPLS 3.0 Professional was used.

3.3 Measures

All questionnaire items were measured on a seven-point Likert scale ranging from “strongly disagree” to “strongly agree”. The DEC, HM, SI, BI, DTRUST, PRIV and SPR constructs were measured with three items; EE, PE, TRUST, PERR and FINR with two items each, SAFE was the only construct measured with four indicators and IP was the only single item construct in the model.

4 Results

4.1 Assessment of the Reliability and the Validity of the Measurement Model

First we examine the indicators‘ reliability, according to Chin (1998) and Hulland (1999) indicator reliability is established if each indicator presents a loading value of 0.70 or higher. Our results demonstrated that the items’ loadings were generally satisfactory.

Next, internal consistency reliability is in turn assessed, Hair et al. (2014) advise to use composite reliability (CR) as a measure for it; a CR of 0.70 or higher is generally regarded as acceptable for research (Bagozzi and Yi, 1988; Chin, 2010; Henseler, Ringle and Sinkovics, 2009; Vinzi, Trinchera and Amato, 2010); our results fully satisfy the required threshold as all estimated values were recorded to be higher than 0.70 (see table 2).

As a result to the first two assessments, the models' reliability is established. Turning to convergent validity, we assessed the AVE values for all our datasets; the values we registered were all higher than 0.50, which is the required threshold for this measure.

Finally, we used the Heterotrait-Monotrait Ratio of Correlations (HTMT) criterion (see table 3) to detect possible discriminant validity issues in the model. According to Hair et al. (2014) HTMT values lower than 0.90 signify the model to be clear of such issues; this condition is fulfilled in all datasets as shown in table 3, hence, discriminant validity is satisfied.

Table 2: Assessment results of the measurement model

Construct	Item	Loading	CR	AVE
BI	Bi1	0.95	0.96	0.89
	Bi2	0.94		
	Bi3	0.94		
DEC	Dec1	0.88	0.84	0.63
	Dec2	0.66		
	Dec3	0.83		
DTRUST	Dtrust1	0.86	0.89	0.73
	Dtrust2	0.87		
	Dtrust3	0.83		
EE	Ee1	0.91	0.91	0.84
	Ee2	0.92		
FINR	Finr1	0.78	0.86	0.76
	Finr2	0.95		
HM	Hm1	0.93	0.95	0.86
	Hm2	0.94		
	Hm3	0.91		
PC	Pc1	0.91	0.93	0.86
	Pc2	0.95		

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Table 2 – continued from previous page

Construct	Item	Loading	CR	AVE
PE	Pe1 Pe2	0.91 0.95	0.92	0.86
IP	Ip1	1.00	1.00	1.00
PERR	Perr1 Perr2	0.87 0.93	0.89	0.81
PIIT	Piit1 Piit2	0.92 0.92	0.92	0.84
PRIV	Priv1 Priv2 Priv3	0.87 0.95 0.93	0.94	0.84
SAFE	Safe1 Safe2 Safe3 Safe4	0.87 0.88 0.77 0.78	0.90	0.68
SI	Si1 Si2 Si3	0.93 0.96 0.94	0.96	0.89
SPR	Spr1 Spr2 Spr3	0.69 0.81 0.89	0.84	0.64
TRUST	Trust1 Trust2	0.90 0.82	0.85	0.74

Table 3: Discriminant validity assessment – HTMT

	DEC	DTRUST	EE	FINR	HM	IP	PC	PE	PERR	PIIT	PRIV	SAFE	SI	SPR	TRUST
SPR															0.08
SI														0.37	0.50
SAFE													0.19	0.08	0.51
PRIV												0.62	0.05	0.12	0.25
PIIT											0.12	0.18	0.31	0.23	0.61
PERR										0.24	0.36	0.72	0.20	0.31	0.57
PE									0.31	0.39	0.04	0.19	0.42	0.07	0.67
PC								0.76	0.41	0.33	0.06	0.19	0.36	0.09	0.60
IP							0.59	0.61	0.53	0.41	0.17	0.40	0.52	0.15	0.67
HM						0.62	0.62	0.60	0.36	0.38	0.11	0.25	0.44	0.16	0.67
FINR					0.20	0.37	0.31	0.17	0.65	0.24	0.28	0.71	0.26	0.21	0.41
EE				0.33	0.58	0.63	0.69	0.74	0.46	0.44	0.14	0.34	0.39	0.05	0.76
DTRUST			0.30	0.20	0.24	0.20	0.18	0.23	0.14	0.40	0.10	0.14	0.31	0.09	0.46
DEC		0.09	0.42	0.56	0.34	0.63	0.42	0.34	0.69	0.16	0.35	0.64	0.19	0.11	0.41
BI	0.51	0.33	0.70	0.47	0.69	0.83	0.63	0.62	0.55	0.58	0.19	0.42	0.60	0.14	0.80

4.2 Assessment of the Reliability and the Validity of the Structural Model

Moving on to the assessment of the validity and reliability of the structural model, first and foremost, we assessed the Variance Inflation Factor (VIF); our findings were that all VIF estimates were smaller than 5; indicating the absence of collinearity issues.

Next, we assessed the significance of path coefficients by calculating t-values; we performed a bootstrapping procedure and used the settings recommended by Hair et al. (2014) (5000 bootstraps, two-tailed tests). The significance thresholds for the t-values are 2.58 for 99% confidence level, 1.96 for 95% confidence level and 1.75 for a 90% confidence level (Hair et al. 2014).

The results of our analysis (displayed in figure 2) show that $PIIT > BI, DEC > BI$, $HM > BI$, $SI > BI$, $EE > BI$, $TRUST > BI$, $DTRUST > TRUST$, $FINR > TRUST$, $PERR > TRUST$ and $BI > IP$ are significant at 99% confidence level (t-value > 2.58); they also show $SAFE > TRUST$ to be significant at 95% confidence level (t-value > 1.96) and SPR $>$ TRUST at 90% confidence level (t-value > 1.75). The relationships that did not satisfy the minimum requirements for significance were $PE > BI$, $PC > BI$, FINR $>$ TRUST and PRIV $>$ TRUST. As a result Hypotheses H4, H7, H10 and H11 are rejected.

The results for the R^2 calculations (displayed in table 4) show that all endogenous variables are well explained by their relationships. The highest R^2 was estimated at 0.71 for BI, followed by IP (0.64) and finally TRUST (0.32). In the field of consumer behavior, a R^2 of 0.20 is usually regarded as high (Hair, Ringle and Sarstedt, 2011; Hair et al., 2014).

In order to perform a group moderation, we used the Multi Group Analysis algorithm available in Smartpls3.0; it allowed us to have an better understanding of whether people of different cultures (USA and Germany), ages ($<$=35 and $>$35) and genders (male and female) would approach autonomous cars‘ acceptance differently, the results are visible in table 4.

Gender and culture were found to play an active role as moderators contrary to age. Our results show that women are more likely to prefer using an autonomous car if they choose to use it; they also show women to be more influenced by their social environment than men; these latter's dispositions to trust were found to play a more active role in them trusting autonomous cars. In regards to culture as

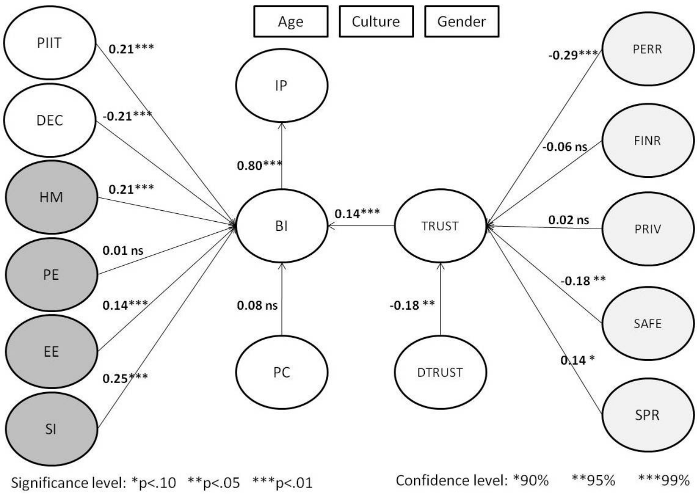

Figure 2: Path coefficients and significance level of the relationships

Table 4: Group moderation - results of the parametric test

Path/Moderator	Gender	Age	Country
BI ->IP	2.03**	0.78	0.29
DEC ->BI	0.63	1.39	0.29
DTRUST ->TRUST	2.24**	0.99	0.70
EE ->BI	1.06	1.14	0.10
FINR ->TRUST	1.65	0.18	0.49
HM ->BI	1.94*	0.27	0.82
PC ->BI	0.33	1.02	0.00
PE ->BI	0.53	0.82	0.33
PERR ->TRUST	0.55	0.96	0.47
PIIT ->BI	0.59	0.07	0.34
PRIV ->TRUST	0.4	0.29	1.36
SAFE ->TRUST	0.34	0.06	0.74
SI ->BI	2.24**	0.12	0.81
SPR ->TRUST	1.22	1.55	2.59***
TRUST ->BI	0.49	0.53	0.25

Significance level: *p<.10 **p<.05 ***p<.01 Confidence level: *90% **95% ***99%

a moderator, findings show that socio-psychological risks are strong in Germany contrary to the USA where they were found to be insignificant.

It is worth noting that in regards to effect sizes (f^2 values), a strong effect size was recorded for BI > IP (1.79); SI > BI (0.17) had the only registered medium effect and all the remaining effects were small, with the exception of FINR > TRUST, PC > BI, PE > BI and PRIV > TRUST (the rejected hypotheses) where the recorded effect sizes were inferior to 0.02 and therefore deemed insignificant.

5 Discussion and Conclusion

The main aim of this study was to identify the drivers and inhibitors governing the consumer‘s behavior in regards to the acceptance of fully autonomous cars.

For that purpose, we conducted an online survey in two countries namely Germany and the USA; the collected data was then analyzed using PLS SEM. The results of the analysis shed light on the main drivers influencing consumers' intention to use fully autonomous cars; they also allowed to gauge the role these drivers play in terms of impact.

Our findings showed that many factors positively influence the user's intention to use an autonomous car; and while some of these factors are related to the technology itself such as it being "easily used" or "enjoyable", others are associated with the user's own personality such as "personal innovativeness" or the influence of the environment on him/her; The key inhibitors to autonomous cars' acceptance were found to be the consumers' thirst for control and risks; Some risks were recorded to have a great influence on a consumer trusting a car, these risks are: the risk of the car being unsafe and the risk of the car malfunctioning. Surprisingly, the performance expectancy of the autonomous cars as well as their convenience were found not to be significant, this can be explained as consumers being more influenced by the negative aspect i.e. the car malfunctioning as well as the unavailability of the car in the market at the present time. Risks that were ascertained to be extraneous are the financial risk as well as the privacy risk as many people did not find them to be "deal breakers".

In terms of implications for theory, the contributed research model comprises all the key elements that play a major role in the acceptance or rejection of fully autonomous cars; as such it can be used in future research as a reference for a contextualized model of technology acceptance in the automobile industry. In terms of managerial and practical implications, the current study presented findings that clarified which elements have an impact -and to which level- making it easier for stakeholders to make a better advised decision when dealing the inhibitors to the acceptance of autonomous cars or when promoting the attractive qualities of these vehicles. Advertizing the benefits of the car should help people have a better understanding of what to expect in terms of productivity and comfort. Decision makers should find ways to promote trust in fully autonomous vehicles, and that through dealing with the consumer concerns' linked to the performance of the car and to the safety of the user, as these were found to be the strongest inhibiting risk factors; they should also find ways to soften and implicate the people who prefer to have constant control while commuting. Findings related to gender, culture and personal innovativeness should ultimately help devise improved strategies to target these specific population segments in a more effective way.

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