ACCEPTANCE OF SHARED AUTONOMOUS VEHICLES – A CORRESPONDENCE ANALYSIS OF NEW CAR BUYER ATTITUDES

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Abstract

The development of autonomous vehicles will significantly change individual transportation as well as the psychological perception of automobiles. Most likely the advance of this technology will alter the concept of car-ownership, as shared mobility services will provide convenient individual mobility at low costs. Next to technical and legal challenges, the success of shared autonomous vehicles will depend upon the widespread acceptance of this service by customers. The present study addresses this aspect by eliciting salient beliefs of individuals towards shared autonomous vehicles. In sum, 41 new car buyers were interviewed upon the delivery of their new automobile at a German premium car manufacturer's delivery center. The semi-structured interviews were designed to evaluate the attitude towards this new technology as well as to collect related salient associations. Based on a two-dimensional correspondence matrix, a pattern of prevalent associations linked to the attitude towards shared mobility services was derived. The results show that acceptance is most strongly linked towards gains in productivity, while rejection is most closely related to reduced driving pleasure and general mistrust in technology. Notably, increased comfort and safety are rather corresponding to neutral beliefs towards this technology.

Keywords: *Acceptance, Autonomous Driving, Shared Mobility, Correspondence Analysis*

INTRODUCTION

The automotive industry is, in general, an innovation-driven industry in which competitiveness is heavily determined by innovativeness and continuous improvement. Accordingly, automobile companies have invested billions into research and development of innovations, such as driver-assistance systems, which increasingly automate the driving task. This development will ultimately lead to fully autonomous vehicles. The rise of this technology, however, will significantly change individual transportation as well as the psychological perception of automobiles. The idea of self-driving vehicles is transformative from an infrastructural perspective as well as from a public health perspective. If cars are able to navigate their way out of crowded cities, this could change the infrastructure of cities, since inner-city parking spaces are no longer needed (Fagnant and Kockelman, 2015). An automated management system of empty vehicles could move the vehicle to the nearest depot or car park (Alessandrini et al., 2015).

Most likely the advance of this technology will also end or at least drastically alter the concept of car-ownership, as Shared Autonomous Vehicles (SAVs) will provide convenient individual mobility at low costs. (Kruger et al., 2016). Currently, the cost of a human driver is the highest proportion in the cost calculation of ride-hailing services, such as Uber or Lyft. Removing the driver from the equation will reduce the cost of using a ride-hailing service below the cost of operating an own car. A recent study (ARK, 2017) even concluded that taking a robot taxi would be significantly cheaper than walking, assuming a per calorie price of $3.99 for a big mac. It can be fairly assumed that the increased viability of this business model will also change customer acceptance. At $3 per mile there is only a very limited market for instant ride-hailing, but at $0.3 per mile these service will outright substitute private car ownership and even many other forms of transportation including public transport and walking. Chart 1 gives an overview about the estimated commuting cost structure.

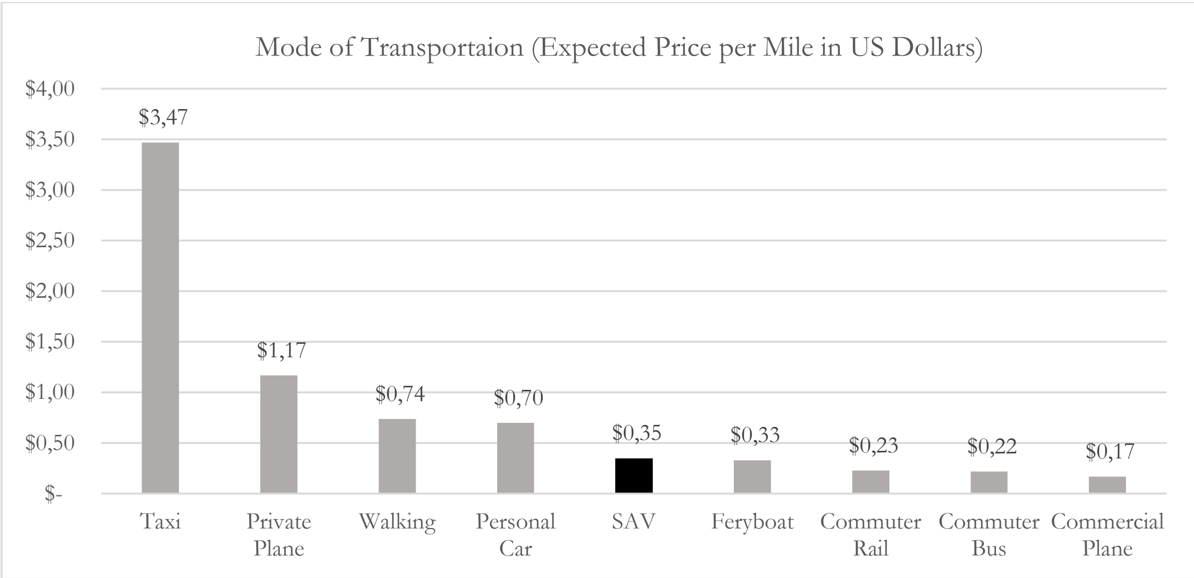

Chart1: Own illustration based on ARK Research (2017)

Second, from the theoretical perspective of innovation acceptance research, the context of SAVs combines some very unique aspects:

1. SAVs are a substitute for a highly emotional product, the automobile.

2. SAVs are aimed at replacing the driving task, which is known to have a special role in the self-identity of consumers

3. SAVs will drastically change learned routines and habits of consumers.

For this reasons, the beliefs towards the acceptance of SAVs are expected to differ substantially from other cases of consumer goods. Consequently, this unique context offers promising insights into the field of innovation acceptance (Burghout, Rigole & Andreasson, 2015; Kruger, 2016). The knowledge of which factors have the strongest influence on consumer acceptance in the case of SAVs will help the industry to develop this technology further in order to better meet customer needs. It is obvious that a profound understanding of the reasons and root causes for the acceptance of SAVs will help governmental institutions to develop more efficient and effective legislative action towards their ultimate goal to in-crease road safety and inner-city infrastructure.

DEFINITIONS

For the purpose of the present research, Shared Autonomous Vehicles (SAV) will be used synonymously with Robo-Taxi, referring to a system that enables automated individual transport on-demand. This system no longer requires a human driver. Following the accepted taxomony of automated vehicle systems this will only be possible with Level 5 automated vehicles. Table 1 shows the taxonomy and definitions for automated vehicle systems (adapted from Diels, Cyriel, and Jelte E. Bos, 2016 and SAE, 2014)

Automation level	Name	Narrative definition	Responsibility for driving task
Human driver monitors the driving environment			
0	No automation	The full-time performance by the human driver of all aspects of the dynamic driving task*, even when enhanced by warning or intervention systems	The driver
1	Driver assistance	The driving mode**-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task	
2	Partial automation	The driving mode-specific execution by one or more driver assistance system of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task	
Automated driving system ("system") monitors the driving environment			
3	Conditional automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene***	The System, driver monitors
4	High automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	
5	Full automation	The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver	The System

Key definitions:

**Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.*
***Driving mode is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).*
****Request to intervene is notification by the automated driving system to a human driver that s/he should promptly begin or resume performance of the dynamic driving task.*

Table 1: Taxonomy and definitions for automated vehicle systems

THEORETICAL FRAMEWORK

The present paper will be based on the Theory of Planned Behaviour (Fishbein and Ajzen, 1967, 2010), which proposes that behaviour is determined by intention, which in turn is determined by two fundamental factors: the attitude towards the behaviour and the subjective norms. Attitudes are basically the positive or negative evaluations of the behaviour in question, while norms represent the perceived social pressure to engage or not engage in the behaviour in question. Attitudes are believed to develop automatically and inevitably as new beliefs are formed about an object. Specifically, people are assumed to have pre-existing evaluations of certain attributes of an innovation that become linked to this object in the process of belief formation. Depending on the strength of these beliefs and the evaluations of the innovation's attributes, the overall attitude towards the object is formed. Thus, in future, the attitude object will automatically activate the summated evaluative response: that is, the overall attitude towards the object. People can, of course, form many different beliefs about an object, but it is assumed that only a relatively small number determine the attitude at any given moment. Only salient beliefs (i.e. beliefs about the object that come readily to mind) serve as the predominant determinants of the attitude (Swartz and Douglas, 2009, p.26).

The present study will focus on these salient beliefs of individuals toward as Shared Autonomous Vehicles.

STATE OF CURRENT RESEARCH

Although the TPB has been widely applied to examine the adoption and acceptance of different technologies, the model itself does not provide a sufficient explanation or prediction for each behavioural context (Chen and Mort, 2007, p.356). Consequently, a growing body of research has focused on developing the model further by extending it with several new, context-specific, constructs. Recently, however, some researchers have also tried to integrate the existing models to examine technology adoption by employing the complementary and explanatory power of different acceptance models taken together. In an attempt to recognize the strengths and weaknesses of different technology acceptance models developed so far, Venkatesh et al. (2003) incorporated Rogers' Innovation Diffusion Theory (Rogers, 2003), the TPB as well as the TAM and several other specialized innovation acceptance models into one unified model, which was consequently referred to as the United Theory of Acceptance and Use of Technology (UTAUT). Yet, also this unified model has to be adopted to each behavioural context to fully explain the acceptance behaviour. It is therefore important to focus on context-related research in order to draw conclusions on acceptance behaviour. While the topic of Shared Autonomous Vehicles has gained relative popularity in commercial publications, the amount of scientific publication towards acceptance factors for Robo-Taxis is still relatively small. This may be due to the fact that the technology is not yet available and thus beliefs are not yet formed by individuals towards the research subject, making it difficult to elicit robust research result. A few studies, however, have derived acceptance and rejection factors towards SAVs. Accoring to Litman (2017), Robo-Taxis would provide the benefit of reduced driving stress, improved productivity and increased mobility. Also SAVs are expected to reduce travel time, especially time to search for parking spaces (Burghout, Rigole & Andreasson, 2015). In a large international survey with 5000 responses from 109 countries, respondents were found to be most concerned about software hacking and general misuse, and were also concerned about legal issues and safety (Kyriakidis, Happee and de Winter, 2015). Other authors found that privacy and data safety may restrict willingness to use SAVs (Glancy, 2012). These factors were used to construct the interview-guideline in the next step.

RESEARCH APPROACH

As only salient beliefs (i.e. beliefs about the object that come readily to mind) serve as the predominant determinants of the attitude towards a new technology, the major challenge was to develop a research model that provides a setting in which respondents form beliefs about a new technology, which is not yet available. It is expected that a random sample of individuals was not a suitable solution in this regard, since most likely they won't have formed salient beliefs about Robo-Taxis. Thus the authors decided to use personal interviews of new car buyers, at the time of handover of their new car. For most new car customers, it can be assumed that this is a highly emotional moment, in which beliefs about a potential shared vehicle concept are most readily available. In sum, 41 new car buyers were interviewed upon the delivery of their new automobile at a German premium car manufacturer's delivery center. Table 2 shows the demographics of the interviewees. The semi-structured interviews were designed to evaluate the attitude towards this new technology as well as to collect related salient associations.

Sample Demographics		
Gender	male	70,7%
	female	29,3%
Age groups	18-24 yrs	31,7%
	25-34 yrs	24,4%
	35-44 yrs	4,9%
	45-59 yrs	19,5%
	above 60	19,5%
Residence	City	36,6%
	Suburban	34,1%
	Rural	29,3%
N=41 new car buyers		

Table 2: Demographics of Interview Participants

Attitude towards Robo-Taxi

In order to assess the Attitude towards Robo-Taxis a three item scale was developed based on a pretest (see Table 3 for the question items). The reliability of the measurement model depends on the average correlation among the observed variables and is usually measured using the Cronbach's alpha. Generally a value greater than .80 indicates a very high level of reliability (Bryman and Bell, 2007; Shelby, 2011). While the Cronbach's alpha coefficient evaluates the overall reliability of the model, the Item-to-Total-Correlation (ITTC) measures how well a single indicator fits within the model.

The ITTC describes the correlation between a single item and the sum of all items that are supposed to represent one factor. Usually the Corrected Item-to-Total-Correlation is used, which indicates the correlation between a single indicator and the sum of all other items minus the item evaluated. The value of ITTC can range from 0 to 1, while generally higher values indicate a good fit and a high convergent validity of the item under investigation (Jais, 2007, p.128).

Number of Items		Cronbach's Alpha		
3		.869		
Item		Arithmetic mean (M)	Standard deviation (S)	Corrected Item-Total Correlation (ITTC)
29.1	Robo-Taxis are a very good way for me to test autonomous vehicles	3.86	1.355	.770
29.2	I like the idea to order a car to my doorstep online within seconds	3.95	1.542	.822
29.3	I would prefer a Robo-Taxi to a normal vehicle, because I can reach my goals easier	3.00	1.496	.670

Table3 : Factor Attitude towards Robo-Taxi

With a Cronbach's alpha value of .8692, the factor Attitude towards Robo-Taxis can be regarded as a valid and reliable factor, which will be used for the further analysis.

Associations and Beliefs towards Robo-Taxis

After a short introduction of the Robo-Taxi concept by the interviewer, the respondents were asked to name three associations they have with the new technology. Afterwards they were guided through nine predefined categories of beliefs commonly held towards this technology. Based on the Literature Review described and an extensive pre-test, these nine major categories of associations with Robo-Taxis were developed: Increased productivity, increased safety, reduced travel time, increased comfort, limited driving pleasure, mistrust in technology, loss of control, liability issues and security and data abuse. These associations were brought up by the interviewer one after another in random order and it was documented whether or not the respondent was instantly supporting the belief or not.

Findings

Firstly, the descriptive statistics were employed to evaluate the attitude towards Robo-Taxis along demographics of the sample group. The age group split surprisingly revealed no clear tendency, weather younger or older people are more open towards this technology. Thus based on our sample age is no predictor for Robo-Car Acceptance.

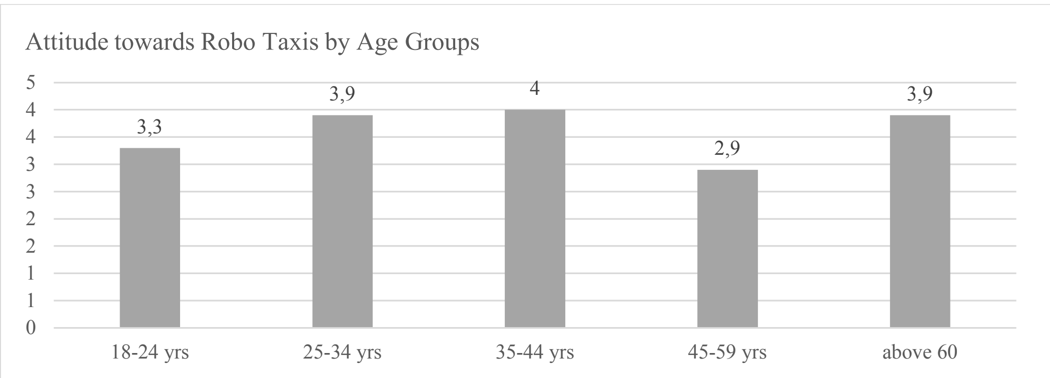

Chart 4: Attitude towards Robo-Taxis by Age Groups

Secondly, splitting the target group be residence reveals a difference between citizens of inner-city regions, suburban regions and rural regions. The results suggest that inhabitants of more densely populated areas generally have a higher acceptance of Shared Autonomous Vehicles.

Chart 5: Attitude towards Robo Taxis by Residence

In order to test the significance of these difference a one-way ANOVA was calculated. Due to heterogeneity of variance in the groups a robust Welch-corrected version was employed (See Table 4). The Statistic was not significant with F(22.2)=3.288, p=.056 assuming a 5% significance level. In the next step a Post-Hoc analysis was used to evaluate individual group differences. Bonferroni corrected pairwise t-tests revealed a significant difference between the group Suburban on the one side and the group Rural on the other side, with t=1.262, p=0.03 (see Table 5). Thus, we can conclude that new car buyers from rural areas are significantly less likely to exchange their car for a Robo -Taxi.

	Statistica	df1	df2	Sig.
Welch-Test	3.288	2	22.246	.056
a. Asymptotic F-distribution				

(I) Residence	(J) Residence	Difference (I-J)	Standard Error	Significance	95%-Confidence Interval	
					Upper	Lower
Suburban	Rural	-1.262*	.465	.030	-2.43	-.10

Table 5: Post-Hoc multiple comparisons (Bonferroni pairwise t-tests)

Correspondence Analysis

Correspondence analysis (CA) is generally accepted as a way of visually displaying the association between two discrete variables, based on their cross tabulation in the form of a two-way table of frequencies. The row and column categories are depicted in a spatial map where certain distances or scalar products may be interpreted as approximations to the original data. CA is thus a particular case of weighted principal components analysis (PCA). In this general scheme, a set of multidimensional points exists in a high-dimensional space in which distance is measured by a weighted Euclidean metric. A two-dimensional solution (in general, low-dimensional) is obtained by determining the closest plane to the points in terms of weighted least-squares, and then projecting the points onto the plane for visualization and interpretation (Greenacre, 2006). For the purpose of the present Study the authors used SPSS Package CORRESPONDENCE Version 1.1 by Leiden University.
Since correspondence analysis is based on categorical data. The dependent Variable Attitude towards Robo-Taxis had to be categorized into three distinct groups, namely accept Robo-Taxi, neutral to Robo-Taxi, reject Robot-Taxi, based on their combined score.

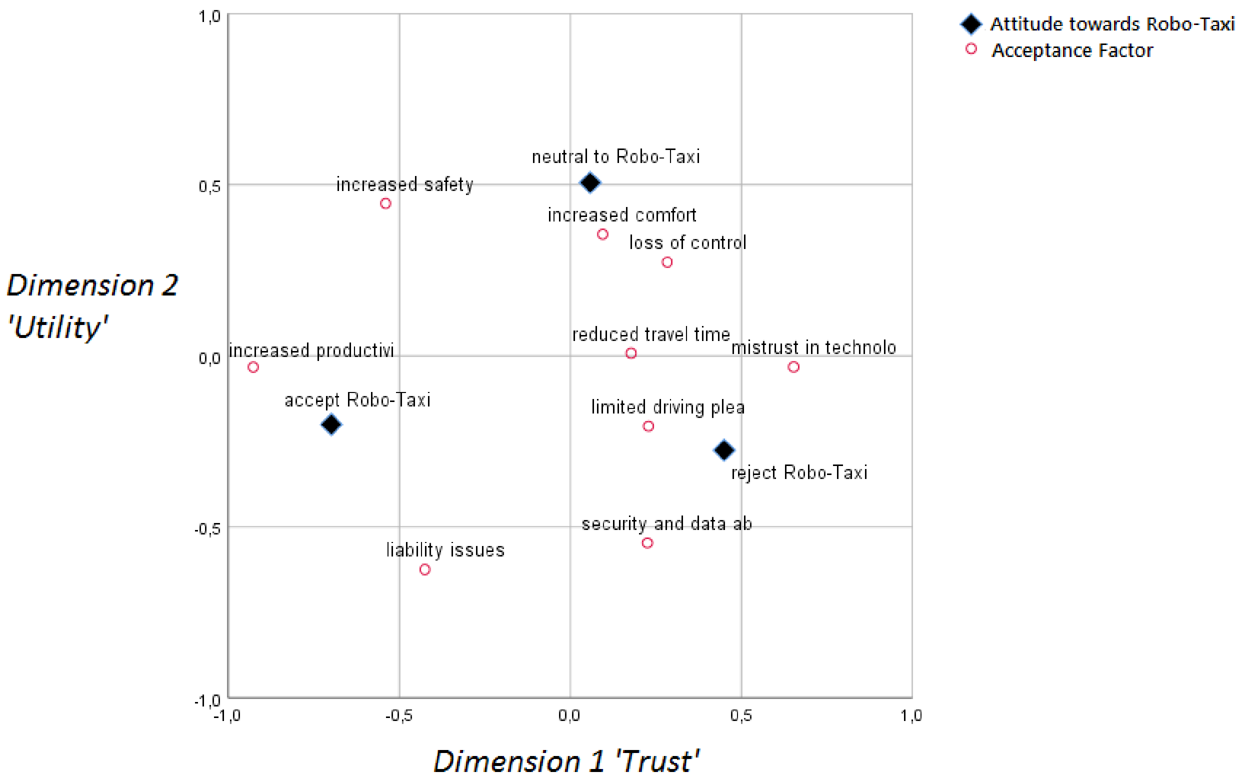

Chart6: Correspondence Analysis of Associations with Robo-Taxis

To interpret the results of the correspondence analysis the euclidean distance between the three vantage points (accept Robo-Taxi, neutral to Robot-Taxi and reject Robo-Taxi) and the associations needs to be regarded. Increased Productivity is closest to acceptance of Robo-Taxi, making it clear that this association is strongest linked to the acceptance of this technology. On the other side, Mistrust in Technology, Limited Driving Pleasure and Security and Data Abuse are most closely linked to the rejection of Robo-Taxi. Thus these associations seem to support a negative attitude towards the shared automated vehicles. Increased Comfort and Safety and Loss of Control correspond rather with a neutral attitude towards this technology.

CONCLUSIONS

The results of the present thesis contribute to this problem by offering an under-standing of which factors are decisive for the acceptance of Robot-Taxis within the target group of German automobile drivers. Based on this understanding, implications can be derived that can help the industry to better market this technology.
Firstly, the study revealed that there is a significant difference regarding the attitude towards autonomous driving between residence groups. Most importantly inhabitants of rural regions have a significantly lower attitude towards Robo-Taxis than suburban and city inhabitants. This may correspond to the availability of such services, since they will most likely be available in densely populated areas first, while in rural areas car ownership will prevail much longer.

The correspondence analysis has revealed three groups of corresponding association, which were named into Persuasive Unique Selling Prepositions (USP), Rational Choice and Rejection Reasons. See Chart 6.

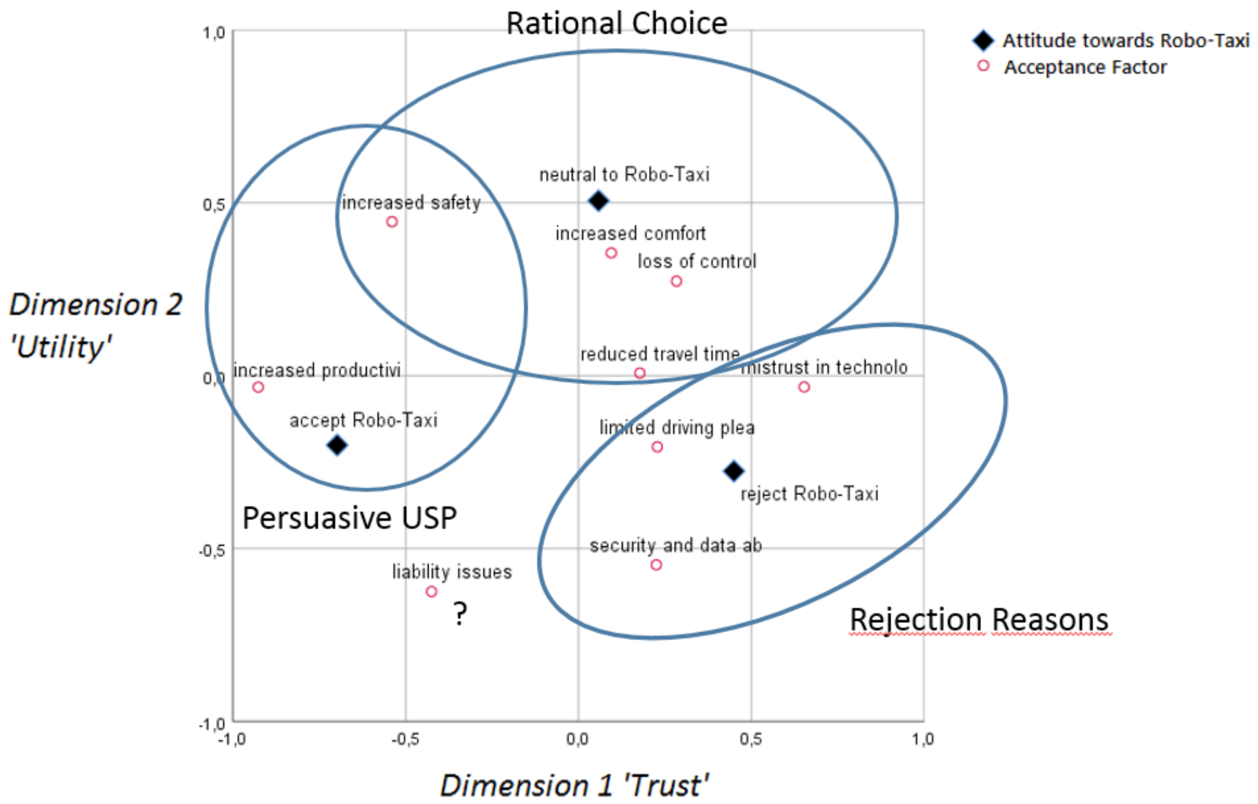

Chart6: Annotated Correspondence Analysis of Associations with Robo-Taxis

These three groups describe the salient beliefs which correspond with either behavior. A few associations, however, were not clearly defined. Increased Safety has a comparable Euclidean distance to Accept and Neutral, thus it is not clear whether safety can really be regarded as a persuasive USP for Robo-Taxis. Increased Comfort and Safety, albeit important aspects, seem not to correspond with a clear cut acceptance decision for Robo-Taxis. Interestingly Liability Issues seem not to correspond with either behavior. This is most probably due to the still very unclear legal situation of self-driving vehicles.

IMPLICATIONS

Since the study revealed that the Perceived Productivity Gains is the most decisive factor in SAV acceptance, the industry should focus its attention on the communication of potential productivity benefits of Robo-Taxis. Most important to reduce are concerns related to the Mistrust in Technology, which turned out to be one of the main reasons for SAV resistance. This factor, however, is affected by Experience with the technology. The more individuals have the chance to experience Robo-Taxis, the less they will have concerns about losing control or personal freedom when driving with driver-assistance systems. Thus, increasing experience will alter the potential belief sets positively and will thus have a positive effect on the acceptance decision (Fishbein and Ajzen, 2010). One of the main opportunities to increase SAV acceptance is to increase trial ability. Trial ability, according to Rogers (2003), is the degree to which an innovation may be experimented with on a limited basis. Thus industry should intentionally lower the barrier to test Robo-Taxis in everyday situations in order to increase acceptance rates. To counter the perceived limited driving pleasure, which is another main factor for resistance towards Robo-Taxis, industry could focus on in-car entertainment and gamification concepts. While the sensory stimulation of driving a car cannot be replaced easily by offer free movies on board, new concepts might be able to include Virtual Reality in order to simulate for instance a racing game along the transportation route.

LIMITATION AND RECOMMENDATIONS FOR FURTHER RESEARCH

It is important to acknowledge that the present sample is restricted by quantity and generalizability of the target population. Since only 41 individuals participated in the study, all customers of one German premium car manufacturer, the conclusions derived from this study cannot be generalized without caution. Future research should broaden the scope by having a larger population with a different demographic or regional scope. Future research should also be directed on the yet unclear associations, such as liability issues. These beliefs seem to be yet undefined in respondents' minds and it will be interesting to see how future events, such as accidents with self-driving cars, will alter these beliefs in either direction.

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