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Abstract

Smart home technology is considered a growth market, which could profoundly affect everyday's life regarding comfort, security and energy efficiency. Further market development does not only depend on ongoing technological progress but especially on users' acceptance and use of smart home technology. Based on adopted versions of the Technology Acceptance Model by Davis and the Unified Theory of Acceptance and Use of Technology by Venkatesh, this paper analyses with an empirical investigation of the German market which factors influence acceptance and use of smart home technology and which potential providers are most trusted by consumers. The empirical investigation confirms the relevance of convenience aspects which have to be balanced against perceived data protection and privacy risks, while ecological considerations are - surprisingly - not significantly relevant. The study confirms that different providers are given considerably different levels of trust, with utilities having a clear confidence advantage over other providers.

Keywords: Smart Home Technology, User Acceptance, Data Protection, Privacy, Utilities, Trust

1. Introduction

Technical progress initiates constant changes in almost all areas of life. One current development is the smart home technology. It enables the networking, regulation and monitoring of technical devices in private households, which can lead to increased personal comfort, perception of higher security and more efficient energy use [1]. In times of increased environmental and climate awareness, the latter could be of particular relevance. In all G20 countries except Russia, a majority of the population considers climate change to be a 'major threat' [2]. However, in addition to overly complicated operation of the technology, the perceived security risk of external intervention in the control of one's own home by hackers or, in particular, a lack of confidence in the adequate protection of the extensive personal data generated by smart homes could have an inhibiting effect [3]. While the obstacle factors of ease of use and protection against hackers are issues of technical development, the protection of personal data is about trust in the technology provider. Potential providers from different industries could be given different levels of trust in the perception of customers.

Smart home technology is considered a growth market with revenue forecasts that predict a 50% increase in the three major economic regions of the USA, China and the EU to a combined EUR 100 billion between 2020 and 2023, distributed into EUR 40 billion in the USA and nearly EUR 30 billion each in China and the EU [4]. Within the EU, Germany is again the largest market, which could reach EUR 6 bn in 2023 [4]. Sensitivity to data protection issues is particularly pronounced in Europe [4], so further market development depends on current and potential users' confidence in technology and providers. In order to provide a better understanding of this, this paper conducts an empirical investigation for the German market of factors influencing the acceptance and use of smart home technology and of potential providers most trusted by consumers.

This paper builds on the Technology Acceptance Model (TAM) by Davis [5] and the

Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh [6], presented in Chapter 1, which is further enhanced for the domain smart home. The further enhanced theory is used in an empirical study to answer the following two questions: 1. Which factors influence the acceptance and use of the smart home technology? 2. Which business sectors enjoy the greatest trust from the consumers' point of view? In order to answer these questions, seven hypotheses are set out in Chapter 3, which are then tested in an empirical study. The questionnaire designed for this purpose uses a six-level Likert scale and was answered online by 372 participants in the fourth quarter of 2019. The statistical evaluation and confirmation or rejection of the hypotheses in Chapter 1 enables a well-founded answer to the questions raised previously. Finally, a summary and outlook on further research issues follow in Chapter 1.

2. Technology Acceptance

Acceptance is a subjective construct that represents the rejection or endorsement of material things and immaterial values or norms [7]. One model that maps factors that explain the acceptance of information technology systems is the Technology Acceptance Model by Davis (TAM) [8]. As decisive factors, Davis focuses on the perceived usefulness and the perceived ease of use. Davis [8] describes the perceived usefulness as the factor that a person believes would improve his or her work performance by using the system. In the technical context, this means that a positive relationship is established between the use of the technology and future performance improvement, supported by a high perceived usefulness of the system. Perceived ease of use, on the other hand, describes the factor by which a person assumes that a technical system can be used without effort. The simpler a technology is experienced, the more useful it is perceived to be and the more likely it is to be used. King [9] demonstrated the success of the TAM in an analysis of 88 studies in which the TAM was used. The results confirmed the validity of the model, but also showed potential for better applicability by using other variables, such as experience, to explain the factors.

Building on TAM, Venkatesh et al. [6] developed an overall construct for the theoretical acceptance and use of technology (Unified Theory of Acceptance and Use of Technology, UTAUT) on the basis of eight theoretical models for explaining and predicting user behavior. Figure 1 shows this further development.

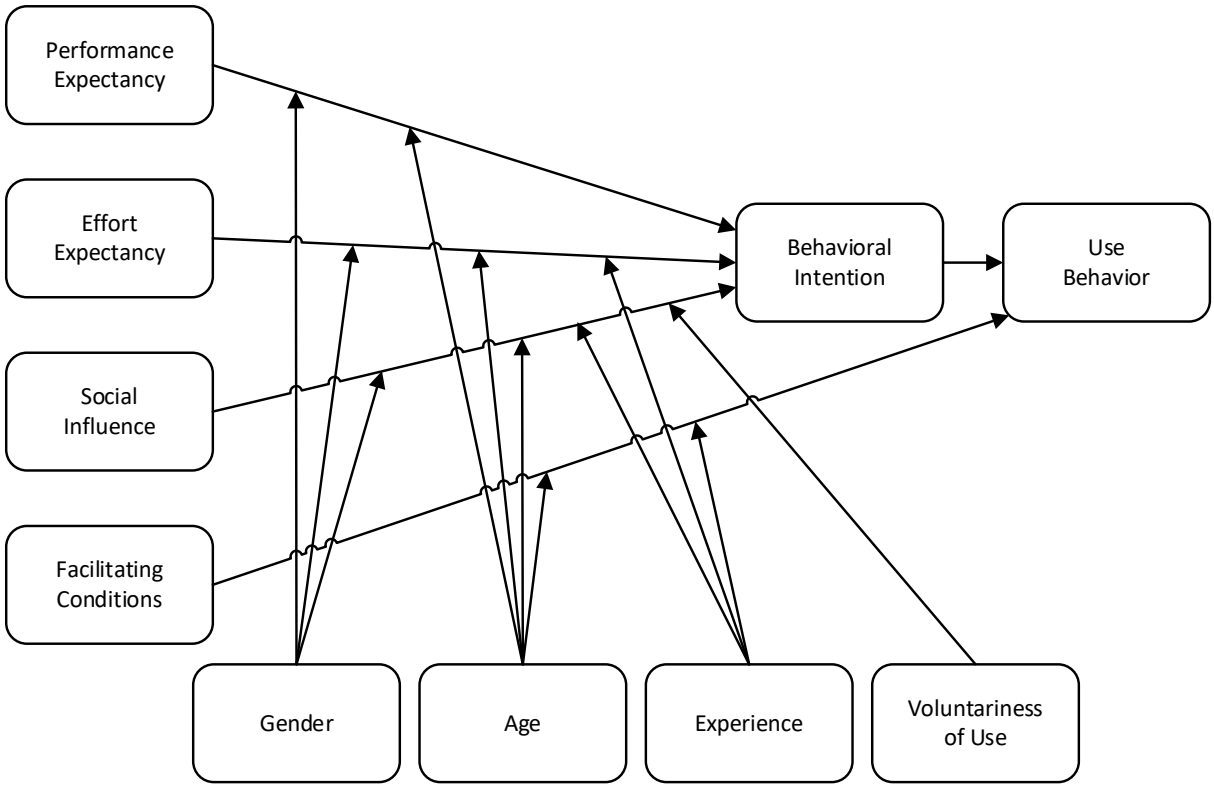

Figure 1: Unified Theory of Acceptance and Use of Technology [6]

UTAUT is based on four core determinants which set the intention and the usage behavior. These are performance expectancy, effort expectancy, social influence and facilitating conditions. These core determinants are in turn governed by moderator variables such as gender, age, experience and voluntariness of use. Overall, the model for UTAUT can be understood as an improved variant of the TAM for presenting an overall picture of acceptance. Furthermore, the model has been successfully used and extended in numerous studies. To this end, Venkatesh et al. [10] analyzed studies in which the UTAUT was used and modified for research. After analyzing the results of 65 scientific studies with integrated UTAUT, Chang [11] also confirms that the four core determinants mentioned above have a significant influence on the intention to use technology.

3. Smart Home

Marikyan et al. have conducted a systematic literature review of smart home and define it as follows:

"The smart home represents smart devices and sensors that are integrated into an intelligent system, offering management, monitoring, support and responsive services and embracing a range of economic, social, health-related, emotional, sustainability and security benefits." [1]

Based on the previously presented theories of acceptance formation and with the help of further determinants of other studies [12, 13], this paper develops the adapted technology acceptance model shown in Figure 2.

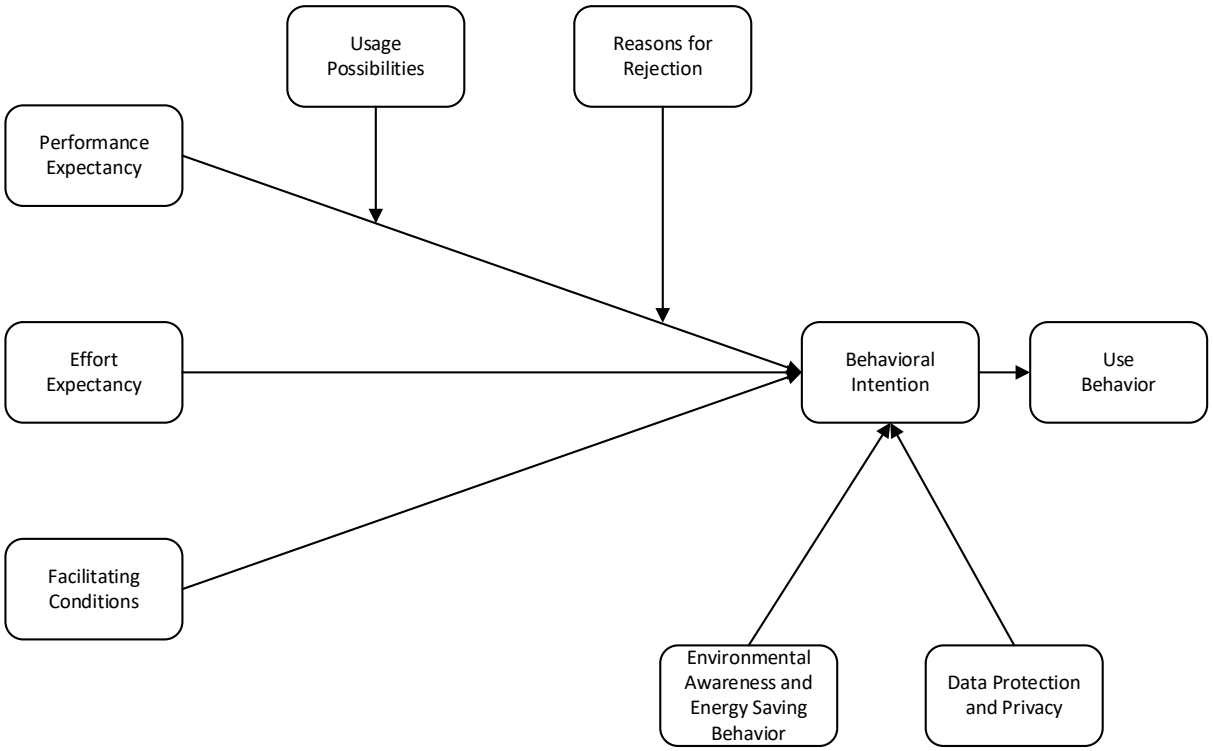

Figure 2 Adapted UTAUT for Smart Home

Based on the adapted UTAUT (Figure 2), the following two questions are derived and seven hypotheses are formed to answer them:

1 Which factors influence the acceptance and use of smart home technology?

H1: The higher the expected performance benefit, the higher the intention to use the technology.

H2: The lower the expected effort of use, the more positive is the intention to use the smart home technology.

H3: The environmental awareness as well as the current energy saving behavior of a person have a positive influence on the intention to use the technology.

H4: The greater the perceived risks regarding data protection and privacy, the lower is the intention to use the technology.

H5: The more usage possibilities are known, the more positive is the expected performance.

H6: The more reasons for rejection are given, the worse is the expected performance.

2: Which business sectors enjoy the greatest trust from the consumers' point of view?

H7: Consumers have different levels of trust in companies from different sectors

4. Research Design

To verify the formulated hypotheses and to answer the research questions posed, an empirical study was conducted in Germany. A population of 53 million people was assumed, who are citizens between 18 and 69 years of age. The assumption is based on the initial situation that tenants and owners of real estate are generally 18 years and older and that in Germany Internet usage, which is a prerequisite for most smart home applications,

drops sharply beyond the age of 69 [14]. Based on the population to be considered and a calculation of the necessary sample size, a minimum number of 272 survey participants was identified. Due to the context of the acceptance object, the use of an online-based questionnaire was appropriate. For this purpose, question constructs were set up which served to directly answer the hypotheses. Exemplary for H3 are "I would describe my general behavior as environmentally conscious" and "I consciously use products that consume less energy". For H7, the question was asked "Who would you entrust your personal data, i.e. usage data, from the smart home to?" with a choice between different provider groups. In addition to questions about the subjective attitude or opinion of the participants statistical data was collected. To operationalize the questions, a six-level Likert scale was invariantly used to enable uniform calculation of sum or average values and better comparability. The extreme points of the scales were labelled "do not agree" and "fully agree". The data collection took place over a nine-week period from 21 October 2019 to 23 December 2019 and was disseminated primarily via social media. A total of 372 people took part in the survey. After adjusting for incomplete and inconsistent data, 286 data sets were used for further analysis. The previously defined sample size of at least 272 participants was thus achieved. To check the reliability of the collected data, a reliability test according to Cronbach's Alpha was carried out before further analysis of the data. It describes the degree of internal consistency of a scale, whereby it can assume values between 0 and 1 [15]. Generally, values > 0.7 are considered acceptable or good [16]. The alpha coefficient for all constructs is between 0.688 and 0.890. In addition, a factor analysis of the selected questions was performed and all related items that load the same factor were considered for further evaluation. This was primarily carried out using linear regression analyses to map relationships between the interval-scaled variables and to determine the significance of the models.

5. Results

The application of the aforementioned methods results in the following findings for the hypotheses formulated in Chapter 3:

Table 1 Empirical Results

	Coefficient of Determination R^2	F-statistics	Sig. (p-values)	Regression Coefficient B	t-statistics	Sig. (p-values)	Confirmed
H1	0.495	277.97	0.000	0.905	16.67	0.000	Yes
H2	0.141	46.52	0.000	0.636	6.82	0.000	Yes
H3	0.001	0.41	0.520	-0.065	-0.64	0.520	No
H4	0.222	80.87	0.000	-0.613	-8.99	0.000	Yes
H5	0.258	98.84	0.000	0.359	9.84	0.000	Yes
H6	0.106	33.53	0.000	-0.361	-5.79	0.000	Yes
H7	No comparable data due to different survey method						Yes

Please note, that the testing of hypothesis H7 (trust in companies) was carried out by specifying a selection (see below). For this reason, no values similar to the hypotheses H1 to H6 can be derived for H7.

The hypotheses H1 (performance expectancy), H2 (effort expectancy) and H4 (data protection and privacy), which explain the intention to use, are significant and confirm correlations between the variables mentioned and the

intention to use. In addition, H5 (usage possibilities) and H6 (reasons for rejection), which support the expected performance (H1), can also be confirmed. The most striking results are described below.

Hypothesis H3 has a particularly poor model quality with $R^2 = 0.001$ and is not significant ($F = 0.41$; $p = 0.520$). In addition, the regression coefficient does not explain any relationship between the criterion variable and the predictor variable either and is not significant ($B = -0.065$; $T = -0.64$; $p > 0.05$). Hypothesis H3 is therefore rejected. According to this, the influence of personal environmental awareness and energy saving behavior has no relevant influence on the intention to use. For this reason, the factors environmental awareness and energy saving behavior in Figure 2 must be questioned.

Hypothesis H7 (trust in companies) was used to answer the second question. To test hypothesis H7, the survey participants were given the opportunity to choose from categories of providers of smart home technology. Possible was a multiple choice as well as to answer not to trust any of the presented categories of providers at all. Additionally, the general willingness to share data was asked.

Figure 3 shows that there are two major groups with regard to the general willingness to share personal usage data. On the one hand those who do not agree at all (42%) to share their data and on the other hand those who would share their data depending on the provider (43%). A minority of around 7% said that they would agree generally to the disclosure of their personal data. The "don't know" option was chosen by 9%. Depending on the available response options for trust in provider categories, most respondents chose not to trust anyone (62%) with their data. Among the respondents who would share their usage data, utilities lead the list of providers with around 60%. 27 percentage points behind them follow manufacturers of electronic equipment (see Figure 4). Internet companies enjoy the least confidence. The H7 hypothesis can therefore be confirmed.

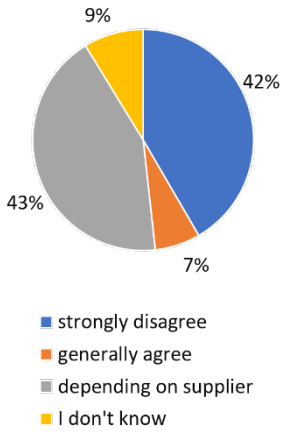

Figure 3 Willingness to Share Personal Data

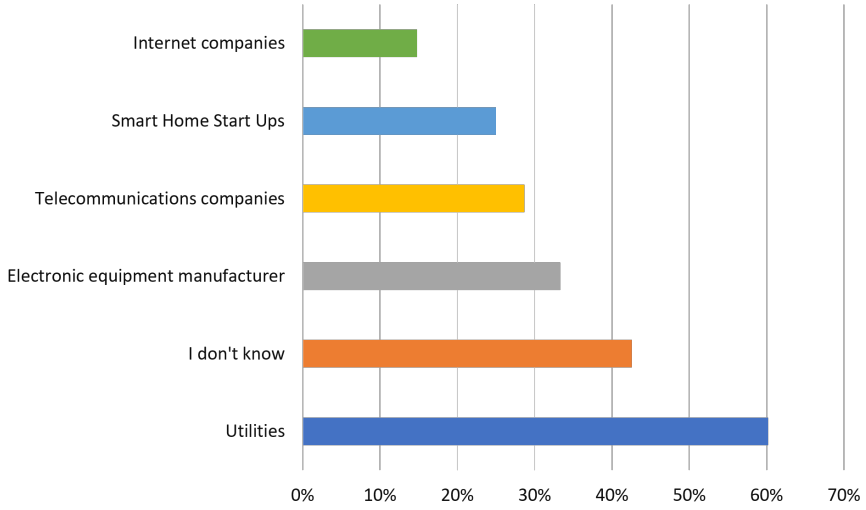

Figure 4 Trust in Providers

6. Related Work

Since a smart home is an information system consisting of users and technology, the analysis of user acceptance with regard to the technology has been the subject of research since the beginning of the development of the technology mentioned above. The results of this research are comparable to the contribution of this paper and are described below.

Bradfield et al. use a survey to analyze the perceptions and needs of homeowners in South Africa regarding smart home technology to monitor and improve the energy efficiency of their homes [17]. The results show that smart home technology strengthens homeowners' perceptions of energy consumption, although knowledge about the technology is very limited among the homeowners surveyed. The respondents show general interest, but see a seamless implementation as a prerequisite. Furthermore, the improvement of the quality of life is seen as a further potential. This paper examines the impact of the technology rather than the acceptance factors that are investigated by this paper.

Guhr et al. answer with their paper the question "How do users' concerns for information privacy influence the intention to use SH (smart home) devices?" [18] Comparable to the methodology of this paper, Guhr et al. base their approach to assess privacy concerns on TAM and formulate 7 hypotheses, which are validated with an empirical study. The results show that privacy concerns can influence the use of smart home technology. The authors emphasize the need to expand their research to investigate further factors influencing the acceptance of smart home technology. This paper provides the mentioned extension.

Analogous to the previously mentioned contribution, the work of Park et al. is also based on TAM [19]. The authors formulate 12 hypotheses to investigate the motivation for using smart home services. For this purpose, an Internet study was conducted in South Korea. The results show that the perceived compatibility, connectivity, control, system reliability and enjoyment of smart home services are positively related to the intention to use them, while there is a negative relationship between perceived costs and the intention to use them. The results are comparable with this paper, which examines the German market and addresses further hypotheses H3 and H7.

Singh et al. investigate the attitudes and perceptions of future smart home users on the basis of an online survey with 234 participants [20]. Improving quality of life and safety were perceived as potential benefits of the technology. In contrast, dependence on technology and observation of private activities were perceived by the respondents as alleged disadvantages. In contrast to this paper, the necessary aspect of user acceptance is not systematically considered in the mentioned contribution. The theoretical approach also differs, as the authors conduct their research without formulating and testing hypotheses.

7. Conclusions and Outlook

For the smart home technology, which is regarded as a growth industry, this analysis of the German market has examined which factors influence the acceptance and use of smart home technology and which potential providers consumers trust most.

The Technology Acceptance Model by Davis [8] and the Unified Theory of Acceptance and Use of Technology by Venkatesh [6] were, based on literature, further developed to answer these questions for the domain smart home. 7 hypotheses were derived from this adapted UTAUT and tested in an empirical study.

As anticipated, it could be confirmed that the intention to use the smart home technology is positively influenced by the expected performance, the effort expectancy and the usage possibilities, while a negative influence comes from the perceived risks regarding data protection and privacy and from the number of known reasons for rejection.

However, despite the global importance of environmental topics and climate change, a connection between environmental awareness and the intention to use smart home products could not be confirmed.

This suggests that the smart home should be seen first and foremost as a convenience product, whose potential environmental benefits, at least at this stage of a still young technology, are at best only a side issue, while confidence in the security of data being assumed to be the sticking point for its further spread.

Fittingly, the study confirms the hypothesis that different providers are given different levels of trust. It is noticeable that utilities show a clear confidence advantage over manufacturers of electronic devices, telecommunications companies and smart home startups.

Whether the existing proximity of smart home technology to energy consumption, where a relationship with the energy company already exists, plays a role in this or the comparatively regional roots of many energy companies in the German electricity market could be the subject of further analysis.

The particular trust that consumers place in utilities with regard to the security of their data could form the basis for research into new business models driven by utilities in the smart home market, which could be developed, for example, in the context of the roll-out of smart metering systems.

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