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Do smart homes influence individual performance?

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Dissertation presented as partial requirement for obtaining the Master's degree in Statistics and Information Management

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DO SMART HOMES INFLUENCE INDIVIDUAL PERFORMANCE?

by

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DEDICATION

I dedicate this dissertation to the ones that made it possible: My parents, for providing me with all the tools and resources without which I would not be able to get this far. My grandparents who always believed in me and gave me all the help I needed to complete this cycle in my life. And last, but not less important, my girlfriend for always being by my side and never letting me give up.

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ABSTRACT

The penetration of smart home devices in people's homes have increased and multiple studies have been done regarding its health, financial and environmental benefits. Given the lack of studies on the psychological and wellbeing benefits, we study if there is an influence of the use of these devices on individual performance, while also studying the main factors influencing the perceived value of this technology. The results of 175 users of smart home devices, show usefulness, enjoyment and perceived fee to be the main dimensions involved in the perceived value of this technology, while its use positively effects individual performance.

KEYWORDS

Internet of things (IoT); Smart Home; Value-based adoption model (VAM); Task technology fit (TTF); Individual performance

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LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|------------|---|
| IoT | Internet of Things |
| TAM | Technology acceptance model |
| TTF | Task technology fit |
| VAM | Value-based adoption model |
| ICT | Information and communications technology |
| IT | Information technology |
| YoY | Year-over-year |

1. INTRODUCTION

The way we live and use technology is changing at a fast rate. We have smartphones, smart TV's and everything in our lives is quickly becoming smarter, including our homes, in a series of products related to the concept of the Internet of Things (IoT). The IoT represents the concept of connecting any device into the network, giving us the possibility of controlling it remotely and monitoring its activities. This concept, that can go from a simple coffee maker to a jet engine of an airplane, had worldwide market representing 24 billion USD and the forecast points to 41 billion USD by 2020 (Statista, 2016). According to Statista (2019), the smart home market had a worldwide revenue of US\$53,2m (+42% YoY), with a total of 101,5m smart homes. In Europe, the revenue was US\$12,5m (+43% YoY), having 24,8m of smart homes. There is not any data available for Portugal regarding this topic. According to a study done in the UK by GfK associated with techUK (TechUK & GfK, 2017), smart homes contain multiple dimensions of connectivity that can facilitate the life of its users: Smart Entertainment, which is appealing to 47% of the respondents, with the cost and the privacy issues still being the main barriers; smart Energy, with 55% agreeing that they changed their environmental behaviour after owning a smart meter; smart health, being appealing to 34% and the strongest category in which peoples don't see any barriers; smart monitoring and control, that is appealing to 37%; smart appliances, appealing to 28% is the category where the price is the bigger barrier. In general, since 2016 cost has been raising as the top barrier to acquire smart home systems, with privacy in 2nd place. Security issues however have raised to the top three concerns in 2018.

Smart home devices have shown benefits in multiple dimensions: Regarding health, smart home devices can provide a cost-effective way to monitor and providing comfort to the elderly and disabled (Chan, Estève, Escriba, & Campo, 2008). These devices also have the capability of reducing and monitoring energy usage, making these devices good to the environment (Aye & Fujiwara, 2014; Balta-Ozkan, Boteler, & Amerighi, 2014; Beaudin & Zareipour, 2017; S. Chen et al., 2017; Elkhorchani & Grayaa, 2016; Kyriakopoulos & Arabatzis, 2016; Zhou et al., 2016) and also to its users finances by providing a way of using energy on a more efficient way (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013; Darby & McKenna, 2012; Hargreaves, Nye, & Burgess, 2013). The last and least studied dimension in which smart home devices have been considered to be benefic is the psychological and social wellbeing of individuals, with some interesting studies showing that this technology can help users overcome the feeling of isolation (Chan et al., 2008; Demiris et al., 2004; Percival & Hanson, 2006). Some studies have also been done in this domain with negative conclusions like the idea that people may not want these kinds of technologies for fear of being stigmatized as vulnerable people (Damodaran & Olphert, 2010; Demiris et al., 2004) or even the negative impact that the absence of face-to-face communications can have on an individual's social life.

The biggest motivation for this research resides in the fact that the effect of smart home devices on the psychological and social wellbeing of individuals have been the least researched dimension (Marikyan, Papagiannidis, & Alamanos, 2019), with specifically no studies done regarding the effect on individual performance, to our best knowledge. By using the task technology fit (TTF) model (Goodhue & Thompson, 1995), we will try to the measure the impact of this technology on performance of users from the fit of it to the tasks that exist in an household environment.

Based on that, our contributions are threefold: First, to the best of our knowledge, there are no studies on individual performance in a smart home environment, which we explained by studying the effect of perceived value, use and TTF on this construct. Secondly, we explained which benefits and sacrifices define the perceived value of smart home devices, concluding that on the benefit side, usefulness is the most important factor, followed by enjoyment. Regarding the sacrifices, only perceived fee influences perceived value, unlike technicality. The last contribution of this paper would be the mediation role of use between the relationship of perceived value and TTF and individual performance, which allowed us to conclude that the perceived value and the fit of this technology for the tasks provided not only impact individual performance by themselves, but also have an effect through the use of the devices – the mediation effect. We also investigate perceived value that moderate individual performance. By analyzing the mediation and moderation effects we may understand previous beliefs and behaviors relating smart homes to individual performance.

In the next section of this document, the concept of smart homes and individual performance will be reviewed, with the research model being presented and discussed in the following. Then the methodology and the results of the model will be presented, followed by the discussion of the theoretical and managerial implications of the study.

2. LITERATURE REVIEW

2.1. SMART HOMES

Smart homes are according to Balta-Ozkan, Amerighi, and Boteler (2014), residences equipped with a network, sensors, devices and other technology that provide help to its inhabitants. The range of devices that compose a smart home can go from a simple toaster or a light bulb to a television or a phone, given that all those devices must be connected to a network to be remotely coordinated and store information. According to the same authors, there are three main dimensions involved in this kind of services, which are security, energy spending and management and lifestyle support. Marikyan, Papagiannidis, and Alamanos (2018) accept and complement this definition by defining three types of smart home technology services, according to their principles: The first one provides help to the inhabitants of the home by recognizing their actions. This help can be in the form of care provided to an older population, assisting in childcare and even monitoring overall health. The second type of smart home services is related to the detection and gathering of videos and photos about people's lives, with the third one being the type that guarantees security and surveillance. There is however a fourth type of smart home technology gaining popularity, with the promotion of environmental stability, monitoring and alerting towards this goal.

There are multiple types of smart home devices, which can provide several types of benefits. Starting with health, these technologies can be a cost-effective way of ensuring home care for the aging and disabled people, by improving the comfort of the inhabitants, monitoring vital activities and even dealing with medical rehabilitation (Chan et al., 2008). Besides that, with today's focus on environmental issues, smart homes have clearly emerged as a technology capable of reducing and monitoring energy consumption in a domestic setting (Aye & Fujiwara, 2014; Balta-Ozkan, Boteler, et al., 2014; Beaudin & Zareipour, 2017; S. Chen et al., 2017; Elkhorchani & Grayaa, 2016; Kyriakopoulos & Arabatzis, 2016; Zhou et al., 2016). Financially, there are also a lot of benefits that can be gained from the adoption of these technology, which are mainly related to the health and environmental benefits mentioned earlier. By being able to analyse the consumption of electrical devices, one's able to reduce that consumption willingly (Balta-Ozkan et al., 2013; Darby & McKenna, 2012; Hargreaves et al., 2013) and compare his tariffs with other providers (Darby & McKenna, 2012; Faruqui, Harris, & Hledik, 2010). In terms of health monitoring, there are also room for cost reductions, by focusing on homecare which can result in cost saving for users (Ehrenhard, Kijl, & Nieuwenhuis, 2014). Aside from all the benefits mentioned, smart homes can also bring positive factors when it comes to psychological wellbeing and social inclusion, by having an important role in socialization and helping the users beat the feeling of loneliness (Chan et al., 2008; Demiris et al., 2004; Percival & Hanson, 2006). By providing aid to its users with everyday's activities, it affects self-perception in terms of self-confidence, adaptability and competence. However, some negative flags have been raised, with some studies claiming that users may not want to use this kind of technologies due to being stigmatized as vulnerable people (Damodaran & Olphert, 2010; Demiris et al., 2004) and others reporting that the replacement of face-to-face communication can have impacts in user's social life (Damodaran & Olphert, 2010). More recently, it has been shown that the perceived social support in a smart home can be improved by the social connectedness between the user and its devices (Yang, Lee, & Zo, 2017).

Some studies have been done recently on user acceptance of smart home devices, proving that attitude, subjective norm and perceived behavioural control are the three main factors involved in the intention to use this kind of technology. On the negative side, attitude seems to be affected by privacy risk, while the physical risk did not have the same effect (Yang et al., 2017). However, there is still some resistance regarding the adoption of this kind of innovation products, with performance expectancy and social pressure as being the main factors able to reduce this resistance and ensure the success of the market. This resistance has been found to be less impactful regarding younger and male individuals (Juric & Lindenmeier, 2019).

Based on the systematic review done by Marikyan et al (2018), regarding the possible and perceived user benefits of smart home adoption, there has been a clear predominance of papers with a focus on the health-related benefits of smart homes, in which can be considered functions of comfort, monitoring, consultancy and support delivery therapy, for instance. The environmental benefits of this new technology have been the most second studied dimension, followed by financial benefits. Having said this, there has been a benefit of smart homes which has been clearly understudied: The benefits in psychological wellbeing and social inclusion, which focus mainly on the service of support (Marikyan et al., 2019). There is clearly a gap regarding this benefit, which may be of extremely importance, which is the reason for why this will be the focus of this study.

2.2. INDIVIDUAL PERFORMANCE

Wellbeing has always been studied with two historical views. One of them is the hedonic view, which assumes that happiness and pleasure are the ultimate objectives of life. This approach has been studied and reinforced by many philosophers along time, mainly with a focus on physical pleasures as the main expression of wellbeing (Ryan & Deci, 2001), with this concept being explained as the balanced relationship between the positive and negative affect (Bradburn, 1969). This view converged into what is called Subjective Wellbeing, which tries to explain wellbeing with the satisfaction with life, existence of a positive attitude and absence of a negative one. However, psychologists who adopted this view, have been more fixated on a broader conception of hedonism, considering not only the physical but also psychological pleasures (Baum & Shevchenko, 1999). Opposed to this view was the eudaemonic approach to the concept of wellbeing, where happiness stopped being the goal and started to be merely a criterion to attain it (Ryan & Deci, 2001). It has since been thought in different ways beginning with a focus on life satisfaction as the key indicator of wellbeing (Andrews & McKennell, 1980).

The study of individual performance has first been proposed by Zmud (1979), who described this as one of some gaps in the literature regarding the use of information systems (IS), and has almost exclusively been looked at in an organizational level, while the technology considered has been mostly prominent in workplaces. DeLone and McLean (1992) are responsible for the widely used theory explaining individual performance as dependent variable of the use of IS, in which they consider the interrelation between use and user satisfaction as predictors of the individual impact.

Later, to further mitigate the gap in the literature between the use of IS and individual performance, Goodhue and Thompson (1995) proposed a model, similar to the one proposed by DeLone and McLean (1992), while adding the importance to how TTF in the explanation can have an effect in the

use of IS and on the performance of the individuals, which is also affected by the use itself. The results found strong evidence that both TTF and use of the technology are important constructs when explaining individual performance. Nonetheless, authors found a difference between the scenario in which individuals are using a system as an obligation or when they are using it voluntarily, with the latest group showing an effect of TTF on use.

The study of individual performance has been done mostly on an organizational level, however aside from work, people also have tasks at home and thus have a need to do them more efficiently. New technology has been linked to individual performance on a more personal level. A good example is the paper published by Tam and Oliveira (2017), where the use of mobile banking has shown a significant effect on the performance of its users. In this paper, we will also focus on this domestic dimension of individual performance by trying to understand how the use of smart homes can help individuals develop tasks more quickly.

3. RESEARCH MODEL

Figure 1 shows the proposed model of this study, in which the final objective resides in explaining how the use of Smart Home Devices affects the individual performance of individuals. In order to evaluate this relationship, we will recur to the Task Technology Fit model, which aims to explain individual performance by considering how well the technology fits the task in question and how much the technology is used (Goodhue & Thompson, 1995). Use also has a mediating effect between TTF and individual performance, which we will also use in our model. The purpose behind the use of both these models reside on the fact that each focus on different dimensions that complement each other. The value-based adoption Model (VAM) is used to evaluate the variants of adoption intention of smart homes as an ICT, assuming that smart home users and not merely technology adopters, but also consumers of this specific service. Part of this framework has also been integrated our model, in order to also obtain information regarding perceived value on the use of Smart Home devices, which hasn't been researched before. Chen and Lin (2015) have studied and found a positive effect of perceived value of blogs on continuance intention to use. All connections to perceived value are adapted from the VAM (H. W. Kim, Chan, & Gupta, 2007), which originated from technology acceptance model (TAM), with a bigger focus on the new information and communications technology as opposed to the more traditional technologies. As the technology studied in this paper is aimed for personal use and voluntary adoption, it is good to consider not only the benefits but also the sacrifice factor involved in this usage, to correctly estimate the perceived value recognized by individuals when using smart home devices.

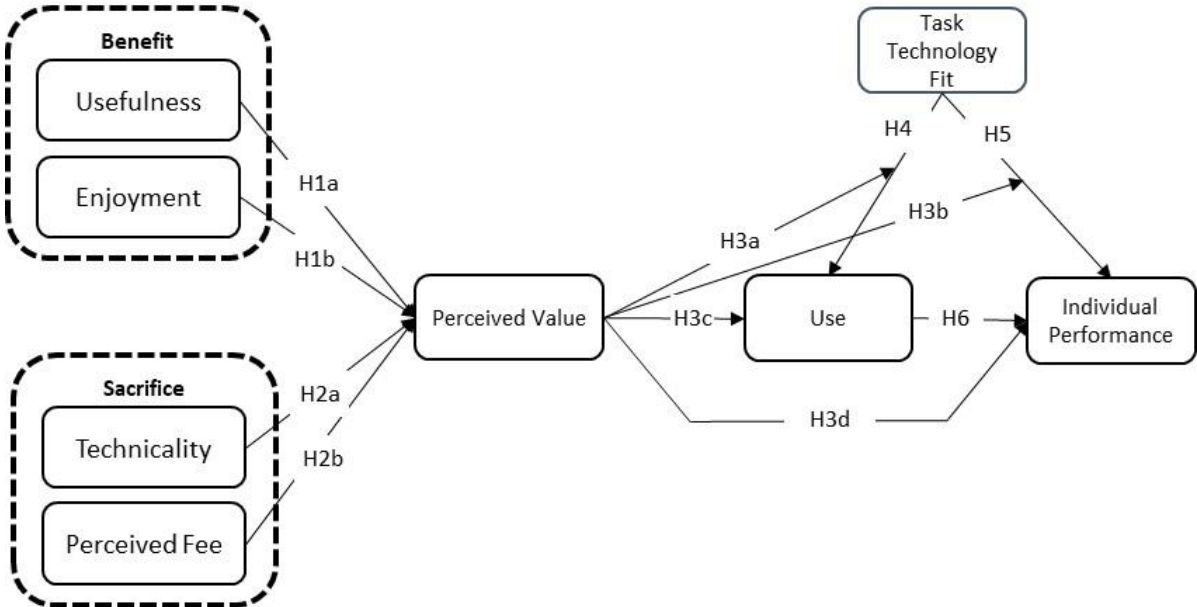


Figure 1 - Research Model

According to the research made by Kim, Chan, and Gupta (2007) our motivation to execute a task can be extrinsic and intrinsic. The first implies that we're executing that task with a specific objective in mind, while the second focus on the benefits that derive from the process itself. In practical terms,

the hypothesis suggested the way we perceive something can be both affected by how useful it will be to us and by how much we enjoy the process of using it. Perceived usefulness has in fact been shown to have an effect on perceived value regarding mobile internet acceptance between university students was found by Roostika (2012). Later, Yang, Yu, Zo, and Choi (2016) found a positive relationship between perceived usefulness of wearable devices and their perceived value. Regarding the more intrinsic benefit, perceived enjoyment, there have also been some studies showing a relationship to perceived value. For instance, it has been found when studying the acceptance of mobile coupon applications (Liu, Zhao, Chau, & Tang, 2015), and the factors affecting the adoption of self-customization services (Yu, Seo, & Choi, 2019). Thus, we hypothesize:

H1a – Usefulness has a significant effect on perceived value

H1b – Enjoyment has a significant effect on perceived value

To correctly assess the big influencers of perceived value, we cannot only consider the perceived benefits, but also the sacrifices that exist when using the technology, which can be monetary or non-monetary (Kim, Chan, & Gupta 2007). The non-monetary one we will be using in our model, based on VAM, is technicality, which represents its users' perceptions of ease of use. This relationship can be found in the literature regarding for instance the continuous intention on accommodation apps (S. H. Kim, Bae, & Jeon, 2019). Before that Ozturk, Bilgihan, Nusair, and Okumus (2016) also found a positive effect between ease of use and perceived convenience. The monetary sacrifice we will consider is perceived fee, since it represents all the costs associated with the use of smart home devices relative to the benefits this service provides, which is also usually referred to as value-for-money. The perceived fee of wireless short messaging devices has been found related to perceived value (Turel, Serenko, & Bontis, 2007). This same relationship has been confirmed by Yu et al. (2019) regarding self-customization services. Thus, we hypothesize the following:

H2a – Technicality has a significant effect on perceived value

H2b – Perceived fee has a significant effect on perceived value

There has been a general belief that perceived value influences the intention to buy or to use a service (Z. Chen & Dubinsky, 2003; Dodds, Monroe, & Grewal, 1991; Yang et al., 2016). According to Venkatesh, Thong and Xu (2012), when the positive benefits outweigh the negatives, such as cost, the price value has a positive impact on the intention to use a technology. More recently, perceived value has also been found to have a significant effect in the intention to use wireless short messaging services (Turel et al., 2007). Chen and Lin (2015) found a positive relationship between the perceived value of blogs and the intention toward their continued use, while Nascimento et al. (2018) also found the same relationship regarding wearable technology. There has also been confirmed that the perceived value of hedonic digital artefacts is significantly related to the intention to use them (Turel, Serenko, & Bontis, 2010). Based on that, we expect that perceived value could impact on use and individual performance. We therefore hypothesize:

H3a – Perceived value moderates the effects of TTF on use

H3b – Perceived value moderates the effects of TTF on individual performance

H3c – Perceived value has a significant effect on use

H3d – Perceived value has a significant effect on individual performance

Goodhue and Thompson (1995) have shown that TTF not only mediates the effect of use on individual performance, but also has significantly impacts use itself. TTF has been found to predict continuance of use of MOOCs (J. A. Chen et al., 2017). Tam and Oliveira (2019) also found a relationship between the TTF of m-banking and its utilization. Thus, we hypothesize:

H4 – TTF has a significant effect on use

As found by Goodhue and Thompson (1995), in an attempt to fill the gap that existed in the literature regarding the link between IT and individual performance, IT can have a positive impact on this variable given that the technology in question is utilized and is a good fit for the task it supports. In regard to home mobile banking, Tam and Oliveira (2017) have found the effect of TTF on individual performance of its users, and reinforced it on a more recent study where the main objective was to find if culture did influence this relationship (Tam & Oliveira 2019). Thus, we hypothesize:

H5 – TTF has a significant effect on individual performance.

Besides all the findings already mentioned in this study, Goodhue and Thompson (1995) also found that the use of technologies has the ability to add value to individual performance. For instance, the use of mobile banking has been found to have a positive effect on the individual performance (Tam & Oliveira, 2017). Thus, we hypothesize:

H6 – Use has a significant effect on individual performance

The mediating role of use

The advantages suggested here from the use of IT influence the nature of the relationship which contributes to the benefits of use. This mediating function is related to the individual performance for IT usage (Goodhue & Thompson, 1995). Based on this, we also intend to check the mediating role of use in complementing the study of direct effect. In this sense, we hypothesize:

H7a – Use positively mediates the relationship between perceived value and individual performance

H7b – Use positively mediates the relationship between TTF and individual performance

4. METHODS

4.1. MEASUREMENT

In order to measure each construct of this model, the indicators were adapted from literature. Usefulness, enjoyment, technicality, and perceived value were all adapted from H. W. Kim et al. (2007). The rest of the constructs – use, task technology fit, and individual performance were adapted from Tam and Oliveira (2017). Appendix A contains the items for all the constructs.

4.2. DATA COLLECTION

The questionnaire used to collect the data was measured with a scale ranging from 1 (totally disagree) to 7 (totally agree). It was first designed in English, based on literature, and later translated to Portuguese. To ensure translation consistency we translated back to English (Brislin, 1970). A pilot was done to assure the validity of all the indicators and guarantee that the questionnaire was properly designed, with the results showing no problems, which allowed the collection to proceed.

To obtain the data, the questionnaire was designed using Google Forms and shared in a first instance with a mailing list of 4000 students and 41 professors from Southern European universities. The number of responses obtained were 175, which correspond to a response rate of about 4%, not considering the forums, since it was not possible to quantify the number of people who received or saw the link. The data was collected between February 2019 and June 2019, with a reminder being sent in May 2019.

The results of this study are entirely based on smart home devices' users, since it was a prerequisite to answer the survey. The sample is perfectly balanced between males and females, with 64% of it being composed by individuals younger than 36 years. The sample in question has a high level of education, with almost 90% of the individuals having a bachelor or higher. About 60% use smart home devices often or frequently, but 88% of the respondents having 5 or less devices, which is expectable since this market is still at an early stage. Detailed descriptive statistics concerning the characteristics of the respondents are given in Table 1.

Table 1 - Sample characterization

| Characterization (n= 175) | | | | | |
|----------------------------------|----|-----|---|-----|-----|
| Gender | | | Smart Home devices usage frequency | | |
| Female | 88 | 50% | Never | 14 | 8% |
| Male | 87 | 50% | Rarely | 21 | 12% |
| Age | | | Sometimes | 34 | 19% |
| < 25 | 38 | 22% | Often | 60 | 34% |
| 25-30 | 53 | 30% | Frequently | 46 | 26% |
| 31-35 | 21 | 12% | # of devices at home | | |
| 36-40 | 17 | 10% | 2 or less devices | 110 | 63% |
| 41-50 | 34 | 19% | 3-5 devices | 44 | 25% |
| >50 | 12 | 7% | 6-10 devices | 9 | 5% |
| Education | | | More than 10 devices | 12 | 7% |
| High School or below | 20 | 11% | | | |
| Bachelor | 93 | 53% | | | |
| Master's degree or higher | 80 | 46% | | | |

5. RESULTS

The analytical part of this study was conducted using structural equation modeling (SEM), a technique which consists of a combination between one descriptive technique and one explanatory technique, which allow us to simultaneously analyse the measurement part of the model and the structural part that allow us to estimate the latent variables. Since our data does not have a normal distribution, the model will be estimated using partial least squares (PLS), which calculates the scores for each latent variable using an iterative process.

5.1. MEASUREMENT MODEL

The measurement model should be evaluated in order to access the reliability, convergent validity and discriminant validity of its constructs before continuing with the study of the structural model.

To access the internal consistence reliability of the model, the Chronbach's Alpha (CA) and Composite Reliability (CR) should be considered. Looking at Table 3 both values are above 0.8 which indicates a good consistency of the model. As expected, since they were adapted from previous research, all the indicators used in this measurement model are reliable, since all the loadings are above 0.7, as we can see in Table 2.

The convergent validity of the constructs can be analysed by looking at the average variance extracted (AVE), which should be above the threshold of 0.50, so at least 50% of the variance of the indicators are explained by the latent variables (Hair, Hult, Ringle, & Sarstedt, 2017; Henseler, Ringle, & Sinkovics, 2009). As seen on Table 3, the AVE of all indicators is above this value. To access the statistical significance of these values we used bootstrapping techniques and analysed the pseudo t-tests, where we verified that all the loadings for each construct are significant ($t > 2.39$).

Lastly, to access the discriminant validity, the Fornell-Larcker-Criterion should be used, in which the discriminant validity is demonstrated for each pair of latent variables if the AVE for both variables are larger than their squared correlation (Fornell & Larcker, 1981). In this case, this verifies, which combined with the fact that all the loadings for each construct are bigger than the cross loadings (Chin, 1998; Götz, Liehr-Gobbers, & Krafft, 2010; Grégoire & Fisher, 2006), indicates a good discriminant validity in this model. Lastly, we also accessed the Heterotrait-Monotrait ratio (HTMT), and all the values were below the recommended value, which is 0.90 (Henseler, Ringle, & Sarstedt, 2015).

In summary, the proposed model for this research shows a good reliability, convergent validity and discriminant validity, which allow us to proceed to the analysis of the structural model.

Table 2 - PLS Loadings and Cross-loadings

| | USEF | ENJ | TECH | FEE | VAL | TTF | USE | IP |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Usefulness | | | | | | | | |
| USEF1 | .897 | .599 | .459 | .287 | .699 | .569 | .409 | .702 |
| USEF2 | .869 | .528 | .412 | .319 | .589 | .516 | .453 | .668 |
| USEF3 | .921 | .598 | .416 | .255 | .646 | .560 | .442 | .732 |
| USEF4 | .864 | .548 | .423 | .279 | .583 | .519 | .491 | .688 |
| USEF5 | .856 | .534 | .389 | .154 | .565 | .536 | .427 | .715 |
| USEF6 | .911 | .618 | .480 | .308 | .666 | .598 | .504 | .721 |
| Enjoyment | | | | | | | | |
| ENJ1 | .524 | .899 | .493 | .179 | .547 | .583 | .529 | .611 |
| ENJ2 | .495 | .898 | .469 | .237 | .513 | .535 | .538 | .561 |
| ENJ3 | .668 | .919 | .521 | .287 | .660 | .639 | .571 | .712 |
| ENJ4 | .599 | .868 | .555 | .352 | .636 | .515 | .466 | .592 |
| Technicality | | | | | | | | |
| TECH1 | .395 | .499 | .812 | .325 | .416 | .482 | .395 | .412 |
| TECH2 | .177 | .368 | .738 | .216 | .240 | .419 | .250 | .241 |
| TECH3 | .350 | .385 | .775 | .258 | .448 | .517 | .374 | .434 |
| TECH4 | .413 | .490 | .864 | .353 | .486 | .608 | .374 | .491 |
| TECH5 | .477 | .479 | .749 | .425 | .530 | .544 | .415 | .551 |
| Perceived Fee | | | | | | | | |
| FEE1 | .125 | .144 | .238 | .804 | .372 | .201 | .258 | .192 |
| FEE2 | .373 | .334 | .398 | .936 | .617 | .366 | .391 | .393 |
| FEE3 | .265 | .286 | .445 | .938 | .580 | .383 | .346 | .313 |
| Perceived Value | | | | | | | | |
| VAL1 | .503 | .513 | .482 | .689 | .839 | .487 | .410 | .532 |
| VAL2 | .623 | .628 | .544 | .557 | .934 | .617 | .599 | .691 |
| VAL3 | .710 | .623 | .535 | .501 | .945 | .606 | .518 | .731 |
| VAL4 | .722 | .646 | .497 | .478 | .921 | .620 | .560 | .748 |
| Task Technology Fit | | | | | | | | |
| TTF1 | .606 | .631 | .631 | .383 | .631 | .915 | .593 | .716 |
| TTF2 | .612 | .603 | .549 | .235 | .591 | .906 | .594 | .734 |
| TTF3 | .503 | .528 | .635 | .372 | .529 | .871 | .516 | .613 |
| TTF4 | .486 | .500 | .568 | .336 | .540 | .881 | .539 | .634 |
| Use | | | | | | | | |
| USE1 | .397 | .514 | .403 | .486 | .577 | .546 | .829 | .545 |
| USE2 | .451 | .501 | .370 | .250 | .443 | .571 | .845 | .628 |
| USE3 | .446 | .487 | .411 | .233 | .443 | .500 | .828 | .532 |
| USE4 | .406 | .445 | .391 | .282 | .453 | .466 | .823 | .537 |
| Individual Performance | | | | | | | | |
| IP1 | .775 | .657 | .585 | .377 | .727 | .738 | .618 | .950 |
| IP2 | .776 | .692 | .588 | .380 | .770 | .741 | .654 | .959 |
| IP3 | .632 | .565 | .378 | .185 | .549 | .606 | .597 | .850 |

Table 3 - Means, standard deviations, correlations, and reliability and validity measures (CR, CA, and AVE) of latent variables

| | Mean | SD | CR | CA | USEF | ENJ | TECH | FEE | VAL | TTF | USE | IP |
|-------------|-------|-------|-------|-------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| USEF | 5.534 | 1.158 | 0.957 | 0.946 | 0.887 | | | | | | | |
| ENJ | 5.282 | 1.343 | 0.942 | 0.919 | 0.646 | 0.896 | | | | | | |
| TECH | 4.978 | 0.993 | 0.892 | 0.851 | 0.487 | 0.572 | 0.789 | | | | | |
| FEE | 3.892 | 1.241 | 0.923 | 0.877 | 0.303 | 0.300 | 0.417 | 0.895 | | | | |
| VAL | 4.990 | 1.227 | 0.951 | 0.931 | 0.708 | 0.665 | 0.565 | 0.602 | 0.911 | | | |
| TTF | 4.877 | 1.325 | 0.941 | 0.916 | 0.621 | 0.636 | 0.665 | 0.368 | 0.643 | 0.893 | | |
| USE | 4.128 | 1.780 | 0.899 | 0.851 | 0.511 | 0.587 | 0.473 | 0.379 | 0.577 | 0.629 | 0.831 | |
| IP | 5.175 | 1.410 | 0.944 | 0.909 | 0.794 | 0.696 | 0.569 | 0.349 | 0.748 | 0.758 | 0.676 | 0.921 |

5.2. STRUCTURAL MODEL

With the measurement model validated and the guaranty that every assumption is met, we should start by analysing the significance of all the paths in the structural model. Similarly, to the measurement model, given the fact that PLS is not a parametric estimation model, we must bootstrap in order to simulate a population and be able to tell the significance of the paths. Figure 2 shows the model results. Multicollinearity was also verified and was not a problem, since VIF was below the threshold of 5.

This model explains 71.6% of the variation in perceived value, with usefulness ($\hat{\beta} = .393$, $p < .001$), enjoyment ($\hat{\beta} = .259$, $p < .001$), and perceived fee ($\hat{\beta} = .377$, $p < .001$), supporting H1a, H1b, and H2b. Technicality does not show a significant effect on perceived value, H2a has not confirmed.

The model also explains 44.7% of the variation in use. Perceived value ($\hat{\beta} = .295$, $p < .001$) and TTF ($\hat{\beta} = .440$, $p < .001$) both have a statistically significant effect on use, supporting H3a and H4. The moderation effect of perceived value in the relationship between TTF and use is not significant, thus H3a has not confirmed.

The model explains 73.2% of the variation in individual performance. Perceived value ($\hat{\beta} = .372$, $p < .001$), TTF ($\hat{\beta} = .371$, $p < .001$) and use ($\hat{\beta} = .200$, $p < .001$), the moderation effect of perceived value in the relationship between TTF and individual performance ($\hat{\beta} = -.165$, $p < .05$), so H3b, H3d, H5, and H6 has confirmed.

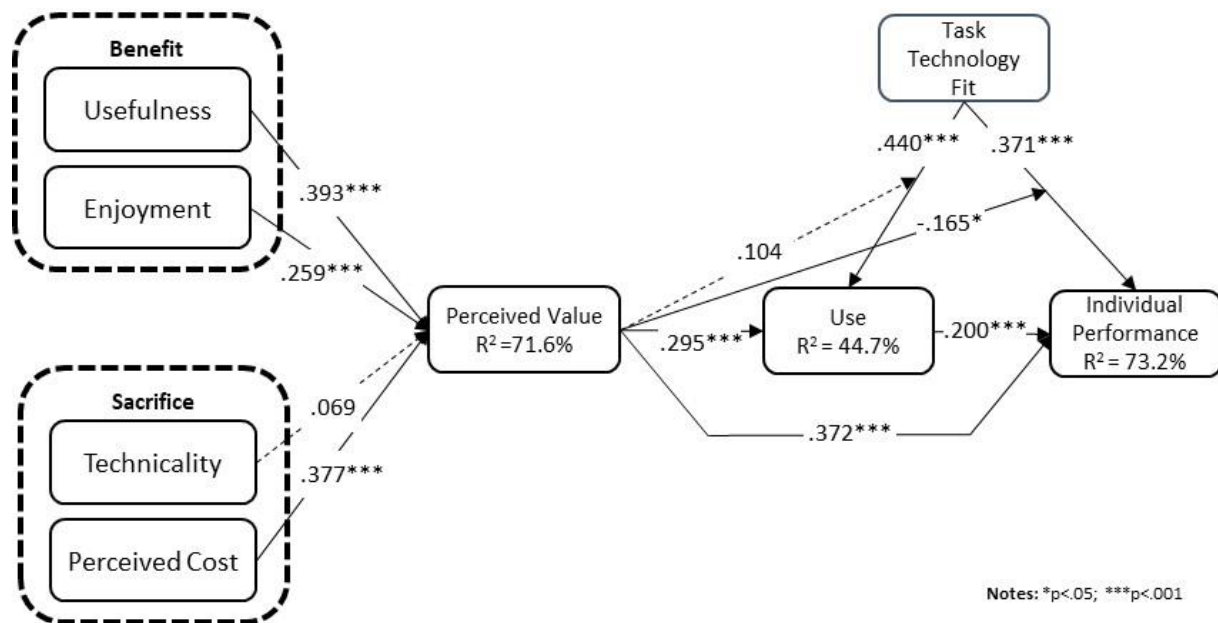


Figure 2 - Results of the Research Model

The findings of the use mediation review are shown in table 4. The role played in the relationship between two variables by a third variable – one independent and one dependent – is called mediation role or indirect effect (Hair et al., 2017). Perceived value has a direct impact on individual performance, but also through use indirectly, thereby confirming H7a, which means partial mediation effect. Confirming H7b, use mediates the relationship between TTF and individual performance. The study also indicates a complementary mediation since both the direct and indirect effects are significant and point in the same direction.

Table 4 – Mediation analysis

| | Beta | SD | t-Test | p-value |
|--|------|------|--------|---------|
| H7a – Partial mediation | | | | |
| (P1) Perceived value -> Use | .296 | .074 | 4.023 | <.001 |
| (P2) Use -> Individual performance | .205 | .058 | 3.523 | <.001 |
| (P3) Perceived value -> Individual performance | .434 | .070 | 6.237 | <.001 |
| (P1*P2) Perceived value -> Use -> Individual performance | .061 | .023 | 2.595 | <.05 |

H7b - Partial mediation

| | | | | |
|--|------|------|-------|-------|
| (P1) TTF -> Use | .440 | .074 | 5.987 | <.001 |
| (P2) Use -> Individual performance | .205 | .058 | 3.523 | <.001 |
| (P3) TTF -> Individual performance | .457 | .077 | 5.951 | <.001 |
| (P1*P2) TTF -> Use -> Individual performance | .091 | .031 | 2.947 | <.01 |

6. DISCUSSION

This research was driven by one general research question: What influences the individual performance of smart homes? To answer this question, this study provides a theoretical framework for investigating the salient context of individual performance at smart homes. Our results show, with the exception of H2a and H3a, that they support our hypotheses. The research model accounts for 73.2% of individual performance variation. Compared the variation of individual performance with other investigations applying TTF model (e.g. (Tam & Oliveira, 2019)), our results are compatible. Our findings also provide evidence that individual performance is a function of perceived value, use and TTF, which in turn proves how smart homes add value to individual performance.

6.1. THEORETICAL IMPLICATIONS

The findings of this study are very similar to those obtained in the study by Kim et al. (2007) in the original value adoption based model, with all the benefits, usefulness and enjoyment being found to have a significant effect on perceived value. Where our results slightly differ from Kim et al. (2007), is regarding technicality, which does not show an effect on perceived value when this model is applied to the reality of smart homes, contrary to what was proposed in their original VAM Model. The explanation for this phenomenon may be that in one side people are becoming more digital, which leads to an easier use of this devices, thus not having an impact on their perceived value, while on the other side, they are more open to this kind of technological experiences. Perceived fee has also shown a positive effect, which confirms the findings of the previous studies mentioned in this paper (Turel et al., 2007; Yu et al., 2019). In fact, the effect of value-for-money on perceived value has been studied for large years, with Zeithaml (1988) arguing that some consumers' perception of value is related to low price while others' is related to a good balance between price and quality. This study also found a direct positive relationship between perceived value and use, which complements the relationship proposed by Turel et al. (2010), where perceived value's effect was only tested regarding behavioural intention, which was then connected to use, only explaining 10% of this construct. The model proposed in this study explains 47% of use of smart home devices, by considering their perceived value and the task technology-fit.

Finally, the greatest contribution of this study to literature is the positive effect between the use of smart home devices on individual performance, since this construct belongs to the field of psychological wellbeing and social inclusion, which has been the least studied according to Marikyan et al. (2019) literature's review on this thematic. Individual performance has been found to be of high importance to organizations and for the individuals working for it (Sonntag, 2002). Since in this paper we are looking at the individual on a personal level and at home as the organization where the tasks are developed, the use of smart home devices can in fact have a very significant impact on the efficiency of task development at home. Additionally, we found the use of smart home devices to be a mediator of the effect between perceived value and individual performance, which suggests that the use of these kind of devices may be governing the nature of the relationship between the perceived value of this technology and the increase of performance that people perceive. Figure 3 shows the impact of statistically significant moderators, the perceived value over TTF to individual performance. The perceived value moderator suggests the major impact of TTF over individual

performance among users with low perceived value. When the moderating effect of perceived value is included to predict individual performance, the adjusted R^2 is 71.9%. Without the moderating effect, the variation of individual performance is 71.2%.

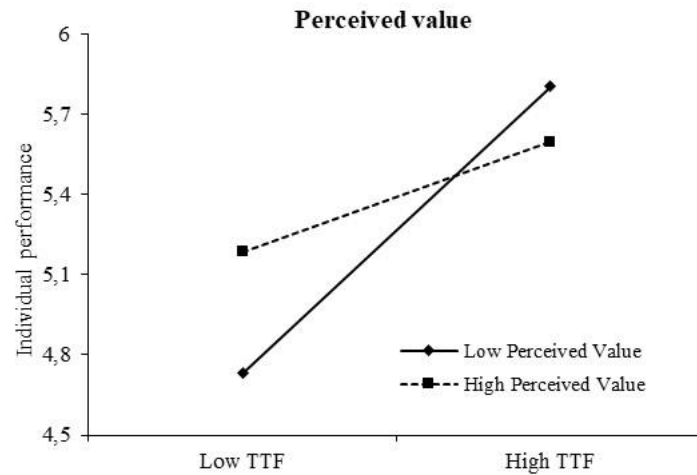


Figure 3 - Moderation effect of perceived value and TTF on individual performance

6.2. MANAGERIAL IMPLICATIONS

The conclusions of this study reinforced that smart home devices need to be primarily useful for their users, but also enjoyable, which correlates with the findings of a study carried out by the market research firm CCS Insight (2017) on smart home users, in which was found that “control when away from home” and “convenience” are the most important reasons for purchase. This combined with a low perceived cost associated with this equipment will increase their perceived value as whole. In fact, users seem to value this kind of devices more from a utilitarian point rather than for enjoyment. With task technology fit having the biggest effect on use, managers should focus on making devices that are useful for their users and efficiently take care of the tasks they are designed to.

What is observed in this study is not only relevant for marketing and design teams, being extremely important for health care services, especially those who work with older or disabled people. Use had a very positive effect on individual performance, which was mediated by the fit of the technology to the task at hand. Given that these segments are the ones who would benefit greatly from an increase in their performance and individual wellbeing, which will increase along with their use of smart home devices, moreover if their functionalities respond to the expectations.

In terms of products, there are many solutions that companies could focus on, with voice assistants being one of the most important, as it can make a lot of tasks easier, like turning off the lights, turning on the music, making calls and so on, therefore highly improving at-home efficiency. There is also space for smaller products that can improve the productivity of individuals, mainly called smart task assistants, which is a line of products that can go from smart sticky notes – tiny screens with e-

ink which can be fed information from other devices - or even smart watches – while not properly a smart home device, this device can be highly connected to a smart home and be used to interact with it.

Lastly, there is a huge window of opportunity for telcos to enter this business and sell bundles of smart home devices. For Statista (2019) this technology still only has about 7% penetration as it is still not easy enough for the average customer to buy and integrate this product into a single ecosystem, which leaves a space open for telecom companies create their own ecosystem with their own products. Not only can this open a new market for these products, it can also leave an opportunity for the upselling of extra security solutions.

7. CONCLUSIONS

Literature on Smart Homes have been done, focusing mainly on its health, environmental and financial aspects. Nonetheless, smart home devices are also believed to have an important part in improving aspects of its users' lives when it comes to social inclusion and psychological wellbeing. In this study, it was concluded that the use of these IoT devices in fact increases its users' individual performance, and that its use increases the more efficient these devices are in finishing the tasks they were designed to. In addition, the perceived value has also been confirmed to have a significant effect on the use of such devices. To conclude, perceived value has shown to be affected by usefulness, enjoyment and price value, which confirms the value adoption-based model. However, technicality did not show a significant effect, which contradicts this theory.

The insights provided by our model provide valuable contributions to companies who which to invest in this technology: First and foremost, it demonstrates that the production of smart home devices should concentrate above all else on functionality, while making them fun to use. There is a wide range of products that companies could focus that can be extremely useful while also being fun, like voice assistants or even smart lights. The impact that these devices have on its users' performance, also make them very useful for healthcare services, mainly those who work with disabled or older people.

The main limitation of these study, as many others, was the sample used. The universe considered was mainly composed from colleagues and teachers from Southern European universities, since according to Remus (1986), students represent typical consumers, and also users from online forums specialized on the topic. Even though, we had to recur to this samples due to the difficulty in finding users of smart homes, the sample we obtained is undoubtedly more educated than the general population. In order to better understand how the whole market could be accessed and how the use of this technology could affect the population, more research should be done on a more heterogeneous sample. This study collected data at single point of time frame, which measure the cross-sectional perceptions. Longitudinal studies are welcome, which allow us to evaluate the perceptions over the time.

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9. APPENDIX

| Construct | Item | Description | Adapted from |
|------------------------|-------|---|--------------------------|
| Usefulness | USE1 | Using Smart Home devices enables me to accomplish tasks more quickly | (H. W. Kim et al., 2007) |
| | USE2 | Using Smart Home devices enhances my task effectiveness | |
| | USE3 | Using Smart Home devices makes it easier to do my task | |
| | USE4 | Using Smart Home devices improves my task performance | |
| | USE5 | Using Smart Home devices saves me time and effort in performing tasks | |
| | USE6 | Smart Home devices are useful in performing my task | |
| Enjoyment | ENJ1 | I have fun interacting with Smart Home devices | (H. W. Kim et al., 2007) |
| | ENJ2 | Using Smart Home devices provides me with a lot of enjoyment | |
| | ENJ3 | I enjoy using Smart Home devices | |
| | ENJ4 | Using Smart Home devices bores me (reversed) | |
| Technicality | TECH1 | It is easy to use Smart Home devices | (H. W. Kim et al., 2007) |
| | TECH2 | Smart home devices can be connected instantly | |
| | TECH3 | Smart home devices take a short time to respond | |
| | TECH4 | It is easy to get Smart Home devices to do what I want it to do | |
| | TECH5 | The system of Smart Home devices is reliable | |
| Perceived Fee | FEE1 | The fee that I have to pay for the use of Smart Home devices is too high | (H. W. Kim et al., 2007) |
| | FEE2 | The fee that I have to pay for the use of Smart Home devices is reasonable (reversed) | |
| | FEE3 | I am pleased with the fee that I have to pay for the use of Smart Home devices | |
| Perceived Value | VAL1 | Compared to the fee I need to pay, the use of Smart Home devices offers value for money | (H. W. Kim et al., 2007) |
| | VAL2 | Compared to the effort I need to put in the use of Smart Home devices is beneficial to me | |
| | VAL3 | Compared to the time I need to spend the use of Smart Home devices is worthwhile to me | |
| | VAL4 | Overall, the use of Smart Home devices delivers me good value | |
| Use | USE1 | I use Smart Home devices | (Tam & Oliveira, 2017) |
| | USE2 | I use Smart Home devices to manage my home | |
| | USE3 | I use Smart Home devices to stream content | |
| | USE4 | I subscribe to services to use them with smart home devices | |
| Individual Performance | PI1 | Smart home devices enable me to accomplish tasks more quickly | (Tam & Oliveira, 2017) |
| | PI2 | Smart home devices make it easier to accomplish tasks | |
| | PI3 | Smart home devices are useful for my home | |

