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A systematic review of the smart home literature: A user perspective

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ABSTRACT

A smart home is a residence equipped with smart technologies aimed at providing tailored services for users. Smart technologies make it possible to monitor, control and support residents, which can enhance the quality life and promote independent living. To facilitate the implementation and adoption of smart home technology it is important to examine the user's perspective and the current state of smart homes. Given the fast pace with which the literature has been developing in this area, there is a strong need to revisit the literature. The aim of this paper is to systematically review the smart home literature and survey the current state of play from the users' perspective. After discussing the systematic methodology, the review presents a comprehensive view of smart home definitions and characteristics. Then the study turns towards a discussion of the smart home types, related services and benefits. After outlining the current state of smart home benefits, the review discusses the challenges and barriers to smart home implementation. This review concludes by providing suggestions for future research.

1. Introduction

The word "smart" has recently become an umbrella term for innovative technology that possesses some degree of artificial intelligence. The key attributes of a smart technology are the ability to acquire information from the surrounding environment and react accordingly (Chan et al., 2008; Balta-Ozkan et al., 2014). The long-term objective of smart technology is to improve the well-being of people and as such it has become the backbone for such an innovative concept as the "smart home" (Alam et al., 2011; Arunvivek et al., 2015; Dawid et al., 2017; Hong et al., 2016). The wave of the transformation of products and services into smart ones has triggered the rise of device interoperability and contributed to the growth of smart home technology turnover globally (Khedekar et al., 2017). The benefits made possible by smart technology have fuelled the interest of both academics and practitioners alike. Significant attention has been paid to home appliances, where smart technology has become intensively researched and practically applied (Balta-Ozkan et al., 2014; Coughlan et al., 2013).

Along with increasing investments of enterprises into the smart home sector, the academic community has intensified its efforts in examining the concept of the smart home, the technological capabilities, its implications and the impact on people's lives. A number of review papers have been published covering smart technologies from different angles (Chan et al., 2009; Patel et al., 2012; Ranasinghe et al., 2016; Amiribesheli et al., 2015; Peetoom et al., 2015; Kim et al., 2013; De Silva et al., 2012; Hosseini et al., 2017; Demiris & Hensel, 2008; Alam et al., 2012). For example, Chan et al. (2009) examined the health-support dimension, by limiting the focus to the ageing population. The authors pointed out that there was a significant potential for the concept of *healthcare* to be replaced by *homecare*. The use of smart homes in the health support of ageing residents was also reviewed by Demiris & Hensel (2008), who supported the viability of the paradigm shift in the healthcare industry. However, they noted that the transformation of traditional healthcare into homecare was in an early phase and there was an extensive need to evaluate people's perceptions towards an emerging trend. Later, Patel et al. explored the use of wearable sensors by the elderly population in the context of a smart living environment (Patel et al., 2012). The authors justified the focus of the review of a single technology by highlighting the significance of wearable sensors in the investigation of cost-feasibility of the shift towards homecare. In line with those studies, Ranasinghe et al. (2016) and Amiribesheli et al. (2015) reviewed smart homes' latest state of play in the context of the health sector. Similarly, Peetoom et al. (2015) and Kim et al. (2013) explored the services for a specific segment of vulnerable users. The authors presented a review of devices that had the potential to prolong independent living for elderly residents. The above-mentioned reviews illustrated how the growing coverage of the literature on the domain of

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smart home technology implications by elderly users was typically accompanied by the emerging focus on the healthcare sector. Beyond the above, the review of De Silva et al. (2012) explored the technological dimension by focusing on the digital ecosystem, such as the utilisation of audio-based technology and computer vision applications. In 2015 Alam et al. (2012) revisited the technical state of smart homes, by reviewing sensors, communication devices, protocols and algorithms that comprise a living environment for an ageing population. In line with the findings of De Silva et al. (2012), authors have recently developed an interest in energy management systems (Hosseini et al., 2017; Saad Al-sumaiti et al., 2014; Han & Lim, 2010; Han et al., 2014; Lillis et al., 2015; Hu & Li, 2013; Zhao et al., 2013), also focusing on algorithms and devices that have been in use to monitor and manage energy consumption. The latest review by Hosseini et al. (2017), published in 2017, provided a specific overview of services for energy management, concluding that smart home technologies offered the necessary capabilities to promote sustainability.

Despite the increasing number of reviews, and beyond the narrow scope of the context examined, research in this domain is confined within the boundaries of three themes. Firstly, papers do not typically consider the multidimensionality of the concept of the smart home, thus leading to a one-sided representation of its implications, services and user segments (Balta-Ozkan et al., 2014). Only Chan et al. (2008) in 2008 offered insights into the state of smart homes adopting a multi-dimensional perspective, rather than focusing on a specific target audience, service or technology. Chan et al. (2008) attempted to cover the technical state of various smart home projects and developed a comprehensive understanding of the current and future challenges that smart homes and smart technologies brought to users. The authors pointed out the tendency to describe the potential benefits of technology ignoring the users' viewpoint and following a product-centric approach. According to them, the prevailing technological focus of the research explains the low acceptance of smart homes in the market. Secondly, papers tend to examine smart homes through a technological perspective, by focusing on the functions of devices, the infrastructure and the architecture of automated homes (Chan et al., 2008; Peine, 2009; Xu et al., 2016). Third, the majority of studies discusses potential benefits that smart home technology is capable of capturing (Peek et al., 2014; Czaja, 2016; Kun, 2001), while providing little empirical evidence regarding the users' perception of the challenges and benefits of the smart home technology use.

In the past few years smart home technology has been rapidly advancing and it has finally reached mainstream markets and user segments. Given the above limitations and the fact that it has been almost a decade since the literature was more holistically reviewed (Chan et al., 2008), there is a strong need to revisit and review the current state of the literature. The objective of this review paper is to adopt a user perspective, by focusing on the user as the unit of analysis and the recipient of smart home technology services and capabilities. This paper aims to synthesise emerging themes that are pertinent to the area of the implications of smart home technology in the key spheres of users' lives. The paper will provide a review of smart home functions, services, benefits and implementation in a critical and comprehensive way. The next section will outline the methodological steps followed, before proceeding to review the relevant literature and suggest future research avenues.

2. Methodology

The review analysed and synthesised the smart home literature from a user perspective following a systematic approach. In order to ensure that the findings were reached in a reliable and valid manner the study followed a three-stage approach, as proposed by Tranfield et al. (2003), namely: planning the review, conducting the review by analysing papers and reporting emerging themes and recommendations. These stages are further discussed in this section.

2.1. Planning stage

The planning stage of the review, which included the preliminary scoping of the literature aiming to identify and refine the objectives of the study and develop review protocols, was undertaken by 3 reviewers. The expertise of the reviewers on the topic facilitated and enhanced the potential of the study to identify novel themes and extend the insights into the topic (Hasson et al., 2000). An initial search of the literature demonstrated a number of gaps, which signalled the need to explore the smart home use from the user perspective systematically, especially when it came to the challenges of acceptance and adoption. Having identified the topic of the study, the next step was to develop the protocol for the review, which included the search criteria, the papers selected for the review and the method of conducting the analysis used in the next stage.

2.2. Conducting stage

The conducting stage of the review involved the systematic search, based on relevant search terms. The electronic database Scopus was selected as it represents the largest database of citations and abstracts of the research literature and provided a wide coverage of the review topic (Bar-Ilan, 2008). The key word selection revolved around the term "*smart home*". The selection of the phrase was justified by the requirement to cover the whole area of the smart home technology implications inside the house and beyond, and aspects such as acceptance of smart home technology. The keyword formulation started from the broader literature and was narrowed down to more specific terms (e.g. smart home, smart homes, smart building, smart home technology and smart technology). The starting point was to review the findings based on the aforementioned keywords search. During the extraction of articles, an advanced search option was enabled that limited results to publications in the form of "articles", "book chapters", "reviews" and "articles in press" published in the English language. The restriction of the search criteria to papers published between 2002 till 2017 was applied, referring to the period when the research in the field became systematic, which is reflected in a steep increase in the literature in 2002 compared to sporadic studies that had been published before that. Since then the research on the topic has been gradually intensifying. Given the domain of our literature review, the subject area of the search was limited to such disciplines as "social science", "multidisciplinary", "business, management and accounting", "art and humanities", "psychology" and "decision science". The search revealed 457 documents. The panel members reviewed the keywords, titles and abstracts of all the downloaded documents to determine the selection of articles for the review. Given the objective of this study, only academic articles relevant to smart homes, smart technologies and their users were included. Non-academic papers, such as newspapers, company reports, magazine articles, interview transcripts and presentations were excluded. Panel members scored papers based on their potential relevance to the topic in a binary manner (yes = 1/no = 0), resulting in scores from 0 (min) to 3 (max). 35 articles gained the highest score 3, whereas only 7 articles obtained a score of 2. Given the limited number of articles the reviewers decided to include both clusters for further analysis. As a result of the systematic literature search and selection process, a total of 42 articles was selected. In order to increase the number of studies for the review and its coverage, a backward citation search was utilised. Proposed by Croom (2009) and Thomé et al. (2016), backward citation is a method of retrieving deeper knowledge about the topic of interest, beyond selected keywords. It is defined as a process of screening and exploring the references cited in the selected articles (Hu et al., 2011). Backward citation screening was applied to the 42 selected articles and resulted in 101 documents being added to the papers downloaded from the database. Combining the list of papers that was compiled by the electronic database search and the backward citation screening, a total of 143 papers was downloaded for the review (Fig. 1).

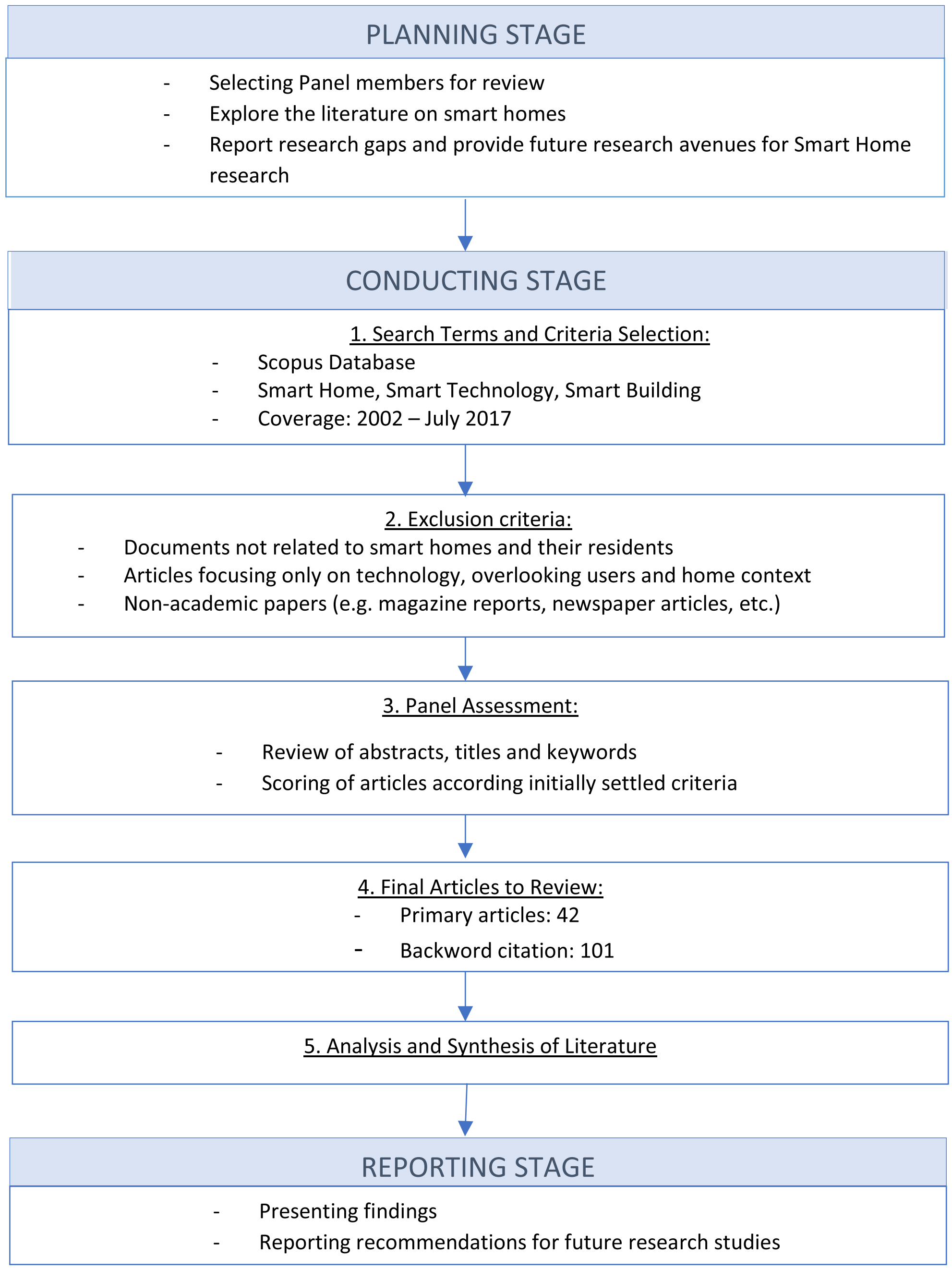

Fig. 1. Summary of smart home literature review.
Adapted from Tranfield et al. (2003).

In order to ensure the rigorousness of the review and eliminate the risks of bias related to inappropriate use of methodology, subjective exclusion of articles and the selectivity of findings, this study adhered to the three following procedures (Thomé et al., 2016). First, a systematic approach of protocol development and database search was closely followed. Second, the involvement of more than one reviewer and clearly identified exclusion criteria minimised the risk of bias in the paper selection process. Lastly, to eliminate the selectivity of findings, the documents extracted from the electronic database were organised in such a way as to provide the opportunity for panel members to review and assign relevance scores independently. The aforementioned procedure made it possible to finalise the relevance of the downloaded articles and increase reliability (Tranfield et al., 2003).

2.3. *Reporting stage*

The final stage of the review process was to report the descriptive statistics of the literature used in the review, the findings of the analysis undertaken and develop recommendations for future research. The frequency analysis demonstrated the publication year of the studies, the research methods employed, the technological domains covered and the keywords used. The highest number of papers was published in the period from 2014 until 2016, whereas only 21 papers were produced before 2005 (Fig. 2). The highest frequency of produced literature was observed in 2016, while the lowest number of papers was published in 2002.

The majority of authors tended to generate theoretical/conceptual papers. Other types of publications included 9 review papers, 32 papers adopting a survey method, 15 case study-design papers, 2 papers

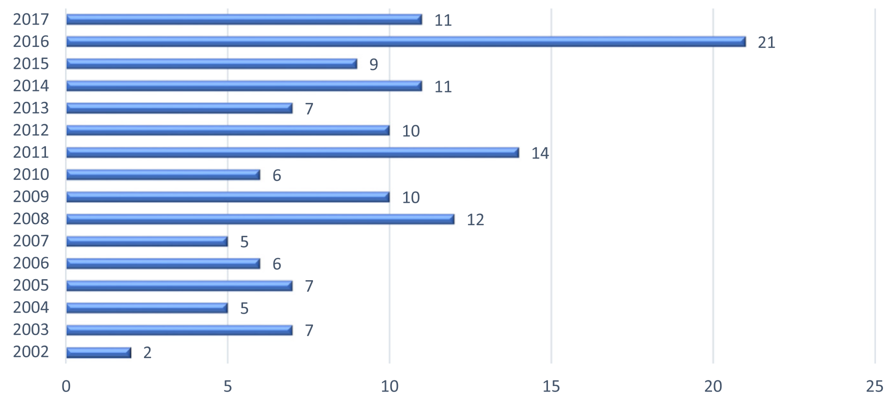

Fig. 2. Publication period.

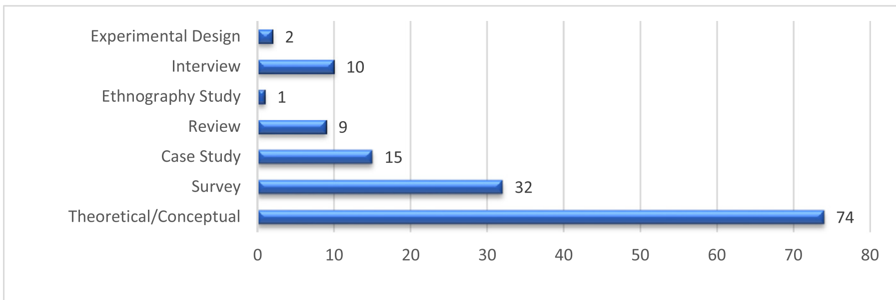

Fig. 3. Research methods utilised by the reviewed articles.

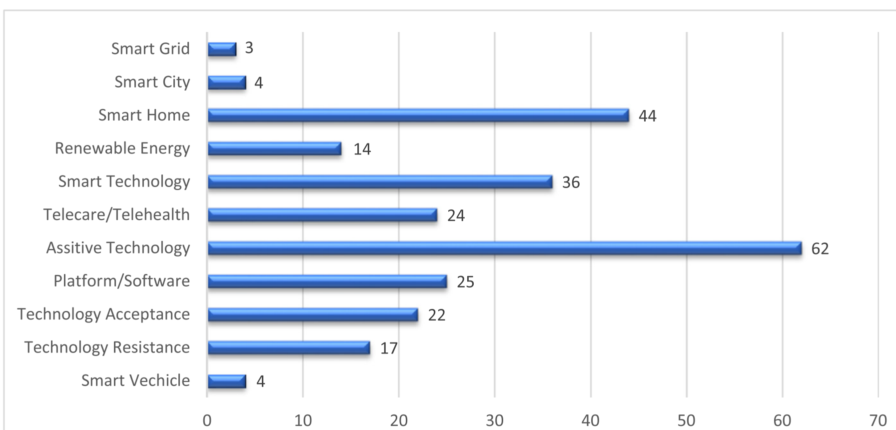

Fig. 4. Primary themes discussed in the reviewed papers.

adopting an experimental approach, 10 papers based on interviews and only one ethnography study (Fig. 3). The majority of the studies (74 out of 143 articles) contextualised their approach towards a specific technological domain. The primary domain was assistive technology applications inside the house (Fig. 4). Among other broad research themes are the benefits and challenges of smart homes and smart technologies, while two articles focused on smart vehicles and the smart grid.

To identify the specific focus of the reviewed papers across broad domains, a semantic categorisation of keywords was applied. The semantic analysis enabled the identification of the nature of the text and allowed a visual presentation of the concepts discussed in the papers (Li et al., 2011; Goddard, 2011). Having utilised the statistical approach proposed by Baker (2004), the most frequently mentioned keywords were extracted from a single or a group of documents. After the extraction process, keywords with synonymous meanings were grouped and calculated, resulting in a number of frequently-mentioned key words, such as technology (148), smart home (155) and ageing (134) (Fig. 5). Basic semantic clusters acted as a touchstone for developing themes for this review.

After providing descriptive statistics of the papers used for the review, the methodologies employed and the frequency of keywords, the study performed the reporting of topics that emerged in the literature by employing thematic analysis (Tranfield et al., 2003; Guest et al., 2011; Fereday & Muir-Cochrane, 2006; Joffe & Yardley, 2004). Thematic analysis was defined by Clarke and Braun (Braun & Clarke, 2006) "*as a method for identifying, analysing, and interpreting patterns of meaning* ("*themes*") *within data*". This study adopted an inductive analytical approach to analysing latent themes. The adoption of this approach implies that the themes were coded without a pre-defined categorisation or frames in the research area (Braun & Clarke, 2006). In order to avoid bias and ensure rigorous results, this review followed a six-phase process (Braun & Clarke, 2006; Ely, 1997). During the first phase, initial

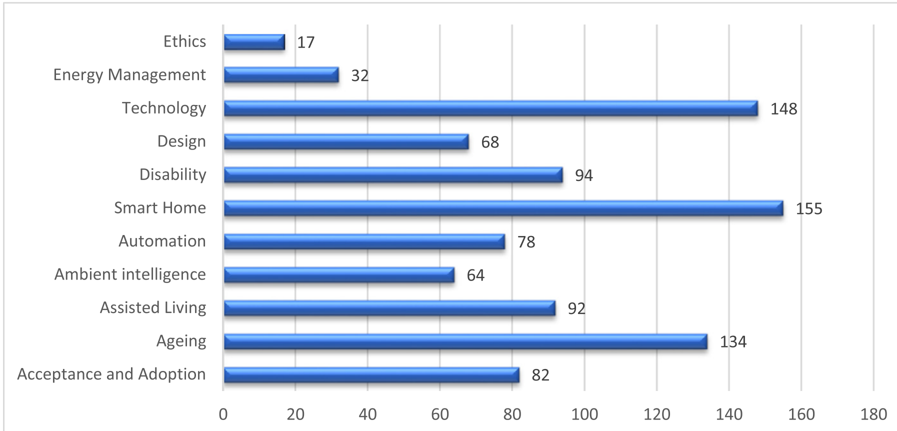

Fig. 5. Frequency of keywords detected in the reviewed articles.

notes were taken through a brief reading of the materials to become familiar with the topic of interest and attain some knowledge of the potential patterns of analysis. In the second phase, initial themes were clustered, based on the analysis of the underlining meaning of the data set. For example, the analysis resulted in a list of broad and specific codes, such as "challenges of technology adoption", "*mistrust*", "*home automation for energy solutions*", "*independent living*" and "*smart home services*" among others. In the subsequent phase, initial codes were categorised into themes and sub-themes, by mapping the relationships between codes. In the fourth phase, themes were refined by evaluating the internal homogeneity, which refers to the coherence of the categorisation of subthemes (i.e. the degree to which subthemes represent a broader theme). External homogeneity was also assessed, which relates to the evaluation of the degree to which the meaning of an individual code reflects the meaning of an entire data set. For example, "*promote independent living*" fell under the category of "*smart home services*", whereas "*mistrust*" became a subtheme of "*challenges of technology adoption*". In the fifth phase, the finalised themes and subthemes were redefined (e.g. "*promote independent living*" was renamed as "support"). In the final phase, the study reported the narrative based on established themes derived from the literature, which are characteristics, services, benefits and barriers. The results of the analysis were presented through interpreting and aggregating data, which served as a comprehensive framework for organising and reporting the analytic observations. The review concluded by reporting the research gaps and recommendations for future research.

3. Literature review: smart homes

3.1. Definition and characteristics of smart homes

Various definitions have been used to conceptualise and define smart homes (Table 1). Among the different approaches, the definitions by Aldrich (2003) and Lutolf (1992) covered the nature of smart homes in a pervasive way. Aldrich (2003) defined a smart home as "*a residence equipped with computing and information technology, which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond*". Their definition embraced the technological component of the phenomenon, the services and functions it provides and the types of user needs that smart homes aim to meet. A similar approach was followed by Lutolf's (1992) definition, which described smart homes as "*the integration of different services within a home by employing a common communication system. It assures an economic, secure and comfortable operation of the home and includes a high degree of intelligent functionality and flexibility*". Although the two definitions share similar principles, they differ in the services that the technology provides and the types of user needs it aims to satisfy. More broadly, the majority of scholars refer to technological attributes when defining smart homes. Balta-Ozkan et al. (2013a) definition states that the "*smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants*". De Silva et al. (2012) followed a similar approach without specifying the technological elements of smart homes. The authors stated that it is "*a home-like environment that possesses ambient intelligence and automatic control, which allows it to respond to the behaviour of residents and provide them with various facilities*". The definitions by Balta-Ozkan et al. (2013a) and De Silva et al. (2012) share the idea of the capability to respond to residents' needs through automated technology. The technological perspective was also supported by Diegel et al. (2005), who described it as a system, enhanced with four levels of smartness, namely smart appliances, smart control, smart management and smart sensors. Integration and collaboration of these four levels of smartness creates a living environment in the house.

The service/context-led definition is another approach to defining the smart home. From the perspectives of Reinisch et al. (2011) and Scott (2007) the main service a smart home provides is the management of energy consumption. The vision of Reinisch et al. (2011) is that an intelligent house is equipped with multiple devices that cooperate with each other as a homogeneous system to monitor electronic appliances, promote efficient energy management and sustainability. Scott (2007) clarified that the service is enabled by the integration of technological features, such as smart heating and smart meters. This group of definitions places more emphasis on sustainability and energy consumption and promotes the potential of smart home services to improve users' comfort. Focusing on a different context, Chan et al. (2008) emphasised healthcare needs from the perspective of ageing users. This definition states that a "*smart home is a house, which promises to provide cost effective home care for the ageing population and vulnerable users*". There are a number of other conceptual explanations that support the concept of smart home technology to meet the needs of ageing people, enhance the quality of life and promote independent living for residents (Alam et al., 2012; Blaschke et al., 2009; Dorsten et al., 2009; Ehrenhard et al., 2014). Remotely controllable assistive technology made it possible to propose services that would meet the demands of an elderly population (Alam et al., 2012).

There is significant overlap among the above-mentioned definitions, which share three characteristics in common: technology, services and the ability to satisfy users' needs. The core of the smart home is the technology, which consists of hardware and software components, including sensors and home appliances. Being represented as objects or electronic devices, sensors are capable of detecting changes in human behaviour and other stimuli from the environment (Arunvivek et al.,

Table 1
Definitions and characteristics of smart homes.

Definition based on theme	Technology			Services				Users' needs						
Authors	Sensors	Devices	Integrated systems	Control/ monitor	Energy management	Support and assist	Anticipate and respond	Cost-efficiency	Comfort	Emotional	Security	healthcare	Quality of life	Sustainability
Aldrich (2003)			x		x		x		x	x	x		x	
Lutolf (1992)			x		x			x	x		x		x	
De Silva et al. (2012)			x	x									x	
Reinisch et al., 2011			x	x	x			x	x			x	x	x
Scott (2007)		x	x		x			x	x				x	x
Balta-Ozkan (2014)	x	x	x	x									x	
Chan et al. (2008)						x		x				x	x	
Diegel et al. (2005)	x	x		x	x								x	
Alam et al. (2012)		x				x						x	x	

2015; Orwat et al., 2008). Sensors are integrated into home appliances through wireless and wired systems that make it possible to monitor and track residents when they are watching TV, cooking, sleeping, cleaning and doing a range of other activities (Orwat et al., 2008). The system represents configurations of appliances and sensors that produce a variability of functions and services, tailored to residents' needs (Chan et al., 2009). Put differently, the architecture of technology determines the services and the benefits the smart home aims to provide (Chan et al., 2008). When it comes to lifestyle support, a smart home represents a house with sensors and domestic devices, linked through a communication network. It empowers users to remotely control household appliances and decrease the burden of everyday household activities (Chan et al., 2009; Amiribesheli et al., 2015). Connected devices provide an opportunity for smart home residents to effectively manage their energy usage, while enhancing their convenience and comfort in their daily routine (Scott, 2007). Fully-automated devices have the potential to improve the quality of life and encourage the independent living of residents, especially for an ageing population through constant health management, and they even provide virtual medical assistance in cases of need (Orwat et al., 2008). 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.

3.2. Types of smart home technology services

This section presents the two main typologies of smart home technologies suggested by De Silva et al. (2012) and Bowes et al. (2012). De Silva et al. (2012) came up with three types of smart homes, classifying them based on the types of services they promote. The first category of smart homes provides assistance to occupants by recognising their actions. This type of home promotes the well-being of occupants inside the house. The services that these smart homes provide are divided into three types: homes providing care for the ageing population, assisting in child care and overall health care. The second type aims to detect and gather multi-media information in the form of videos and photos of the occupants' lives. This type of smart home concept may raise privacy concerns and a feeling of intrusion. The third type is the "surveillance home". This aims to process data to forecast and alert residents in case of upcoming natural disasters or security interventions. The function of these smart homes is to capture the data from the environment to detect and make people aware of burglary threats. Hardly any project has succeeded in combining all the services that the surveillance home is meant to offer (De Silva et al., 2012). The typology of smart homes provided by De Silva et al. (2012) can be potentially extended by an additional category. A number of scholars recognised that the emergent drive for ecological awareness has led the way to a special type of smart home (Balta-Ozkan et al., 2014; Balta-Ozkan et al., 2013a; Chen et al., 2017; Bhati et al., 2017; Elkhorchani & Grayaa, 2016; Zhou et al., 2016; Beaudin & Zareipour, 2015; Zhou et al., 2014). These smart homes aim to promote environmental sustainability by enabling residents to monitor and control their energy supply against demand. The literature presents the smart home as a novel and profound solution to reducing energy usage and promoting environmental sustainability (Balta-Ozkan et al., 2014; Chen et al., 2017; Bhati et al., 2017; Zhou et al., 2016; Balta-Ozkan et al., 2013b; Paetz et al., 2011). Special sensors and automatic monitoring systems in smart homes make it possible to achieve a reduction of energy usage without intrusion into residents' lives and the need to change behaviour (Lach & Punchihewa, 2007).

Following the studies developed by Doughty et al. (1996) and Brownsell & Bradley (2003), Bowes et al. (2012) classified the smart home technology and telecare systems into four generations based on the level of technological sophistication. The categorisation made it possible to see the evolution of smart home technology and telecare services. The *first-generation* smart home systems represented the technologies not embedded with artificial intelligence (AI) but which were activated by the motions of residents. The *second-generation* home technology employed elementary forms of AI-based devices. They were designed to detect changes in the surrounding environment through sensors, to monitor health conditions and detect body inconsistency through wearable devices, and assist in daily tasks through in-house appliances with built-in function programmes. Whereas the *second-generation* home technology had stand-alone devices, the *third-generation* marked the era of technology interoperability and multi-functionality. This was possible due to the introduction of the voice-activated control and the connectivity with other devices that made it possible to capture, process and transmit data within the network of devices. The *fourth generation* of smart home technologies is predicted to come into effect by 2020, and will replace existing sensors by ones that are embedded under the skin. These sensors have great potential for remote health monitoring and management (Brownsell & Hawley, 2005).

Smart home services can be added to homes gradually, effectively creating a spectrum beyond a "traditional home" and a "fully smart" one. Having this in mind, academic researchers and smart home service providers sought to observe and examine occupants' activities in traditional houses. Through practical research studies and smart home projects, scholars provided guidelines on the development of smart home technologies that would generate different services, to improve the living standards of inhabitants. For the purpose of systematising smart home services, the relevant literature was analysed by identifying commonly recurring patterns. The identification of common patterns made it possible to classify the services based on underpinning smart devices and the functions they provide. Table 2 presents the services and enabling technologies, grouped into five categories, which are *comfort*, *monitoring*, *health therapy*, *support* and *consultancy*. The majority of the reviewed papers (41 articles) discussed the functions that are aimed at ensuring a comfortable life, 31 papers studied the monitoring service, fewer articles were focused on health therapy and the supportive functions of smart home technology. Only two papers discussed the consultancy service that smart sensors are able to provide.

A number of research studies have attempted to practically understand the technical side of the smart home. Over the years, there has been a gradual move from the examination of the technical side of smart homes towards the user perspective. This has offered a richer insight into the implications of smart homes in users' lives and raised the need to summarise the emerging perspective in the review. The review will now turn towards the user perspective and examine the benefits and implications for adopting and accepting smart home technologies.

4. User benefits of smart homes

The literature discusses the potential and perceived benefits of smart homes in terms of the immediate advantages that smart homes could offer to users and their long-term impact on users' lives and the environment. The papers focusing on potential benefits consider possible positive outcomes of smart home technology utilisation by users (e.g. Peek et al., 2014; Czaja, 2016; Kun, 2001). The studies on perceived benefits examine the users' perceptions of smart home technology and the motivational influence of perception on technology acceptance (e.g. Kim & Shin, 2015; Mayer et al., 2011; Paetz et al., 2012). The juxtaposition of the perceived benefits against the potential ones reveals the discrepancies and overlaps between the two perspectives. The user perspective makes it possible to understand the factors underpinning the promotion of smart homes in the mainstream market. The rest of this review will discuss four groups of benefits (Table 3), the health-related, environmental, financial benefits and the psychological ones related to wellbeing and users' social inclusion. The widely-discussed benefits fall into the health-related category (41 papers). Environmental and financial benefits were less frequent topics in the reviewed papers, and the least attention was given to psychological well-being and social inclusion (8 papers).

4.1. Health-related benefits

Smart home technology can support the ageing population, vulnerable people and people with chronic conditions both inside and outside of the house (Chan et al., 2008; Demiris et al., 2008; Demiris & Hensel, 2009; Reeder et al., 2013; Courtney et al., 2008; Rantz et al., 2005; Demiris et al., 2004; Finkelstein et al., 2004). Health-related benefits can be achieved when technology performs the services of operational efficiency (comfort), monitoring and management, and consultancy. The core advantages of such technology for people with health problems are the operational functions, care accessibility and availability, and users' safety, resulting in quality health care (Chan et al., 2009; Czaja, 2016; Demiris, 2004; Finkelstein et al., 2004; Mynatt et al., 2004; Celler et al., 2003; Finch et al., 2008). The second function of the smart home when it comes to users' health is monitoring and disease management. The cognitive state of elderly people can be monitored through smart home devices, which can alert users in case of any health inconsistency (Czaja, 2016). These innovative actions enable professionals to monitor health remotely, detect life threatening changes at an early stage and even provide distant medical care when necessary (Chan et al., 2009; Demiris, 2004; Finkelstein et al., 2004; Mynatt et al., 2004; Celler et al., 2003; Finch et al., 2008; Walsh & Callan, 2011). When monitoring chronic illnesses, the use of e-health records, remote management and electronic e-prescriptions optimise the data and help to keep a register, potentially leading to a reduction in medical errors (Cavicchi & Vagnoni, 2017). Finally, the consultancy function of smart home applications implemented during the virtual medical visits aims to promote well-being for an ageing population through replacing physical visits to clinics and hospitals with remote medical therapy or consultation (Czaja, 2016).

From the users' perspective, the health-related services of comfort, remote consultancy and monitoring are not always perceived to be benefits and have an ambiguous influence on the intentions to use smart home technology. On the one hand, empirical studies have reported that respondents were generally positive towards the smart home technology, outlining a number of benefits (Rahimpour et al., 2008; Matlabi et al., 2012; Finch et al., 2008). Among the benefits that participants preferred most were the time and cost efficiency that telecare can provide compared to physical visits to hospitals (Chan et al., 2009; Demiris, 2004; Finkelstein et al., 2004; Mynatt et al., 2004; Celler et al., 2003; Finch et al., 2008; Walsh & Callan, 2011). Kerbler's study (Kerbler, 2013), on the other hand, revealed that older users are sceptical towards the benefits that smart home technology can bring (Rahimpour et al., 2008; Matlabi et al., 2012; Finch et al., 2008). The difference in the results of Kerbler's research (Kerbler, 2013) can be explained by the geographical location where the research took place, which might reflect the variety of the level of technological awareness. These factors can potentially moderate the variety in the perceptions regarding assistive technology in smart homes across countries.

4.2. Environmental benefits

Smart homes have become the state of the art in the reduction and monitoring of energy usage within a residential setting. Emerging threats such as climate change, global warming and volatility in energy prices have fuelled the interest in smart systems. The use of energy efficient devices and innovative technologies has made it possible to reduce energy consumption, which is vital in order to meet growing electricity demand and utilisation (Balta-Ozkan et al., 2014; Chen et al., 2017; Elkhorchani & Grayaa, 2016; Zhou et al., 2016; Beaudin & Zareipour, 2015; Kyriakopoulos & Arabatzis, 2016; Kiesling, 2016; Aye & Fujiwara, 2014; El-hawary, 2014). The benefit of energy efficiency has become possible through the implementation of four services: 1)

Table 2
Smart home functions and devices.

Service	Function	Device	Source	Frequency of papers
Comfort	Automation of daily routines Remote home management Intelligent environmental and sustainable services Smart leisure	Dishwasher Washing machine Refrigerator Cooker Closet/drawer/mirror Window/door/gate Mailbox/garden devices Heat/gas/electricity/light TV/radio/home cinema	Chan et al. (2008); Arunvivek et al. (2015); De Silva et al. (2012); Alam et al. (2012); Diegel et al. (2005); Scott (2007); Chen et al. (2017); Balta-Ozkan et al. (2013b); Lach & Punchihewa (2007); Martin et al. (2008); Kleinberger et al. (2007); Zwijsen et al. (2011); Kerbler (2013); Masuda et al. (2005); Das et al. (2002); Demiris et al. (2008); Demiris & Hensel (2009); Kyriakopoulos & Arabatzis (2016); Kiesling (2016); Aye & Fujiwara (2014); El-hawary (2014); Rahimi et al. (2011); Darby & McKenna (2012); Hargreaves et al. (2013); Faruqui et al. (2010); Park et al. (2017); Brandt et al. (2011); Yang et al. (2017); Jacobsson et al. (2016); Alsulami & Atkins (2016); Sun et al. (2010); Kim & Shcherbakova (2011); Fuchsberger (2008); Friedewald et al. (2005); Stringer et al. (2006); Wu & Fu (2012); Wilson et al. (2017); Bregman & Korman (2009); Cutler (2006); Triboan et al. (2016); Yusupov & Ronzhin (2010)	41
Monitoring	Health and lifestyle monitoring	Infrared sensors Wearable sensors Wearable accelerometer Internal sensors (to monitor physiological signs) EGG (epileptic seizure, sleep disorder) Heart rate Blood oxygen level Blood pressure Blood glucose level Temperature	Chan et al. (2008); Arunvivek et al. (2015); Chan et al. (2009); Patel et al. (2012); Ranasinghe et al. (2016); Amiribesheli et al. (2015); Peetoom et al. (2015); Kim et al. (2013); De Silva et al. (2012); Demiris & Hensel (2008); Alam et al. (2012); Scott (2007); Martin et al. (2008); Kleinberger et al. (2007); Zwijsen et al. (2011); Kerbler (2013); Demiris et al. (2008); Kiesling (2016); Andoh et al. (2004); De Silva & Darussalam (2008); Kim & Shin (2015); Rahimpour et al. (2008); Steele et al. (2009); Percival & Hanson (2006); Damodaran & Olphert (2010); Chan et al. (2012); Kotz et al. (2009); Diegel (2005); Theoharidou et al. (2016); Courtney (2008); Chiang & Wang (2016)	31
Health therapy	Remote interaction Remote therapy	Telehealthcare Tremor delivery Drug delivery Hormone delivery	Chan et al. (2008); Chan et al. (2009); Patel et al. (2012); Amiribesheli et al. (2015); Alam et al. (2012); Brownsell & Bradley (2003); Brownsell & Hawley (2005); Kerbler (2013); Rahimpour et al. (2008); Percival & Hanson (2006); Damodaran & Olphert (2010); Chan et al. (2012); Kotz et al. (2009); Diegel (2005); Demiris (2004); Matlabi et al. (2012); Chang et al. (2009); Wells (2003); Hanson et al. (2007)	19
Support	Support patients with hearing issues Support during home rehabilitation Assist patients with mobility issues Support with socialisation Patients with Visual disabilities	Alarm system based on visual signs Teletype machine Special electronic display screen for hearing-impaired people Special display screen Robotic devices for rehabilitation Tailored interface Companion robot Mobility devices (e.g. electronic wheelchair) Computerised voice generation (in order to communicate) Robots Audible beacon Tailored screen Specially designed remote control (e.g. voice recognition)	Chan et al. (2008); Chan et al. (2009); Amiribesheli et al. (2015); Dorsten et al. (2009); Kleinberger et al. (2007); Zwijsen et al. (2011); Kerbler (2013); Masuda et al. (2005); Kyriakopoulos & Arabatzis (2016); Kiesling (2016); Alsulami & Atkins (2016); Sun et al. (2010); Fuchsberger (2008); Friedewald et al. (2005); De Silva & Darussalam (2008); Matlabi et al. (2012); Meng & Lee (2006)	17
Consultancy	Suggestions	Sensors	Paetz et al. (2011); Hargreaves et al. (2013)	2

monitoring the information on energy consumption, 2) controlling the consumption patterns through remote devices and direct control, 3) management of the service, aimed at achieving efficiency and optimisation, and 4) consultancy (Zhou et al., 2016; El-hawary, 2014). On a nationwide scale, greater control over energy usage can eliminate carbon emissions and lead the way to a transformation of the traditional energy systems into renewable sources of electricity generation (Elkhorchani & Grayaa, 2016; Aye & Fujiwara, 2014). Research effort has already been invested in studying the implementation of wind, solar, biomass and geothermal energy in the smart home energy systems (Zhou et al., 2016) The embeddedness of renewable systems into smart houses could speed up the outcome of wise electricity and demand management.

Despite the on-going discussion about the role of smart home technology in ecological sustainability, a number of studies adopt a user's perspective by differentiating the perceived benefits from the potential ones (Balta-Ozkan et al., 2014; Balta-Ozkan et al., 2013a; Paetz et al., 2011; Paetz et al., 2012). A comparative study revealed that among users from different countries, rural and urban areas have different attitudes towards the environmental benefit (Balta-Ozkan et al., 2014). Accordingly, the influencing power of this factor in the intention to shift to smart home technology varies. The study revealed that environmental sustainability has become a more significant factor for users in rural areas. This result is explained by the stronger role of economic benefit for urban citizens, which outweighs the environmental concern. The variety of consumption patterns, attitudes and values could potentially be explained by diverse factors, including the housing type, the availability of services, social contact among others (Balta-Ozkan et al., 2014).

Table 3
Potential and perceived user benefits of smart home adoption.

Benefit	Service	Immediate advantage	Long-term impact	Sources	Frequency of papers
Health-related benefits	Comfort Monitor Consultancy Support deliver therapy	Care accessibility and availability Users' safety Social connectivity and communication Detection of life threatening events Reduction of medical errors	Promote well-being of ageing and vulnerable people	Chan et al. (2008); Chan et al. (2009); Patel et al. (2012); Amiribesheli et al. (2015); Peetoom et al. (2015); Kim et al. (2013); Demiris & Hensel (2008); Alam et al. (2012); Czaja (2016); Diegel et al. (2005); Scott (2007); Ehrenhard et al. (2014); Balta-Ozkan et al. (2013b); Martin et al. (2008); Kleinberger et al. (2007); Demiris et al. (2008); Demiris & Hensel (2009); Brandt et al. (2011); Fuchsberger (2008); Friedewald et al. (2005); Rahimpour et al. (2008); Steele et al. (2009); Percival & Hanson (2006); Damodaran & Olphert (2010); Chan et al. (2012); Kotz et al. (2009); Diegel (2005); Theoharidou et al. (2016); Chiang & Wang (2016); Demiris (2004); Chang et al. (2009); Hanson et al. (2007); Reeder et al. (2013); Rantz et al. (2005); Finkelstein et al. (2004); Mynatt et al. (2004); Celler et al. (2003); Finch et al. (2008); Harris & Hunter (2016); Singh (2010); Courtney et al. (2008)	41
Environmental benefits	Monitor Consultancy Comfort	Reduce energy usage Feedback on consumption Suggestions how to use electricity efficiently	Environmental sustainability Reduction of carbon emissions	Chan et al. (2008); Balta-Ozkan et al. (2014); Alam et al. (2012); Saad Al-sumaiti et al. (2014); Balta-Ozkan et al. (2013a); Reinisch et al. (2011); Scott (2007); Ehrenhard et al. (2014); Chen et al. (2017); Bhati et al. (2017); Elkhorchani & Grayaa (2016); Zhou et al. (2016); Beaudin & Zareipour (2015); Zhou et al. (2014); Balta-Ozkan et al. (2013b); Paetz et al. (2011); Kyriakopoulos & Arabatzis (2016); Kiesling (2016); Aye & Fujiwara (2014); El-hawary (2014); Darby & McKenna (2012); Hargreaves et al. (2013); Faruqui et al. (2010); Brandt et al. (2011); Wilson et al. (2017); Paetz et al. (2012); Hensel et al. (2006); Gauld (2014)	28
Financial benefit	Consultancy Monitor	Cheaper cost of virtual visits	Affordability of health care Sustainable consumption	Balta-Ozkan et al. (2014); Khedekar et al. (2017); Saad Al-sumaiti et al. (2014); Balta-Ozkan et al. (2013a); Scott (2007); Ehrenhard et al. (2014); Balta-Ozkan et al. (2013b); Paetz et al. (2011); Das et al. (2002); Kyriakopoulos & Arabatzis (2016); Kiesling (2016); El-hawary (2014); Darby & McKenna (2012); Hargreaves et al. (2013); Faruqui et al. (2010); Park et al. (2017); Kim & Shcherbakova (2011); Wilson et al. (2017); Rahimpour et al. (2008); Damodaran & Olphert (2010); Chan et al. (2012); Kotz et al. (2009); Chiang & Wang (2016); Paetz et al. (2012)	24
Psychological wellbeing and social inclusion	Support	Entertainment Virtual interaction	Overcome the feeling of isolation	Chan et al. (2008); Balta-Ozkan et al. (2014); De Silva et al. (2012); Brandt et al. (2011); Friedewald et al. (2005); Rahimpour et al. (2008); Percival & Hanson (2006); Demiris et al. (2004)	8

4.3. Financial benefit

The financial benefits of smart homes are typically associated with the environmental and health-related benefits. While in the long-term perspective the utilisation of energy saving devices leads to environmental sustainability, the immediate benefit of efficient energy consumption management is the reduction of electricity expenses. The financial benefits can be realised in two ways. First, the use of smart electric appliances and smart meters leads to higher awareness of the consumption habits, by regular monitoring of the energy use (Balta-Ozkan et al., 2013a; Darby & McKenna, 2012; Hargreaves et al., 2013; Paetz et al., 2012). Second, the transparency of the energy consumption makes it possible to compare tariffs against other energy providers (Darby & McKenna, 2012; Faruqui et al., 2010). In contrast to the potential benefits, perceived financial benefits have been studied as a distinctive group of factors underpinning users' motivation and intention to switch from traditional home appliances to smart ones. Despite the commonly-stated financial benefits of smart homes use, consumer studies have hardly confirmed this assumption. For example, due to perceived maintenance costs and relatively low savings, users do not find financial benefits a reason for adoption (Balta-Ozkan et al., 2013a). Another empirical study about the perceived barriers to and drivers of smart homes revealed that users are generally interested in acquiring smart home technology, due to its ability to reduce expenses on energy consumption. However, the opinion that investing in such technologies does not result in the expected return on investment underlines the reluctance of users to adopt smart home technologies (Balta-Ozkan et al., 2014; Balta-Ozkan et al., 2013b; Paetz et al., 2011). In addition, the strength of the motivational power of financial benefit depends on the two conditions that need to be looked at when analysing the perception of the financial benefits of smart homes: the location where the technology is implemented and the relative importance of other motives (Balta-Ozkan et al., 2014; Balta-Ozkan et al., 2013a; Park et al., 2017). The geographical differences of users may have a positive relation with the socio-economic status, thus, resulting in different perceptions of the cost factor. For example, users from countries with a higher utilitarian mentality and non-urban areas could be more sensitive towards the cost-saving benefit of the technology (Balta-Ozkan et al., 2014; Park et al., 2017).

In relation to other benefits, the financial factor may play a leading or a secondary role (Balta-Ozkan et al., 2013a; Park et al., 2017; Steele et al., 2009). The convenience and the compatibility of the technology in some instances may outweigh the dominance of the financial benefit. These factors refer to the connectivity of the smart home technology with other components of the house that increase the reliability of the service and improve the user experience (Balta-Ozkan et al., 2013a; Park et al., 2017). Potential financial benefits are also associated with health-related benefits, whereby the shift towards homecare can result in economic savings for users (Ehrenhard et al., 2014). Acknowledging the increasing interest in and debates regarding home-care cost efficiency compared to traditional medical care, the studies concluded that the cost efficiency is dependent on the health condition of the patient and the package of services he or she needs to receive (Kun, 2001). This finding suggests that the financial benefit is a context-dependent factor that may or may not affect the decision to use the technology.

4.4. Psychological wellbeing and social inclusion

Smart homes can improve socialisation and even help users overcome the feeling of isolation (Chan et al., 2008; Percival & Hanson, 2006; Demiris et al., 2004). This can be achieved by the implementation of services related to support and assistance (Chan et al., 2008). The enabling power of the smart home technology to assist and support people with everyday activities has an effect on the self-perception in terms of self-esteem, adaptability and competence. Self-perception is defined as a psychosocial impact, and refers to the evaluation of one's own position in life within the context, culture and values and relative to their expectations (Brandt et al., 2011). However, studies on perceived benefits rarely support this statement. As an example, users may not wish to use assistive technologies, due to concerns that they will be stigmatised and labelled as vulnerable people (Damodaran & Olphert, 2010; Demiris et al., 2004; Gaul & Ziefle, 2009). Additionally, it has been reported that smart home technologies may negatively affect their social life, by replacing actual face-to-face communication (Damodaran & Olphert, 2010). The isolation from social and physical interaction could be an effect of the support-independency of elderly and vulnerable users enhanced by technology (Kim et al., 2013). The aforementioned findings suggest that the role of the technology in physical or operational independence represents a coin with two sides.

Balta-Ozkan et al. (2013a) and Balta-Ozkan et al. (2013b) have raised a concern regarding the impact of the financial factor on users' socialisation. According to these authors there is a threat that only higher-income users may benefit from smart home technology and experience social inclusion in the society of luxury technology holders. The technology would have a divisive impact and would create a social gap between technology beneficiaries and financial outsiders (Balta-Ozkan et al., 2013a; Balta-Ozkan et al., 2013b). Still, given the rapid advance of the technology and orientation of the technology producers on the mainstream market, smart home technologies are expected to become more affordable over time (Khedekar et al., 2017) and this may not be an issue in the future.

5. Smart home implementation and barriers

Despite the potential benefits of smart homes, the adoption and diffusion rate remains low (Chan et al., 2008; Balta-Ozkan et al., 2013a; Ehrenhard et al., 2014; Yang et al., 2017; Jacobsson et al., 2016; Kim & Yeo, 2015; Anderson, 2007). It is therefore important to examine smart home acceptance and adoption and the users' perspective on the barriers (Table 4) which may hinder the implementation of smart homes. The section discusses the main technological barriers which were considered to be the major stumbling block when it comes to the adoption of smart home technology. Slightly less emphasis was given to the concerns related to financial, ethical and legal issues and the barriers caused by the knowledge gap and psychological resistance.

5.1. Technological barriers

Technology fit is the most important factor to address when developing smart homes (Balta-Ozkan et al., 2013a). It can be described as the users' perception of the technology compatibility, connectedness and the system's reliability. These three factors are strongly associated with the perception of the technology's usefulness (Park et al., 2017; Yang et al., 2017). In line with this perspective, smart home technology adoption studies have been gradually increasing their focus on the features of technology that could potentially pose threats to users and influence the perception of the technology.

Technology automation, mobility and interoperability are considered to be facilitating factors of adoption (Yang et al., 2017). In addition, the usability barrier, which refers to the reliability and ease of use, was shown to have a crucial role in the acceptance of the smart home technology, whereby the complexity of the technology leads to refusal to adopt it (Balta-Ozkan et al., 2013a; Alsulami & Atkins, 2016). However, there are a number of current smart home devices which are complex to use. Since the majority of smart home projects used to be purely technical, the user's perspective on the ease of use was under-researched (Czaja, 2016; Diegel, 2005). The reliability factor relates to the potential of the technology to serve users for a long time, with expectations of a product's lifecycle typically being at least 5 to 10 years (Balta-Ozkan et al., 2013a). Users expect smart homes to recognise their needs and provide tailored assistance (Kim & Shcherbakova, 2011). However, it was found that people are generally sceptical about the

Table 4
Users' perspective on barriers to smart home adoption.

Barriers	Examples	Source	Frequency of papers
Technological	Security Usability Privacy intrusion Reliability Complexity	Balta-Ozkan et al. (2013a); Dorsten et al. (2009); Ehrenhard et al. (2014); Balta-Ozkan et al. (2013b); Paetz et al. (2011); Kleinberger et al. (2007); Zwijsen et al. (2011); Kerbler (2013); El-hawary (2014); Darby & McKenna (2012); Park et al. (2017); Yang et al. (2017); Jacobsson et al. (2016); Alsulami & Atkins (2016); Sun et al. (2010); Kim & Shcherbakova (2011); Fuchsberger (2008); Friedewald et al. (2005); Wu & Fu (2012); Wilson et al. (2017); Rahimpour et al. (2008); Steele et al. (2009); Percival & Hanson (2006); Damodaran & Olphert (2010); Theoharidou et al. (2016); Courtney (2008); Chiang & Wang (2016); Matlabi et al. (2012); Meng & Lee (2006); Paetz et al. (2012); Rantz et al. (2005); Mynatt et al. (2004); Courtney et al. (2008); Mani & Chouk (2017); Lorenzen-Huber et al. (2011); Chan & Perrig (2003)	36
Financial, ethical and legal	Price Cost of installation Cost of repair and maintenance Concern about misuse of private data The requirement for formal consent from patients Lack of legal conduct Uncertainty with regulation conflicts between smart home service providers and users	Chan et al. (2008); Balta-Ozkan et al. (2014); Coughlan et al. (2013); Chan et al. (2009); Balta-Ozkan et al. (2013a); Scott (2007); Ehrenhard et al. (2014); Balta-Ozkan et al. (2013b); El-hawary (2014); Park et al. (2017); Alsulami & Atkins (2016); Kim & Shcherbakova (2011); Fuchsberger (2008); Friedewald et al. (2005); Rahimpour et al. (2008); Steele et al. (2009); Damodaran & Olphert (2010); Chan et al. (2012); Kotz et al. (2009); Chiang & Wang (2016); Hanson et al. (2007); Paetz et al. (2012); Anderson (2007); Mani & Chouk (2017); Yamazaki (2006); Harkke et al. (2003); Chung et al. (2016)	27
Knowledge gap and psychological resistance	Human barrier Resistance to using innovative technology Lack of prior knowledge or/and experience	Balta-Ozkan et al. (2014); Coughlan et al. (2013); Chan et al. (2009); Kim et al. (2013); Czaja (2016); Balta-Ozkan et al. (2013a); Paetz et al. (2011); Kerbler (2013); El-hawary (2014); Alsulami & Atkins (2016); Sun et al. (2010); Kim & Shcherbakova (2011); Fuchsberger (2008); Rahimpour et al. (2008); Percival & Hanson (2006); Damodaran & Olphert (2010); Chan et al. (2012); Courtney (2008); Matlabi et al. (2012); Paetz et al. (2012); Mani & Chouk (2017); Lorenzen-Huber et al. (2011)	22

reliability of smart home products (Balta-Ozkan et al., 2013a). Given the fact that smart homes have started to move towards the mass market it is important to ensure reliability, by providing safe and secure services to potential users.

5.2. Financial, ethical and legal concerns

The second group of barriers comprises financial, ethical and legal concerns. The financial factors include the price of the technology, and the cost of installation, repair and maintenance, which discourages users from adopting smart home technology (Balta-Ozkan et al., 2013a; Steele et al., 2009; Chan et al., 2012). Some people expressed a lack of understanding of how smart homes could help them save money, which triggers mistrust towards the technology (Balta-Ozkan et al., 2013a). Healthcare related literature indicated that the implementation of the technology in the health industry is cost-intensive. This finding does not support the assumption that assistive home devices can financially benefit both the users and hospitals, by replacing a traditional visit with virtual therapy (Chan et al., 2008). However, Wells (Wells, 2003) claimed that the implementation of the smart home concept in healthcare would require high investments, as financial investment and the training of medical staff will be necessary to safely and ethically utilise smart home technologies, such as e-prescribing and EMR technologies in the health industry.

The ability of smart homes to collect and store a vast amount of private data raises ethical concerns, such as privacy and security (Chan et al., 2009; Balta-Ozkan et al., 2013a; Jacobsson et al., 2016; Friedewald et al., 2005; Kotz et al., 2009). In a number of countries, smart home technologies cannot be practised in healthcare without the consent of the patient, who should be fully informed regarding the service procedure (Sundström et al., 2002). This exemplifies an overwhelming distrust of users meaning they will not allow the collection of personal data (Coughlan et al., 2013; Hanson et al., 2007). The risk of privacy intrusion acts as a major inhibitor to smart home acceptance and adoption, which is confirmed by a number of studies (Paetz et al., 2011; Yang et al., 2017; Jacobsson et al., 2016; Wilson et al., 2017; Theoharidou et al., 2016; Paetz et al., 2012; Chung et al., 2016). A breach of privacy of users may happen as a result of unwilling information disclosure, and the inability to control the interference of automation systems in private life (Chan et al., 2009; Zwijsen et al., 2011; Yang et al., 2017; Courtney, 2008). As for the perception of the privacy and security risk, the opinions of users are split. Some people seemed to be able to embrace the benefits of the technology without being bothered by privacy issues (Lorenzen-Huber et al., 2011). Others saw that home automation and remote control may pose security threats when disclosed and used by third parties (Balta-Ozkan et al., 2013a). As the solution to this challenge, the development and implementation of sophisticated safety protocols aims to eliminate the risks of fraudulent intrusion and misuse of the technology (Chan & Perrig, 2003).

Legal issues are a stumbling block in smart home technology acceptance, especially in relation to the medical and social care industries (Chan et al., 2008; Chiang & Wang, 2016; Anderson, 2007; Harkke et al., 2003). Smart home technology, including the concept of e-health, is a relatively new discipline with a lack of written legal conduct regarding the use of smart home technology. In order to ensure wide acceptance of this technology, governments should adjust laws on the practices. Given the gap in legislation, policy makers could introduce laws to regulate conflicts between smart home service providers and users over the obtained product (Balta-Ozkan et al., 2014). Policy makers also need to address privacy law in order to guarantee users' data protection and security and avoid any intentional or accidental breach of privacy law. However, when the health-related data of smart home users are shared with a hospital or individual physician, the assumption of data privacy changes (Chan et al., 2008). Therefore, it is vital to delineate the boundaries between privacy intrusion and data protection, especially in the healthcare sector.

5.3. Knowledge gap and resistance to change

The low rate of the perceived usefulness of smart homes can be explained by the lack of knowledge, trust and experience to embrace the benefits of the technology (Balta-Ozkan et al., 2013a; Kerbler, 2013). As smart home technologies are emerging technologies, people are not fully aware of their functions, potential risks and benefits. Lack of knowledge regarding smart home technologies impedes the wider implementation of smart homes in the mass market (Balta-Ozkan et al., 2013a). For instance, a study examining the perception of smart meters indicated that people are used to traditional flat electricity rates and that there is a lack of knowledge regarding the benefits that smart technologies could create (Kim & Shcherbakova, 2011). Also the perception of emergent technologies is heavily affected by the feedback of technology adopters, which may not always be positive (Hu et al., 2003). Thus, the lack of users' awareness coupled with negative word-of-mouth can play a negative role in smart home technology acceptance by potential users (Yang et al., 2017).

Mani & Chouk (2017) attempted to explore the challenges of the smart technology acceptance through the theory of innovation resistance originally proposed by Ram & Sheth (1989). The findings of the aforementioned study suggest that perceived novelty and usefulness has a significant negative effect on the consumers' resistance to accepting smart products. In line with this finding the study by (Alam et al. (2011) confirmed that an innovative product that does not fit the pre-existing environment and requires a change in the lifestyle and behaviour of users might fail to enter the mass market. Users are more committed to already established habits and strongly resist changing their behaviour and living style to accept the smart home technology (Kleinberger et al., 2007; Sun et al., 2010; Fuchsberger, 2008). To overcome the psychological barrier and knowledge gap, technology design can tackle users' lifestyles and norms (Stringer et al., 2006). The low perception of usefulness results in a feeling of losing control over the technology, which brings about resistance to accepting the technology. To overcome this barrier, smart home products could feature software systems that are adjustable and flexible to users' habits (Keith Edwards & Grinter, 2001; Hu et al., 2011).

The notion of becoming isolated and lacking human interaction could pose a challenge for smart home acceptance (Wu & Fu, 2012; Meng & Lee, 2006). Social exclusion may result in two scenarios. In the first one, the technology replaces human interaction by virtual communication, gradually excluding users from the society within the physical environment (Wu & Fu, 2012; Meng & Lee, 2006). In the second one, the adoption of the technology by one cluster of wealthy users would leave non-users excluded and stigmatised by socio-economic status (Balta-Ozkan et al., 2013a). The two perspectives are contradictory, leaving room for further examination.

6. Future research avenues

The review has made it possible to identify the gaps in the literature that could potentially be addressed by future research studies. The revealed gaps and future research avenues are summarised in Table 5.

Despite the numerous potential benefits, there is a dearth of research from the user perspective. This gap was highlighted in the majority of studies. The literature predominantly focuses on the technical characteristics of smart homes (Xu et al., 2016; Zhou et al., 2016; Jacobsson et al., 2016; Toschi et al., 2017; Das et al., 2016; Yang et al., 2016; Vastardis et al., 2016; Pennick et al., 2016; Yang et al., 2016; Kim et al., 2016; Park, 2015; Ahvar et al., 2016), which means that there is a need for the adoption of the user perspective in research on the development of technologies. Studies that employed users' perspectives focused on the needs of an ageing population (Blaschke et al., 2009; Alsulami & Atkins, 2016; Gauld, 2014; Harris & Hunter, 2016; Atoyebi et al., 2014; Morris et al., 2014; Peine et al., 2014), overlooking other user segments. However, it is important to explore and understand the role of different stakeholders that could potentially partake in smart home acceptance. The shift from technology-driven research to a consumer-centric approach will enable researchers to explore the potential development of a wider spectrum of services to satisfy broader user segments and embrace all the potential advantages of smart home technology. Given the above, future research could focus on the functions and services of smart home technology from the perspective of mainstream users.

Current studies have attempted to examine users' perceptions towards specific technology and services, which creates another widely-discussed prospect to be addressed in future research. For example, some scholars have investigated users' needs, the usability and the perception of values of the standalone devices rather than the fully-connected smart homes (e.g. Chan et al., 2008; Ehrenhard et al., 2014; Bregman & Korman, 2009; Hale, 2005). The focus on a single device might not give an adequate picture (Ehrenhard et al., 2014). First of all, such a perspective does not fit the evolutionary stage the smart home is currently at, reflected by the interoperability and multifunctionality of devices. Against the backdrop of intensifying IoT development and the rise of integrated entertainment systems (Ehrenhard et al., 2014), companies such as Apple and Google have set the trends towards converging all objects (e.g. watches, glasses, cars, home appliances) through IoT-based platforms (Hong et al., 2016). The convergence of previously separated devices will erase physical boundaries of homes and re-define the concept of smart home technology and industries in general. For example, Apple has connected the “CarPlay” and “Home Kit” platforms, enabling users to control home devices while driving. That initiative signals a high possibility that companies across different industries might enter the smart home technology market. However, despite on-going developments, little research has been done in the area of smart home ecosystems so far (Hong et al., 2016). Given this fast-paced development, research needs to turn from single-devices to integrated systems. Secondly, research on particular devices touched upon a very narrow package of services. Future studies need to take into account the types of smart homes. The contextual difference may underpin the distinctive factors to be exhibited in the acceptance and the adoption process.

There has been little empirical evidence when it comes to issues of acceptance and the adoption of smart home technology. Such empirical studies may provide potentially different insights given the personal and pervasive nature that the technology is used in. Future research may contribute to theory, which would tackle both the psychological and technological factors that could drive the adoption of smart home technology. The exploration of the change of pre-adoption and post-adoption perceptions of the technology will help in understanding the cognitive process of technology adoption. The examination and understanding of the behavioural change would help to promote implementation of the technology in the mass market.

The few studies that adopted a consumer perspective to examine the perceived benefits of and barriers to smart home technology adoption provided contradictory results (Ehrenhard et al., 2014; Kerbler, 2013; Alsulami & Atkins, 2016). The contradictions of previous findings demand further examination of users' perceptions. Future research could examine the emotional, psychological, symbolic, functional and financial antecedents that trigger users to accept or reject smart home products. In addition, it is important to explore the constructs that underline users' value perception, because they influence the intention to use technology. For example, further to the study by Balta-Ozkan et al. (2014), the control of the geographical difference between respondents and socio-demographic factors is an important variable to measure, which may reveal the influence of individual factors, economic and social status on the perception. The individual and financial factors may define the relative importance of the benefits for the particular group of users, which may be an important condition to control in future research (Balta-Ozkan et al., 2014). Secondly, following the study by Mani & Chouk (2017), the role of psychological resistance is

Table 5
Summary of future research suggestions.

Areas of gaps	Future research suggestions	Sources	Frequency of papers
User-centric research	User perception of smart home technology	Chan et al. (2008); Coughlan et al. (2013); Chan et al. (2009); Amiribesheli et al. (2015); Kim et al. (2013); Demiris & Hensel (2008); Alam et al. (2012); Peek et al. (2014); Czaja (2016); Balta-Ozkan et al. (2013a); Diegel et al. (2005); Bowes et al. (2012); Chen et al. (2017); Bhati et al. (2017); Balta-Ozkan et al. (2013b); Paetz et al. (2011); Demiris et al. (2008); Brandt et al. (2011); Stringer et al. (2006); Wu & Fu (2012); Chan et al. (2012); Chiang & Wang (2016); Matlabi et al. (2012); Paetz et al. (2012); Demiris et al. (2004); Gaul & Ziefle (2009); Courtney et al. (2008); Yamazaki (2006); Hong et al. (2016); Vilas et al. (2010)	30
	Demographics and geographic change	Balta-Ozkan et al. (2014); Balta-Ozkan et al. (2013a); Blaschke et al. (2009); Hargreaves et al. (2013); Yang et al. (2017); Mayer et al. (2011); Gaul & Ziefle (2009); Hong et al. (2016); Sugihara et al. (2015)	9
	Smart home technology benefits for users	Chan et al. (2008); Chan et al. (2009); Kim et al. (2013); Balta-Ozkan et al. (2013a); Diegel et al. (2005); Bowes et al. (2012); Gaul & Ziefle (2009)	7
	Focus on ageing population	Khedekar et al. (2017); Patel et al. (2012); Demiris & Hensel (2008); Alam et al. (2012); Peek et al. (2014); Czaja (2016); Ehrenhard et al. (2014); Bowes et al. (2012); Reeder et al. (2013); Demiris et al. (2004); Courtney et al. (2008); Atoyebi et al. (2014); Morris et al. (2014); Peine et al. (2014); Cassarino & Setti (2016)	15
Technical-centric research	Smart home technology services and characteristics	Chan et al. (2008); Arunvivek et al. (2015); Khedekar et al. (2017); Coughlan et al. (2013); Amiribesheli et al. (2015); De Silva et al. (2012); Demiris & Hensel (2008); Alam et al. (2012); Scott (2007); Chen et al. (2017); Elkhorchani & Grayaa (2016); Zhou et al. (2014); Kyriakopoulos & Arabatzis (2016); El-hawary (2014); Rahimi et al. (2011); Park et al. (2017); Percival & Hanson (2006); Chan et al. (2012); Hamill (2006); Denti (2014); Loviscach (2011); Ziefle (2011)	22
	Integration of devices	Chan et al. (2008); Balta-Ozkan et al. (2014); Patel et al. (2012); Peetoom et al. (2015); Alam et al. (2012); Reinisch et al. (2011); Ehrenhard et al. (2014); El-hawary (2014); Jacobsson et al. (2016); Ahvar et al. (2016); Petersson (2016)	10
Smart homes acceptance and adoption	Smart home technology acceptance factors	Chan et al. (2008); Dawid et al. (2017); Khedekar et al. (2017); Chan et al. (2009); Peetoom et al. (2015); Kim et al. (2013); Peek et al. (2014); Balta-Ozkan et al. (2013a); Diegel et al. (2005); Ehrenhard et al. (2014); Bowes et al. (2012); Balta-Ozkan et al. (2013b); Kleinberger et al. (2007); Demiris et al. (2008); Park et al. (2017); Yang et al. (2017); Alsulami & Atkins (2016); Steele et al. (2009); Mayer et al. (2011); Paetz et al. (2012); Gaul & Ziefle (2009); Courtney et al. (2008); Mani & Chouk (2017); Chung et al. (2016)	24
	Utilisation of quantitative methodology	Peek et al. (2014); Balta-Ozkan et al. (2013a); Petersson (2016)	3
Regulations	Smart home technology policies and ethics	Chan et al. (2008); Balta-Ozkan et al. (2014); Coughlan et al. (2013); Chan et al. (2009); Demiris & Hensel (2008); Diegel et al. (2005); Scott (2007); Dorsten et al. (2009); Bowes et al. (2012); Demiris et al. (2008); Demiris & Hensel (2009); Darby & McKenna (2012); Percival & Hanson (2006); Chan et al. (2012); Paetz et al. (2012); Demiris et al. (2004); Walsh & Callan (2011); Anderson (2007)	18

an important factor to examine. Future research needs to investigate the variables that underline the cognitive state of mind of users and the perception of technology usefulness. This may offer novel insights into the difference in attitudes among users and the factors that underline the resistance. Thirdly, the development of adequate regulation systems and policies was not a leading agenda item for future research. However, a number of studies investigating the barriers to smart home adoption in the market stressed the importance of the intervention of business policies and regulations to mitigate ethical concerns.

When it comes to the methodologies used by empirical papers in this review, these utilised qualitative methodologies, including focus groups, case studies and interviews (Balta-Ozkan et al., 2014; Balta-Ozkan et al., 2013a; Paetz et al., 2011; Paetz et al., 2012). In the future, a quantitative approach could also be used to study consumers' attitudes and preferences. Finally, the majority of the research studies have been conducted in the UK and USA. Further to Stringer et al. (2006), the cultural, economic and geo-political contexts influence norms, attitudes and beliefs. They might reveal new variables that underpin or control the intention to adopt the smart home technology. To test the context-dependence of the perception of the benefits and services of smart homes, future research needs to shift the focus to Eastern countries.

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