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Aligning smart home technology attributes with users' preferences: a literature review

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ABSTRACT

Smart home technologies play a crucial role in reshaping the use of residential spaces, aspiring to enhance user experiences and foster a more efficient way of living. Assessing the state-of-the-art smart home technologies is essential for supporting their implementation and acceptance, particularly considering the rapid evolution within this field. This study, through a literature review, explores the taxonomy of smart home technology attributes, users' preferences, and their alignment. The research reveals three primary themes of smart home attributes: technology, function, and user. Users' preferences are categorized into functional aspects, value and benefits, social and cultural influences, ethical and responsible considerations, and user control and trust. The analysis shows disparities between some smart home technology attributes and users' preferences, particularly in the dimensions of privacy, security and data usage, ethical consideration, social and environmental responsibility, cultural and demographic factors, trust, and social influence. Additionally, compatibility and cost of technology are often neglected. This paper contributes to the existing literature by presenting a taxonomy of smart home technology attributes and users' preferences. We also call for a shift in design paradigms to ensure a more holistic integration of users' preferences into smart home technologies.

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Smart home technology; attributes; user preferences; user expectations; needs and concerns; residential buildings

1. Introduction

A smart home refers to a living space where residents are provided with various services through interconnected sensors, devices, and electronic appliances (Li et al. 2021). Ultimately, smart home technologies are utilized with the aim to enhance the occupants' quality of life by leveraging information and communication technologies, ensuring a convenient and seamless living experience (Chang and Nam 2022; Micovic et al. 2022). These technologies enable occupants to control and automate a wide range of the functions of the home, e.g. lighting, heating, ventilation, and air conditioning (HVAC), security and entertainment (Chkroun and Azaria 2021; Gu et al. 2019). As technologies evolve, smart homes are expected to play a vital role in shaping occupants' lives, offering not only convenience but fostering sustainable lifestyles (Tuomela, Iivari, and Svento 2019).

Attributes of smart home technology refer to the distinct features and capabilities that make these systems intelligent and responsive, enabling them to react promptly (Li et al. 2018). These attributes include monitoring (Garg and Cui 2022), connectivity (Chang and Nam 2022), automation (Leonidis et al. 2021) to convenience (Chang and Nam 2022), entertainment (Jensen et al. 2022) and enhanced life (Micovic et al. 2022). This research extends beyond technical attributes by delving into the human-centered aspects, e.g. users'

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motivations and user engagement. Understanding and analysing the taxonomy of attributes are essential for a comprehensive exploration of the impact and potential improvements in smart home technology.

While for the successful implementation of smart home technologies, it is imperative to consider user experience, well-being, and diverse needs of individuals (Chang and Nam 2022; Sun et al. 2021), the design of smart technologies in residential buildings has commonly been focused on addressing technical aspects with no consideration of residents' needs nor expectations (Castaño-Rosa et al. 2024). Furthermore, while previous studies have demonstrated the positive impacts of specific features of smart homes (Avila et al. 2021; Biermann, Schweiger, and Jentsch 2019), it is equally important to identify the concerns (Arthanat et al. 2020; Avdic 2019; Bahrini et al. 2020). Therefore, when referring to user preferences, we encompass users' expectations, needs and concerns, as these factors may impact the usability and acceptance of smart home technologies.

Defining attributes and users' preferences for smart homes is necessary for several reasons. First, the fast-evolving nature of technology enables constant development and innovation. Examining these issues helps stakeholders with information on current state-of-the-art technology, fostering a better understanding of what smart home technology can offer. Second, user preferences evolve with developing technology. Understanding the attributes and user preferences may enable better acceptance, ensuring that consumer preferences are met, and attributes encompass the most relevant and desired functionalities. Moreover, it plays a significant role in standardization within the industry, providing a common language for users, researchers, and developers, and to do so supports interoperability and compatibility among different smart home devices.

The existing literature predominantly highlights the revolutionary potential of smart home technologies. Nevertheless, there are disparities in the alignment between the attributes and the actual preferences of users within residential spaces. This study, through a systematic literature review, aims to provide novel insights into key attributes of smart home technology solutions and users' preferences. Thus, this research addresses the following two research questions:

RQ1: What are the key attributes of smart home technologies?

RQ2: What are users' preferences to use smart home technology solutions?

This article is structured as follows: Section 2 provides insight into the method utilized for the systematic literature review. Subsequently, Section 3 presents a descriptive analysis of the literature, covering findings related to the overview of smart home technology solutions, and users' preferences. In Section 4, the alignment between attributes and users' preferences is discussed. Finally, Section 5 concludes the paper with the main contributions of the research.

2. Method

To answer the two research questions, a systematic literature review was conducted, enabling to collection of evidence on existing knowledge and providing an insightful synthesis of the findings (Gough, Oliver, and Thomas 2017). The PRISMA-based literature review method (Page et al. 2021) was used to systematically explore existing research on smart home technologies (Figure 1). Google Scholar and Web of Science were chosen for broad interdisciplinary coverage, while the ACM Digital Library was selected for its focus on computer science and information technology. The search was based on the terms 'smart', 'intelligent', 'automatic', 'digital' in combination with 'home', 'dwelling', 'residence', 'apartment', 'technology', AND 'application', 'robot', 'device', AND 'user', 'human', 'occupant', 'resident'. Relevant studies were chosen based on the inclusion and exclusion criteria: (1) only peer-reviewed articles and conference proceedings from 2018 to 2023 in the English language were included. This time frame was chosen due to the fast-evolving nature of smart technology and its relevance to the current context. (2) The selected research papers had to focus on smart home technologies, excluding those without explicit user consideration or those addressing technologies in non-residential contexts.

The search was conducted to find the search terms in the title, abstract and keywords of the papers, which resulted in 622 articles. After removing duplicates, 551 articles were included for screening. A blind review process was employed to minimize reviewer bias, resolving discrepancies through discussion. The screening occurred in two stages: (1) Using Rayyan software (Anon 2023a), the first exclusion criteria was applied in titles and abstracts, resulting in 135 articles. (2) Later, 62 articles were removed as they primarily focused on technology without considering user-related aspects. Therefore, for a comprehensive analysis and data extraction, a total of 73 articles were included.

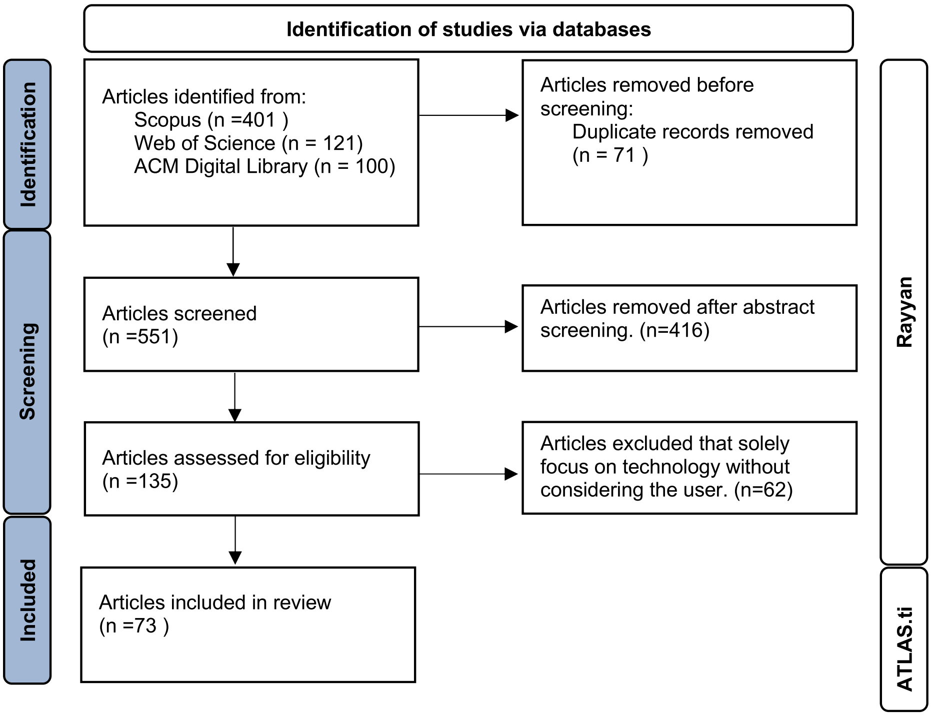

Figure 1. A systematic PRISMA-based literature review methodology was used in this study (Page et al. 2021).

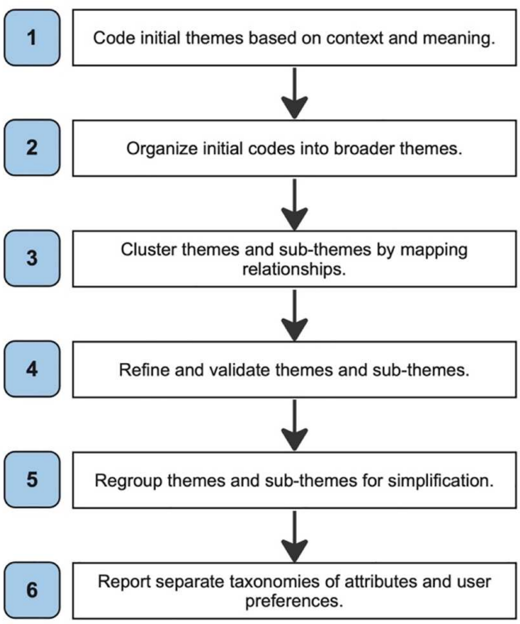

Figure 2. Summary of coding and analysis of stages.

For data extraction and analysis, a thematic analysis approach using ATLAS.ti (Anon 2023b) software was employed. This study embraced coding and grouping codes into potential themes without predetermined categorizations in the field. The coding and analysis process comprised six stages (Figure 2). First,

Table 1. Attributes of smart home technologies from the systematic literature review.

Attributes			References
Technology	Types of technology	Hardware	Alomar et al. (2022), Fiawoyife and Louis (2018), Sovacool and Del Rio (2020), Velichkovsky et al. (2021)
		Software	Biermann, Schweiger, and Jentsch (2019), Czajkowski et al. (2021), Leonidis et al. (2021), Senarathna, Muthugala, and Jayasekara (2018)
	User interface	Augmented reality	Chen, Tu, and Wu (2023), Faltaous, Eljaki, and Schneegass (2019), Lee and Park (2020), Liu et al. (2021), Mattioli and Paternò (2022)
		Gesture control	Chamunorwa et al. (2022), Chen, Tu, and Wu (2023), Lau et al. (2022)
		Interactive display	Chamunorwa et al. (2022), Chen, Tu, and Wu (2023), Czajkowski et al. (2021), Fongbedji, Krami, and Bouya (2020), Leonidis et al. (2021)
		Voice	Chamunorwa et al. (2022), Chen, Tu, and Wu (2023), Sun et al. (2021)
	Persuasive technique	Behavioral nudging	Alomar et al. (2022), Faltaous, Eljaki, and Schneegass (2019)
		Scarcity	Alomar et al. (2022), Avila et al. (2021)
		Social comparison	Alomar et al. (2022), Avila et al. (2021)
Function	Functionality	Monitoring	Garg and Cui (2022), Leonidis et al. (2021), Micovic et al. (2022)
		Automation	Garg and Cui (2022), Leonidis et al. (2021), Liu et al. (2021), Martins et al. (2020), Senarathna, Muthugala, and Jayasekara (2018), Sovacool and Del Rio (2020)
		Sensing	Chang and Nam (2022), Faltaous, Eljaki, and Schneegass (2019), Martins et al. (2020), Zheng et al. (2018)
		Connectivity	Chang and Nam (2022), Faltaous, Eljaki, and Schneegass (2019), Garg and Cui (2022), Micovic et al. (2022), Ahmed, Ibrahim, and Osama (2019), Sovacool and Del Rio (2020)
		Control	Martins et al. (2020), Micovic et al. (2022), Senarathna, Muthugala, and Jayasekara (2018)
		Communication	Chang and Nam (2022), Gu et al. (2019), Micovic et al. (2022), Zheng et al. (2018)
	Energy	Efficiency	Avila et al. (2021), Caldera et al. (2023), Inoue and Yamamoto (2022), Motlagh, Khatibi, and Aslani (2020)
		Consumption	Avila et al. (2021), Caldera et al. (2023), Micu et al. (2021), Tuomela, Iivari, and Svento (2019)
	Sustainability	Renewable energy	Hasan et al. (2022), Motlagh, Khatibi, and Aslani (2020), Sovacool and Del Rio (2020)
		Carbon emission	Avila et al. (2021), Ganvir and Kalita (2022), Kadavil et al. (2018)
		Recycling	Czajkowski et al. (2021), Lee and Park (2020)
User	User motivations	Comfort	Fongbedji, Krami, and Bouya (2020), Garg and Cui (2022), Jensen et al. (2022), Micovic et al. (2022)
		Convenience	Chang and Nam (2022), Fongbedji, Krami, and Bouya (2020), Garg and Cui (2022), Jensen et al. (2022)
		Entertainment	Garg and Cui (2022), Jensen et al. (2022)
		Security	Fongbedji, Krami, and Bouya (2020), Senarathna, Muthugala, and Jayasekara (2018)
		Assistive service	Micovic et al. (2022), Ahmed, Ibrahim, and Osama (2019), Sovacool and Del Rio (2020)
	User engagement	Accessibility and usability	Avila et al. (2021), Chamunorwa et al. (2022), Chen, Tu, and Wu (2023)
		Behavior change	Alomar et al. (2022), Avila et al. (2021), Faltaous, Eljaki, and Schneegass (2019), Leonidis et al. (2021)
		Education and awareness	Alomar et al. (2022), Caldera et al. (2023), Chamunorwa et al. (2022)
		Personalization	Biermann, Schweiger, and Jentsch (2019), Erol et al. (2020), Sieger et al. (2022)
		User behavior mining	Alomar et al. (2022), Avila et al. (2021), Inoue and Yamamoto (2022), Leonidis et al. (2021)

initial themes were coded based on the context and meaning in the text, e.g. 'energy', 'motivation', and 'ease of use'. Then, the initial codes were organized into broader themes, forming clusters like 'energy', 'energy consumption', 'energy efficiency' and 'renewable energy'. In the subsequent phase, themes and sub-themes were clustered by mapping the relationship between codes; for example, the theme 'energy' included sub-themes like 'energy consumption' and 'energy efficiency'. The fourth stage of the research involved refining and validating the themes and sub-themes, involving cross-referencing the coded data. In the fifth stage, themes and sub-themes are regrouped to simplify and consolidate related concepts. In the final phase, a cluster of attributes, and a cluster of users' preferences are reported separately (Tables 1 and 2).

Table 2. Users' preferences of smart home technology found in the reviewed literature.

Preferences		References
Functional Aspects	Energy efficiency	Hargreaves, Wilson, and Hauxwell-Baldwin (2018), Jensen et al. (2018, 2022), Larsen and Gram-Hanssen (2020), Micu et al. (2021), Tuomela, Iivari, and Svento (2019)
	Technical support and reliability	Aiswarya et al. (2021), Chang and Nam (2022), Liu et al. (2021), Williams et al. (2020)
	Compatibility	Chang and Nam (2022), Ganvir and Kalita (2022)
	Usability, ease of use, and complexity	Aiswarya et al. (2021), Ganvir and Kalita (2022), Liu et al. (2021), Schmidt and Braunger (2018), Ahmed, Ibrahim, and Osama (2019), Sieger et al. (2022), Williams et al. (2020); Wu et al. (2022)
	User experience and design	Aiswarya et al. (2021), Chang and Nam (2022), Ganvir and Kalita (2022), Martins et al. (2020), Micovic et al. (2022), Micu et al. (2021), Yan, Hou, and Han (2021)
Value and Benefits	Cost and availability	Aiswarya et al. (2021), Chang and Nam (2022), Ganvir and Kalita (2022), Micu et al. (2021), Ahmed, Ibrahim, and Osama (2019), Williams et al. (2020)
	Perceived value	Williams et al. (2020)
	Convenience and well-being	Chang and Nam (2022), Garg and Cui (2022), Sieger et al. (2022)
Social and Cultural Influences	Social influence	Förster and Block (2022), Liu et al. (2021), Pillan, Costa, and Aureggi (2019), Voit et al. (2020)
	Cultural and demographic factors	Beneteau et al. (2020), Förster and Block (2022), Ganvir and Kalita (2022), Pillan, Costa, and Aureggi (2019), Voit et al. (2020), Zanocco et al. (2021)
Ethical and Responsible Considerations	Social and environmental responsibility	Chang and Nam (2022), Ganvir and Kalita (2022), Hargreaves, Wilson, and Hauxwell-Baldwin (2018), Ahmed, Ibrahim, and Osama (2019), Williams et al. (2020)
	Privacy, security, and data usage	Aiswarya et al. (2021), Chang and Nam (2022), Ganvir and Kalita (2022), Javed, Sethi, and Jadoun (2019), Lin and Parkin (2020), Liu et al. (2021), Micu et al. (2021), Parsons, Panaousis, and Loukas (2020), Ahmed, Ibrahim, and Osama (2019), Sovacool and Del Rio (2020), Zheng et al. (2018)
User Control and Trust	Perceived control and actual control	Chang and Nam (2022), Pillan, Costa, and Aureggi (2019), Ahmed, Ibrahim, and Osama (2019), Sieger et al. (2022)
	Trust	Förster and Block (2022), Ganvir and Kalita (2022), IEEE Robotics and Automation Society, SIGCHI (Group : U.S.), ACM SIGAI, and Institute of Electrical and Electronics Engineers (2019), Ürge-Vorsatz et al. (2012), Lin and Parkin (2020), Liu et al. (2021), Micu et al. (2021), Ahmed, Ibrahim, and Osama (2019), Sieger et al. (2022)

3. Findings

3.1. Descriptive analysis of the reviewed publications

Figure 3 presents the chronological distribution of the reviewed literature spanning from 2018 to 2023. The majority of the reviewed studies were conducted between 2021 and 2022, i.e. 36 out of 74 publications. Notably, there is a trend indicating an increasing focus on smart home technology research over time. It is important to note that the low number of publications in 2023 is because this research occurred in the early months of 2023.

Figure 4 shows the research methods employed in the reviewed publications, with a notable emphasis on interviews, surveys, and literature reviews. Surveys and questionnaires (n = 25) and interviews (n = 25), including expert interviews and focus group interviews, and literature reviews (n = 20) are the most frequently utilized methods, showcasing a strong reliance on qualitative data. In addition to the listed methods in Figure 4, each of the following methods was found in one of the papers: observation, wizard of oz, quasi-experimental design, prototype, crowdsourcing, expert interview, and co-design session. Some reviewed articles used mixed methods; therefore, these articles might include two research methods indicated in the table separately.

3.2. Smart home technology attributes

This section presents results related to Research Question 1.

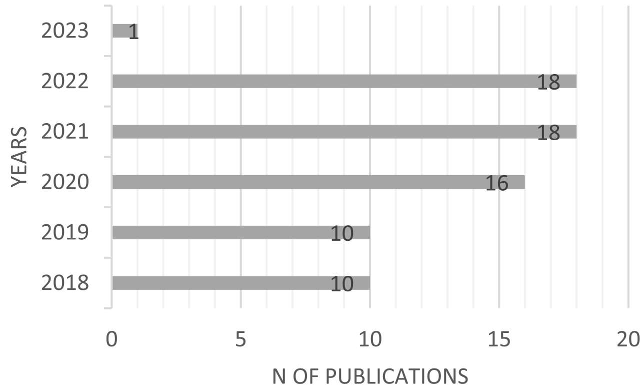

Figure 3. Chronological distribution of the reviewed publications.

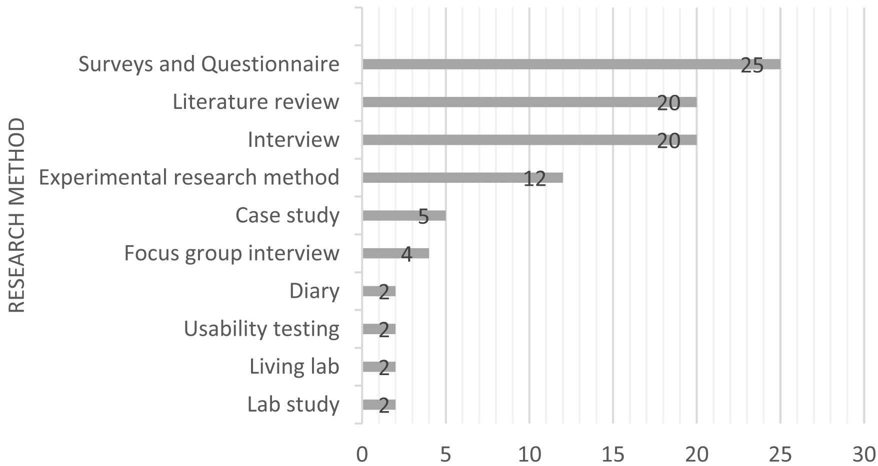

Figure 4. The most often used research methods employed in the reviewed publications.

Through an inductive approach, a list of attributes associated with smart home technologies has been developed and presented in Table 1. The following attributes encompass eight aspects related to smart home technology solutions: types of technology, user interface, persuasive technique, functionality, energy, sustainability, user motivations, and user engagement. Analyzing these results further, the highlighted attributes are not isolated concepts but rather a network of interrelated components that collectively describe the different aspects of smart home technology solutions. These characteristics were then categorized into three themes: *technology, function*, and *user*, each of which represented a cohesive cluster of linked attributes to provide a thorough comprehension. By structuring the analysis around these attributes, the aim has been to provide a comprehensive understanding of the diverse facets of smart home technology solutions. Each attribute is further unfolded below.

Types of Technology. This attribute outlines the foundational elements of smart home systems, containing a diverse range of both tangible hardware components (Alomar et al. 2022; Fiawoyife and Louis 2018; Hasan et al. 2022) and intangible software elements (Biermann, Schweiger, and Jentsch 2019; Czajkowski et al. 2021; Senarathna, Muthugala, and Jayasekara 2018). These components include sensors, actuators, devices, and software systems, that collectively support the functionality of smart homes. It specifies both physical and digital domains within the smart home ecosystem, facilitating interaction between hardware and software.

User Interface. The user interface encompasses various interaction methods such as augmented reality, gesture control, interactive displays, and voice commands. For instance, augmented reality, integrated digital information onto the real world, offers immersive experiences and simplifies automation rules (Chen, Tu, and Wu 2023). Augmented reality applications span various domains, such as tabletop devices and virtual reality, enabling spatial manipulation tasks, menu interactions, and multimodal input using hand and foot gestures (Chen, Tu, and Wu 2023). Similarly, gesture control provides touchless interaction options, enhancing usability and accessibility for users (Chen, Tu, and Wu 2023). Furthermore, interactive displays, including touchscreens, enable direct engagement, particularly in surface computing contexts (Chamunorwa et al. 2022; Chen, Tu, and Wu 2023). Voice user interfaces have gained popularity recently, especially with the integration of speech assistants into smart home devices. They have proven to be valuable in various use cases e.g. information services, media consumption, and control of smart home appliances. Nevertheless, they may encounter challenges e.g. real-time speech processing and natural language understanding (Biermann, Schweiger, and Jentsch 2019).

Persuasive Techniques. Persuasive techniques such as behavioral nudging, scarcity, and social comparison, aim to influence user behavior towards desired outcomes like energy conservation or sustainable practices (Alomar et al. 2022). For instance, an interface proposed in Alomar et al. (2022) combines intrinsic and extrinsic elements to promote home-focused energy savings, utilizing features like notifications, tips, and energy community collaboration. This approach fosters a sense of fulfillment and belonging among users, encouraging them to improve their efforts and engage in positive peer pressure through competition and social comparison (Alomar et al. 2022; Faltaous, Eljaki, and Schneegass 2019).

Functionality. The functionality of smart homes encompasses several subcategories, including monitoring, automation, sensing, connectivity, control, and communication (Garg and Cui 2022; Leonidis et al. 2021; Martins et al. 2020; Micovic et al. 2022; Senarathna, Muthugala, and Jayasekara 2018). Monitoring systems provide real-time insights into home components, allowing residents to track energy usage, security, and environmental conditions (Hasan et al. 2022). Automation enables the creation of intelligent routines, adapting devices to occupants' preferences and schedules through trigger-action rules (Liu et al. 2021). For instance, smart lighting systems can adjust brightness and color temperature to mimic natural sunlight (Fongbedji, Krami, and Bouya 2020), although challenges like timing issues and device selection may arise (Liu et al. 2021). Sensing technologies, like motion detectors, enhance system responsiveness (Motlagh, Khatibi, and Aslani 2020). Connectivity solutions facilitate device communication, while control mechanisms empower users to customize their environment effortlessly (Chamunorwa et al. 2022). Communication functionalities enable smart devices to interact with users, providing alerts, updates, and remote monitoring and control (Bradford et al. 2018).

Energy. This attribute encompasses smart home technology solutions that focus on energy-related aspects, including consumption and energy efficiency. According to Caldera et al. (2023), the development of detailed energy-consumption information models is crucial for informing users and improving their behaviors towards energy use. Home energy management systems offer data on usage and adaptability to variable pricing, resulting in reduced costs (Caldera et al. 2023; Kadavil et al. 2018; Tuomela, Iivari, and Svento 2019). Occupant-centric control strategies, like HVAC optimization, promise significant energy savings as well (Jensen et al. 2022; Stopps et al. 2021), enhancing overall efficiency and comfort. Although onsite field studies are essential to confirm these findings.

Sustainability. The sustainability aspect of smart technology solutions focuses on promoting sustainable behaviors and environmental conservation. Research suggests three key practices for engaging users in sustainable behaviors: making sustainability enjoyable and rewarding, creating positive peer pressure, and using gamification to drive meaningful action (Avila et al. 2021). Furthermore, studies underscore the importance of understanding homeowner behavior to enhance residential demand response programs. It is essential to offer diverse incentives, including carbon emission reduction, to encourage successful participation (Jensen et al. 2018). The authors also stress the need for a thorough examination of occupancy and building characteristics to effectively reduce energy consumption and greenhouse gas emissions in residential settings (Sieger et al. 2022).

User motivations. Smart home users are driven by a variety of motivations to adopt smart home technologies. Comfort is one of the key factors, with users seeking effortless control over living spaces for relaxation and well-being, e.g. temperature and lighting adjustments (Avila et al. 2021). Convenience drives the desire for seamless automation of daily tasks like lighting and security systems integration (Avila et al. 2021). Entertainment is another motivator, with users embracing smart technologies for immersive audio-visual experiences and streaming services (Chamunorwa et al. 2022). Security concerns prompt the adoption of surveillance and alarm systems, leading to the continuous development of encryption techniques and secure data transmission protocols. Yet, privacy and security concerns persist, necessitating ongoing efforts to address them (Bahrini et al. 2020). Additionally, addressing users lacking technical proficiency is crucial with games and educational tools playing a pivotal role in raising awareness and implementing effective security measures (Bahrini et al. 2020). Assistive services also attract users seeking solutions to enhance accessibility and simplify daily routines (Wang and Mao 2021).

User Engagement. User engagement in smart technology includes subcategories like accessibility, behavior change, education, personalization, and user behavior mining. For instance, the DHOMUS IoT platform monitors energy consumption to enhance engagement and awareness (Caldera et al. 2023). Smart metering systems also play a crucial role in fostering energy awareness by providing usage forecasts and energy-saving advice (Caldera et al. 2023). Usability is essential, with user studies and expert evaluations guiding the development of intuitive devices and interfaces (Wu et al. 2022). Incorporating user feedback enhances the overall experience, potentially leading to positive behavior change for sustainable energy practices. Additionally, user behavior mining provides insights into needs and habits, enabling personalized solutions (Alomar et al. 2022); algorithms predict appliance usage patterns and schedule actions based on user habits, leveraging deep learning techniques (Alomar et al. 2022).

3.3. Users' preferences of smart home technology

This section presents results related to Research Question 2.

Users' preferences for smart home technologies were categorized into five groups (see Table 2): Functional aspects, value and benefits, social and cultural influences, ethical and responsible considerations, and user control and trust.

Functional aspects include the main aspects targeted by the users when choosing a smart home technology, e.g. improving energy efficiency by monitoring and controlling their energy consumption (Jensen et al. 2018). Furthermore, technical reliability and compatibility between devices have been seen to promote acceptance (Beneteau et al. 2020), while usability and complexity of interfaces, and user experience and design are key drivers for rejection (Hargreaves, Wilson, and Hauxwell-Baldwin 2018).

Value and benefits emphasize financial feasibility and cost of technology, as significant factors influencing users' decision to acquire a specific smart technology (Micu et al. 2021). Similarly, the usefulness and perceived value of purchasing a specific smart technology in relation to its cost plays a key role in decision-making (Williams et al. 2020), followed by lifestyle factors, e.g. convenience and well-being (Sieger et al. 2022).

Social and cultural influences cluster highlights how the experiences of close social networks (i.e. friends, relatives, colleagues) from using smart home technologies influence residents' decision-making (Liu et al. 2021). A novel aspect is the role of cultural and demographic factors, e.g. age, cultural background, ethic, socioeconomic status, or educational level, to promote user acceptance (Ganvir and Kalita 2022; Voit et al. 2020; Zanocco et al. 2021).

Ethical and responsible considerations represent a group of users whose environmental and social values, i.e. implications of using smart technologies to promote sustainable living and reduce carbon footprint, may steer their decision-making and smart technology acceptance (Avila et al. 2021; Ganvir and Kalita 2022; Williams et al. 2020). Transparency on how the data is used and stored, joined to the feeling of being 'monitored'/'observed', has been found to impact user adoption of smart home technologies (Lin and Parkin 2020; Parsons, Panaousis, and Loukas 2020; Zheng et al. 2018).

User control and trust show the importance of promoting the feeling of control over smart home technologies (Pillan, Costa, and Aureggi 2019), and how poor comprehensiveness and personalization can influence the feeling of control and ownership (Chang and Nam 2022). Similarly, the feeling of control over a specific smart technology (i.e. 'I am not told what to do or how to feel') is closely interconnected with the perceived risk of privacy and security breaches, which often leads to a lack of trust in the device, service provider, and smart home system in general (Ahmed, Ibrahim, and Osama 2019; Förster and Block 2022; Schmidt and Braunger 2018).

4. Discussion

To comprehend the alignment between smart home technology attributes and users' preferences, a list of these attributes and users' references was identified and thoroughly gathered. Subsequently, these attributes and preferences were mapped onto a matrix, enabling an analysis of their alignment and disparities. Through this examination, neglected factors were identified where weak or nonexistent alignment

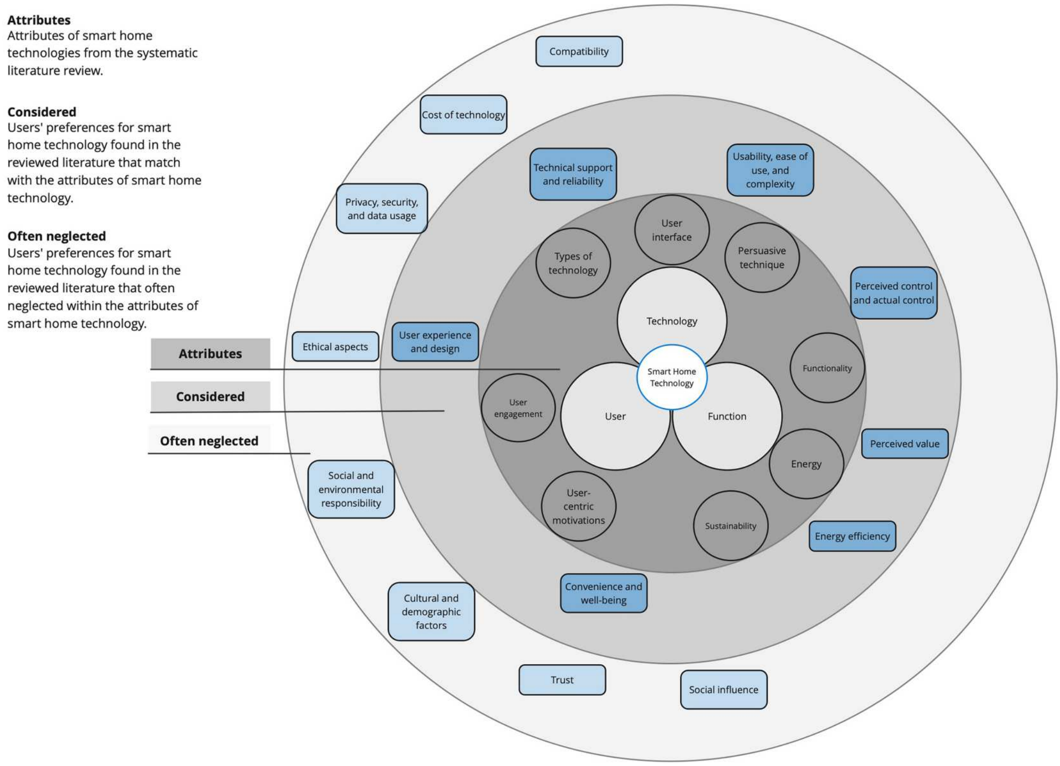

Figure 5. Alignment between attributes of smart home technologies with users' preferences.

was evident. This systematic comparison underscores the significance of considering factors such as, (1) privacy, security, and data usage, (2) ethical considerations, (3) social and environmental responsibility, (4) cultural and demographic factors, (5) trust, and (6) social influence, (7) compatibility and (8) cost of technology which are often neglected in the design and advancement of smart home technologies (see Figure 5).

Regarding (1) privacy, security, data usage, weak relationships suggest a mismatch between user expectations and the built-in features of smart home technologies. (2) Ethical consideration that ensure that innovation aligns with principles of fairness, transparency, and respect for individual rights and freedoms is another often neglected factor. Similarly, despite users expressing their concerns about the potential of using smart technologies at home to affect the environment, (3) social environmental responsibility, results showed that this aspect is often neglected by smart technology designers. The weak correlation between (4) cultural and demographic factors implies that users' backgrounds are not often considered for the design of smart home technology features. (5) Trust, which plays a significant role in user acceptance, highlights the importance of communication and strong privacy measures. (6) Social influence exhibits a comparatively weaker relationship with smart home technology attributes as well. Compatibility and cost of technology emerge as two technology dimensions with a direct and robust relationship with user preferences. (7) Compatibility, denoting the interoperability and interconnectedness of devices, shows that users place a high value on seamless integration, and it may influence their acceptance of smart home technologies. Similarly, (8) cost of technology of smart home solutions impacts users' decision-making processes that are closely tied to practicality and financial feasibility.

When smart home technology attributes align with users' preferences, in which technology is successfully integrated into users' daily lives, smart home technologies can effectively address users' preferences. However, as has been shown in previous studies (Castaño-Rosa et al. 2024; Förster and Block 2022; Garg and Cui 2022; Lin and Parkin 2020), there is a need to overcome the current status quo by bringing users' preferences to the core of the discussion to design optimal and inclusive technical functionalities of smart home technologies.

While some studies state smart home technologies are designed to meet users' preferences (Wang and Mao 2021), the results of this work showed that there is still a disparity between users' preferences and attributes of the technology. In this respect, this study states the need to prioritize placing users at the forefront of the design process, ensuring that technology seamlessly integrates into their lives and meets their preferences. By actively engaging end-users throughout the design and development phases, their invaluable input and feedback contribute to the creation of products that are not only intuitive and efficient but also deeply meaningful for their everyday experiences (Giacomin 2014).

Figure 5 shows the relation between the identified attributes of smart home technologies in the reviewed literature (dark gray color circle) and the reported users' preferences (squares in blue color). The further the distance away from the center, represents which factors (users' preferences) are more often neglected.

The neglect of certain attributes in smart home technology often stems from a prioritization of technological innovation over user-centered approach. Developers might emphasize advancing technical capabilities such as AI integration, IoT connectivity, and automation efficiency to remain competitive in the market. This focus can overshadow crucial user preferences such as privacy concerns, usability for diverse demographics, and compatibility with existing infrastructure. Furthermore, economic pressures and time-to-market demands may lead to compromises in thorough user research and iterative design processes. Consequently, features that could enhance user experience or address ethical considerations may be overlooked, resulting in smart home technologies might fail to fully meet the diverse needs and expectations of users.

A paradigm shift towards comprehensive user-centered design methodologies is essential. This approach entails rigorous user research at all stages of product development, including early concept ideation, prototyping, and post-release evaluation. By prioritizing empathy-driven design practices, developers can gain deeper insights into user preferences, behaviors and concerns related to smart home technologies. Additionally, collaboration with interdisciplinary teams can provide holistic perspectives on the societal impacts of technological implementations. Moreover, regulatory frameworks that emphasize data protection, accessibility standards, and transparency in algorithmic decision-making can guide developers in aligning smart home features with ethical principles. Ultimately, integrating these strategies foster a more inclusive and responsive design process, ensuring better alignment between smart home technologies attributes and user preferences.

It is important to note some limitations of this study: first, due to the time frame defined for the literature review (2018–2023), new research on smart home technologies may have emerged, adding further insights on this topic. Concurrently, older studies were excluded to focus on recent advancements, future research could consider incorporating a broader temporal scope to include foundational insights. Therefore, the results of this research are based on the reviewed literature (i.e. peer-reviewed academic articles excluding gray literature) as per the scope of this study. Secondly, while we did not conduct a quality assessment and meta-analysis in this review, the decision was influenced by the heterogeneity and variability – in terms of methodologies, participant characteristics, and outcome measures – among the included studies, which could have compromised the robustness of the analyse.

Future research avenues may explore validating the taxonomy and examining alignment and disparities through user studies across diverse smart home applications. These may include caregiver support, childcare and their interaction, security surveillance, and smart home management, considering varying cultural and demographic influences. Conducting context-based smart home analyses will provide a more comprehensive understanding of how these technologies are utilized in different settings, thereby enhancing the generalizability of findings across various contexts and regions.

5. Conclusion

This review provides a comprehensive overview of the main attributes of smart home technologies and the reported user's preferences. The main attributes of smart home technologies from the literature review were categorized into three main themes: (1) *Technology* covering main types of technology, user interfaces, and persuasive techniques, (2) *Function* derived from main smart technologies' functionalities, energy and sustainability aspects targeted, and (3) the *User* category, covering user motivations and user engagement. Furthermore, users' preferences reported in the literature were analysed and organized into five categories: functional aspects, value and benefits, social and cultural influences, ethical and responsible considerations, and user control and trust. Analysis of the smart home technology attributes and users' preferences revealed the following findings:

- The study identified the taxonomy of smart home technology attributes and users' preferences.
- Users' preferences are not fully met with the existing smart home technologies, mainly due to the primarily technical approach.
- Privacy, security, and data usage, ethical consideration, social and environmental responsibility, cultural and demographic factors, trust, and social influence are not addressed in many of the reviewed smart home technologies, which may lead to low rates of acceptance of the technologies.
- Compatibility and cost of technology are two technology dimensions often neglected despite their direct and robust relationship with user preferences.

In conclusion, these findings contribute to the existing research in identifying users' preferences that are often neglected in existing practices in the design and implementation of smart home technologies. Based on our findings, there is a need for alignment between smart home technology attributes and users' preferences.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

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