Malaysian Journal of Sustainable Environment
Special issue, Dec (2024) 17-36
doi: 10.24191/myse.v11i3.3899

EXPLORING THE KEY VARIABLES OF HUMAN-COMPUTER INTERACTION (HCI) CHARACTERISTICS FOR SMART HOME DESIGN

Yan Yan*[1], Khalil, N.[2] & Ali, I.M.[3]
***Corresponding Author**
[1]School of Culture Creative, Anhui Finance and Trade Vocational College, Hefei, 231281 Anhui, China,
[2,3]College of Built Environment, University Teknologi MARA, Perak Branch, 32610 Perak, Malaysia

37859954@qq.com, natas582@uitm.edu.my,
irwan9471@uitm.edu.my
Received: 22 May 2024
Accepted: 29 September 2024
Published: 31 December 2024

ABSTRACT

With the rapid development of the Internet of Things and artificial intelligence technology, the smart home system has become an important part of the modern living environment. Human-Computer Interaction (HCI), is a key factor of smart home user experience, the optimization of its mode and attributes is crucial to improve user satisfaction. Smart home system provides a convenient life experience, but the complex interaction mode and unclear interaction attributes may lead to user operation difficulties and affect user acceptance. Therefore, a further study of the mode and attributes of HCI is of great significance for the design of a more humanized intelligent home system. The purpose of this study is to explore the variables related to the characteristics and attributes of HCI in the existing smart homes. The key variables are extracted through an extensive literature review, collecting and organizing existing relevant studies of smart home HCI characteristics and attributes. A comprehensive framework of HCI characteristics is constructed based on the literature findings while the interactions are revealed through the constructed model towards theoretical support and practical guidance for future smart home design. The findings will help smart home developers and designers gain a deeper understanding of user needs in designing a more efficient, intuitive, and satisfactory smart

home interaction system.

Keywords: *Human-computer interactions (HIC), Smart home design, HIC characteristics, Literature review, Qualitative analysis*

INTRODUCTION

Human-Computer Interaction (HCI) plays a crucial role in developing smart home systems. Effective HCI design not only improves device accessibility but also enhances user satisfaction and loyalty. Consequently, exploring the key variables of HCI characteristics in smart home design has become a priority in current research. This study aims to identify the key variables of HCI in smart home design and analyze how these variables collectively shape the interactive experience within smart homes. Through a comprehensive literature review and research, this study establishes a preliminary theoretical model that illustrates how the key variables of HCI interact and their influence on design outcomes. This framework is intended to assist designers, technical developers, and researchers in better understanding user needs and in creating smart home products that align more closely with user expectations.

Research Background and Purpose

With the release of China's "Smart Home Product Interconnection Middleware Technical Standard, "Made in China 2025" initiative, and the advent of Industry 4.0, alongside the proposal of the "Belt and Road" strategy, the smart home sector is poised for significant development and market potential both in China and globally. Currently, numerous researchers are engaged in the study of intelligent home human-computer interaction. Zhang Fengjun (2016) noted that the user interface serves as a conduit for transferring and exchanging information. He identified three key characteristics of human-computer interaction in immersive virtual reality environments: immersion, interaction, and imagination. By examining the relationship between human-computer-environment systems engineering and optimal matching, Liu Wei (n.d.) established a qualitative analysis model for human situational awareness that incorporates multi-level triggering, task complexity, visual saccades, situational awareness, operational performance,

and workload relationships. To address the requirements for extensibility, stability, and reliability in the design of smart home control systems, Li Jun (2018) designed the system architecture based on the characteristics of the Internet of Things, dividing it into three layers: the perception layer, the network layer, and the application layer. He developed access methods for both web and mobile platforms, enabling users to select their preferred option.

The selection and optimization of human-computer interaction (HCI) modes is a critical area of research. This study aims to explore the relevant variables that influence the choice of HCI modes in smart homes, to provide theoretical guidance for future smart home design. This paper will analyze multiple perspectives, including user demographics, design principles, and user behavior and psychology, to identify the optimal HCI mode.

METHODOLOGY

To thoroughly explore the characteristic variables of smart home hyper-convergence, this study employs a qualitative research method through a literature review. By extensively reviewing existing literature, the theoretical framework, technological advancements, and user behavior studies within the smart home domain are systematically organized.

Literature Screening and Analysis

This study conducted a comprehensive and in-depth literature search using the IEEE Xplore, Scopus, Google Scholar, CNKI, and VIP Information databases. Subsequently, the CNKI literature database was selected for further analysis. The CNKI (China National Knowledge Infrastructure) document database is the largest digital knowledge repository in China, created and maintained by the Institute of Science and Technology Information of China (ISTIC). The literature search on topics related to "smart home" within the CNKI database yielded 20,550 academic papers. This substantial number of publications highlights the widespread interest and growing trend of research in the field of smart homes. Through a metadata analysis of these papers, a series of graphs were constructed to illustrate the distribution of research results over time, the diversity of

research topics, and the intersections of various subject areas. The following specific analyses are presented:

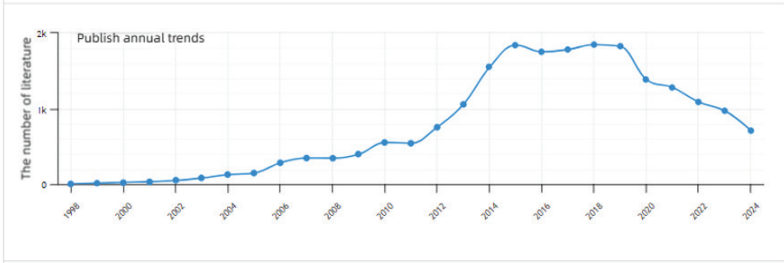

Figure 1. Annual Trends of Literature Publication

Source: China CNKI, 2024

From the annual trend list, the number of documents related to smart homes increased significantly between 1998 and 2015. A sharp rise in the volume of literature was observed between 2009 and 2017, likely due to technological advancements, heightened market demand, and increased awareness of the importance of human-computer interaction (HCI) in smart homes. After 2018, the volume of literature remained consistently high. This indicates that smart homes, as a research field, have garnered extensive attention and have undergone in-depth investigation.

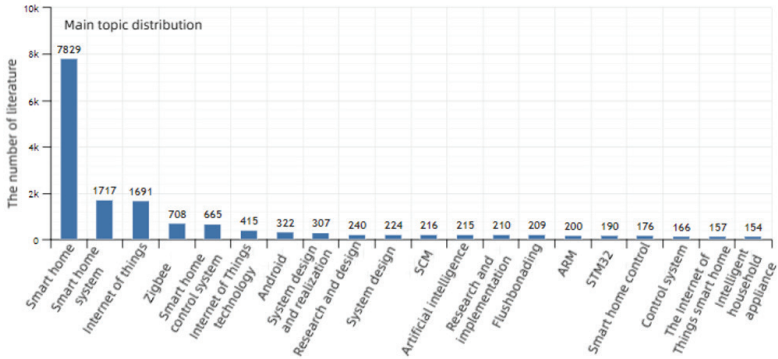

Figure 2. Distribution of Major Themes

Source: China CNKI (2024)

From the topic distribution map, it is evident that research topics in the field of Human-Computer Interaction (HCI) related to smart homes are quite diverse, reflecting the breadth and interdisciplinary nature of research

in this area. Among these topics, the number of publications related to smart homes reached 7,829, making it the most prevalent, followed by topics on smart home systems and the Internet of Things (IoT). Many research areas focus on technological advancements, innovative methods, and applications of HCI within the context of smart homes.

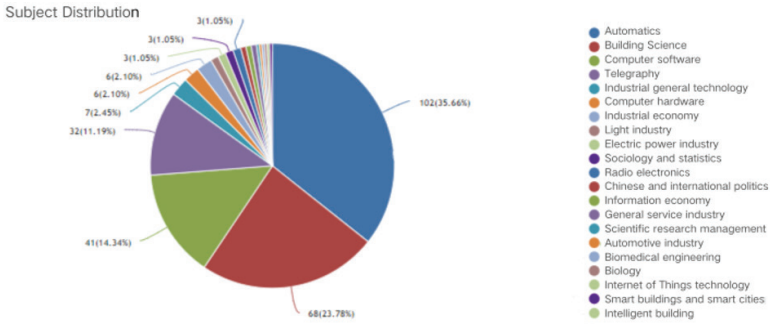

Figure 3. Subject Distribution

Source: China CNKI website

As illustrated by the subject distribution map, the field of smart home technology is inherently interdisciplinary, encompassing automation technology, building science and engineering, computer software, and various other domains. This indicates that the advancement of smart home systems necessitates not only technological innovation but also collaboration and research across multiple disciplines.

Literature Analysis Method

First, formulate the research objectives, keywords, and both exclusion and inclusion criteria, and develop a comprehensive research plan. The terms "smart home" and "human-computer interaction" were selected as the search keywords. Article titles, abstracts, and keywords were searched using the CNKI academic search engine, which includes open-access journals, dissertations, and monographs. Inclusion and exclusion criteria were established (see Table 1) to facilitate the effective selection of relevant articles.

Table 1. Exclusion Criteria and Inclusion Criteria

Inclusion criteria	Exclusion criteria
The literature must focus on HCI in a smart home environment	Non-peer-reviewed articles, such as conference abstracts, reports, book chapters, etc.
Research should provide raw data or have a substantive discussion of the user experience.	Studies with no direct association with smart home HCI
Publication time should be in nearly 10 years to ensure the timeliness of the study.	Marketing literature that focuses on specific product promotion rather than universal design principles

Source: Author

In this study, 65 articles were selected through preliminary reading, extracting sections that are either obvious or potentially related to smart homes. This process facilitated a comprehensive understanding of smart home research from three perspectives: user group differences, user behavior and needs, and design principles. Consequently, several relevant variables about the human-computer interaction (HCI) characteristics of smart homes were summarized from the literature. This paper also proposes a set of research and analysis flowcharts.

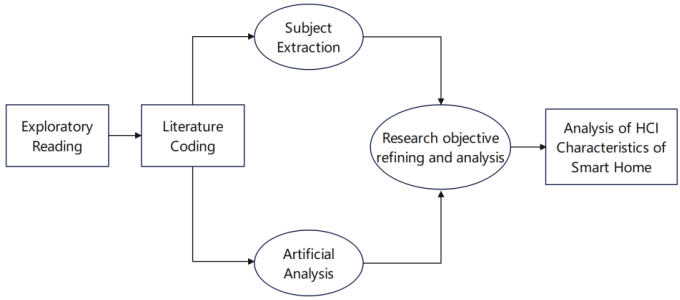

Figure 4. Flow Chart of the Study Analysis

Source: Author

Through this research analysis process, this paper will identify the key variables and characteristics in the field of smart home human-computer interaction (HCI), offering valuable insights and guidance for future research and practice.

STUDY AND ANALYSIS PROCESS

After conducting exploratory reading and coding the literature, the process of encoding begins with the construction of literature labels. Based on the exploratory reading, six preliminary label types can be identified: research objectives, user groups, design principles, user behavior and psychology, technology involved in the research, and interaction. Each label type encompasses a variety of descriptors. According to the understanding and analysis of the literature, these descriptors have been summarized as shown in Table 2. A total of 65 pieces of literature fall into three distinct research dimensions.

By organizing 65 articles, statistics and division were made from three dimensions: user grouping, design principles, and user behavior and psychology, and the results are shown.

Table 2. Classification Results from the 65 Articles

Research dimension	Classify	N(%)
User group	Children / Adolescents	10(15.38)
	Elderly people	11(16.92)
	Family members / Multiple users	16(24.62)
	Specific user groups	9(13.86)
	No designated group	16(24.62)
Design principles	Availability	9(13.85)
	Systematicness	10(15.38)
	learnability	7(10.77)
	Measurability	9(13.85)
	No obstacles	6(9.23)
	Error prevention	12(18.46)
	Contextualization	7(10.77)
User behavior and psychology	Technology acceptance	7(10.77)
	Quick response	11(16.92)
	security	12(18.46)
	Privacy	14(21.54)
	Convenient degree	7(10.77)
	Emotional connection satisfaction	8(12.31)
	Cultural value preference	6(9.23)
	Total	65(100%)

Source: Author

Classification of User Groups

In the review of the relevant literature on smart home human-computer interaction (HCI), it is evident that the classification of user groups plays a crucial role in smart home HCI research, influencing system design, functional implementation, and interaction modes. Age is a significant distinguishing factor identified in the literature. Younger users tend to be more receptive to the latest technologies and sophisticated interactive interfaces, while older users often prioritize ease of use and security features. Special attention must be given to the security and interactive design for child users. For instance, Qian Yuxing (2021) designed and developed an intelligent system tailored for the elderly, which includes fall monitoring and follow-up alarm settings to address the daily safety concerns of seniors living alone.

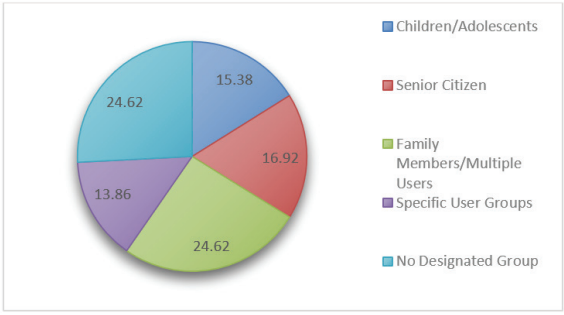

Figure 5. Analysis of User Groups from the Literature Based on Percentage
Source: Author

After further reading, analysis, and refinement, the results are presented in Figure 5.

i. Children and adolescents, as a distinct user group, represent 15.38% of the research on Human-Computer Interaction (HCI) in smart homes. This segment of the literature primarily emphasizes the educational and recreational needs of children and adolescents, along with their adaptability and safety requirements concerning technology.

ii. The elderly represent a significant proportion of 16.92% in research related to smart homes. As the population continues to age, it is crucial to investigate how smart home technology can better serve the elderly and enhance their quality of life. This exploration may encompass aspects such as ease of operation and accessibility design.

iii. The number of smart home interaction studies focusing on family

members or multiple users accounted for 24.62%, indicating a broad research field. In a home environment, multiple users share the same system, making it particularly important to investigate how to meet the diverse needs of different users, the interactions between users, and the provision of personalized services.

iv. Specific user group research encompasses individuals with disabilities, professionals, and users with specialized interests. This segment of the research constitutes 13.86% and typically concentrates on particular needs, including accessibility, customized functionalities, and professional applications.

v. No designated group accounted for 24.62%, which is the same proportion as the family member/multi-user category, representing the highest percentage. This indicates that a significant amount of research is exploring smart home technology not for specific user groups, but rather addressing broader, universal issues.

Classification of Design Principles

In organizing and analyzing the relevant literature on Human-Computer Interaction (HCI), the classification of interaction design principles is essential for understanding how to create interactive systems that meet user expectations and technical requirements. This classification ensures that the system's interactions are both intuitive and effective. The following types of interaction design principles have been extracted from the literature (see Figure 6):

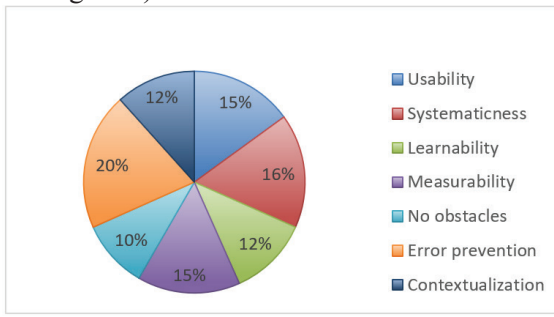

Figure 6. Analysis of Classification Proportions Based on Design Principles

Source: Author

i. Availability accounts for 13.85%. The study involved designing the user interface, simplifying the operational process, and enhancing the overall user experience. This indicates that designers must prioritize

the needs of their users.

ii. Systemic factors account for 15.38%, highlighting the design and implementation of smart home systems. This includes the system architecture, the collaborative interactions among components, and the overall stability and scalability of the system. This significant proportion suggests that the overall design, component collaboration, stability, and scalability of smart home systems have garnered considerable attention in the study of human-computer interaction (HCI) within this context. This emphasis may stem from the fact that systematization is a crucial element in ensuring the long-term and effective operation of smart home systems.

iii. Ease of learning accounted for 10.77%, emphasizing how users can quickly learn and master the use of smart home technology. This involves minimizing the learning curve for users and enabling new users to get started swiftly, which is essential for promoting smart home products.

iv. Measurability accounted for 13.85%, which is equivalent to availability, indicating that the quantitative evaluation of performance and effectiveness plays a significant role in smart home human-computer interaction (HCI) studies. This may be attributed to its capacity to assist designers and researchers in evaluating and optimizing system performance.

v. No barriers accounted for 9.23%, ensuring that all users, including those with disabilities or special needs, can utilize the smart home system. This involves eliminating both physical and cognitive barriers while providing an inclusive design. This relatively low percentage suggests that few studies in the smart home human-computer interaction (HCI) literature concentrate on designing for accessibility for individuals with disabilities or special needs. This may highlight an area that requires greater attention.

vi. Error prevention accounted for 18.46%, indicating that designers must thoroughly consider potential errors during the design process and implement measures to prevent and correct these issues. This approach enhances the stability and reliability of the system while minimizing the challenges users may encounter during operation.

vii. Contextualization accounts for 10.77%, indicating that the system must be capable of adapting to various environments and the specific situations of users. In the realm of smart homes, this encompasses

personalized settings, environmental adaptability, and context awareness.

It can be concluded that, in the study of the design principles of Human-Computer Interaction (HCI) in smart homes, error prevention is the most critical area of concern. For instance, Zhang et al. (2023) argue that utilizing multiple input channels when the input is ambiguous or subject to interference can effectively reduce errors and the need for corrections, thereby significantly improving the recognition rate. The second area of focus is systematization and usability, which emphasizes that, during the design process of smart homes, preventing user operation errors and ensuring the integration and ease of use of the system are paramount. Additionally, learning capability and measurability also represent a substantial proportion of the research, reflecting scholars' interest in user learning and systematic evaluation. Although the emphasis on obstacles and contextual factors is relatively low, they remain essential components of the design principles that should not be overlooked.

Classification of User Behavior and Psychology

When sorting through and analyzing the relevant literature on smart home Human-Computer Interaction (HCI), it becomes evident that the classification of user behavior and psychology reveals users' attitudes, beliefs, motivations, and emotional experiences regarding the use of new technologies. This understanding provides a theoretical foundation for designing interaction systems that effectively meet user needs.

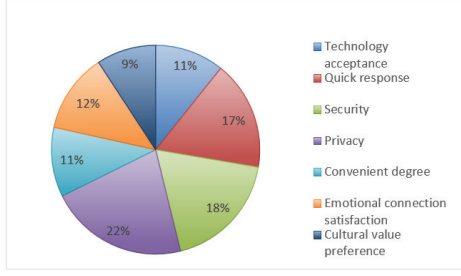

Figure 7. Literature Analysis of User Behavior and Psychology

Source: Author

The following categories of user behavior and psychology are extracted from Figure 7:

i. Technology acceptance accounts for 10.77%, reflecting the level of

user acceptance and adoption of technology. The data indicates that the quantity and proportion of literature addressing this aspect are relatively low, suggesting that it may not be a primary concern.

ii. Fast response accounts for 16.92%, emphasizing the speed of technology in responding to user requests. The volume of literature is slightly greater than the degree of technical acceptance, and this proportion has also increased.

iii. Safety accounted for 18.46%, with the volume of literature surpassing that of rapid response, indicating a higher proportion. This suggests that security is a significant area of focus in user behavior and psychological research, reflecting users' high expectations regarding the safety of technology.

iv. Privacy accounted for 21.54%, representing the largest number of publications among all dimensions and the highest proportion overall. This strongly indicates that privacy is one of the most valued aspects of user behavior and psychological research, highlighting users' significant concern for the protection of their privacy.

v. Convenience accounted for 10.77%, which corresponds to the number of documents related to the degree of technical acceptance and reflects the same proportion. This suggests that convenience and technology acceptance receive comparable levels of attention in user behavior and psychological research.

vi. Emotional connection satisfaction accounts for 12.31%, with the number of documents addressing this topic falling between security and privacy, representing a moderate proportion. This indicates that the emotional connection between users and technology is a significant area of research, although it may not be the primary focus.

vii. Cultural value preferences accounted for 9.23%, representing the smallest segment of the literature and the lowest proportion overall. This suggests that cultural value preferences have garnered less attention compared to other characteristics.

Combining the aforementioned data, we can conclude that privacy and security are the primary concerns in user behavior and psychology research, while cultural value preferences are relatively underexplored. For instance, Tian et al. (2018) point out that the development of security authentication technologies utilizing unique personal characteristics, such as electrocardiograms, voice patterns, and facial features, is shaping the

trajectory and scope of Human-Computer Interaction (HCI) technology.

DISCUSSION AND CONCLUSION

Variables in Smart Home Interaction Design

After selecting the relevant variables identified in the literature survey, the characteristics and significance of smart home interaction design are discussed based on the proportion and level of interest associated with each variable. The following key characteristic variables are summarized: availability, measurement capability, system design, security, privacy, rapid response capability, and fault tolerance. Collectively, these characteristic variables constitute the foundation of a smart home system, ensuring that users enjoy an efficient, convenient, and secure home experience. The relationships among these characteristics are illustrated in Figure 8.

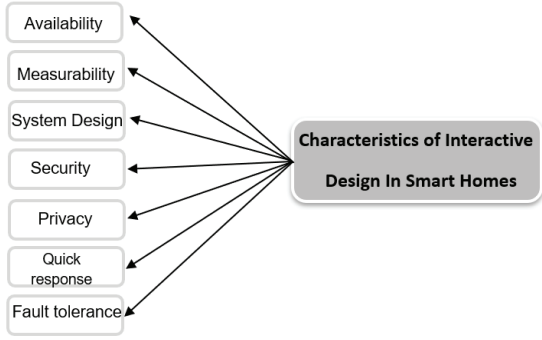

Figure 8. Characteristics of Interactive Design In Smart Homes
Source: Author

i. **Availability**: ISO (2006) defines availability as the effectiveness, efficiency, and satisfaction of a product when utilized by a specific user in a particular context to achieve a defined goal. Consequently, Zhang et al. (2023) argue that product usability is primarily concerned with the user's subjective perception of whether the product can meet a specific objective and how efficiently it does so. Smart home systems should be user-friendly, allowing individuals to operate and control them without difficulty. This encompasses an intuitive user interface design and clear instructions that can be easily understood

by users of all ages. It is related to components such as "instruction wake-up, command execution, and feedback evaluation. Huang Jin et al. (2016) noted that for users, good availability of an application is characterized by easy learning, effective task performance, a low error rate, high satisfaction, and a low user churn rate. Reason: The revisions improve clarity, enhance vocabulary, correct grammatical errors, and ensure proper punctuation and formatting.

ii. **Measurability**: Smart home systems should be capable of collecting and analyzing data to quantitatively assess and measure the efficiency, effectiveness, and user experience of interactions between users and computer systems. These systems must monitor the home environment and user behavior, provide personalized services, facilitate the easy addition of new devices, possess robust expansion capabilities, and optimize performance through data analysis. Measurability is typically associated with elements such as scalability, compatibility, and unified multi-mode linkage control. Xiao-Na et al. (2022) highlighted that multimodal networks will be a crucial aspect in the development of future network systems, and polymorphic modeling and design can effectively reconcile the differences among various network services, levels, and environments. ### Reason: Improved clarity, readability, and technical accuracy while correcting grammatical and punctuation errors.

iii. **System Design**: The interaction design of a smart home must consider the collaborative functionality of the entire system to ensure compatibility and interoperability among devices, as well as the overall stability of the system. This design is primarily associated with three key elements: measurement, identification, and reliability. Rui and Wei (2023) pointed out that the design and integration of human-machine systems aim to establish an optimal relationship among people, machines, and the environment, focusing on efficiency, safety, comfort, and cost-effectiveness.

iv. **Security**: A smart home system must address three key aspects: residential security, information security, and privacy security, to ensure user safety, which encompasses both physical and network security. This implies that the system should possess the capability to prevent unauthorized access and protect user data while implementing comprehensive measures to secure the Human-Interaction-Centric (HIC) process. Huang et al. (2023) expressed concerns in their research

study regarding data privacy and security trends in smart homes from the perspective of HIC.

v. **Privacy**: Privacy is crucial to intelligent household design, design. In the design and application of HIC Home Intelligent Control (HIC) systems, it is essential to prioritize not only should convenience and efficiency of technology, technology also to consider the user's privacy rights and interests, interests. Corresponding protective measures must be implemented to ensure that the users' information and habits are not collected, storage stored, or disseminated without permission. Their consent. This approach allows us to use utilize products and services safely and safely. Securely. The review of literature research from the past five years, (Huang Huang al., al. (2023) identified key research hotspots which include: user needs, network data privacy and security, and understanding awareness of functions and risks associated risks.

vi. **Response Capability**: Home systems should be able to respond quickly and promptly to users' instructions and needs, provide immediate feedback, and enhance the overall experience. Response The speed of response, the accuracy of responses, response the degree of correction degree related to all critical factors. Wang and Zhuang (n.d.) argue whether man-machine friendliness beautiful, aesthetic appeal of the human-machine interface, along with speed, operational stability, advantages ease of use, affects the influence on the user's operation operational (Li Additionally, Li al., al. (2023) conducted experiment on the system time, revealing robots prefer tend to delay their responses by one second, mimicking pause in a conversation, conversation. This in human-computer conversation interaction has a significant impact on users that should not be ignored or overlooked.

vii. **Fault Tolerance**: The system shall must able capable of managing errors, avoid preventing interruption interruptions to failure, failures, be either self-repairing prompt prompting the user to for intervention. Fault tolerance is critical of HIC Human-Computer Interaction (HCI) which enhances the experience and improves ease of usability and reliability of products. It is associated with elements features such as guide guidance restriction operational restrictions, feedback mechanisms, and help resources. Huang al., al. (2016) noted that error tolerance enables the system to maintain a stable and interactive environment despite users, environment, environmental factors, other factors, and influences.

SUMMARY

This study aims to explore the interrelationship among seven key feature variables in the smart home Human-Computer Interaction (HCI) system: availability, measurability, system design, security, privacy, quick response, and fault tolerance. These characteristic variables are essential for evaluating and designing efficient, user-friendly, and secure smart home human-computer interaction (HCI) systems. A comprehensive analysis of these variables reveals a complex interdependence among them. For instance, a system with high availability must incorporate robust security and privacy protection measures to gain the trust of its users. Furthermore, the quality of system design directly influences both Availability and measurability. Furthermore, the capabilities for quick response and fault tolerance collectively determine the stability and reliability of the system, thereby impacting the overall user experience. Future studies could build on these findings to further investigate how to achieve an optimal balance of these characteristic variables across various design contexts and user groups.

In conclusion, this study presents a comprehensive framework of characteristic variables for the design and evaluation of future smart home human-computer interaction (HCI) systems. Through an in-depth analysis of these characteristic variables and their interrelationships, this research offers valuable theoretical support and practical guidance for designers, developers, and researchers. This work aims to advance the field of smart home HCI towards greater accessibility, enhanced security, and improved user experience.

ACKNOWLEDGMENT

I would like to express my deepest gratitude to Professor Natasha and Professor Irwan for their invaluable guidance and support throughout the process of writing this paper. Their expertise and insights have been instrumental in shaping my research and assisting me in navigating the complexities of academic writing. Professor Natasha's extensive knowledge in the field has provided me with a solid foundation upon which to build my arguments. Her thoughtful feedback and constructive criticism have chal-

lenged me to think critically about my work and have pushed me to strive for excellence. Similarly, Professor Irwan's unwavering commitment to me and passion for teaching have been a source of inspiration for me. His willingness to share his time and resources has made a significant difference in my academic journey.

Their dedication to fostering a culture of intellectual curiosity and academic rigor has not only enriched my education but has also had a lasting impact on my personal growth. I am truly grateful for their mentorship and cannot thank them enough for their generosity and kindness.

FUNDING

There is no funding for this research.

AUTHOR CONTRIBUTIONS

The authors would like to acknowledge the individual contributions of each member to the research paper. Yan Yan was responsible for data collection and analysis, as well as drafting the initial manuscript. Natasha Khalil provided expert guidance on the theoretical framework and contributed to the refinement of the paper's arguments. Irwan Mohammad Ali offered valuable insights into the experimental design and assisted in the interpretation of results. All authors participated in the review and approval of the final manuscript. Their collaborative efforts ensured the paper's academic rigor and depth of analysis.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Huang Jin, T. F., Jin, H., Dongqi, H., Yineng, C., Feng, T., Hongan, W., & Guozhong, D. (2016). A Survey on Human-Computer Interaction in Mixed Reality. *In Journal of Computer,28*(6).

Huang, L., He, Y., Ma, Z., Mi, H., & Yao, Y. (2023). Analyzing Smart Home Research Trends from the Human-Computer Interaction Perspective. In Jisuanji Fuzhu Sheji Yu Tuxingxue Xuebao/*Journal of Computer-Aided Design and Computer Graphics , 35*(2), 65–184. Institute of Computing Technology. https://doi.org/10.3724/SP.J.1089.2023.20047.

ISO2006. (n.d.). http://www.fullsearcher.com/n200581614148735. asp.

Jun, L. (2018). *Design and Implementation of Highly Scalable Intelligent Home Control System*. China Computer & Communication, 6. https://doi.org/1003-9767 (2018) 06-103-04.

Li, M., Zha, S., Gong, W., & Jia, Y. (2023). A Survey of Human-Computer Interaction Technology in Intelligent Home for Children's Learning. Jisuanji Fuzhu Sheji Yu Tuxingxue Xuebao/*Journal of Computer-Aided Design and Computer Graphics, 35*(2), 248–261. https://doi.org/10.3724/SP.J.1089.2023.20051.

Liu Wei, Y. X. (n.d.). *Human-computer interaction design and evaluation*. Science Publishing House.

Qian Yuxing, L. H. Z. W. (2021). The Predicament and Countermeasures of the Elderly-Oriented Online Community Information Services: Lessons from the Shutdown of "Yinling.com." *Academic Focus*, 02, 68–109.

Rui, N., & Wei, L. (2023). P*opulation Aging, Artificial Intelligence, and Industrial Consumption" Double Upgrade"*. https://doi.org/10.19629/j.cnki.34-1014/f.230516014.

Tian, F., Fan, J., Dai, G., Du, Y., & Liu, Z. (2018). Thoughts on human-computer interaction in the age of artificial intelligence. *SCIENTIA SINICA Information, 48*(4), 361–375. https://doi.org/10.1360/n112017-00221.

Wang, J., & Zhuang, Z. (n.d.). *Research on a knowledge-defined*

polymorphic network attainable service architecture. 43(4). https://doi.org/10.11959/j.issn.1000−436x.2022076.

Xiao-Na, M. A., Zhang, Y.-X., & Qian, Y. U. (n.d.). *Smart Home Design Based on Multimodal Information Interaction*. https://doi.org/10.19554/j.cnki.1001-3563.2022.16.006.

Zhang, F., Pan, Z., & Lu, Y. (2023). AIoT-enabled smart surveillance for personal data digitalization: Contextual personalization-privacy paradox in smart home. *Information and Management, 60*(2). https://doi.org/10.1016/j.im.2022.103736.

Zhang Fengjun, D. G. X. (2016). An Overview of Human-Computer Interaction in Virtual Reality. *Science China Press, 46*(12), 1711–1736. https://doi.org/10.1360/N112016.