

Elderly-Oriented Intelligent Wooden Sofas: Mapping Mental Models to Furniture Design

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Wood-based furniture, which is valued for its durability and timeless elegance, remains popular among the elderly. Intelligent wooden sofas now transform traditional usage patterns through technological integration. This study explores elderly users' needs and challenges in intelligent wooden sofa interaction. It examines user experience (UX) and user interface design (UI) trends for seniors in Intelligent furniture systems, followed by market analyses of existing wooden sofa designs and control apps. Quantitative surveys and qualitative interviews were used to assess elderly preferences toward intelligent wooden furniture. Survey results were used to inform user personas based on wooden furniture habits, with affinity diagrams identifying material perception mental models. The study involved 116 elderly participants, and questionnaire data for 16 indicators were analyzed using IBM SPSS Statistics 27, confirming a four-dimensional structure through factor analysis (KMO=0.869, $p<0.01$). Based on the results, key areas for software improvement were identified, including 'discoverability', 'usefulness of content', and 'aesthetics of the interface'. These findings are crucial for addressing user experience problems, correcting the product development direction, establishing a user-centric iterative path, and providing foundational insights for developing elderly-friendly intelligent wooden sofa designs.

DOI: 10.15376/biores.20.4.9944-9961

Keywords: Age-friendly wood furniture; Mental models; Interaction design; Intelligent sofas

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INTRODUCTION

As society continues to evolve and medical technology advances, the issue of global population aging has become increasingly prominent (Fang *et al.* 2020). Wood-based furniture plays a pivotal role in the lives of elders, which can be attributed to its natural materials and user-friendly design. Moreover, the rapid development of the intelligence industry has significantly impacted the elderly, with wood-based intelligent sofas becoming increasingly prevalent in their daily routines (Liu *et al.* 2023). The widespread adoption of smart home technology has the potential to enhance the efficiency of elderly individuals in completing household tasks (Fahad and Tahir 2021). The interface stands as the vital connection between the smart home system and the user (Zhou *et al.* 2023), and well-designed interfaces can greatly improve the usability and user experience of these systems (Reig *et al.* 2022).

As people age, they may become less open to new things and feel intimidated by new technologies (Hill *et al.* 2015; Lee and Coughlin 2015; Miller *et al.* 2016).

Understanding the cognitive characteristics and emotional needs of the elderly can help them accept intelligent products. As everyday furniture, sofas are used by the elderly for various static and dynamic activities (Fabisiak *et al.* 2021). Suitable sofas play an important role in improving the quality of life for the elderly, which presents significant development opportunities for the scenario-based design of intelligent sofas (Zhou *et al.* 2022). Currently, there are very few intelligent sofas specifically designed for the elderly. The selection of wooden materials plays a crucial role in enhancing the quality of life for the elderly, providing significant potential for the contextual design of intelligent sofas. By focusing on user experience, designers can shape age-friendly designs and ensure that products meet practical needs, enhancing the quality of life for older individuals (Alves *et al.* 2020; Zhou *et al.* 2023). Designing sofas that cater to the habits and health needs of the elderly will be an important direction for future age-friendly furniture design.

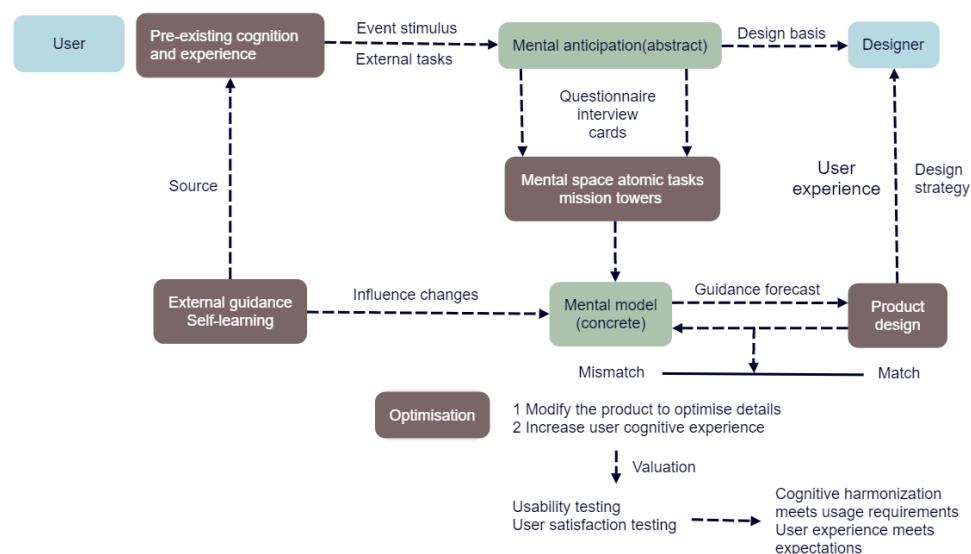


Fig. 1. Picture user-designer mind matching contact chart

User experience covers a wide range of elements. In interaction design, user experience design includes the products users interact with and the design of human-computer interfaces. This encompasses the results users achieve and their psychological and physical sensations (Martín and Macías 2023). The theory of mental models was adopted for research in the present work. A mental model is the internal cognitive structure that influences how people perceive, understand, and behave within it (Jones *et al.* 2011). This concept was initially introduced by British psychologist Kenneth Craik (Craik 1967). As shown in Fig. 1, in design, grasping a user's mental model is crucial for creating products that align with user perceptions and expectations (Yamaoka *et al.* 2012), and for developing more effective communication and educational approaches.

In the study conducted by Doi *et al.* (2021) regarding user-designer consistency, researchers explored the effects of differing mental models between users and designers on the usability of systems. The study concluded that when mental models are asymmetric, users may encounter challenges in operating systems, particularly in understanding device status and screen structure. As a result, the study proposed design principles to address these issues. In Jan's study on children's cognition of Earth's shape, maintaining consistency in mental models was employed to ensure the accuracy of literature research (Jelinek 2021).

In product design, Francalanza suggests that design requirements should be categorized into basic needs, performance needs, and expected needs (Francalanza *et al.* 2019). Surveys can collect users' subjective preferences, interviews can uncover users' needs and life experiences, and observation methods aim to record users' actual operations, helping to identify hidden issues. Hurtienne *et al.* (2010) propose that inclusive design refers to creating interactive products that need to align with users' extensive prior experiences and cognitive abilities.

The study focuses on how the elderly interact with smart home technologies. It is important to consider that the elderly's abilities and behaviors can be affected by their circumstances and external factors. To address potential issues with understanding these technologies, Wei *et al.* (2023) suggest that the younger generation plays a crucial role in guiding and assisting the elderly. Group classification design can be incorporated in interactions between the elderly and products. Du *et al.* (2018) propose that mental models are influenced by perception and cognition, and elderly individuals of different ages, professions, and educational levels form different mental models. Maintaining consistency among research subjects is crucial for reliable results.

The design process based on mental models follows these steps: segment the target users, obtain atomic tasks (which refers to the smallest, indivisible unit of work that cannot or should not be further broken down during execution) through methods such as questionnaires, observation, and interviews; construct a task hierarchy, and organize the mental space (which refers to the cognitive structure and anticipated behavioral framework that users construct internally when interacting with a product) according to the steps users take when using the product.

The current design of intelligent sofas often overlooks the unique needs of elderly users. Given that older adults may have reduced perceptual and cognitive abilities, as well as fears regarding new technologies and challenges related to perceptual decline, their interactions with smart home products can be significantly affected. In light of these concerns, this study delves into the realm of intelligent wooden sofas, examining the specific needs and mental models of the elderly to ensure that their requirements are adequately addressed. Based on the analysis, three key questions were proposed:

1. What are the differences between existing products in the market and products that truly meet the needs of the elderly?
2. What are the demand factors in the interaction process of elderly users? Are they core intrinsic needs?
3. Can the problems faced by elderly users be addressed through corresponding designs, and what do their mental models entail?

PRE-EXPERIMENTAL PREPARATION: RELEVANT PRODUCT MARKET RESEARCH

Comparison of Interaction Methods

As shown in Table 1, intelligent sofas are increasingly being controlled using mobile apps. Controlling *via* mobile apps offers several advantages over other methods, such as location independence, suitability for personalized customization, real-time feedback of data, and strong intuitive performance. At the same time, compared to traditional handheld remote controls, using smartphone apps to control smart home devices is more convenient because it eliminates the need to search for a remote control. However,

in recent years, handheld remote controls have become simpler and rely more on users' understanding of smart products operation. This has made some elderly people hesitant to use handheld remote controls and limited the expansion of remote controls functions.

Table 1. Common Intelligent Sofas Interaction

Interaction Methods	Examples
Voice Control	Users can interact with the intelligent sofa through voice commands, such as using the built-in intelligent speaker of the intelligent sofa to recognize user voice commands for adjusting the angle of the intelligent sofa.
Control Via Mobile App	Users can download the corresponding intelligent sofa app and control it on their phones, allowing for more scenario-based operations and expanding the range of product services.
Gesture Recognition	Using mathematical algorithms to recognize user gestures, enabling computers to understand human behavior. Users can control or interact with devices using simple gestures, for example, making specific gestures in the air to adjust the state of the intelligent sofa.
Handheld Remote Control	Remote control <i>via</i> handheld remote control is a more traditional product interaction method, widely used in home interaction.
Sensor-triggered	The intelligent sofa device can automatically identify users based on sensor data, establishing a connection between the user and the product. However, there are significant limitations to achieving diverse functionality.
Automation Rules	Set up automation rules, for example, issuing reminders at specific times.

Comparison of Sofa Materials

In the design of sofas, wooden materials are favored by the elderly for their natural and warm characteristics. Compared to traditional metal or plastic materials, wood offers a more inviting and comfortable feel, while also being more environmentally friendly and durable. Market research indicates that elderly individuals are more inclined to choose furniture made from wood because it evokes memories of the past and aligns with their pursuit of a natural and healthy lifestyle.

Software Analysis

In this work the authors chose to conduct direct and reference competitor analyses due to the lack of research and development on age-friendly interfaces for intelligent sofa controls. When comparing the main interfaces of intelligent sofas control apps from a macro perspective, they are all comprised of product renderings or acupoint diagrams and functional buttons. Most app functions are carried out using touch and swipe interactions. The Rongkang Intelligent Massage Sofa app includes hidden interactions that are not easily discovered. In terms of visual design, most apps have light-colored backgrounds, and the animation effects are relatively rigid.

Upon reviewing current relevant apps, it has been found that most intelligent sofas are primarily designed for massage functions. The multitude of massage modes inevitably drives up the cost of hardware development. Some products lack the function of adjusting sitting posture, and none of them involve functions such as posture correction and assistance in getting up. Only a few apps include features that create ambiance through music and other forms. Currently, the products do not sufficiently reflect age-friendly characteristics.

In order to better meet the needs of elderly users, the APP design of intelligent sofas should, in addition to following the aging-friendly design specifications, give special consideration to the following seven key points: firstly, provide multiple user log-in modes to adapt to the technological proficiency of different elderly users; secondly, design a simple and intuitive product structure to reduce the complexity of the hierarchy, so as to make it convenient for users to quickly find the functions they need; thirdly, enhance the color contrast to help elderly users with poor eyesight distinguish interface elements more easily; fourth, use clear and real photos to visually display product features and operation steps; fifth, strengthen the division of areas between different function cards on the interface to avoid misuse; sixth, appropriately design a user education module to help elderly users become familiar with the use of the APP through simple and easy-to-understand tutorials; lastly, provide extended services, such as customer service support and health consultation to increase the added value of the product. These design considerations will help enhance the experience of elderly users and make the intelligent sofa more approachable and easier to use.

EXPERIMENTAL

Research Methods

This study strictly adhered to the ethical principles outlined in the Declaration of Helsinki. All participants provided written informed consent prior to the study, with a clear understanding of the purpose of data collection, how their data would be used, and their rights, including the right to withdraw from the study at any time. To protect participants' privacy, all collected data were anonymized and stored on secure servers with local encryption. Access to the data was restricted to authorized members of the research team to ensure data security and prevent any unauthorized disclosure.

This study employed a combination of methods, including participant observation, in-depth interviews, competitive product analysis, structured observation, questionnaire surveys, and user experience evaluation. Both quantitative and qualitative investigations were conducted with elderly participants through questionnaires and in-depth interviews, aiming to explore their needs in the context of sofa chair usage and their behavioral preferences when interacting with smart products. The core questions of the interview outline focused on the following aspects: (1) typical scenarios and challenges encountered by elderly users when using sofa chairs in daily life; (2) their understanding of and acceptance toward smart furniture functions; (3) their acceptance level and pain points in using smartphones and mobile apps; (4) their practical needs and emotional responses regarding assistive design; (5) their genuine needs and emotional responses toward assistive design.

During the data analysis phase, an open coding method was employed to analyze the interview transcripts line by line, identify initial concepts, categorize them, and summarize key themes, from which design insights were extracted. The entire coding process was independently carried out by two researchers and cross-validated to reduce subjectivity and enhance the reliability of the results. Based on the findings, user personas were constructed, from which mental models were derived to summarize user pain points and identify potential design opportunities.

Stratified sampling was used in this study to ensure representativeness across different subgroups. The reliability of the questionnaire data was tested using Cronbach's α coefficient method, indicating a high level of internal consistency.

Questionnaire Survey on Elderly Groups

In a previous survey, the usage of smart products among the elderly population was measured. Based on the characteristics of the elderly, 23 positive statements were formulated, and feedback was collected using a Likert scale to gauge attitudes. The scale included options for 'Strongly Disagree', 'Disagree', 'Neutral', 'Agree', and 'Strongly Agree'.

A questionnaire with 41 multiple-choice questions was used. A total of 128 questionnaires were distributed, and 123 valid responses were received, with 94 being filled out online and 29 offline. The recovery rate for the questionnaires was 96.1%.

Questionnaire reliability analysis

This study utilized the Cronbach's α coefficient method to test the reliability of the data. IBM SPSS Statistics 27 software was employed for this purpose. Generally, a Cronbach's α coefficient exceeding 0.7 indicates good consistency in the questionnaire data. All items in this scale had Cronbach's α coefficients greater than 0.7, demonstrating high overall reliability. This implies that the study has good internal consistency overall.

Questionnaire validity analysis

The validity of this study was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test, as well as exploratory factor analysis. Firstly, the KMO measure was analyzed. If the KMO value is greater than 0.5 and the significance level of Bartlett's test is less than 0.05, it is suitable for factor analysis. The results of the questionnaire in this study showed a KMO value of 0.805, meeting the prerequisites for factor analysis. Additionally, the data obtained a value lower than the significance level of 0.05 in Bartlett's sphericity test. This suggests that the data is suitable for further factor analysis. After analyzing the 23 survey questions from the Smart Product Use Scale for the Elderly Group using principal component analysis, there were 6 factors with initial eigenvalues greater than 1, explaining a cumulative variance of 76.548%. This indicated that these six factors effectively represent the original data. Therefore, these 6 factors provide substantial insight into the behavior and preferences of older users when using smart products.

Following the principal component analysis, this study identified six pivotal factors that significantly shape the elderly's interaction with smart products: (1) External Support, highlighting the instrumental role of family and peer encouragement in fostering seniors' affinity for smart technology; (2) Smart Needs, mirroring the intrinsic curiosity and demand among older users for intelligent devices; (3) Existence of Necessity, underscoring the perceived indispensability of smart products in the daily lives of the elderly; (4) Product Understanding, reflecting a clear recognition of the utilities and advantages offered by smart products; (5) Self-perception, indicating strong smart product use among older adults; (6) Active Learning, depicting a proactive and assured approach of older adults towards mastering smart devices. With factor loadings surpassing the threshold of 0.7, these dimensions not only exhibit a robust correlation with the respective variables but also offer invaluable insights for designing smart products catered to the senior demographic.

Questionnaire results analysis

Descriptive Statistics: A descriptive statistical analysis was conducted on the basic characteristics of the respondents. The results of the survey showed that the majority of respondents were aged between 60 and 70 years old (51.22%). The predominant educational level was high school (43.09%), and most individuals were retired and lived at home (88.62%), with caregiving mainly provided by children, spouses, or both. The monthly disposable income mostly fell between 1001 and 3000 RMB (63.41%). Most respondents were suffering from chronic diseases, experiencing symptoms such as dizziness, discomfort in the lower back, and other issues when standing up or sitting down.

On the use of smart products, the results of the survey showed that 74.8% of elderly individuals own smart eldercare products, and they prioritize cost-effectiveness and ease of operation when selecting smart products. Smartphones are widely adopted among the elderly, with the majority using them for over 10 years. A minority, 17.1%, indicated encountering difficulties in usage. Common learning methods include learning from relatives and friends or self-study, and frequent operations involve tapping and swiping. Understandability and error correction are the main issues with smartphone applications. The scale data showed that users generally had positive attitudes toward the necessity, demand, active learning, and external support for smart products. However, they expressed some reservations regarding their understanding of the products and their self-perception, as indicated in Table 2. The small standard deviation of the findings suggests that the respondents' opinions were relatively consistent.

Table 2. Descriptive Statistical Analysis of Variables (N=123)

	Minimum Value	Maximum Value	Mean	Standard Deviation
Existence Necessity	2.00	5.00	4.13	0.42
Smart Needs	2.00	5.00	4.02	0.52
Product Understanding	1.00	4.00	2.30	0.37
Active Learning	2.00	5.00	4.01	0.48
External Support	2.00	5.00	4.16	0.42
Self-Perception	1.00	4.00	2.17	0.31

Differential analysis

Based on the statistical analysis in Table 3, there was a significant difference between gender and attitude toward the use of smart products in five dimensions ($P < 0.05$). Specifically, in the 'necessity' dimension, men were found to agree more with the necessity of smart home products than women; in the 'smart demand' dimension, men's intrinsic demand for smart products and acceptance of new technologies were significantly higher than women's; in the 'product comprehension' dimension, men showed a slightly better level of knowledge of smart products than women; in the 'active learning' dimension, women were significantly more motivated than men; in the 'self-perception' dimension, women's motivation was significantly higher than men's; in the 'external support' dimension, the gender difference was not significant, indicating that the views and attitudes of males and females on this point were closer.

Table 3. Gender Difference Test in Perception of Intelligent Products

Variable	Men (N=57)	Women (N=66)	T
Necessity	4.592±0.452	3.739±0.666	8.408***
Smart Demand	4.272±0.722	3.807±0.835	3.278**
Product Understanding	2.496±0.791	2.140±0.781	2.502*
Active Learning	3.970±0.715	4.389±0.661	3.363**
External Support	4.135±0.799	3.894±0.749	1.722
Self-perception	2.334±0.877	2.020±0.718	2.144*

* indicates P value less than 0.05, ** indicates P value less than 0.01, *** indicates P value less than 0.001

Related Group Interview Survey

Qualitative research was carried out through in-depth interviews that were designed to be simple and easy to understand, particularly for older individuals. Using complex language may result in interviews being difficult and frustrating for the elderly. Due to the pandemic, some interviews were conducted online with the assistance of family members. The researcher asked questions during the interviews, recorded them on a computer and digital recorder, and reviewed them immediately after each session. A total of 18 people participated in the interviews, including 10 invited participants and 8 follow-up participants. Among them, there were 14 elderly individuals and 4 middle-aged and young caregivers. The age distribution of the 14 elderly interviewees ranged from 60 to 76 years, with an average age of 66.5 years. All participants were classified as mild to moderately aged individuals capable of basic activities of daily living. Additionally, they possessed experience in using smart products in their daily lives, such as smartphones and voice assistants, with a male-to-female ratio of 3:4, meeting the user screening criteria.

Summary of interviews with the elderly group

After conducting in-depth interviews and analyzing the elderly user group, this study summarized a series of potential design points to enhance the user experience of the intelligent sofa. Firstly, in terms of appearance, elderly individuals were found to generally prefer sofa chairs with a combination of wooden frames and upholstery. This design not only offers a warm and natural feel but also aligns with their traditional aesthetic preferences. The combination of the sturdiness of the wooden frame and the comfort of the upholstery provides an attractive and practical seating option for the elderly, reflecting their dual need for functionality and comfort in furniture. Secondly, in terms of interface interaction, the design of the app should pursue a simple and intuitive operational flow, taking into full consideration the usage habits of the elderly. It should adopt a framework structure with customized elements to improve ease of use. Moreover, in terms of product function, the design should pay attention to the backrest adjustment speed of the intelligent sofas and their visibility, the design for easy mobility, the selection of materials with non-slip characteristics, as well as the use of appropriate materials to maintain a comfortable body temperature. Additionally, it should be equipped with additional functions such as heating, and the needs of the elderly should be taken into account to assist them when they get up and sit down. In addition, product interaction design should fully consider the physiological and psychological acceptance of the elderly and ensure that the design style is in line with their aesthetic and operating habits. In terms of emotional design, the perception and feedback mechanism of the product should be enhanced to satisfy the desire of the elderly for independent living. Finally, in terms of product guidance, given that most older people can search for information on their own, the guidance design should draw on

what they are familiar with, providing intuitive and easy-to-understand tutorials and tips. Together, these design points constitute a user-centered design framework for the intelligent sofa, to provide a more comfortable, convenient, and responsive product experience for elderly users.

Summary of design points from caregiver group interviews

Based on in-depth interviews with caregiver groups, several key design points were identified. First, Moderate Interactive Design aims to balance caregivers' concern for the elderly with the elderly's need for privacy, avoiding over-concern. Second, Intelligent Concealment Design focuses on preventing disease and tracking health through daily home medical check-up functions, such as monitoring blood glucose and blood oxygen levels, unobtrusively. Third, Intelligent Universalized Design aims to increase caregivers' positive acceptance of smart home technology to reduce older people's unfamiliarity and resistance to smart products. Lastly, Old and Young Inclusive Design emphasizes promoting interactions between older people and children through product functionality to satisfy older people's desire to connect with the younger generation. These design points together constitute a comprehensive strategy to enhance user experience, promote family harmony, and increase the appeal of smart products.

User Personal Construction

User profiling involves turning gathered user data into distinct, relevant personas to aid designers in gaining a better understanding of users, thinking empathetically, and communicating effectively. By creating different user profiles, designers can gain diverse research perspectives and avoid the limitations of a single viewpoint. This study has developed three representative user profiles based on the initial survey to address the varied needs of different user groups.

Grandma Li is an aging elder whose main source of enjoyment comes from the companionship of her elderly partner. However, as she ages, she faces many challenges in her daily life. These challenges include mobility problems that make it difficult for her to get up, especially after sitting for a long period. She also experiences sleep deprivation and easily nods off, which have become daily problems for her. Additionally, she is dealing with memory loss, which affects her ability to manage her medication and causes concern for her and her partner's health. Despite these difficulties, Grandma Li has not given up her desire to learn new things; however, she lacks the appropriate learning opportunities. Therefore, she is looking for a comfortable sofa that will help her get in and out of her seat easily, a system that will remind her of important things to avoid forgetfulness, and an easy way for her and her partner to monitor each other's health and encourage each other to exercise. Grandma Li hopes to have other meaningful activities in her free time to enrich her life. She believes that with the help of these technologies, she can improve the quality of life for herself and her partner and enjoy a healthier, happier life.

Grandpa Gao is an optimistic and cheerful old man who lives alone. He actively embraces old age, is curious about new things, and stays connected with the community through apps such as Jitterbug and Taobao. However, Gao faces various challenges in his daily life, including dizziness when getting up quickly, fatigue after sitting for long periods, concerns about being out of touch with the times, boredom when sitting alone for long periods, and his children's excessive attention to his life. As a result, Grandpa Gao is looking for an adjustable seat that will remind him to avoid being sedentary at the right time and provide other activities to pass the time during breaks. He also has a strong desire

to learn new things to keep up with the pace of an aging society and is eager to prove to his children that he is in good health to ease their concerns.

As a busy career woman, Ms. Tian's life is filled with the dual pressures of work and family. While taking care of her children, she also has to take care of her elderly parents from time to time, constantly worrying about their health and daily life. Ms. Tian's pain points center on concerns about her parents' mobility and health, especially in winter; difficulties in visiting her parents during work; her parents' longing for their children; and the fear that her caregiving will cause trouble for her parents. Her needs and visions, therefore, include ensuring her parents' safety, monitoring their health data remotely, reducing their sense of isolation, receiving feedback on their condition, and minimizing the impact of her own activities on them.

User Mental Model Construction

The first step in understanding user needs is to create a user profile. User profiles make it possible to focus on specific user groups, such as the elderly, and better understand their behavioral habits and psychological characteristics. After creating a user profile, the user's usage habits and behavioral logic can be understood, and a mental model is constructed of the user's intelligent sofa usage and task operation based on their psychological condition and decision-making changes.

In the present work, a behavioral affinity diagram approach was used to create this mental model based on the overall task flow and system functionality. This approach aims to simplify user operations by combining and removing steps. The goal is to simplify operations while ensuring that the user's ultimate goal is not compromised. The mental space of elderly users when using the intelligent sofa was divided into three parts: cognitive space, behavioral space, and emotional space. Each of these corresponds to the different psychological and behavioral needs of users when using the product. The cognitive space was subdivided into four task towers (As a metaphor or model to illustrate the hierarchical structure of tasks.): 'feeling', 'memory', 'thinking', and 'imagination', according to the processing of information. These task towers reflect the different stages of the user's cognitive process. The behavioral space is divided into five stages: 'leaving seat', 'entering seat', 'in-seat', 'getting up', and 'all stage' to capture the user's behavioral changes during product use. Emotional space classifies users' emotional responses such as "Achievement - Frustration and Backwardness", "Expression and Atmosphere – Loneliness", "Security and Confidence – Helplessness", and "Positive and Negative" to deeply understand the user's emotional experience. As shown in Fig. 2, through this detailed division, 14 task towers were constructed, and 57 requirement points and design contents were extracted from them. These task towers and requirement points provide a comprehensive and in-depth perspective to analyze and summarize the needs of the elderly community when using intelligent sofas. There was a close correlation between the hardware product and the software product. During the design, the task flow and system functions were examined as a whole to ensure the integrity and coordination.

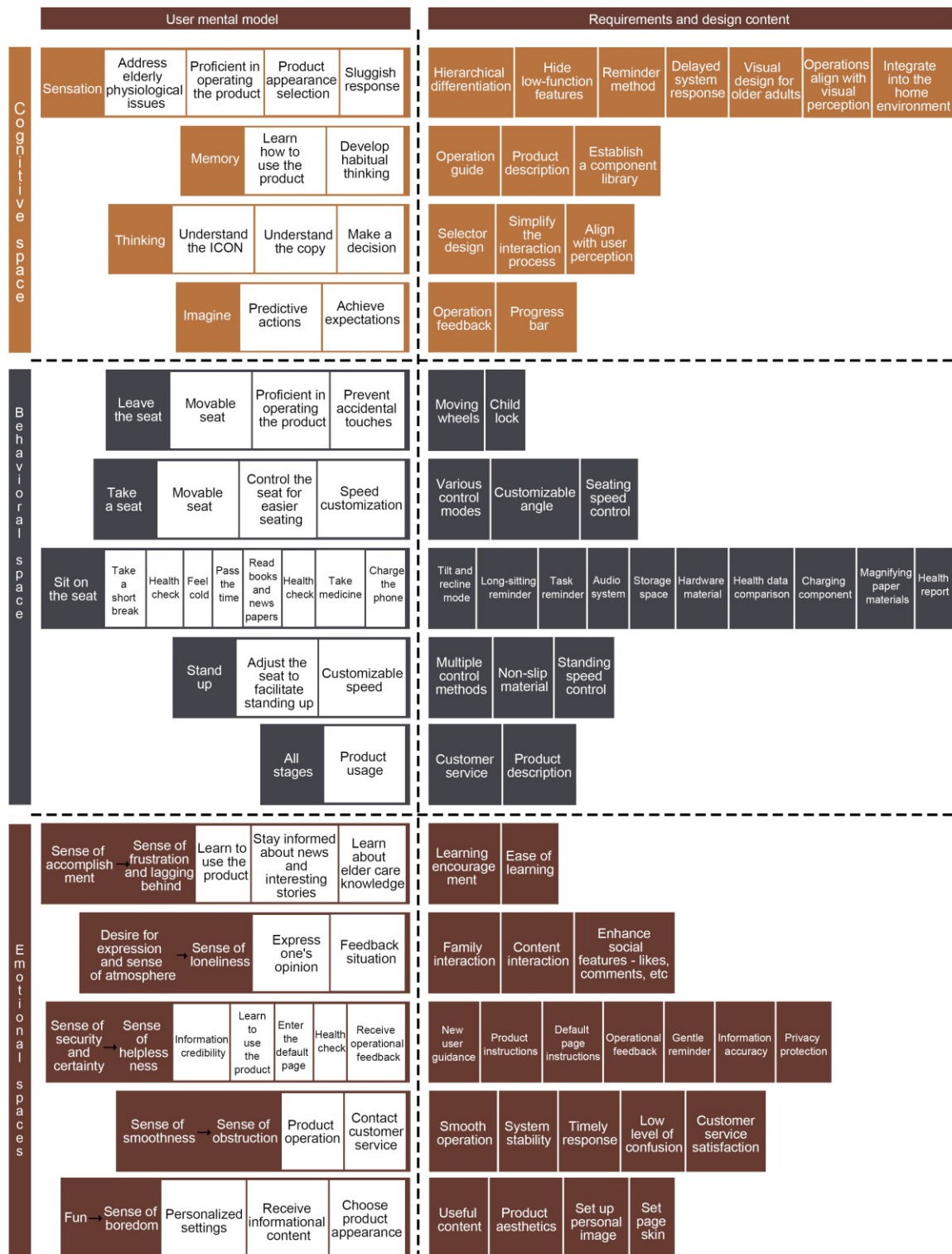


Fig. 2. The merged mental model

Market research, surveys, and in-depth interviews provided a deep understanding of the needs of elderly users and elderly-friendly intelligent sofas. Market research indicated that controlling the sofa *via* a mobile app is the optimal method, and competitive product analysis provided design inspiration. Surveys revealed the characteristics of the

elderly and their mobile phone usage habits, with six-dimensional and gender difference analyses aiding in personalized design. In-depth interviews further uncovered the needs of the elderly. Three user personas were created, and 57 design demand points covering cognitive, behavioral, and emotional domains were identified, providing a foundation for products and services aimed at improving the quality of life for the elderly. Additionally, the needs of caregivers should also be considered to offer a comprehensive elderly care solution.

RESULTS AND DISCUSSION

Design Practice

The software resulting from this work is primarily designed to assist elderly individuals in easily operating their intelligent sofas. Its main function is to control the hardware device. Additionally, the software offers auxiliary functions such as schedule management, child lock, messaging, viewing health data, and accessing product usage instructions. These functions are categorized into four main tabs in the application: ‘Home’, ‘Data’, ‘Discover’, and ‘My Home’. The hardware layer consists of the hardware implementation and the functions to be implemented by the attached handheld remote control.

The default homepage of the APP is called ‘Home’ and acts as the control center for the intelligent sofa. Users can use this section to adjust their seated posture, turn on the heating function, and view real-time usage information such as seating time and current seating status. The homepage includes common functions like to-do reminders, child locks safety settings, and quick customer service entry for a convenient user experience. The ‘Data’ section displays health data collected by the intelligent sofa’s built-in physical signs detection module, including BMI, blood oxygen, blood pressure, and body temperature. Users can view daily data and track monthly and yearly trends. The platform provides personalized health advice based on this data, and family members can share and view each other’s health data for family health management. The ‘Discover’ page provides learning and entertainment content for users while they relax on the sofa. It offers information and learning materials such as smartphone usage tips, health tips, and fraud prevention knowledge. Additionally, it serves as a platform for user interaction and content exploration, enhancing their engagement and motivation to learn. The “My” section is dedicated to managing the user’s personal account. It includes functions for setting personal information, selecting family members, and providing detailed instructions and safety precautions for the product. Our goal in designing these four sections is to create a comprehensive, user-friendly, and educational intelligent sofa control system that caters to the diverse needs of the elderly user community.

Primary Page Design

The first-level page of the app, including “Home”, “Data”, “Discover”, and “My”, constitutes the main portal of the product. These are the core entrances for users to enter and explore the functions of the product. The home page of the app is carefully designed, dividing the main functions and frequently used functions by users into six clear parts: daily message area, product usage information area, primary function area, common functions area, common switch area, and customer service hovering entrance. The “Daily Message Area” at the top of the page is designed to attract users’ attention and is updated

every day. This not only adds humanistic care to the app but also brings users closer to the app emotionally. Users can click to view past messages. The “Product Usage Information Area” focuses on the real-time status of the product, displaying the current users of the intelligent sofa, the status of the intelligent sofa, as well as the angle between the backrest and the seating surface, and the recommended activities. This helps the user to make the right choice of actions and activities. At the same time, it also tracks the user’s sedentary time and provides different status alerts based on the user’s seating time, such as sedentary reminders and feedback to the caregiver group. The “Rise” and “Tilt” buttons on the “Primary Function Area” are at the heart of the app, allowing the user to easily control the angle of the intelligent sofa, assisting the user in rising and adjusting their posture. The “Common Functions Area” provides six buttons designed around user scenarios, including heating settings, quick access to instructions, posture correction, to-do reminders, magnifying glass functions, and more additional services to meet users’ diverse needs. The “Common Switch Area” at the bottom of the page is frequently used and provides quick access to the sedentary reminder and child lock functions. The homepage includes the “Customer Service Hovering Entrance”, making it easy for users to contact customer service at any time. The app interface design focuses on functionality and readability, improving users’ efficiency through the use of white space and a clear layout. Users can personalize their experience by setting a preferred image as the background, reflecting their taste, and harmonizing the app’s color scheme with the background image. The background image can be easily uploaded by the user on the ‘My’ page, creating a warm and personalized environment similar to a photo in a frame, adding a sense of warmth and comfort to the home.

Visual Design

Uphold the principles and guidance of user experience-centered, inclusive, and friendly visual design. Ensure that the interface is intuitive, logical, and clear. It should be friendly to guide the user and reduce the user’s learning cost. Always prioritize the content presentation and minimize the interference of irrelevant design elements for the user. The interface design maintains consistency by using uniform icons and colors to ensure that information is communicated clearly. Visual elements such as font sizes, lines, and rounded corners are carefully designed to create a sense of high-end quality and are in line with the preferences of the majority of users, making the process enjoyable.

Assessment Process Overview

This evaluation aims to enhance the designer’s understanding of user behavior. It requires thorough quantitative data analysis to establish an overall evaluation system and evaluate the usability of the product. The goal is to identify and solve the problems encountered by users in the experience process, correct the direction of product development, provide a product that better meets the needs of the user, and establish an iterative path for the product based on the evaluation system. To achieve this, 116 elderly people were invited to participate in the offline product experience evaluation, with a male-to-female ratio of 13:16. All participants were without cognitive disabilities and were briefed on the product objectives, usage environment, and usage functions before the evaluation. In terms of the experience measurement method and process, the evaluation subjects first needed to have an overall understanding of the product. In addition to the free walking survey, they also needed to complete four basic tasks, including setting the seat state to tilt, adding a to-do list, calling the customer service network, and checking the data

change of the seating time. Subsequently, a questionnaire was issued to score the product experience, and the weight of each indicator and the total user experience score were calculated at the end, with the specific scoring method shown in Fig. 3.

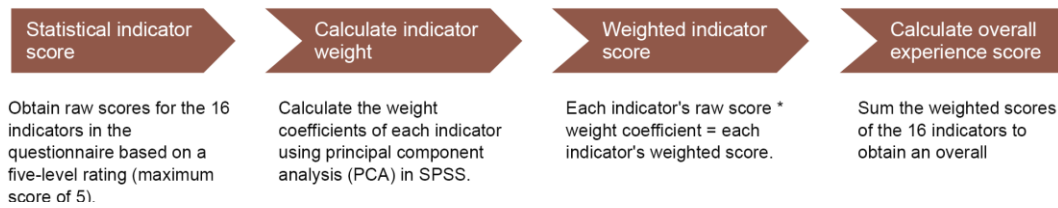


Fig. 3. Scoring method

In addition, based on Maslow's hierarchy of needs theory, there were four dimensions of the software layer and 16 metrics under them, as shown in Fig. 4. These metrics include task completion, information accuracy, content usefulness, *etc.* These metrics can be categorized as 'Effectiveness', 'Ease of use', 'Aesthetics', and 'Satisfaction'. The 16 metrics were transformed into statements about user feelings and behaviors. These statements were then scored on a Likert scale to calculate a total score. The total score was then used to identify the product's strengths, weaknesses, and areas for improvement. This process is designed to provide a scientific foundation for enhancing the product through systematic metrics and analysis.

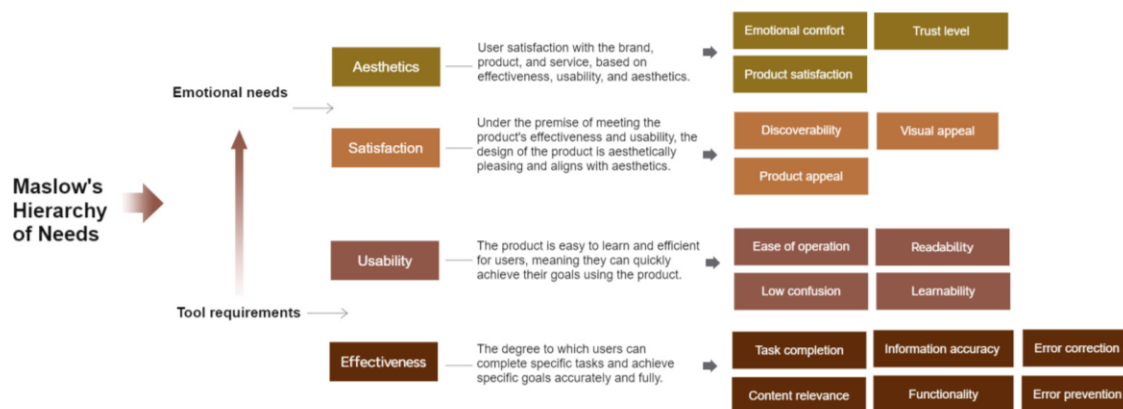


Fig. 4. Dimension and index division

Evaluation Analysis and Summary of Results

In this assessment, the questionnaire data was analyzed for 16 indicators by importing them into IBM SPSS Statistics 27 software. The KMO value was 0.869, meeting the prerequisites for factor analysis. The data passed Bartlett's test of sphericity with a significance level of less than 0.01, verifying that the 16 indicators were indeed attributed to 4 dimensions, consistent with our initial hypothesis. Next, the weights of the indicators were calculated using the total variance explained and the component matrix. By multiplying the raw scores of each indicator with the corresponding weight coefficients, the weighted scores for each indicator were obtained. Adding the weighted scores of these 16 metrics produced a total experience score on a five-point scale, which was further converted to a percentage scale for a more intuitive understanding of the overall level of

user experience. Finally, the metrics were compared to identify the product's current strengths and weaknesses and prioritized subsequent optimization iterations accordingly. The results of this comparison are presented in the form of a chart, as shown in Fig. 5, with the horizontal axis indicating the weighting coefficients and the vertical axis indicating the indicator scores, visually demonstrating the performance and importance of each indicator. This systematic evaluation and analysis provide a scientific basis for the continuous improvement and optimization of the product to better meet the needs of elderly users.

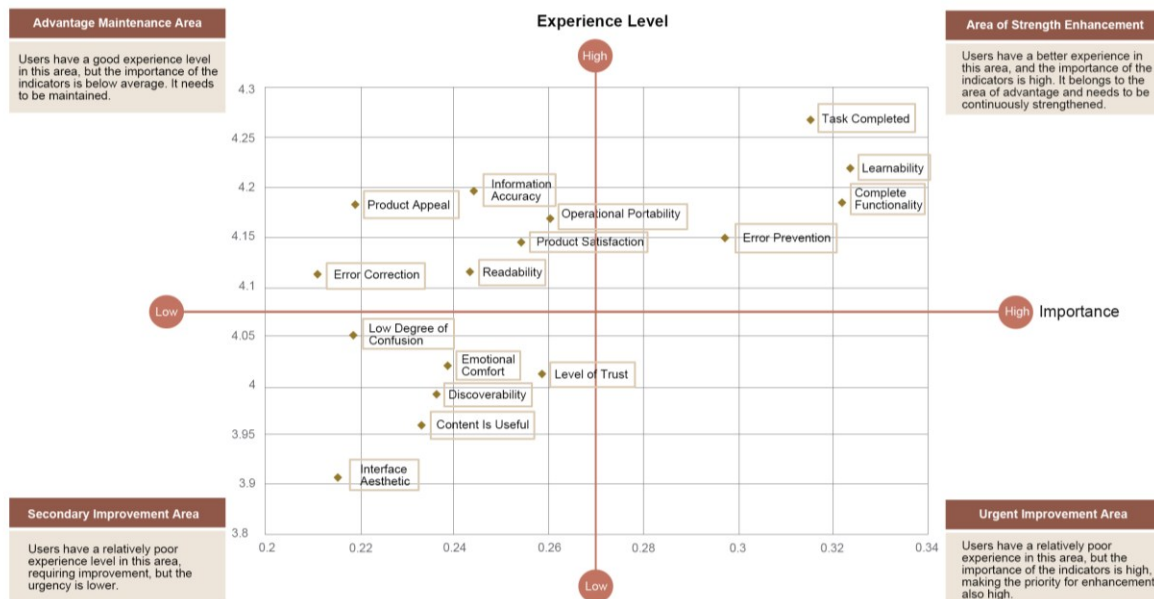


Fig. 5. Dimension and index division

Design Optimization

Based on the results of the experience metrics in the previous section, areas for improvement in the software, including 'discoverability', 'usefulness of content', and 'aesthetics of the interface' were identified. Through interviews with 10 evaluators the main issues are concentrated in the frequently used function area, the content of the discovery page, and the product usage information area on the home page, which need to be optimized. Statistical analysis also showed a high correlation in the evaluators' ratings of items requiring optimization across the defined dimensions. Older users must be able to easily and quickly access information simply and intuitively. To improve the 'discoverability' of features, the design of the on/off buttons will be modified to make it clearer whether they are on or off, for example, by changing their color and size. The connection between the 'Data' page and the 'Discovery' page will be strengthened to help users find relevant scientific information more easily after viewing health data. Additionally, clear visual cues when switching between pages will be provided. To make the content of the 'Discovery Page' more intuitive and user-friendly, the text will be structured to avoid long sentences, aiming to enhance the efficiency of information retrieval. For older users, the text descriptions and steps of the nodes will be displayed, and the node numbers will remain fixed at the top of the page when scrolling, allowing users to quickly jump to the section they are interested in. This will require careful organization and classification of the text content according to the required materials, operation steps, and precautions. To address the issue of 'interface aesthetics', areas of the software with

inappropriate color combinations will be improved to better align with the preferences of elderly users. To alleviate the visual contrast between areas with more information and the surrounding environment, gradient colors and use color blocks will be adjusted to enhance the accessibility and inclusiveness of the interface. Through these targeted optimization measures, the user experience for elderly users will be enhanced, and the software will be better aligned with their needs and usage habits.

Research Limitations

Due to constraints in personnel, resources, and other conditions, this study still had certain limitations that require further improvement, as detailed below:

In the market analysis of elderly-friendly sofa chairs, a total of 12 brands were considered, among which only 4 participated in offline field research. This limited the comprehensiveness of our analysis. Future research will involve more in-depth market investigations and broader analytical dimensions to better align product development with real market environments.

Due to limited personal networks and the relatively high user acceptance threshold of elderly-friendly smart sofas at present, user feedback from individuals with actual usage experience remains insufficient. When conditions allow, the authors aim to engage more directly with relevant user groups and further supplement user evaluations of existing products in future studies.

CONCLUSIONS

1. This study collected 123 valid questionnaires and conducted interviews to analyze users' basic conditions, wooden furniture usage contexts, and smart wooden product usage. Insights into user characteristics from six dimensions were provided, with particular focus on material interaction patterns in domestic wooden furniture environments. Based on in-depth interviews with elderly individuals living alone, elderly individuals with cognitive impairments, and their caregivers, combined with cluster analysis results, this study identified three representative user personas: slow-response elderly, elderly living alone, and caregivers. Each persona was developed across three dimensions—user stories, pain/gain points, and needs/aspirations—to vividly capture user characteristics and uncover potential design needs. On this basis, key design opportunities within the intelligent wooden furniture ecosystem were identified to inform and guide subsequent design practices.
2. Conducting in-depth user experience analysis on the scenarios of elderly individuals using intelligent wooden sofas is essential to thoroughly understand their needs and pain points in material-technology interactions. This analysis aims to develop relevant user personas and wooden furniture-centered cognitive models. These insights will serve as the foundation for wood-integrated design, ensuring that products meet the genuine needs of elderly users in wooden living spaces and provide exceptional user experiences with natural material integration in practical usage scenarios.
3. User experience theory and the hierarchy of needs theory were applied to derive an experience measurement model for elderly-friendly intelligent wooden sofas. Wooden sofa interface interaction details were optimized, enhancing material-conscious product usability, and improving wooden furniture compatibility in user experience. This

approach is not only applicable to the design of wooden elderly-friendly intelligent sofas but also promotes theoretical research and application in wooden furniture human-computer interaction fields, providing valuable references and insights for wood-based smart product design in other domains.

ACKNOWLEDGMENTS

The authors are grateful for the support of the 2022 Culture and Tourism Research Topics of Jiangsu Provincial Department of Culture and Tourism, Grant No. 22Y09.

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Article submitted: April 4, 2025; Peer review completed: May 29, 2025; Revisions accepted: August 13, 2025; Published: October 1, 2025.

DOI: 10.15376/biores.20.4.9944-9961