

Design of Companion Robots for the Elderly from an Inclusive Perspective

Aijia Wang *

School of Creative Arts, Trinity College Dublin, Dublin D02 XH97, Ireland

* Corresponding Author Email: aj3321469559@163.com

Abstract. With the rapid aging of China's population and the growing number of elderly individuals, the mental health of this demographic has increasingly garnered attention from society. Grounded in inclusive design theory, this study analyzes the needs of the elderly population and proposes a companion robot design. This design is informed by an analysis of the current research on existing robots, the physiological and psychological characteristics of the elderly, and the results of a questionnaire survey. The findings of this study indicate that inclusive design is a feasible approach for developing companion robots for the elderly, contributing to improvements in their psychological well-being and overall quality of life.

Keywords: Industrial design, Inclusive design, Companion robot.

1. Introduction

In recent years, China's population aging process has accelerated, leading to an ever-increasing elderly population, and the issue of aging has gradually become a major societal concern. To address the needs of an aging society, the Chinese government has implemented a series of policies and measures, including reforms in elderly care, medical services, and social welfare. However, insufficient attention is still paid to the mental health of the elderly. Amid rapid societal development and changes in family structures, older adults face numerous challenges in their daily lives. Mental health issues, such as a lack of companionship, increased loneliness, and depression, have become increasingly prominent.

In 2021, the Blue Book on the Status of Mental Health of the Elderly in China published by the Chinese Academy of Sciences (CAS) reported that nearly one-third of elderly individuals suffer from depression, significantly impacting their quality of life and sense of well-being. While there are excellent examples abroad, China lags in the design of companion products for the elderly. For instance, the MARIO intelligent companion robot, designed by Mannion in 2019 [1] for elderly dementia patients, alleviates loneliness through voice dialog. The elderly can also browse photos of important events on a touch screen to recall memories. However, such companion products have yet to emerge in the domestic market.

This study aims to explore the impact of companion product design on the mental health of the elderly by applying the theory of inclusive design. Additionally, this study seeks to encourage society to pay greater attention to the mental health needs of the elderly and to develop more effective companion products and services for this demographic.

2. Fundamental research

2.1. Overview of inclusive design theory

Inclusive design is an approach that leverages human diversity in the design process. The term first appeared in 1994, originating in the West. In 2005, BS 7000-6, published by the British Standards Institution (BSI), formally defined inclusive design as the development of mainstream products and services that are easily accessible to as many people as possible, across various global contexts, without the need for special adaptations or highly specialized designs. The primary objective of

inclusive design is to foster environments, products, and services that are more user-friendly for a broader range of individuals while minimizing demands on human capabilities [2].

2.2. Analysis of physical and psychological characteristics of the elderly population

2.2.1. Physiological characterization

As people age, they experience a gradual decline in physical functioning, which includes reductions in sensory functioning, muscle strength, and flexibility. Sensory functions primarily involve vision, hearing, and touch. Studies have shown that, in older adults, the lens of the eye gradually hardens with age, leading to a decrease in visual accommodation, which in turn affects vision [3]. Common visual problems include hyperopia, myopia, and astigmatism. Older adults may experience blurred vision and have difficulty seeing details or distant objects. In terms of hearing, older adults may develop age-related hearing loss (presbycusis), perceiving their hearing as muffled and becoming more sensitive to high-pitched sounds. Regarding the sense of touch, older adults may exhibit diminished tactile sensitivity and difficulty with touch localization, meaning they struggle to accurately identify where on their skin a touch occurs. This can affect their ability to perform daily tasks, such as pressing keys or holding pens. Additionally, reduced muscle strength and flexibility make it more challenging for older adults to perform everyday activities like climbing stairs, lifting heavy objects, or standing up.

2.2.2. Analysis of psychological characteristics

As people age, the psychological characteristics of the elderly often manifest in a lack of self-confidence, diminished self-identity, and a fear of social interactions, making them more prone to low self-esteem, anxiety, and depression. These psychological changes are typically attributed to declines in memory, cognitive habits, and learning ability, which result from the deterioration of brain function [4]. Empty-nest elderly individuals are especially susceptible to feelings of loneliness and more frequent depression due to the absence of companionship and care from loved ones. Studies have shown that empty-nesting older adults report a lower quality of life, reduced subjective well-being, and experience heightened levels of anxiety and depression [5]. Therefore, addressing the depressive symptoms of empty-nesting older adults is crucial for maintaining their mental health.

2.3. The feasibility of introducing the concept of inclusivity into the design of companion robots

Inclusive design is a comprehensive design approach that accounts for the full diversity of users. It emphasizes meeting the needs of individuals across different age groups and abilities, aiming to develop products and services that can be adapted to a wide range of user contexts. From product conceptualization to final production, inclusive design permeates the entire design process, ensuring inclusivity across various use scenarios [7]. According to the user pyramid model, inclusive design prioritizes the needs of individuals with severe disabilities at the top. Once the needs of this group are addressed, those with lesser disabilities and able-bodied users at the base of the pyramid can also benefit [8]. Previous foundational research indicates that the behavioral and psychological characteristics of the elderly population align well with the principles of inclusive design. Thus, synthesizing the findings of both domestic and international scholars, along with prior research analysis, it can be concluded that inclusive design is a highly effective method for developing elderly companion robots.

3. User study and demand analysis of companion robots for the elderly

3.1. User requirements research

A survey and research study targeting users of elderly companion robots is conducted to gain a comprehensive understanding of the challenges faced by the elderly in the process of using these robots, as well as to explore their expectations regarding the form and function of the companion

robot. Through the questionnaire survey, pain points at each stage of use can be identified, allowing for a comprehensive summary and generalization of user needs. This information will provide valuable references for subsequent product concept proposals and development.

3.1.1. Research user selection

To ensure the accuracy and reliability of the findings, I screened potential users of companion robots designed for the elderly. I selected a broadly representative sample of elderly individuals and their family members or caregivers from various regions, social backgrounds, and economic conditions to ensure the diversity and representativeness of the sample. A total of 145 questionnaires were collected, including 78 completed by elderly respondents and 67 by their families and caregivers. All 145 questionnaires were deemed valid, accounting for 100% of the total collected. To gain a deeper understanding of their needs, the questionnaires were categorized into three main sections: basic information, physical needs of the elderly, and psychological needs. By analyzing the results of the questionnaire feedback, it is possible to derive the preferences of elderly individuals regarding the appearance, structure, functions, and interactions of companion robots. Finally, I will implement the design based on the research findings.

3.1.2. User profile

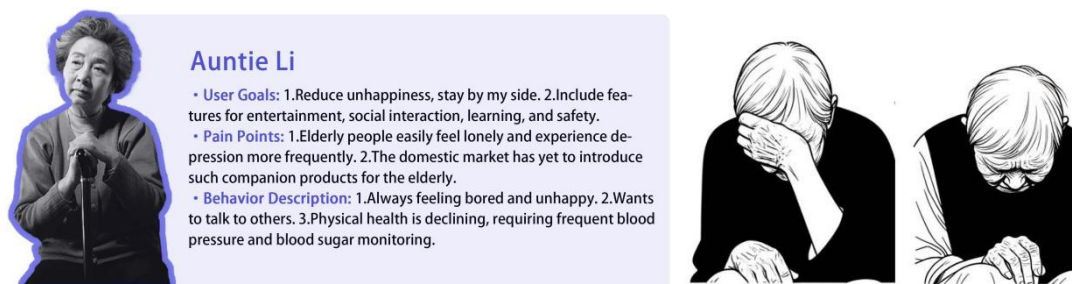


Figure 1. User profile analysis

3.1.3. Analysis of questionnaire results

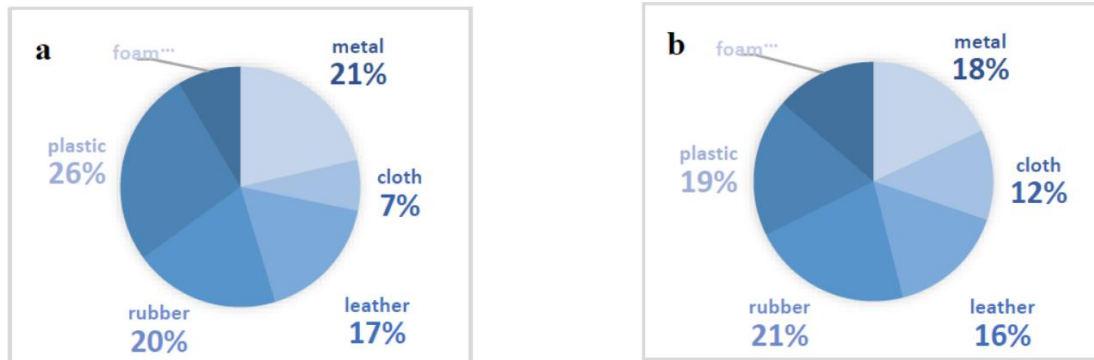
The basic statistics of the research participants, in terms of age distribution, reveal that individuals aged between 60 and 70 years comprise 76.19% of the total sample. Those aged between 71 and 80 years account for 14.29%, while the proportion of individuals aged 80 years and older is 9.52%.

Among the family members and caregivers of the elderly, 83.33% were family members, while 16.67% were caregivers. After analyzing the relevant demographic data and basic information, it can be concluded that the target user group participating in this questionnaire research effectively meets the requirements of the target sample. Therefore, these research data provide a valuable reference for the research findings to a certain extent.

As shown in Table 1(a) and Table 1(b), statistics on material preferences for companion robots reveal that elderly individuals prefer plastic materials (26%), while family members and caregivers of elderly individuals favor both plastic and rubber materials (19% and 22%, respectively). Plastic is typically lighter than rubber, making it easier for the elderly to handle. Additionally, plastic can be made stronger and more rigid by incorporating fiber reinforcement or altering its molecular structure, rendering it superior plastic.

Table 1. Material Preferences of Elderly Individuals and Caregivers

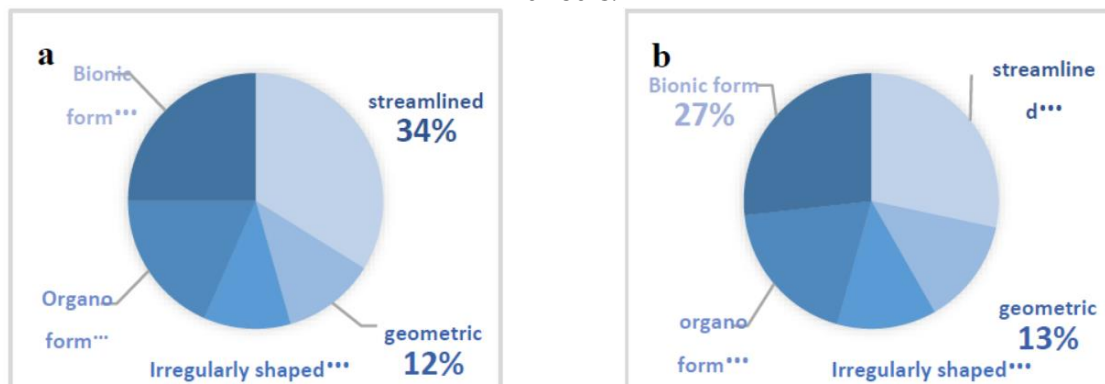
(a) Material preferences of elderly individuals. (b) Material preferences of caregivers and family members.



As shown in Table 2(a) and Table 2(b), statistics on the appearance and styling preferences for the companion robot indicate that elderly individuals, along with their families and caregivers, prefer a streamlined shape (34% and 28%, respectively). Therefore, the companion robot will adopt this streamlined design. In creating the companion robot with a streamlined shape, I will utilize the golden ratio to guide the proportions and structure of its various components. This could involve setting the total length of the product to be 1.618 times that of other components, or ensuring that one section of a curve is 1.618 times the curvature of another section. Employing the golden ratio will result in a more harmonious overall proportion and curvature of the product.

Table 2. Appearance Preferences of Elderly Individuals and Caregivers

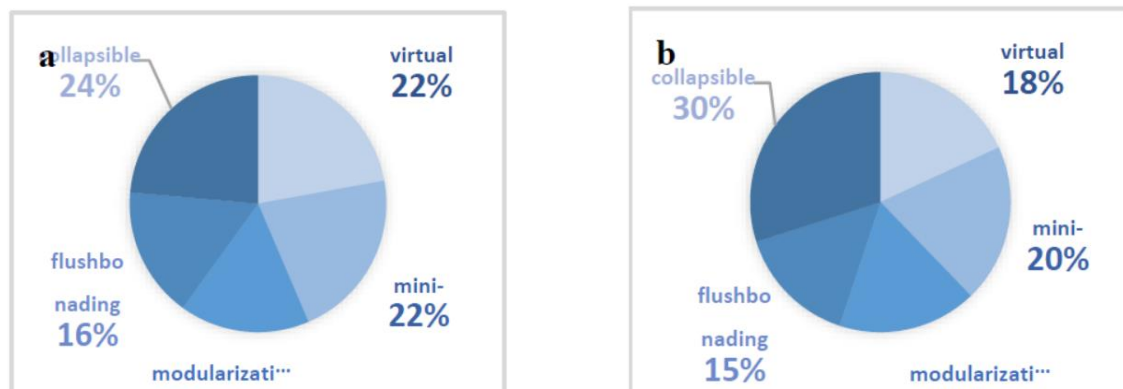
(a) Appearance preferences of elderly individuals. (b) Appearance preferences of caregivers and family members.



As shown in Table 3(a) and Table 3(b), statistics on the structural preferences for companion robots reveal that elderly individuals, along with their families and caregivers, prefer collapsible designs (24% and 30%, respectively). Therefore, the companion robots will feature collapsible structures.

Table 3. Structural Preferences of Elderly Individuals and Caregivers

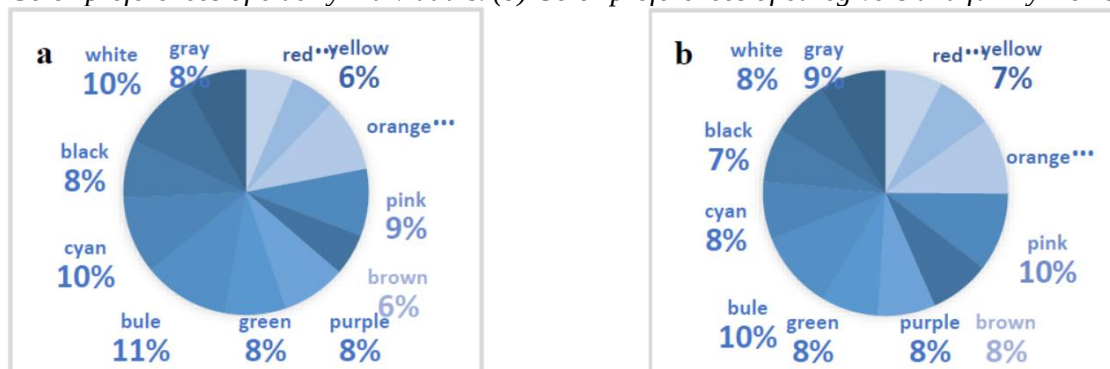
(a) Structural preferences of elderly individuals. (b) Structural preferences of caregivers and family members.



As shown in Table 4(a) and Table 4(b), statistics on the color preferences for companion robots indicate that older individuals prefer blue (11%), while family members and caregivers of older adults also favor blue, along with orange and pink (all at 10%). Older individuals may prefer blue due to its association with inner peace and tranquility, especially after retirement, as the color conveys a sense of serenity. Family members and caregivers of older adults might also prefer blue because it is linked to health and cleanliness, reflecting their focus on the well-being and hygiene of the elderly. Furthermore, blue provides good visual comfort and minimizes visual fatigue, which is particularly important for the elderly as their vision may decline with age. Therefore, the companion robot will adopt blue as its primary color.

Table 4. Color Preferences of Elderly Individuals and Caregivers

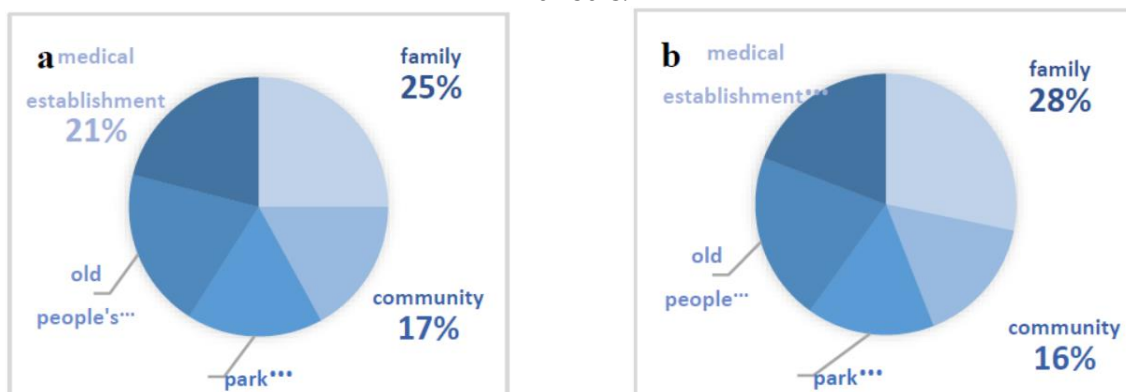
(a) Color preferences of elderly individuals. (b) Color preferences of caregivers and family members.



As shown in Table 5(a) and Table 5(b), statistics on the preferences of companion robots for use scenarios: the elderly and their families and caregivers prefer to use them at home (25% and 28%, respectively), because the home is the most familiar and comfortable environment for the elderly, and the use of companion robots at home will make them feel more intimate and relaxed without having to adapt to unfamiliar environments, and therefore companion robots should be used in the home.

Table 5. Use Scenarios Preferences of Elderly Individuals and Caregivers

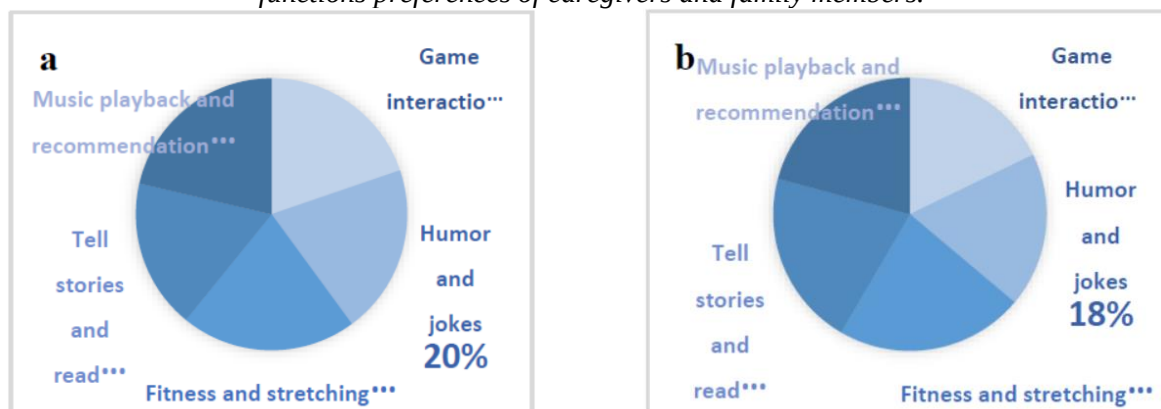
(a) Use scenarios preferences of elderly individuals. (b) Use scenarios preferences of caregivers and family members.



As shown in Table 6(a) and Table 6(b), statistics on the preferences for leisure and entertainment functions of companion robots indicate that elderly individuals, along with their family members and caregivers, prefer health and stretching activities (21% and 22%, respectively), storytelling and reading (18% and 21%, respectively), and music playback and recommendation functions (21% for both groups). These functions contribute to a more energetic and enjoyable life for older adults at home while simultaneously alleviating the burden on family members and caregivers. Therefore, companion robots should incorporate health and stretching activities, storytelling and reading, as well as music playback and recommendation functions.

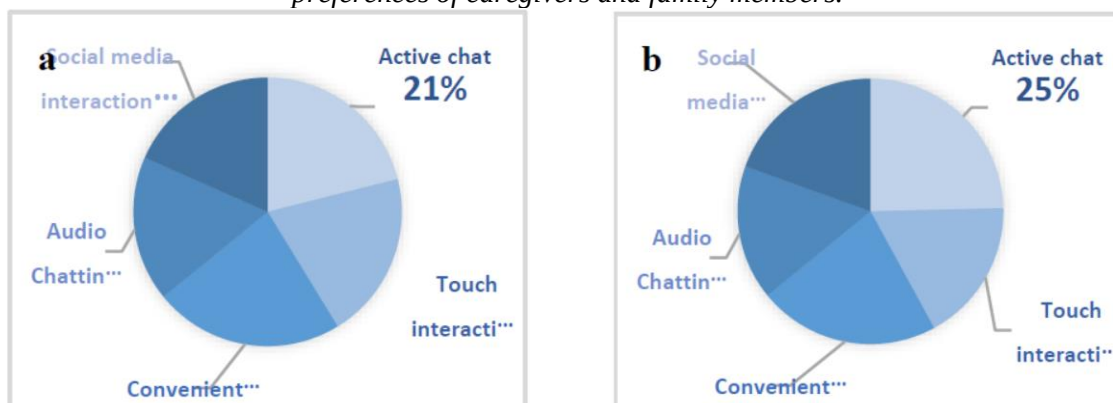
Table 6. Leisure and Entertainment Functions Preferences of Elderly Individuals and Caregivers

(a) Leisure and entertainment functions preferences of elderly individuals. (b) Leisure and entertainment functions preferences of caregivers and family members.



As shown in Table 7(a) and Table 7(b), statistics on the preferences for leisure and social functions of companion robots indicate that elderly individuals prefer the convenient contact function (23%), while family members and caregivers of older adults favor the active chat function (25%). These features can help reduce anxiety and depression among elderly individuals, contributing to their overall happiness. The convenient contact function is particularly important for emergencies or simple daily communication, enhancing the sense of security for both elderly individuals and their family members and caregivers. Therefore, companion robots should incorporate both active chatting and convenient contact functions.

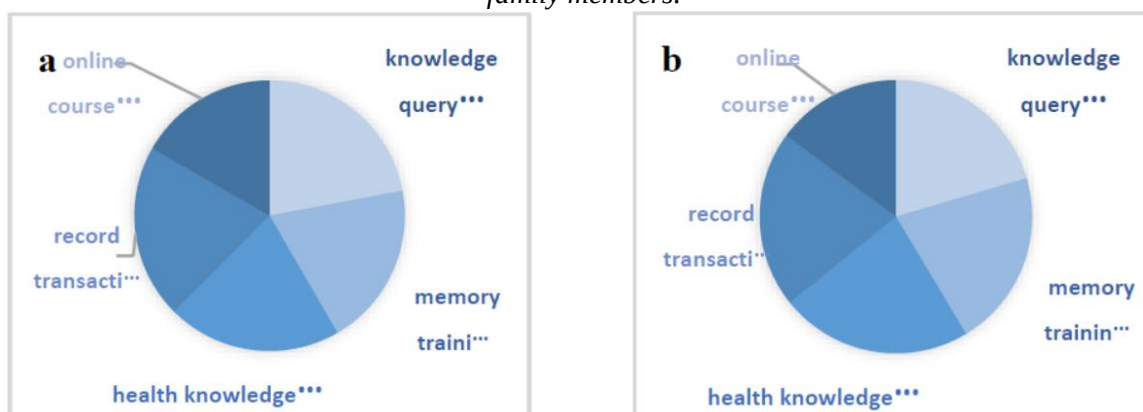
Table 7. Leisure and Social Functions Preferences of Elderly Individuals and Caregivers
(a) Leisure and social functions preferences of elderly individuals. (b) Leisure and social functions preferences of caregivers and family members.



As shown in Table 8(a) and Table 8(b), statistics on the learning function preferences of companion robots indicate that older individuals prefer knowledge query functions (22%), while family members and caregivers of older adults favor health knowledge functions (23%). Older individuals require more health management and attention. The knowledge query and health knowledge functions provided by the companion robot can facilitate quick access to answers and improve their understanding of health-related issues. Therefore, knowledge query and health knowledge functions should be incorporated into the learning capabilities of companion robots.

Table 8. Learning Function Preferences of Elderly Individuals and Caregivers

(a) Learning function preferences of elderly individuals. (b) Learning function preferences of caregivers and family members.

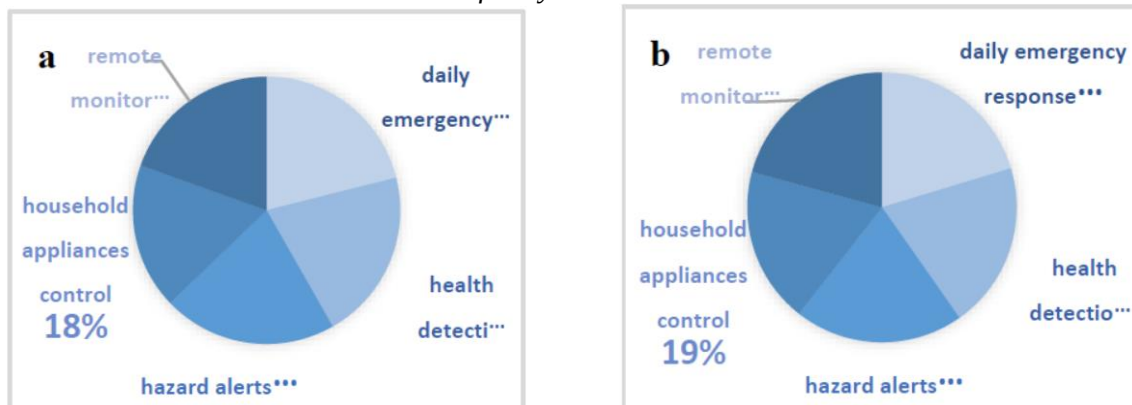


As shown in Table 9(a) and Table 9(b), statistics on the safety function preferences for companion robots indicate that elderly individuals, along with their families and caregivers, prefer daily emergency response (21% and 20%, respectively), health detection (21% and 20%, respectively), and danger warning functions (21% and 20%, respectively). Families and caregivers of older adults are particularly concerned about the remote monitoring function (21%). Elderly individuals are prone to encountering emergencies in their daily lives, such as falls or sudden illnesses. The emergency function of companion robots can quickly respond to these situations and contact family members and relevant organizations for assistance. Additionally, the health condition of older individuals needs to be monitored regularly; companion robots can help detect potential health problems in advance. They can also monitor for potential hazards in the environment, such as fire alarms, gas leaks, or intrusion alarms. Timely warnings of danger can help seniors and their families take proactive measures to minimize risk. The remote monitoring function enables doctors or caregivers to oversee the health status of older adults and provide relevant support and advice. Therefore, the safety features

of companion robots should include daily emergency response, health detection, hazard alerts, and remote monitoring.

Table 9. Safety Function Preferences of Elderly Individuals and Caregivers

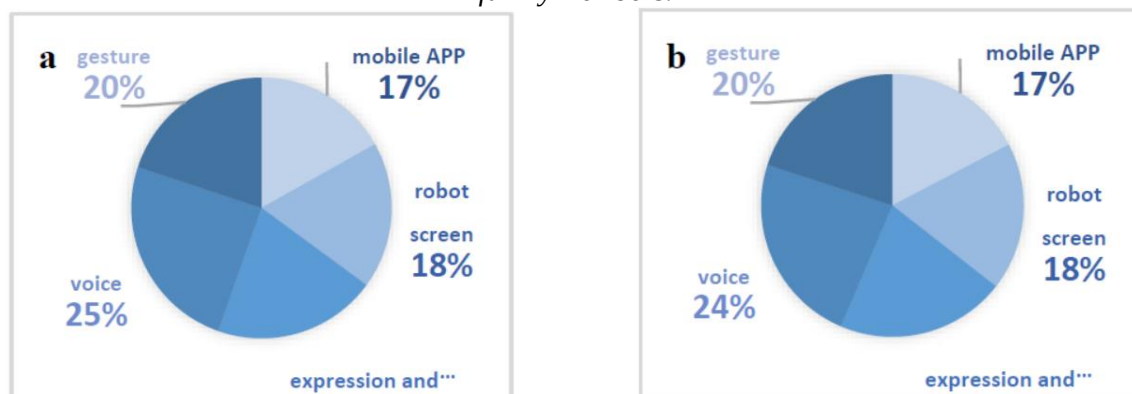
(a) Safety function preferences of elderly individuals. (b) Safety function preferences of caregivers and family members.



As shown in Table 10(a) and Table 10(b), statistics on interaction mode preferences for companion robots indicate that elderly individuals, along with their families and caregivers, favor voice interaction modes (25% and 28%, respectively). Voice interaction is a natural and intuitive method of communication with companion robots, allowing users to engage without needing to master complex technical skills or learn intricate user interfaces. Therefore, the companion robot should adopt voice interaction as its primary mode of communication.

Table 10. Interaction Mode Preferences of Elderly Individuals and Caregivers

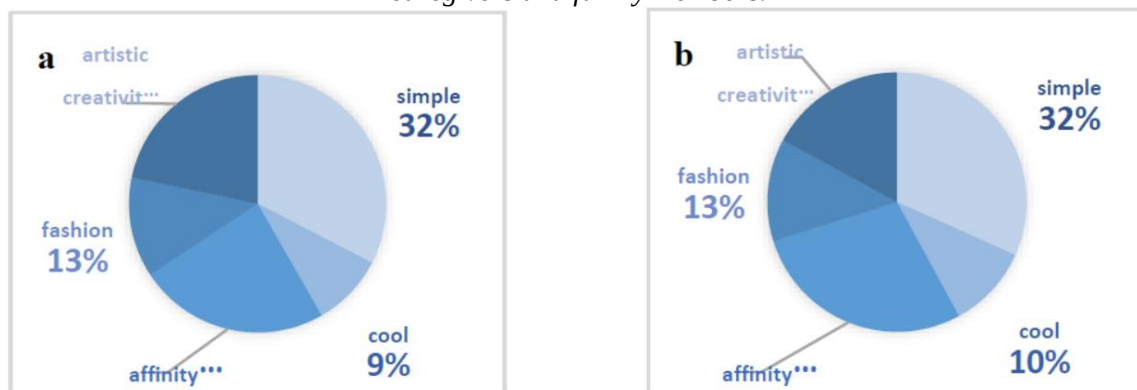
(a) Interaction mode preferences of elderly individuals. (b) Interaction mode preferences of caregivers and family members.



As shown in Table 11(a) and Table 11(b), statistics on the preferred interface styles for accompanying robots indicate that both the elderly and their families, as well as caregivers, favor a simple interface style (33% and 32%, respectively). A simple interface is typically more intuitive and easier to understand, facilitating the elderly's ability to learn how to use the robot. Therefore, it is essential for accompanying robots to adopt a simple interface style.

Table 11. Preferred Interface Styles Preferences of Elderly Individuals and Caregivers

(a) Preferred interface styles preferences of elderly individuals. (b) Preferred interface styles preferences of caregivers and family members.



4. Strategies for the design of companion robots for older persons from an inclusive perspective

4.1. Appearance and structural design

Through an analysis of the physiological characteristics of the elderly, which includes the gradual deterioration of vision, sense of touch, and muscle strength, combined with the results of the questionnaire survey, the shell of the robot is constructed from lightweight and easy-to-touch materials, such as smooth plastic, to provide a comfortable tactile experience. The robot features a folding design, making it easy for elderly users to carry and pick up. Additionally, the streamlined design reduces operational difficulty by avoiding complex appearances and structures, thereby facilitating understanding and use among elderly individuals. The color scheme employs a high-contrast combination of blue and white, enhancing the elderly's ability to identify the robot. Furthermore, the calming color palette contributes to a soothing atmosphere, offering a more comfortable companion experience and alleviating anxiety stemming from declines in auditory and tactile sensitivity.

4.2. Functional design

By analyzing the psychological characteristics of the elderly and integrating the results of the questionnaire survey, the companion robot is designed to initiate conversations, remember and follow up on past exchanges, and engage with the elderly as an old friend or child would. With advancements in technology, AI plays a crucial role in providing mental health support and emotional assistance for older adults. By designing proactive, goal-oriented, and context-based conversations, AI can effectively empathize with this demographic.

In terms of functional design, companion robots can assess the psychological state of the elderly and respond appropriately to changes in their emotional well-being. This capability allows the robots to regulate users' emotions while focusing on leisure and entertainment, social interaction, learning, and safety. For instance, the robots soothe the emotions of the elderly by offering entertainment functions such as healthy activities, storytelling, and music recommendations. The active chat and convenient contact functions address the social isolation often experienced by older adults, while the knowledge query and health knowledge features help maintain cognitive engagement. To ensure the physical and mental well-being of the elderly, safety functions such as health detection and emergency response are also integrated.

4.3. Interaction design

Through the analysis of the physiological and psychological characteristics of the elderly, it is evident that sensory functions, particularly in visual and auditory domains, gradually deteriorate with age. Considering these factors and integrating the results of the questionnaire survey, the interaction mode of the companion robot should prioritize voice interaction. This system should be equipped with high-quality voice recognition and synthesis capability, allowing for communication with the elderly in a gentle tone. Such an approach will enhance the user experience and foster a caring atmosphere, making interactions with the robot feel as intimate as conversations with their relatives.

5. Elderly companion robot design practice

5.1. Product appearance and structural design

When designing this companion robot, the design strategy was integrated into all aspects of the product by analyzing the physiological and psychological characteristics of the elderly, in conjunction with the results of the questionnaire survey. Considering the physiological characteristics of older adults, who often experience weakened muscle strength, the robot is constructed from smooth and lightweight plastic material. This choice provides a comfortable hand feel, reduces fatigue during extended use, and facilitates the long-term handling of the robot.

In terms of structure, the folding design enables easy carrying and storage, addressing the need for simplified usability among elderly users. The streamlined structure minimizes complex details in the robot's appearance, while the curvature and proportions adhering to the golden ratio ensure that the design remains both simple and user-friendly.

Regarding the color scheme, high-contrast tones of blue, white, and grey were selected to aid elderly users in recognizing the robot more clearly, taking into account the common decline in eyesight associated with aging. Through design practice, the design strategy is effectively translated into product features, ensuring that the robot meets the aesthetic, tactile, and operational needs of the elderly.

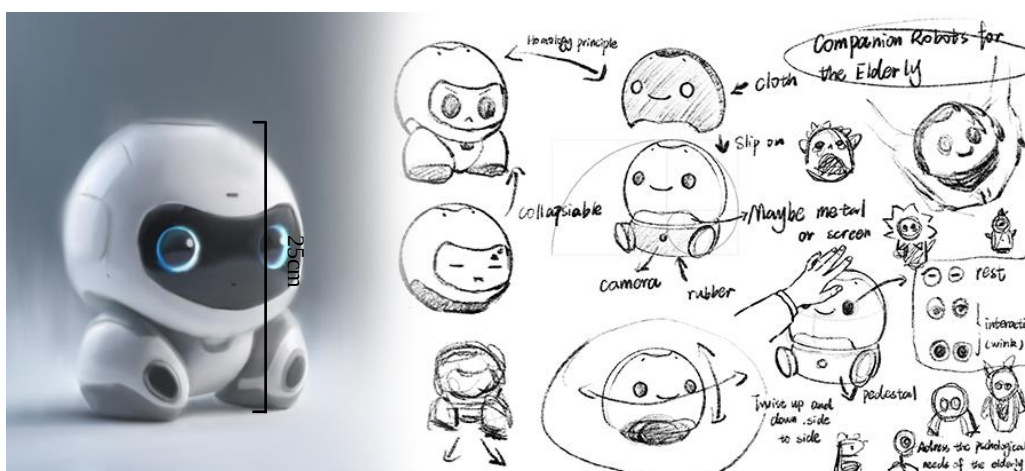


Figure 2. Design plan for a companion robot

5.2. Product functional design

In the design practice, a robot that provides emotional support and psychological companionship has been developed by integrating the psychological characteristics of the elderly population with the results of the questionnaire survey. Active chatting and emotional analysis form the core components of the functional design. Through an examination of the psychological traits of older adults, a voice and behavior analysis module has been integrated into the robot, enabling it to monitor the intonation, expressions, and daily behaviors of the elderly in real-time.

Based on the analyzed data, the robot can accurately identify mood changes in the elderly, such as feelings of loneliness, anxiety, or pleasure. During product use, the robot is capable of providing timely emotional responses, offering comfort when seniors are feeling down, and delivering positive feedback when encouragement is necessary. This context-based design is rooted in the concept of “empathic emotional support” within the overarching design strategy.

5.3. Product interaction design

To facilitate better communication with elderly individuals whose visual functions have deteriorated, the objective is to enhance the interactive experience between the robot and older adults through both visual and emotional means. The robot will be equipped with expression recognition capabilities. As they age, older adults may find it challenging to comprehend information conveyed through text or complex interfaces in their daily lives. The expression recognition feature in the companion robot can analyze and interpret the facial expressions of elderly users to assess their emotional states.

The robot's diverse visual expressions, such as smiles, concern, and encouragement, are achieved through display and animation technology, allowing for real-time changes in response to interactions with the elderly. This intuitive expression display compensates for the elderly's limitations in information reception. By utilizing expression display technology, the robot can convey complex emotional information to the elderly in a more direct manner, facilitating easier understanding and emotional communication in response to the robot's interactions.



Figure 3. Scenarios of companion robot use and anthropomorphic expression interaction

6. Conclusion

This study addresses the social problems stemming from the accelerated aging process in China, focusing on the mental health needs of the elderly and exploring the feasibility of developing a companion robot through inclusive design. Through an in-depth analysis of the physiological and psychological characteristics of older adults, as well as research and needs assessments of the target users, this study designs a companion robot that provides emotional support. The findings indicate that the inclusive design approach is highly applicable in the development of companion robots for the elderly, which can enhance their quality of life and effectively alleviate feelings of loneliness and depression. In the design practice, this study integrates user survey results to create a robot with an appearance, structure, and functions that have high user acceptance. The physiological constraints and psychological needs of the elderly are considered in selecting materials, color schemes, functional design, and interaction modes. The results demonstrate that companion robots developed using inclusive design methodology can significantly improve the mental health of the elderly, offering society new product design ideas and innovative solutions. It is hoped that this study will draw greater social attention to the mental health issues faced by the elderly, promote the research, development, and application of more companion products, and further enhance the quality of life and sense of well-being among older adults.

References

- [1] Mannion A, Summerville S, Barrett E, et al. Introducing the Social Robot MARIO to People Living with Dementia in Long Term Residential Care: Reflections [J].
- [2] Lai Fang and Dong Hua: The development and challenges of universal design and inclusive design principles [J].
- [3] Ariela Gordon - Shaag David P. Piñero, Cyril Kahloun, David Markov, Izadok Parnes, Liat Gantz, Einat Shneor: Validation of refraction and anterior segment parameters by a new multi-diagnostic platform (VX120).
- [4] Ye Tao, Chen Jian, Qiu Changchang, Zhao Mengfan: Ergonomic design of a smart medicine box for the elderly [J].
- [5] He Meiling, Long Chunling, An Fengrong, Ma Yun, Guo Zhihua, Li Zhanjiang, Cheng Xiangmei: A study of the effects of cognitive-behavioral group interventions on the depressed mood of empty-nesting older adults [J].
- [6] Tao Tao, Jin Guangzhao, Guo Yalong: Empty-nesting situation of elderly families and basic characteristics of empty-nesting elderly groups in China [J].
- [7] Chao Zhao: Design for ageing: inclusive stance and critical attitude [J].
- [8] Lei Wu, Juan Li: A review of research on inclusive design and design ethics for ageing service robots [J].