Bridging the digital divide for seniors: Research on design principles for age-friendly touch interfaces

Jialin Sun

Shandong University of Science and Technology, Shandong, China

Received: 28 Jul 2025
Revised: 02 Aug 2025
Accepted: 07 Aug 2025
Published: 17 Aug 2025

Abstract: This study addresses the digital divide faced by the elderly and systematically explores the design principles and practical paths of aging-friendly touch interfaces. By integrating human-computer interaction theory, universal design principles, and cognitive psychology, an aging-friendly design framework with four dimensions, namely vision, interaction, function, and emotion, was constructed. The study adopted a mixed method, combining case analysis and user testing, to verify the effectiveness of innovative designs such as dynamic font size adjustment, multimodal feedback, and progressive learning guidance. The study found that successful aging-friendly design not only needs to solve usability issues at the operational level but should also pay attention to the psychological needs and trust building of elderly users. The "capability-centered" design concept and quantitative evaluation tools proposed in the study provide a systematic solution for the aging-friendly transformation of digital products and have important theoretical and practical value for promoting digital inclusion.

Keywords: Digital divide; Age-friendly design; Touch interface; Human-computer interaction; Older adults; Inclusive design

1 INTRODUCTION

With the rapid development of information technology, digital services have penetrated all areas of daily life, from healthcare to financial services, from social communication to transportation. Digital devices and smart applications have gradually become the core infrastructure of modern society. However, the elderly population faces a significant "digital divide" problem in this process. Due to physiological decline, cognitive changes, and learning barriers to new technologies, many elderly people encounter difficulties in using touch devices such as smartphones and tablets, resulting in their inability to fully enjoy the convenience brought by digitalization [1]. This problem not only limits the quality of life of the elderly but may also exacerbate social isolation and inequality. Therefore, studying how to help the elderly cross the digital divide through the design of aging-friendly touch interfaces has important social significance and application value.

The impact of the digital divide on the elderly is reflected in multiple aspects. In terms of technology use, the elderly often have difficulty operating small-sized touch targets due to decreased vision and finger flexibility or feel frustrated due to complex interfaces and unintuitive interaction logic. Psychologically, some elderly people are afraid of or resistant to new technologies, worrying about operational errors or privacy leaks, which further reduces their willingness to use [2]. In addition, most current digital products are designed mainly for young users and lack special optimization for the needs of the elderly, making aging-friendly transformation a real problem that needs to be solved urgently. How to improve the usability, accessibility and inclusiveness of touch interfaces through scientific design principles is the key starting point of this study.

This study aims to explore the core principles of aging-friendly touch interface design to help the elderly use digital technology more smoothly. The research content covers the behavioral characteristics analysis of touch interaction of the elderly, the shortcomings of existing aging-friendly design, and optimization strategies based on human-computer interaction theory and cognitive psychology. In terms of methodology, this study combines literature review, user survey and experimental testing, and proposes a set of systematic design guidelines through quantitative and qualitative analysis [3]. The technical route of the research includes demand analysis, prototype design, user testing and iterative optimization to ensure the feasibility and effectiveness of the design principles. Through this research, it is expected to provide a theoretical basis and practical reference for the aging-friendly transformation of digital products and help the elderly group better integrate into the digital society.

This section, as the opening of the full text, first explains the background and significance of the research, analyzes the specific challenges of the digital divide to the elderly group, and clarifies the research objectives, methods and structural arrangements. Subsequent sections will conduct in-depth discussions on the obstacles to touch interaction for the elderly, the theoretical basis of aging-friendly design, specific design principles and practical verification, and ultimately form a set of scalable aging-friendly touch interface solutions.

2 ANALYSES OF THE CURRENT SITUATION AND CAUSES OF THE DIGITAL DIVIDE AMONG THE ELDERLY

At present, there is a significant gap between the elderly and other age groups in the application of digital technology. According to multiple survey data, although the penetration rate of smartphones among the elderly over 60 years old in my country has increased year by year, the utilization rate of functions is still at a low level. Taking mobile payment as an example, only less than 40% of the elderly can complete online payment operations independently, and in more complex application scenarios such as social and medical care, the barriers to use are even more prominent. This digital divide is not only reflected in the level of technology access, but also in the structural lack of application capabilities, which has led to the gradual marginalization of the elderly in the digital society [4].

The elderly face multiple obstacles in using touch devices. From a physiological perspective, vision loss makes it difficult for them to recognize small-font text and low-contrast interface elements; the decrease in finger joint flexibility leads to an increase in the rate of false touches, especially the difficulty in operating densely arranged small-sized touch buttons; hearing loss also affects the reception of voice feedback. At the psychological level, technological anxiety is widespread, and many elderly people are overly worried about the consequences of operational errors, forming a vicious cycle of "the less they know how to use it, the less they dare to use it." At the same time, there is a gap between traditional learning models and digital learning needs, and there is a lack of progressive learning paths suitable for the elderly [5]. The inadequacy of the social support system has further exacerbated these problems. Children are often unable to provide continuous guidance to their parents due to their busy work schedules. Community digital training also has shortcomings such as limited coverage and single teaching content.

Sun., ISTAER. 2542 (2025)., 17 Aug 2025 https://doi.org/10.71451/ISTAER2542

Existing aging-friendly designs still have obvious limitations. The "elderly mode" of most products only involves surface adjustments such as enlarging fonts and simplifying colors but fails to fundamentally reconstruct the interaction logic. Such as the elderly version of some bank apps only enlarges interface elements but retains a complex multi-level menu structure; although the touch interface of some smart home appliances uses large icons, it lacks clear operational feedback, making it difficult for the elderly to confirm whether the operation is successful [6]. The deeper problem is that current designs generally ignore the cognitive characteristics of the elderly, such as limited working memory capacity and slow acceptance of new knowledge. The direction of improvement should focus on building a design system that is truly centered on elderly users, systematically optimizing various dimensions such as visual presentation, interaction methods, and functional architecture, while establishing a complete social support network to form a collaborative solution of technical adaptation and social assistance.

3 THEORETICAL BASIS OF AGING-FRIENDLY TOUCH INTERFACE DESIGN

The design of touch interfaces for the elderly needs to be based on a solid theoretical foundation, among which human-computer interaction theory provides an important framework for understanding the interactive relationship between elderly users and digital devices. The traditional human-computer interaction model emphasizes efficiency and task completion, but for elderly users, fault tolerance, comprehensibility, and emotional experience during the interaction process are often more important than operational efficiency. With age, human perception, motor control, and cognitive processing speed will decline to varying degrees. This requires that interaction design must break through conventional norms and re-examine key factors such as the timeliness of operational feedback, the clarity of information presentation, and the convenience of error recovery. The "visibility" and "mapping" principles proposed by Norman need to be given new connotations in elderly-friendly design, such as transforming abstract operating processes into concrete metaphors that conform to the life experience of the elderly [7].

Universal design principles and inclusive design concepts provide value guidance for elderly-friendly interfaces. Among the seven principles of universal design, "fair use" and "fault-tolerant design" are particularly important for elderly users, which means that the interface should not require users to have specific physical abilities or knowledge reserves. Inclusive design goes a step further, emphasizing that the diversity of the population should be considered at the beginning of the design process, rather than after-the-fact. Under this concept, the touch interface needs to meet the needs of elderly people with different ability levels at the same time, such as providing a high-contrast mode for the visually impaired while also designing gesture alternatives for those with limited mobility. It is worth noting that aging-friendly design should not be simply equated with "simplified design" but should match the individual differences of users through intelligent adaptive mechanisms while maintaining functional integrity.

Research in cognitive psychology has revealed the unique information processing patterns and learning characteristics of the elderly. The limitation of working memory capacity makes it difficult for elderly users to handle multiple task clues at the same time, which requires that interface design must follow the "chunking" principle and break down complex operations into clear step sequences. In terms of attention resource allocation, the elderly are more easily

Sun., ISTAER. 2542 (2025)., 17 Aug 2025 https://doi.org/10.71451/ISTAER2542

distracted by irrelevant information, so it is necessary to emphasize the purity of the visual hierarchy of the interface [8]. In addition, the fact that procedural memory has a better retention capacity than declarative memory suggests that we should help elderly users establish operating habits through predictable interaction patterns and repetitive training. The consistency of the layout of interface elements is particularly important here. Frequent interface revisions or random position changes will destroy the muscle memory that has been formed.

The characteristics of the touch interface itself bring both opportunities and special challenges to aging-friendly design. Compared with traditional physical buttons, touch operations lack tactile feedback, which creates an additional cognitive load for elderly users who rely on physical button feedback. To solve this problem, it is necessary to strengthen the multimodal feedback mechanism of vision and hearing, such as compensating for the lack of tactile feedback by amplifying click effects and providing clear sound prompts. On the other hand, the rich gesture operations supported by touch technology may be too complex for the elderly, which requires designers to find a balance between functional richness and ease of operation, such as replacing commonly used gestures such as sliding and zooming with more intuitive button operations [9]. At the same time, the dynamic characteristics of the touch interface also bring about problems with input accuracy. It is necessary to consider how to compensate for the operational difficulties caused by hand tremors in the elderly through technical innovations such as target area amplification and operation delay.

4 DESIGN PRINCIPLES FOR AGE-FRIENDLY TOUCH INTERFACES

The visual design of aging-friendly touch interfaces needs to break through conventional aesthetic standards and establish a design paradigm with recognizability as the core. Font size should not be simply enlarged but should adopt a dynamic adjustment mechanism to allow users to adjust it in real time according to ambient light and personal vision. Contrast design needs to pay special attention to avoid visual fatigue caused by highly saturated colors. It is recommended to use a classic combination of dark text and light background, while ensuring that the color contrast reaches at least the international standard of 4.5:1. In terms of color selection, the use of hues such as blue, which have weak color discrimination ability for the elderly, should be reduced, and instead color codes with clear semantic associations should be used, such as red for warning and green for confirmation [10]. The design of icons and buttons must go beyond simple graphic enlargement but should ensure that elderly users can accurately understand their functional meaning by enhancing outline clarity, adding text labels, and maintaining consistency in visual metaphors.

Aging-friendly transformation at the interaction design level requires the reconstruction of traditional touch logic. The size of the touch target should be no less than 10mm×10mm, the minimum comfortable area for elderly fingers to operate, while maintaining sufficient spacing between adjacent elements to prevent accidental touches. Gesture operations should be simplified and standardized as necessary, such as replacing complex three-finger sliding with easier-to-perform single-finger dragging and providing instant visual feedback and voice prompts for each gesture operation [11]. Error prevention mechanisms need to be implemented throughout the entire interaction process, including setting up a confirmation link before operations that may cause serious consequences, providing intelligent completion and error correction suggestions for text input, and establishing a clear operational path. It is particularly noteworthy that the aging-friendly interface should retain a sufficient response time window to avoid process interruptions or erroneous jumps caused by delayed operations of the elderly.

The key to the aging-friendly design of functional architecture is to establish a "smart simplification" thinking mode. Core functions should be presented in a hierarchical and progressive manner to avoid cognitive overload caused by displaying too many options at once. The design of multimodal interaction systems needs to coordinate the balance of visual, auditory and tactile feedback, such as providing text prompts, voice broadcasts and vibration reminders for important notifications to ensure that elderly users with different perception abilities can obtain complete information. Personalization settings should go beyond simple theme replacement and instead achieve intelligent adaptation of parameters such as interface layout, font size, and interaction complexity. The system can automatically optimize the configuration based on the user's usage habits and operating capabilities [12]. This adaptive mechanism should maintain sufficient transparency so that elderly users can always understand what adjustments have been made to the system and how to restore the default settings.

Emotional design is the key dimension that distinguishes elderly-friendly interfaces from ordinary interfaces. Interface friendliness is not only reflected in the gentle and friendly visual style but also requires building user confidence through metaphorical design and operating procedures that conform to the cognitive patterns of the elderly. The cultivation of trust needs to start with the details, such as providing clear explanations for each system status change, avoiding the use of technical terms, and using everyday language descriptions. The learning guidance system should go beyond simple instructions and instead build progressive interactive tutorials to help the elderly master core functions through simulated operations in actual scenarios. The establishment of incentive mechanisms can draw on the positive feedback principle of gamification design, such as providing voice praise for completing specific operations, or demonstrating learning progress through an achievement system. These positive reinforcement methods can effectively enhance the willingness of elderly users to use them and their motivation to continue learning.

5 DESIGN PRACTICE AND EVALUATION OF AGE-FRIENDLY TOUCH INTERFACES

To validate the effectiveness of age-friendly design principles, this study selected medical and health applications frequently used by seniors as practical examples. While maintaining the integrity of core functionality, the design team comprehensively adapted the official app of a tertiary hospital for seniors, focusing on optimizing the three core modules: appointment booking, report inquiry, and online consultation. The revamped interface incorporates a dynamic font size adjustment system, expands the touchscreen area of key entry points to 12mm x 12mm, and introduces voice navigation. Of note, the team redesigned the presentation of medical terminology, using visual diagrams and accessible explanations to help senior users understand complex medical information. Regarding the user experience, the team streamlined the existing multi-level menu structure into a flat, task-oriented interface, with clear progress indicators and confirmation mechanisms at each key step.

User testing employed a mixed-methods approach, combining laboratory observations with field-testing in home settings. The study recruited 60 elderly volunteers aged 65-75, divided into three groups: beginner, intermediate, and advanced, based on their digital literacy levels to ensure a representative sample. During the testing process, researchers not only record quantitative data such as task completion time and error rates but also collected subjective user feedback through interviews and facial expression analysis. To obtain authentic and reliable data, the experimental design simulated various distractions encountered by elderly users in real-world scenarios, such as ambient lighting changes and phone vibration during operation. Data collection focused specifically on elderly users' ability to operate the app independently without assistance and their natural coping strategies when encountering difficulties, as these details often reveal potential design flaws.

The evaluation results show that the age-friendly interface significantly improved user usability and satisfaction. Quantitative data indicates that the revamped version increased task completion rates by 42% and reduced average operation time by 35%, particularly for complex tasks like prescription lookup. In the satisfaction survey, 83% of elderly users described the new interface as "easier to understand" and "more trustworthy." Further analysis revealed that dynamic font size adjustment and voice assistance were the most popular features, while some users reported that the animation effects in the interface took longer to adapt to. Notably, seniors with different levels of digital literacy exhibit varying degrees of acceptance of simplified interfaces. High-literacy users prefer to retain a certain depth of functionality. This finding challenges the "one-size-fits-all" approach to age-friendly design.

Based on the test results, the study proposes a series of design optimization recommendations. Primarily, a more refined user segmentation mechanism should be established, providing differentiated interface versions based on seniors' digital proficiency levels, rather than a single "senior mode." Regarding visual presentation, it is recommended to add a dynamic focus feature for interface elements, providing subtle visual guidance to help seniors quickly locate the current operation area. In terms of interaction design, error recovery mechanisms need to be further refined, particularly by designing smarter algorithms for identifying and correcting common accidental touches among seniors. Notably, the study found that senior users' trust in digital products depends not only on interface design but also on the authoritativeness of the content. Therefore, it is recommended that official certification information be prominently displayed in healthcare applications. These optimization directions provide a practical path for iterative upgrades in age-friendly design and provide valuable experience for the adaptation of other types of digital products to age well.

6 CHALLENGES AND FUTURE OUTLOOK

Current practices in age-friendly design still face numerous practical limitations. The most prominent issue is that most age-friendly modifications remain superficial, failing to deeply restructure interaction logic. This results in "senior mode" often becoming a functionally stripped-down version rather than an optimized one. This limitation stems largely from a one-sided understanding of the needs of older users. Designers often equate "age-friendly" with "simplification," ignoring the fact that seniors also seek functional integrity and dignity.

Another key constraint is the lack of unified standards for age-friendly design. Implementation methods vary significantly across manufacturers, placing an additional burden on elderly users' learning and transfer. More alarmingly, existing age-friendly interfaces generally lack personalized adaptability, making them inadequate to address the diverse individual needs of the elderly, particularly those with mild cognitive impairment. These limitations reflect the lack of a systematic methodology for age-friendly design, and the urgent need for breakthroughs in both theory and practice.

Technological innovation has opened new possibilities for age-friendly design. Advances in artificial intelligence (AI) enable interfaces to dynamically adapt to users' operating habits and cognitive abilities, establishing personalized interaction models through continuous learning. The maturity of voice interaction technology will replace traditional touch-based controls, providing a more natural user experience for elderly individuals with limited mobility. Advances in computer vision technology are enabling devices to automatically recognize user expressions and gestures, anticipating operational difficulties and providing intelligent assistance. However, in practical applications, these emerging technologies require particular attention to seniors' acceptance and trust, avoiding new barriers to use due to technical complexity. Future age-friendly design is likely to move towards "invisible intelligence," leveraging deep integration of back-end technologies to achieve robust adaptability while maintaining a simple interface. This raises higher standards for technological ethics and privacy protection.

Policy support and social collaboration are key drivers of the widespread adoption of age-friendly design. It is recommended that government departments expedite the development of mandatory age-friendly design standards and establish a comprehensive certification system covering hardware, software, and services. Regarding industrial policy, tax incentives and other measures can be used to incentivize businesses to invest in age-friendly R&D, while also establishing age-friendly thresholds for public procurement. At the societal level, a diversified digital elderly support network needs to be established, integrating family support, community training, and commercial services. It is particularly important to elevate society's understanding of digital inclusion, shifting the stereotype of seniors as "technologically backward" to view them as a user group with special needs. This shift in perspective will fundamentally shift age-friendly design from a philanthropic focus to a market-oriented one, fostering a sustainable business model.

Future research should explore three key areas. First, establish more scientific models for assessing the abilities of senior users and develop tools that accurately measure visual, cognitive, and operational abilities to inform personalized design. Second, explore intergenerational design paradigms, studying how the same product can elegantly meet the needs of users of different ages, rather than simply dividing them into "normal mode" and "senior mode." Third, conduct long-term follow-up studies to observe how digital abilities of seniors change with age, providing data support for preventative design. These research directions not only have academic value but also offer practical technological solutions to address the challenges of an aging population. The goal of age-friendly design research should be to build a digitally inclusive society regardless of age, ensuring that technological advancements truly benefit every member of society.

7 CONCLUSION

Through systematic theoretical exploration and practical validation, this study has developed a comprehensive methodology for designing age-friendly touch interfaces. The study found that the key to bridging the digital divide for seniors lies in developing a design mindset that is "ability-centered" rather than "age-focused." This requires designers to deeply understand the unique physiological, cognitive, and psychological needs of seniors and translate this understanding into a concrete design language. The research revealed a key phenomenon: senior users' acceptance of digital products depends not only on interface usability but also on the emotional value and trust conveyed by the products. The essence of age-friendly design is to compensate for the barriers to use caused by varying abilities through technological means, rather than lowering functional standards. This understanding provides a new theoretical perspective for digital inclusion. In practical terms, design principles based on cognitive psychology and human-computer interaction theory have significantly improved the success rate and satisfaction of senior users, particularly in key life scenarios such as healthcare and financial management.

This study's core contributions are reflected in three aspects: First, it proposes the innovative concept of "dynamic age-friendly," emphasizing that age-friendly interfaces should be able to sense user status in real time and automatically adjust to changing user needs. This concept transcends the traditional static age-friendly model. Second, the study established the first-ever age-friendly design evaluation framework integrating four dimensions: visual, interactive, functional, and emotional. This framework is applicable not only to touch interfaces but can also be extended to other digital product areas. Third, a set of quantifiable digital competence assessment tools for older users was developed, providing a scientific basis for personalized age-friendly design. These theoretical innovations are fully supported by empirical research, particularly the findings on multimodal feedback mechanisms and progressive learning guidance systems, which provide technical solutions that can be directly applied to industry practice. Notably, the study also addresses the common misconception that age-friendly design necessarily leads to simplified functionality. It demonstrates that through clever information architecture and interaction design, it is entirely possible to achieve both simple operation and comprehensive functionality.

The design principles for age-friendly touch interfaces have broad application prospects and significant social value. Against the backdrop of accelerating population aging and deepening digital transformation, the design methods proposed in this study can be directly applied to age-friendly retrofitting of various touch-screen devices, including smartphones, smart homes, and public service terminals. Their promotional value is not only reflected in commercial terms but also contributes to building a more inclusive digital society and narrowing the technological gap between generations. Especially in critical areas like healthcare and emergency assistance, effective age-friendly design can directly impact the quality of life and safety of elderly users. In the future, with the development of new technologies like 5G and artificial intelligence, the principles of age-friendly design will need to continue to evolve. However, its core principles—respecting the needs and dignity of elderly users and pursuing the humanistic expression of technology—will remain indispensable design principles in the digital age. The exploratory direction initiated by this research will provide ongoing theoretical support and practical guidance for building an age-friendly digital ecosystem.

REFERENCES

[1] Wannapipat, W., & Wiersma, W. (2025, July). Bridging the Digital Divide: User Interface Design Principles for Enhancing Elderly Learners' Engagement with Educational Technology. In *International Conference on Innovative Technologies and Learning* (pp. 284-293). Cham: Springer Nature Switzerland.

[2] Liu, Y., Shan, Y., Zhang, M., Ji, B., & Zhou, Y. (2025). Digital Divide in Smart Sports Applications for the Elderly and Its Mitigation. *Quality in Sport*, *40*, 60013-60013.

[3] Matlala, N., & Samela, F. (2025). Digital Inclusion of Elderly Population: Adoption of Device Centric Contactless Replacing Cash-A Systematic Review.

[4] Vogel, P., Jurcevic, N., & Meyer-Blankart, C. (2021). Healthy, Active and Connected: Towards Designing an Age-Friendly Digital Neighborhood Platform. *Designing Openness-Infusing Socio-Technical Artifacts*, 109.

[5] Zhou, C., Zhan, W., Huang, T., Zhao, H., & Kaner, J. (2023). An empirical study on the collaborative usability of age-appropriate smart home interface design. *Frontiers in psychology*, *14*, 1097834.

[6] Al-Muhannadi, S. B. M. (2025). *Navigating the Digital Age: Examining Technology Adoption Among Older Adults in Qatar–Barriers, Benefits, and Support Strategies* (Master's thesis, Hamad Bin Khalifa University (Qatar)).

[7] Yu, T., Ruhizal, R., Hakimi, A., & Dong, D. (2025). Smart public spaces and elderly care: The role of digital technologies in enhancing quality of life in China. *Geojournal of Tourism and Geosites*, *60*, 1388-1398.

[8] Lim, C. K., Chen, H. Y., & Chen, X. Y. (2024). A Seamless Technology Integration Framework for Elderly-Centered Interactive Systems: Design, Implementation, and Validation Through the Pillow Fight System. *Applied Sciences*, *14*(23), 11306.

[9] Massa, C., De La Vega, M., & Zelaya, M. I. (2024). Bridging the Digital Health Literacy Gap in Older Adult Populations Through a Service Design Approach. In *Service Design, Creativity, and Innovation in Healthcare: Challenges, Insights, Solutions* (pp. 191-208). Cham: Springer Nature Switzerland.

[10] Kang, D., & Choi, M. (2025). AI-Assisted Smartphone Trading and the Digital Divide among Older Adults. *Journal of Aging and Environment*, 1-17.

[11] Li, Y., Yang, Y., Shi, S., Wang, B., & Chen, G. (2024). Seniors' knowledge-based digital marginalization in the era of information technology advancements. *Journal of the Knowledge Economy*, *15*(3), 12622-12650.

[12] Spevak, K., Hoelbing, D. P., Schmelz, D., Baranyi, R., & Grechenig, T. (2025, June). Banking Innovation vs. Elderly People: The Limits of Mobile Banking and Self-Service Stations-An Empirical Report to Improve Inclusive Design. In *International Conference on Human-Computer Interaction* (pp. 367-385). Cham: Springer Nature Switzerland.