Research on the R&D Direction of Smart Home Technology for the Elderly Group Based on the Influencing Factors of Purchasing Group and Behavior

Xingyu Huang [1, a, *], Xin Du [1], Mengjie Gao [2]

[1] School of Overseas Education, Changzhou University, Changzhou 213164, China

[2] School of Business, Liu Guojun School of Management, Changzhou University, Changzhou 213159, China

[a] 2974128070@qq.com

[*] Corresponding author

Abstract

As populations age globally, the application of smart home technology in elderly care services has garnered significant attention. This research employed a combination of online questionnaires and offline interviews to collect data, investigating the purchasing demographics and factors influencing the acquisition of smart home products. Findings indicate that ease of operation and safety assurances play crucial roles in consumers' decision-making processes. Differences exist among various demographics regarding their focus on health management functions, home security features, and price sensitivity. Based on the realities and needs of different groups, this study proposes a series of specific recommendations, including interface optimization, dialect voice recognition, and financial subsidies. These measures can promote the integration of the smart elderly care industry and foster sustainable market development. Furthermore, these research findings provide valuable reference points for enterprises to refine their products and for governments to formulate policies.

Keywords

Smart Home, Purchasing Groups, Purchasing Behavior, Silver Economy.

1. Introduction

China's society is aging rapidly. During the "14th Five-Year Plan" period, the population aged 60 and above is expected to exceed 300 million, over 20% of the total, and by 2035, it may reach approximately 420 million, over 30%. Concurrently, the lifestyle and consumption habits of the elderly demographic have undergone significant transformation. Advances in technologies such as the Internet of Things and artificial intelligence have enabled smart home systems to potentially enhance the safety and comfort of elderly lives.

However, many current smart home products face challenges including complex operation and poor dialect recognition, which hinders their adoption and sustained use among the elderly. Against the backdrop of rapid population aging and a market struggling to meet the needs of older adults, the development and application of smart home products tailored for the elderly are of paramount importance.

This research investigates the current situation of smart home use by the elderly through online questionnaires and offline interviews. Based on 786 valid questionnaires, combined with the Technical Acceptance Model and User-Centered Design theory, it analyzes the functional preferences and price sensitivity of different users. The research aims to clarify their acceptance mechanism and usage characteristics. This will provide theoretical and practical references for optimizing product design and promoting the sustainable development of the silver economy.

2. Literature Review

2.1. Purchasing Behavior and Its Influencing Factors

Purchasing behavior for smart home devices is experience-driven. The likelihood of testing prior to purchase is 47% higher than for traditional appliances, as consumers require personal evaluation to assess functionality [1, 2]. Post-purchase behavior follows a dual-dimensional model: the depth of feature usage is determined by technical compatibility, while the continued investment in the same brand of device (ecosystem loyalty) is associated with sentimental value [3].

The influencing factors cover both internal and external levels. Internally, the Means-End Chain theory elucidates how core perceived values (e.g., convenience) influence privacy concerns and brand selection [4], and at the external level, social media recommendations, 5G network coverage, and policy subsidies (e.g., political subsidies that increased adoption by 31% in pilot areas) collectively exert influence. This underscores the need to incorporate contextual dynamics into behavioral models [5].

2.2. The Transformation From Behavioral To Technical Requirements

A multi-faceted approach is required to extract technical needs from behavioral data. Qualitative methods (e.g., grounded theory) can identify needs such as "non-invasive health monitoring" in older adults [6]. Conversely, quantitative techniques (e.g., association rule mining) can detect real-time behavioral patterns, such as the habitual adjustment of thermostats during nighttime hours.

To operationalize these insights, the Kano model, combined with Quality Function Deployment (QFD), can translate fuzzy requirements into specific technical specifications, such as defining "ease of use" as ≤ 3 steps of operation and response latency ≤ 500 milliseconds [7]. However, static studies struggle to track evolving requirements, necessitating longitudinal behavioral data to assess adaptive technology requirements [6, 8, 9].

2.3. The Impact of Technical Requirements on the Direction of R&D Activities

Empirical evidence is increasingly guiding adaptive R&D priorities: joint analyses reveal that 78% of young users prefer "natural language interaction" [10], while older users place greater emphasis on "fault self-diagnosis" [2, 11]. Scenario-based requirements (e.g., "merchant model") are driving the development of edge-cloud hybrid algorithms to reduce multi-device synchronization latency and address the shortcomings of one-size-fits-all solutions [3].

2.4. Research Gaps and Future Directions

The existing literature lacks an integrated model that systematically connects demographic characteristics, behaviors, needs, and R&D. This gap results in fragmented research findings [9], highlighting the need for future research to establish a comprehensive framework.

Future research should: (1) establish a theoretical framework integrating behavioral economics and engineering design, and simulate the dynamic relationship between demand and R&D; (2) conduct longitudinal studies on the co-evolution of demand and technology to address R&D rigidity; and (3) investigate cross-cultural differences (e.g., family center versus personal characteristics) to inform global R&D strategies [12, 13].

2.5. The Technology Acceptance Model and User-Centered Design Theory

The Technology Acceptance Model (TAM) serves to explain the user's acceptance of a new technology or system [14]. Its core elements are perceived ease of use—the degree to which a user believes using the system would be free of effort—and perceived usefulness—the degree to which a user believes the system would enhance their task performance. Existing research has largely been confined to these two elements, with scant consideration given to the influence of user group characteristics. This paper introduces the usage patterns of elderly groups with smart home devices as a variable within the TAM, investigating how this variable influences their perceptions of ease of use, perceived usefulness, and intention to use.

User-Centered Design (UCD) theory emphasizes placing users at the core of the entire product development process [15]. Applying UCD to smart home development for the elderly involves an iterative process of gathering and integrating their feedback into the design. This approach ensures that the final products are tailored to their specific needs, thereby enhancing usability, convenience, and overall satisfaction.

3. Research Methods and Data Collection

3.1. Survey Subjects and Scope

This study targeted households across all 13 prefecture-level cities in Jiangsu Province, and it combined online questionnaires with offline interviews. The online survey was directed at family members aged 16 to 65, who provided feedback on smart home usage among elderly family members; to compensate for the limited coverage of online surveys among the elderly population, offline interviews were also conducted with individuals aged 65 and above. The research team distributed a total of 820 questionnaires, and received 786 valid responses, yielding a valid response rate of 96%.

3.2. Sampling and Data Collection Methods

3.2.1. Sampling Design

Pilot survey: Prior to the formal survey, the research team conducted extensive research to understand the respondents' perceptions, usage patterns, and needs for smart homes, and designed the first draft of the questionnaire accordingly. Adjust the order of questions and delete unclear content based on feedback to finalize the questionnaire and improve reliability and validity.

Calculating the sample size: Under simple random sampling, the formula for determining the sample when estimating the population proportion is as follows:

$$n_0 = \frac{z^2_{\alpha/2} p(1-p)}{E^2} \tag{1}$$

In formula (1), z is the standard normal distribution statistic, and the confidence level is 95%, α is 0.05, resulting in $z^2_{\alpha/2}2$ =1.92; p is the sample ratio, with p = 78% in the pre-survey, and E is 5%, leading to a sample size of approximately 680 under simple random sampling.

Given Jiangsu Province's permanent resident population of approximately N = 85.26 million, the finite population correction factor was applied:

$$n = \frac{n_0}{1+\frac{n_0-1}{N}} \tag{2}$$

Rounded up sample size n = 680. Considering the recovery and effective rate, the sample size was increased by 20%, and the final sample size was 820.

3.2.2. Sampling method

(1) Sampling 13 prefecture-level cities in Jiangsu Province were stratified according to population ratio;

(2) PPS sampling is used for district-level units (proportional to population size);

(3) Combine convenient sampling and snowball sampling to expand coverage.

3.2.3. Data Collection Tools and Analysis Methods

The structured questionnaire, designed to gather comprehensive data, includes modules such as personal information, smart home cognition, usage status, purchase concerns, and functional requirements. Offline interviews are aimed at the elderly over 65 years old, focusing on operating experience and implicit needs.

Descriptive statistics present the usage status, K-means clustering identifies the characteristics of purchasing groups, principal component analysis extracts the influencing factors of purchasing behavior, and text mining (word cloud graph) captures unquantified needs.

3.3. Reliability and Validity Test

Reliability: Reliability analysis examines whether data are authentic and dependable. Using SPSS statistical software, Cronbach's alpha coefficients were calculated for the scale items in the questionnaire, with results shown in Table 1.

Table 1: Cronbach's Alpha Table

Analyze items	Cronbach's Alpha	Cronbach's Alpha based on standardized items	Number of items
Concerns and barriers in using smart home Products	0.799	0.799	7
Future improvements and innovations for devices	0.742	0.742	5
Total scale	0.771	0.771	12

The Cronbach's alpha coefficients indicate reliable data, with the total questionnaire scoring 0.771 and dimension coefficients of 0.799 and 0.742 for “usage barriers” and “functional improvements” respectively (both > 0.700), indicating reliable data.

Validity: Validity analysis assesses the rationality of scale item design. Structural validity of the questionnaire was examined using SPSS statistical analysis software, with results shown in Table 2.

Table 2: KMO and Bartlett test tables

		Collectivity	Use smart home products concerns and obstacles	Future improvements and innovations in smart home devices
KMO		0.836	0.865	0.807
Bartlett’s test	Approximation chi-square	497.10	631.3	362.87
	Significance	<0.010	<0.010	<0.010

The KMO value was 0.836, and Bartlett's sphericity test was significant ($p < 0.010$), indicating good construct validity.

4. Research Results

4.1. Purchasing Group Characteristics and Technical Needs Mapping

4.1.1. Cluster Analysis

A cluster analysis was conducted using IBM SPSS software to categorize the 786 respondents into four distinct groups: A, B, C, and D, as shown in Table 3; the final clustering results include four groups of users. Overall, the four groups are evenly distributed, indicating a good overall clustering effect. K-means cluster analysis also categorized the purchasing groups into four categories, as shown in Table 3.

Table 3: Summary of basic information of cluster categories

Cluster Class	Frequency	Percentage (%)
Class A	104	13 %
Class B	346	44 %
Class C	204	26 %
Class D	132	17 %
Total	786	100 %

After obtaining the cluster categories, statistical results indicate significant differences across all variables ($p < 0.05$), confirming the validity of the four-cluster classification. This article divides them into High-Price Feature Seekers, Mass Practical Users, Budget-Conscious Pragmatists, and Premium Integrated Solution Seekers. The specific classifications are shown in Table 4.

Table 4: Cluster distribution characteristics of purchasing group characteristics

Category	Category A (High-Price Feature Seekers)	Category B (Mass Practical Users)	Category C (Budget-Conscious Pragmatists)	Category D (Premium Integrated Solution Seekers)
Scale	104 people	346 people	204 people	132 people
Price-Sensitive	Low	High	High	High
Functionality-Sensitive	High	High	High	High
Ease of use Sensitive	High	High	High	High
Health management needs	Real-time monitoring, health warnings, and emergency rescue	Sleep quality monitoring, health warnings	Real-time monitoring and health warnings	Real-time monitoring, sleep quality monitoring, health warnings
Home security needs	Smart door locks, intrusion alarms, smoke alarms	Smart door locks, intrusion alarms	Smart door locks, intrusion alarms	Smart door locks, intrusion alarms, smoke alarms, environmental monitoring and control

4.1.2. Its Characteristics and Behavioral Preferences Directly Point to Technical Needs

Mass Practical Users value practical functions and ease of use. They often use basic devices like smart locks and lighting, and are interested in device connectivity. Their technical requirements include simplifying operational processes, improving response speed, enhancing compatibility between devices from different brands, and optimizing large-font interfaces for elderly vision.

Budget-Conscious Pragmatists prioritize value for money, preferring affordable devices with core functions, such as smart door locks and smoke detectors, and are less tolerant of redundant features. Their technical requirements include optimizing functional modules, developing dialect-supporting voice control systems to improve recognition accuracy, and replacing touchscreens with physical buttons to reduce errors.

High-Price Feature Seekers are less price-sensitive and value health monitoring and emergency rescue features. They often use devices like real-time heart rate monitoring and fall alarms, and expect their data to be linked to medical systems. Their technical requirements include integrating multi-parameter sensors, such as blood pressure and fall radar, to ensure accurate monitoring data, building emergency response mechanisms, and enabling rapid synchronization of alarms with children and community health centers.

Premium Integrated Solution Seekers seek intelligent connectivity across all scenarios, prioritize scenario-based features like "Away Mode," and place high demands on device synchronization speed and intelligence. Technical requirements include optimizing edge-cloud hybrid computing architectures to reduce latency; developing user behavior learning algorithms to automatically adjust device parameters based on sleep patterns; and opening APIs to expand compatibility with mainstream device brands.

4.2. Factors Influencing Purchasing Behavior and Technology-Driven Directions

4.2.1. Principal Component Analysis

This paper conducted a principal component analysis on 14 factors that influence smart home purchasing decisions. It extracted five common factors with eigenvalues greater than 1. Their cumulative variance contribution rate was 60%, as shown in Figure 1.

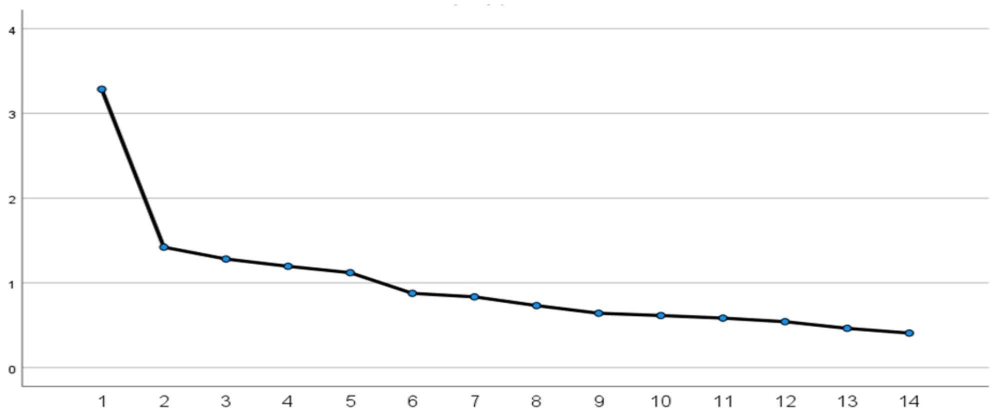

Figure 1: Factor Eigenvalue Results (Scree Plot)

Based on the scree plot, it is noteworthy that approximately 40% of the variance is unexplained, so these five factors represent the main but not the only influencing factors. The total variance explained is shown in Table 5.

Table 5: Total Variance Explained

Component	Initial Eigenvalues			Extracting the Sum of Squares of Loadings			Sum of Squares of Rotating Loads		
	Total	Percentage of Variance	Accumulation %	Total	Percentage of Variance	Accumulation %	Total	Percentage of Variance	Accumulation %
1	3.29	23.47	23.47	3.29	23.47	23.47	3.26	23.32	23.32
2	1.42	10.16	33.62	1.42	10.16	33.62	1.31	9.37	32.69
3	1.28	9.15	42.78	1.28	9.15	42.78	1.31	9.33	42.02
4	1.20	8.54	51.32	1.20	8.54	51.32	1.23	8.77	50.79
5	1.12	8.00	59.32	1.12	8.00	59.32	1.19	8.53	59.32

After factor rotation, the factor loading matrix is shown in Table 6.

Table 6: Rotation Component Matrix

Project Information	Component				
	1	2	3	4	5
Price	-.050	-.112	.863	-.112	-.120
Functionality	-.004	-.669	-.311	-.472	.204
Ease of Use	-.034	-.111	-.158	.877	.113
Brand Awareness	.000	.854	-.163	-.288	.083
Entertainment	-.013	.195	.594	-.024	.491
Safety	-.007	-.064	-.042	.091	.804
More User-Friendly Interactive Experience	.663	.038	.074	-.075	-.023
Higher Level of Intelligence	.645	-.137	.116	.016	.022
Improved Device Compatibility and Operability	.642	.046	-.095	.172	.140
Stronger Security and Privacy Protection	.637	.006	-.003	-.054	.262
Enhanced Environmental Protection and Energy Saving	.703	-.086	-.067	-.177	.001
Data Security Issues	.535	-.109	-.046	.242	-.307
System and Device Issues	.666	.056	-.026	-.028	-.150
Complex and Difficult User Interface	.602	.154	-.151	.064	-.160

We analyzed the five extracted factors based on the rotated component matrix:
(I) Component 1: Comprehensive Experience and Performance Factor. Indicators such as "More User-Friendly Interactive Experience," "Higher Level of Intelligence," "More Environmentally Friendly and Energy-Saving," and "System and Equipment Issues" all had relatively high loadings, reflecting the demand for overall product performance and user experience.
(II) Component 2: Brand Influence Factor. This factor is primarily driven by "Brand Awareness" and negatively correlated with "Functional Practicality" (-0.669). This suggests that some users (such as those who prefer low prices and practicality) prioritize functionality over brand.
(III) Component 3: Cost-Effectiveness-Entertainment Attribute Factor. This factor is dominated by "Price" and includes the "Entertainment" attribute, reflecting users' expectations for basic entertainment features while focusing on cost.
(IV) Component 4: Safety Function Factor. This factor, centered on "Operational Ease" and linked to functional practicality and data security, focuses on product usability and safety.
(V) Component 5: Safety Assurance Factor. This factor is almost entirely driven by the "Safety Assurance" indicator, reflecting users' core concerns about safety and security.

4.2.2. Based on Principal Component Analysis, Five Key Factors Were Extracted To Clarify The Priorities for Technology Research and Development

Comprehensive Experience and Performance Factor: Focus on optimizing the user experience and resolving negative issues. For example, developing voice recognition features compatible with dialects like Wu and Jianghuai; designing hardware that prevents touch failure; and enhancing system self-diagnosis capabilities to reduce hardware failures.

Brand Influence Factor: Emphasize improving the practicality and stability of core functions (such as smart door lock unlocking efficiency and security system response speed), enhancing product value for money, and reducing reliance on brand premiums.

Cost-Effectiveness Factor: Technology R&D can balance cost control with the development of simple entertainment features. While maintaining cost control, basic entertainment features can be integrated and simplified (such as one-click play) to meet user leisure needs.

Convenience and Safety Factor: Focus on improving after-sales service efficiency, enhancing the device's automatic fault diagnosis and early warning capabilities, supporting remote troubleshooting by technicians, and providing simple text and audio guides to help users resolve common problems on their own. Security factors: Build a multi-level security protection system and equip the equipment with physical switches to achieve physical disconnection from the network; medical data is stored locally by default, and third-party access is granted only with authorization limited to 24 hours; and all data is highly encrypted.

5. Discussion and Suggestions

5.1. R&D Directions Based on Group Characteristics

For general, practical needs, R&D should focus on developing low-cost dialect voice recognition modules and "one-click scenario" algorithms to enhance accessibility. In addition, a universal protocol conversion plug-in should be proposed to reduce technical barriers to cross-brand integration.

For those who prefer low-cost, practical features, R&D focuses on developing a "basic edition" for seniors with physical buttons and a monochrome screen to control costs, and a "single-action" chip to solidify high-frequency commands.

For high-priced, function-focused devices, R&D focuses on: developing low-power multi-sensor fusion chips; designing edge computing-based "device-community" emergency linkage algorithms; and developing a health data storage module that supports authorized access by medical institutions.

For high-end, comprehensive needs, R&D focuses on: optimizing edge computing chips to reduce latency; developing neural network-based behavior prediction models; and advocating for the formation of cross-brand ecosystem alliances to unify integration standards.

5.2. Technological Breakthroughs Based on Behavioral Factors

Comprehensive User Experience Optimization: A "dual-mode interface" should be adopted, with large icons and voice control for the elderly user, and customization via the app for children. Frequently used operations, such as "turn on the light" and "set the alarm," are recorded and pinned to the top. Firmware upgrades can reduce device linkage failure rates.

Security Technology Upgrade: Focusing on "external risk isolation" and "internal trust balance," hardware physical protection eliminates privacy concerns. Tiered permissions and operation traceability are implemented to ensure user control. Encryption utilizes a mature and stable national encryption algorithm.

Self-diagnosis and After-Sales Technology: Device operation logs are used to predict failures and provide "text and audio" repair guides. A remote debugging function for children is developed to shorten repair time.

Limitations: This study's sample size is limited to Jiangsu Province, which may limit the generalizability of the findings nationwide due to regional differences in culture, economic levels, and consumer attitudes. Future research could expand the sample size to enhance the generalizability of the findings. In addition, the cumulative contribution rate of principal component analysis only reaches 60%. The currently selected variables may not fully include all influencing factors. Future research can try to include more variables to enhance the explanatory power of principal component analysis and present the influencing factors behind related phenomena more comprehensively.

Acknowledgements

The authors gratefully acknowledge the financial support provided by the Jiangsu Students' platform for innovation and entrepreneurship training program (Grant No. 202510292013).

References

[1] Li, R. Y. M., Shi, M., Derek, A. A., Xu, Y., Richter, A., Kelvin Tsun, W. N., & Song, L. (2022). Exploring the market requirements for smart and traditional ageing housing units: A mixed methods approach. Smart Cities, 5(4), 1752.

[2] Zheng X, Shan X. Research on the Differences in the Intention of Use of the Elderly to Different Smart Home-based Elderly Care Technology Based on TAM Model [J]. International Journal of Frontiers in Sociology, 2021, 3.0(18.0):

[3] Xu, W. (2022). Sixth discussion on user-centered design: A human factors approach to intelligent human-computer interaction. Chinese Journal of Applied Psychology, 28(3), 195–213.

[4] Etrata, A., Biling, V. J., Peralta, K., & Relucio, R. M. (2022). Credible or reliable information: What affects Shopper's trust and buying behavior? Journal of Business and Management Studies, 4(1), 257-263.

[5] Wang E S T, Chou N P Y. Consumer characteristics, social influence, and system factors on online group-buying repurchasing intention [J]. Journal of Electronic Commerce Research, 2014, 15(2): 119-132.

[6] Myeounggon L, Kinker R M, Anmol M, et al. Smart-Home Concept for Remote Monitoring of Instrumental Activities of Daily Living (IADL) in Older Adults with Cognitive Impairment: A Proof of Concept and Feasibility Study [J]. Sensors, 2022, 22(18):6745-6745.

[7] Li, Z. R., Li, H. J., & Chen, S. Y. (2023). Research on the health needs of elderly living alone for smart home based on the Kano model. Packaging Engineering, 44(16), 145–153.

[8] Zeng, Y., Fu, J., Cao, W., Chen, Y., & Yang, Z. (2024). Research hotspots and knowledge framework of digital healthcare service management from the perspective of the silver economy. Sustainability, 16(22), 9735.

[9] Ding, L. F. (2025). Analysis of the dynamic interaction mechanism between functional new product development and market demand. IT Manager World, (3), 111–113.

[10] Qiu, D. K. (2022, March 8). Strengthening age-friendly smart homes and empowering home-based elderly care with silver tech. Shanghai Securities News, p. 9.

[11] Liu, Z., & Qiao, Y. J. (2024). Design of elderly smart walking aids based on an improved technology acceptance model. Journal of Mechanical Design, 41(12), 175–180.

[12] Zhang, Y. F., & Lu, M. F. (2025). A mechanism study on the integration of first-mover and silver economies driving new quality productive forces from a multidimensional innovation perspective: Based on a three-dimensional framework of technological empowerment, intergenerational collaboration, and supply-demand optimization. Journal of Shanghai Business College, 1–15.

[13] Yi-Kyung, H., Ze-Yu, W., & Ji, Y. C. (2022). Global research trends on smart homes for older adults: Bibliometric and scientometric analyses. International Journal of Environmental Research and Public Health, 19(22), 14821. doi:https://doi.org/10.3390/ijerph192214821

[14] Davis F D. Perceived usefulness, perceived ease of use, and user acceptance of information technology [J]. MIS Quarterly, 1989, 13(3):319-340.

[15] Dong, J. M., & Fu, L. M. (2003). Human-computer interaction: User-centered design and evaluation. Tsinghua University Press.