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Positive Strategies for Enhancing Elderly Interaction Experience in Smart Healthcare through Optimized Design Methods: An INPD-Based Research Approach

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Abstract: The breakthrough in artificial intelligence technology and the development of smart healthcare models have significantly improved modern healthcare services. However, the elderly population still faces numerous challenges. Therefore, the aim of this study is to enhance the interactive experience of elderly users and to propose effective design strategies through optimized design methods. Based on the INPD research methodology, the design process is divided into four stages. First, in the SET phase, product opportunity gaps are identified, followed by in-depth interviews and surveys to gather user needs. Second, the AHP method is used to establish a hierarchical model and judgment matrix to determine the subjective weights of each need, while the EWM method, based on survey data, determines the objective weights of each need. To ensure the scientific nature of the overall weight, a combined weighting approach is used, followed by a final prioritization of needs. Third, after translating user needs into design requirements, three design schemes are produced, and the TOPSIS method is used to calculate the weights and evaluate the optimal scheme. Fourth, the product opportunities are implemented and tested. The research results indicate that the proposed optimization design method is effective and not only reduces the barriers and challenges elderly users face when interacting with intelligent products but also enhances their overall experience. Moreover, it provides a practical approach to the sustainable development of smart healthcare. As an essential component of future healthcare services, the sustainability of smart healthcare will depend on a deep understanding of user needs and continuous optimization. The design strategy proposed in this study offers practical application value, improving elderly users' satisfaction while also providing insights that may be useful for other smart services.

Keywords: design methods; interactive experience; user experience design; elderly smart healthcare; INPD

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1. Introduction

The widespread adoption of the Internet and big data technologies has indeed greatly facilitated people's lives. However, the reality is that China's aging population is continuously increasing, and the country has entered the ranks of aging nations. For the elderly, these conveniences often come with higher cognitive and learning costs. This is particularly true when medical systems integrate with intelligent and Internet technologies, which may seem unfamiliar to older individuals who rely heavily on traditional medical systems [1]. Therefore, in the context of smart healthcare, it is crucial to thoughtfully and thoroughly research how to bridge the digital divide faced by the elderly in order to provide high-quality medical services and a positive healthcare experience.

Currently, scholars have made some valuable contributions to improving the interaction experience of elderly users with smart healthcare [2]. These include usability testing of systems and the design of smart terminal products [3,4]. Multiple test results indicate that while these strategies can effectively increase certain aspects of user satisfaction, they have not fully considered the interactions among various factors and still exhibit notable shortcomings [1,4,5]. For example, the interaction between system usability and cognitive load is particularly evident [6]. A complex interface design and an overload of information can increase the cognitive load for elderly users, causing confusion and inconvenience when using smart systems, which in turn lowers their user experience. Therefore, simplifying the design can significantly improve elderly users' satisfaction [7,8]. Additionally, the way information is presented is closely related to cognitive load. Clear and intuitive information presentation can help elderly users better understand complex medical information, thereby reducing their cognitive burden [9]. Moreover, the sense of security and privacy protection plays a crucial role in technology acceptance. If users do not trust the system's privacy protection, their willingness to use it will greatly decrease [9]. There is also a noticeable interaction between information presentation and technology acceptance, as the complexity of information presentation directly affects users' acceptance of and satisfaction with the system [10,11]. However, many current interactive applications face issues such as complex interactions and poor universality in their efforts to offer richer content. The design process has not adequately considered the abilities and needs of elderly users, resulting in problems with ease of use and satisfaction [1,12].

Although many scholars have conducted comprehensive studies on user needs, there remains a gap between user needs and design outcomes, leading to unsatisfactory usability results [13]. Therefore, to establish a good supply–demand relationship between smart healthcare and elderly users, it is necessary to use optimized design methods to assist designers in better translating design requirements [14,15]. The optimized design method effectively addresses the limitations of traditional design models, which rely more on designers' experience and conventional design rules, often failing to fully consider complex user needs and market dynamics. By utilizing systematic, multi-stage decision-making and quantitative evaluation methods, this approach significantly reduces the impact of human bias, achieving multi-stage, multi-dimensional system optimization and ensuring the scientific and reliable nature of design decisions [16,17].

Therefore, this research framework, as an experimental smart healthcare system, aims to propose an integrated optimization design method combining INPD-AHP-EWM-TOPSIS, using elderly users' smart healthcare as a case study, with Chinese elderly users as the target population. The focus is on addressing the difficulties and needs they face during the healthcare process to ensure the feasibility and effectiveness of the design solutions. The INPD method, as the foundational part of this framework, plays a crucial role. Firstly, the INPD method integrates multiple design stages such as need identification, solution design, and user feedback, fostering collaboration across interdisciplinary teams and ensuring consistency and innovation throughout the entire process, from needs analysis to final design. The advantage of INPD lies in its focus not only on functional development but also on optimizing user experience. This is particularly effective in designing smart healthcare interaction experiences for elderly users, as it can effectively identify and address their specific needs. Therefore, we conducted in-depth interviews to gather elderly users' feedback on the system and analyzed their healthcare behaviors and intentions. This information provided qualitative data for our subsequent research. This paper accurately translated these needs into design requirements and, through the AHP-EWM method, calculated and ranked the importance of these needs. The TOPSIS method was then used to select the optimal design solution.

This optimization method provides the design team with a more defined path for improvement, rather than relying on a single design phase or experience-based decision-making. It makes the design of smart healthcare more targeted, scientific, and actionable. At the same time, it provides a new theoretical perspective and methodological framework for addressing smart healthcare for the elderly, effectively optimizing existing service models, enhancing the experience and satisfaction of elderly users during healthcare, and advancing the intelligence of medical services.

The remainder of this study is organized as follows: Section 2 provides an overview of the theoretical framework and the current research status in related fields. Section 3 explores user behavior and needs through qualitative research methods employed in this study. Section 4 uses elderly users' smart healthcare as a case study, identifying core needs through data statistics and analysis, and constructs design requirements accordingly. Section 5 discusses the research results and provides design strategies to enhance user experience. Section 6 summarizes this study, discusses its significance and limitations, and suggests directions for future research.

2. Literature Review

2.1. Theoretical Background

Integrated new product development (INPD) is a design methodology primarily studied by professors Cagan J. and Vogel C. M. from Carnegie Mellon University in their book *Creating Breakthrough Products*. It is a user-centered, comprehensive approach to integrated new product development [18]. INPD, as an integrated method spanning the entire product design process, guides product development from need identification and conceptualization to final realization [19,20]. This method comprises four stages, from product planning to project approval: identifying opportunities/defining product opportunities, understanding the opportunity, conceptualizing the product based on identified opportunities, and realizing the opportunity [21,22]. Unlike previous empirical methods based solely on personal experience and subjective judgment, INPD considers multiple factors comprehensively, ensuring the continuous involvement of core users and experts from various fields in every stage of product design [19,23]. INPD explores theories, methods, and tools for new product development from three perspectives: user needs, engineering practices, and market trends, aiming to enhance development efficiency and reduce errors [19]. This makes the approach a valuable guide for comprehensive system planning in modern design.

Existing studies have examined how INPD enhances product user experience through user participation and collaborative design. Sanders et al. [24] proposed a co-creation design method that emphasizes user involvement in the early stages of product design, which has been widely applied in the design of medical products. In recent years, with the development of Virtual Reality (VR), artificial intelligence (AI), and the accelerating aging population, INPD has also been applied in the intelligent domain, with researchers increasingly focusing on optimizing design methods to enhance the smart healthcare interaction experience for older adults. For instance, Ming Cheung [19] utilized INPD for the innovative design of surgical products.

The Analytic Hierarchy Process (AHP) was introduced in the mid-1970s by the American operations researcher Thomas L. Saaty [25,26]. It is a method that addresses complex problems by establishing a hierarchical structure, characterized by its universality, systematization, and hierarchical nature [27]. AHP uses a tree-like hierarchical structure to divide a complex multi-objective decision problem into several simpler sub-problems, each of which can be independently analyzed [28]. The method involves solving the eigenvectors of the judgment matrix to determine the priority weight of each element at each level relative to the elements at the preceding level. Finally, a weighted summation method is used to aggregate the results, calculating the overall weight of each alternative against the overall goal. The alternative with the highest weight is identified as the optimal solution. AHP effectively combines quantitative and qualitative analysis for multiple decision-making objectives and enables systematic and model-based analysis of limited data samples [29,30], thereby reducing subjective bias in decision-making during complex problem analysis [31,32].

AHP has been widely applied across various fields. Pant et al. [33] applied AHP in monitoring the health management of smart healthcare systems, providing solutions for multi-criteria decision-making problems. Zaidan et al. [34] integrated AHP with TOPSIS to evaluate the selection of open-source Electronic Medical Record (EMR) packages.

Wu et al. [35] utilized an integrated INPD-AHP-QFD approach to design high-speed train seats in the post-pandemic era. Singh et al. [36] employed a KANO-AHP-TOPSIS-based approach to solving multi-criteria decision problems, offering optimal solutions from multiple perspectives for users. Neira-Rodado et al. [28] validated the use of KANO-AHP-DEMATEL-QFD for the design of assistive devices for hip replacement surgery for older adults, providing better design decisions for this demographic.

The entropy weight method (EWM) is an objective weighting method for multi-criteria decision-making, characterized by clear mathematical principles and approaches. It effectively captures the intrinsic patterns and information contained within data, determining attribute weights and conducting comprehensive evaluations while minimizing errors caused by human factors, thus providing scientific decision support for decision-makers [37–39]. According to the definition of the entropy weight method, the smaller the information entropy presented by the data, the greater the impact of the data, which translates into a higher weight in the results. Conversely, the larger the information entropy, the smaller the weight [40]. With the development of the EWM method, its applications have extended beyond improvements and optimizations of the method itself to include integration with other decision-making methods, enhancing its flexibility and comprehensiveness [41].

Li et al. [42] utilized FAHP-EWM to assess fire risk in ancient dwellings and villages. Zhang et al. [43] improved the VIKOR method using EWM, developing a new analytical algorithm for the custom ranking of products. Du et al. [44] employed a hybrid EWM-PBD-CCD approach to optimize multi-component extraction and purification processes. Zhang et al. [45] constructed corresponding strategies within smart home systems to enhance user satisfaction.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a method used for comprehensive comparison and ranking of multiple alternatives under multi-quality characteristics. By calculating the proximity of evaluation alternatives to the positive ideal solution and the negative ideal solution, the alternative closest to the positive ideal solution and furthest from the negative ideal solution is considered the optimal choice. This method is often used to build evaluation models to solve complex multivariate index analysis problems [46]. TOPSIS allows for objective comprehensive comparison and ranking of alternatives while incorporating the subjective preferences of evaluators, making it a commonly used and effective multi-attribute decision-making method [47]. Research on this method not only focuses on its improvement but also shows significant progress in its integration with other methods.

Fan et al. [48] proposed a new TOPSIS method based on decision-making to select ideal products, enhancing user purchasing decisions. Zavadskas et al. [49] systematically improved the fuzzy TOPSIS method to address fuzzy decision-making issues in construction engineering, demonstrating its superiority under uncertainty. Zhang et al. [50] improved the AHP-EWM-TOPSIS design method to address expert subjectivity, using autonomous navigation equipment failure modes as an example. García-Cascales et al. [51] combined AHP with TOPSIS for prioritizing renewable energy projects, highlighting the advantages of this integrated approach in multi-criteria decision-making.

According to relevant literature, while methods such as INPD, AHP, EWM, and TOPSIS have been integrated in various fields, there is still no unified research model, leaving room for optimization in design methods. In this study, INPD serves as the overarching framework guiding the entire product design process, ensuring a sustained focus on user needs, while AHP, EWM, and TOPSIS function as quantitative tools at a micro-level, executing specific evaluation and optimization tasks. These methods are not independent but rather interact and complement each other. INPD provides systematic guidance from need identification to design evaluation, while AHP, EWM, and TOPSIS offer a solid foundation for the quantitative assessment of needs and the optimization of design solutions. Research on integrated approaches can fully leverage the strengths of each method, enhancing the scientific, accurate, and adaptive nature of decision-making and effectively addressing complex multi-criteria decision-making environments in practical applications.

2.2. Current Research Status on the Interaction Experience of Elderly Users with Smart Healthcare

With the rapid advancement of technology, smart healthcare is leading a transformation in medical services. It leverages advanced technologies such as artificial intelligence, the Internet, and big data to provide personalized and precise medical services [52]. Particularly in the realm of smart healthcare, the goal is to enhance user experience and simplify medical processes [53]. In recent years, research on the interaction experience of elderly users with smart healthcare has become an interdisciplinary hot topic, involving fields such as medicine and human–computer interaction. Existing studies mainly focus on three areas: the acceptance of the technology by elderly individuals, principles of interactive interface design, and strategies to improve user experience [1,54,55]. However, elderly populations still face unique needs and challenges in this field [56].

Several studies have indicated that elderly individuals, due to their unfamiliarity and fear of new technologies, often lack confidence and exhibit resistance toward smart healthcare devices [54,57]. Vassli et al. [58] noted that elderly people generally have poor adaptability to technology and are concerned about making mistakes during use, which could have negative consequences. Additionally, research has found that social support systems significantly impact the acceptance of smart healthcare technology among the elderly. Encouragement and guidance from family members or healthcare professionals can enhance the elderly's trust in and willingness to use the technology [57].

This study primarily focuses on improving the interaction experience of elderly users during smart healthcare processes. Although current intelligent technologies offer conveniences for the elderly, there are still numerous challenges in their use. The interaction process in smart healthcare is a key factor affecting user experience. While many researchers have proposed design principles for elderly-friendly systems, such as simplifying operational processes, creating clear and concise interface designs, and displaying easily understandable information, these principles are widely accepted in theory but often inadequately implemented in practice [2,55,59]. This is due to a lack of in-depth understanding of elderly users' actual needs and insufficient communication and testing with the target user group, leading to products that fail to address the real issues elderly users face [4,60]. Moreover, there are significant individual differences among the elderly in terms of physiological, cognitive, and technological acceptance [61], but design approaches often use a "one-size-fits-all" method, neglecting the specific needs and capabilities of elderly users [1,62].

Research by Mitzner et al. [3] indicates that elderly individuals have a positive attitude toward new technologies, but many design studies have failed to adequately consider their needs. Chen [1] points out that existing research on age-friendly design still has significant shortcomings and should account for changes in sensory, cognitive, and operational abilities among the elderly. Additionally, accessibility and adaptability issues remain major flaws in current research [61]. Although some studies have started to address these issues, most products still lack sufficient interface adaptability. Vaportzis [8] found that existing products often prioritize comprehensive functionality, leading to complex interface designs and information overload, which may not be necessary for elderly users [55]. Furthermore, effective user feedback mechanisms are crucial for enhancing user experience, but research and practice in this area are relatively insufficient [57]. For example, many products have rudimentary feedback mechanisms or even lack timely feedback prompts, causing elderly users to make errors during operations that they cannot promptly correct, thereby reducing the effectiveness and satisfaction of the product.

3. Method

This study follows the INPD research methodology as its main framework, utilizing a comprehensive design optimization approach that combines both qualitative and quantitative methods. The first step involves identifying product opportunities through the SET analysis method (Social, Economic, Technological Analysis) [63]. In the second step, we conducted user research through qualitative interviews to clarify the value of these opportunities and identify users' preliminary needs. Interviews serve as an effective method for gaining deep insights into and exploring user perspectives; however, they carry a degree of subjectivity. To mitigate this, after collecting qualitative data, we applied a combination of AHP (Analytic Hierarchy Process) and EWM (entropy weight method) to conduct quantitative analysis. This approach systematically verifies the identified needs and ranks their priorities, transforming user needs into design opportunities. In the third step, the design team selects design concepts and develops multiple conceptual products, with the optimal solution evaluated using the TOPSIS method. The fourth step involves translating the concepts into design solutions, creating models, refining the product design, and testing the feasibility of the design solutions. As shown in Figure 1.

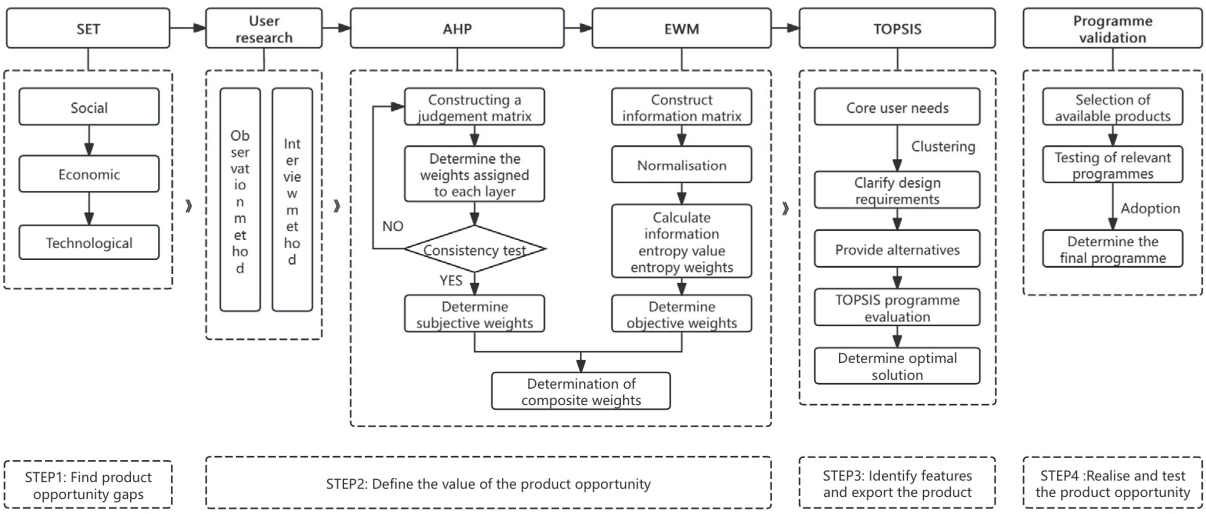

Figure 1. Research methodology framework.

In conclusion, by combining qualitative and quantitative methods, this study aims to improve the objectivity of the research. This approach strikes a balance between the richness of qualitative data and the rigor of quantitative analysis. It allows us to quantify and validate needs from a broader, more objective perspective, reducing the influence of any single participant's subjective opinion and ensuring the scientific accuracy of user needs.

3.1. Step 1: Identifying Product Opportunity Gaps

The SET analysis method is a tool used to comprehensively assess the impact of social, economic, and technological factors on a specific topic or issue [63]. It provides important insights into the early stages of product development. On the social level, it assesses factors such as users' age structure, cultural background, and social values, which are crucial for understanding user behavior patterns and needs. The economic dimension includes an analysis of users' purchasing power, market size, and relevant economic factors, ensuring that product design aligns with users' financial capabilities and affordability. The technological dimension focuses on trends in technology development, assessing the feasibility of the product and how to innovate within the current technological environment [18].

Therefore, the SET method helps in understanding the social environment, economic conditions, and technological trends surrounding users, thereby providing better insights into their needs, expectations, and behaviors [64]. It also aids product developers in identifying opportunities, effectively avoiding potential design risks, and encouraging companies to continuously improve their products to maintain competitiveness (e.g., Apple, Huawei, Xiaomi, etc.). Therefore, SET analysis is regarded as a critical first step in capturing product opportunities. As shown in Figure 2.

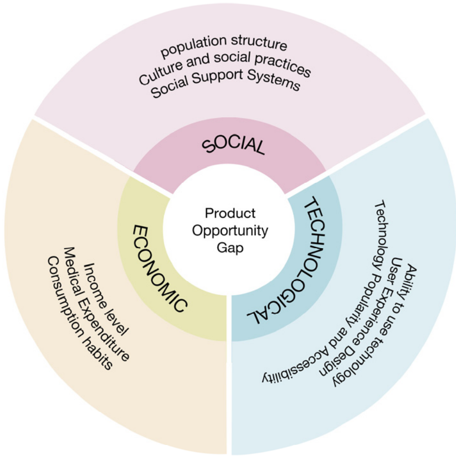

Figure 2. SET (social–economic–technological) factors.

3.2. Step 2: Clarifying Product Opportunity Value

3.2.1. User Needs Research

This study first needs to identify the research subjects and develop an interview outline for users. Then, through non-participant observation and in-depth interviews, the entire process and behaviors of target users are thoroughly documented. This approach is aimed at deeply uncovering the key behavioral touchpoints of stakeholders and obtaining firsthand user data to prepare for the next step in analyzing target user behavior.

3.2.2. AHP Determination of Subjective Weights

In the integrated innovation of INPD, individual perspectives and priorities vary, often based on subjective and qualitative judgments. This can lead to differing goals during the design process, which may hinder smooth progress. AHP (Analytic Hierarchy Process) addresses this issue by logically and quantitatively analyzing complex problems, thereby making design objectives clearer and evaluation methods more substantiated.

(1) Establishing the Hierarchical Model and Constructing the Judgment Matrix

First, the hierarchical structure of the research subject is determined, breaking it down into several levels, including the goal level, criteria level, and alternatives level. The goal level represents the overall objective of the study, the criteria level includes the factors that need to be considered to achieve the goal, and the alternatives level consists of specific methods or solutions to meet the criteria. A hierarchical analysis model is constructed for each level of meaning [65,66]. Then, based on the nine-point importance scale developed by American operations researcher Thomas L. Saaty [67], the expert method is used to conduct pairwise comparisons of the criteria level indicators, establishing a pairwise comparison judgment matrix.

Assuming there are n indicators at the criteria level, n experts are invited to compare the importance of each evaluation indicator using a 1–9 rating scale and to provide scores. Based on the evaluation scores, a judgment matrix $A = (a_{ij})_{n \times n}$ is constructed, where $a_{ij} = 1/a_{ij}$, and a_i, a_j (where $i,j = 1, 2, \ldots, n$) represent the elements at the criteria level, with a_{ij} indicating the relative importance of a_i compared to a_j.

$$A = (a_{ij})_{n \times n} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

(2) Calculating Relative Weights and Consistency Check

The weights of each indicator are calculated based on the judgment matrix, followed by a consistency check. The specific steps and formulas are as follows:

Using the judgment matrix, normalize the elements in matrix A using the product of sums method.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

Sum the normalized elements in each row, and then divide by n to calculate the weight values of the indicators.

$$w_i = \frac{\sum_{j=1}^{n} \bar{a}_{ij}}{n} \quad (2)$$

To calculate the consistency of the judgment matrix, first determine the maximum eigenvalue.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(Aw)_i}{nw_i} \quad (3)$$

Finally, consistency is checked by verifying the CR.

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (4)$$

$$CR = {}^{CI}/_{RI} \quad (5)$$

The RI value, used in this check, can be obtained from a reference Table 1. If the CR value is less than 0.1, the judgment matrix is considered to have passed the consistency check, making the weights valid. If the CR value is 0.1 or greater, the judgment matrix needs to be adjusted [68]. Sort all the weight values W_i in ascending order; the indicators with larger weights represent the core meaning.

Table 1. Average random consistency.

n	3	4	5	6	7	8	9	10	11	12
RI	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54

3.2.3. EWM for Determining Objective Weights

Since AHP often reflects the importance of evaluation indicators based on expert scoring, it is heavily influenced by subjective judgment. To make the weight distribution more scientific and rational, EWM is introduced. EWM is a method based on information entropy, which measures the inherent information content of each indicator through data dispersion. It quantifies the amount of information or uncertainty of various factors and determines the objective weight of each factor by calculating the entropy value [69,70]. According to the definition of the entropy weight method, the smaller the information entropy presented by the data, the greater the influence of the data, which is reflected in a higher weight in the results. Conversely, the larger the information entropy, the smaller the weight [40].

This method can more accurately reflect the differences and impact of various factors, thereby providing a more objective and comprehensive result for determining weights. The steps for using the entropy weight method to calculate the weights of audience needs are as follows [71,72].

Assume there are m alternatives and n evaluation indicators, with r_{ij} representing the original value of the j-th evaluation indicator for the i-th alternative. The original data matrix is constructed as $R = (r_{ij})_{m\times n}$, where $i = 1, 2, \ldots, m$.

$$R = (r_{ij})_{m\times n} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

To address the issue of significant differences in magnitude among evaluation indicators due to different dimensions, the original data are normalized to obtain the standardized matrix $R' = (r'_{ij})_{m\times n}$. The normalization formulas for positive and negative indicators are as follows:

$$r\prime_{ij} = \frac{r_{ij} - \min(r_{ij})}{\max(r_{ij}) - \min(r_{ij})} \tag{6}$$

$$r\prime_{ij} = \frac{\max(r_{ij}) - r_{ij}}{\max(r_{ij}) - \min(r_{ij})} \tag{7}$$

Calculate the characteristic ratio of the evaluation value under the j-th evaluation indicator for the i-th alternative, that is, the indicator weight value of the j-th evaluation indicator in the i-th alternative, to obtain the matrix $P = (p_{ij})_{m\times n}$.

$$p_{ij} = \frac{r\prime_{ij}}{\sum_{j=1}^{n} r\prime_{ij}} \tag{8}$$

Calculate the entropy value e_j of the j-th indicator.

$$e_j = -\frac{1}{1n(n)}\sum_{j=1}^{n} p_{ij}1n(p_{ij}) \tag{9}$$

Calculate the information entropy redundancy (difference) d_j.

$$d_j = 1 - e_j \tag{10}$$

Calculate the weight value w_j for each indicator.

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{11}$$

3.2.4. Determining the Comprehensive Weight of User Needs

To make the comprehensive weight of the indicators more scientific, an additive synthesis method is used to calculate the combined weight. A function is established with the goal of minimizing the sum of squared deviations, balancing both the subjective preferences of expert users and the objective differences in the indicator values, making the evaluation results more reliable.

$$\min s = \sum_{j=1}^{n} \left[\left(H_j - w_i\right)^2 + \left(H_j - w_j\right)^2 \right] \tag{12}$$

$$H_j = \beta w_i - (1-\beta) w_j \tag{13}$$

By combining Formulas (12) and (13), with β set to 0.5, a linear comprehensive weight vector is formed [73], resulting in the final design evaluation function:

$$H_j = 0.5w_i + 0.5w_j \tag{14}$$

3.3. Step 3: Define Functions and Output the Product

3.3.1. Define Design Requirements

After identifying user needs and their importance through SET analysis and AHP-EWM, the core needs are transformed into design requirements. This transformation process concretizes the abstract user needs, making them actionable during the design and development phases. It not only clarifies the design direction but also ensures that key functions and features are prioritized. Additionally, it provides clear standards for subsequent design validation and optimization, thereby enhancing the final product's quality and user satisfaction.

3.3.2. TOPSIS Evaluation of the Optimal Solution

(1) Solution Provision

Once the core needs are translated into specific design requirements, detailed development and design are carried out based on these needs, resulting in three alternative design solutions. Each solution meets the core needs to varying extents and reflects a deep understanding of user preferences and usage contexts. This systematic design process not only enhances the product's relevance and user experience quality but also provides a solid foundation for subsequent solution selection.

(2) Solution Evaluation

Based on the above design solutions, TOPSIS is used to select the solution that best meets user needs. This method provides a clear proximity score for each solution, directly reflecting their strengths and weaknesses [74,75]. The TOPSIS approach is flexible, simple to compute, and highly intuitive, making it widely applicable in academia and business management. It is also highly suitable for this research.

Assuming there are m alternatives and n evaluation criteria, a raw decision matrix K of size m × n is constructed, where the element k_{ij} represents the value of the i^{th} alternative under the j^{th} criterion. To eliminate the influence of different units of measurement among criteria, the raw decision matrix is normalized to obtain the normalized decision matrix K. The common method for normalization is vector normalization.

$$K = \begin{bmatrix} k_{11} & k_{12} & \dots & k_{1n} \\ k_{21} & k_{22} & \dots & k_{2n} \\ \dots & \dots & & \dots \\ k_{m1} & k_{m2} & \dots & k_{mn} \end{bmatrix}$$

Convert the data into positive and negative indicators.

$$Z_{ij} = \frac{K_{ij} - K_{min}}{K_{max} - K_{min}} \tag{15}$$

$$Z_{ij} = \frac{K_{max} - K_{ij}}{K_{max} - K_{min}} \tag{16}$$

Based on the normalized matrix K/Z, use the cosine method to identify the positive ideal solution and the negative ideal solution. The positive ideal solution Z^{+} is composed of the maximum value of each column element, while the negative ideal solution Z^{-} is composed of the minimum value of each column element.

$$Z^{+} = (Z_1^{+}, Z_2^{+}, \dots\dots, Z_m^{+}) \tag{17}$$

$$Z^{-} = (Z_1^{-}, Z_2^{-}, \dots\dots, Z_m^{-}) \tag{18}$$

Calculate the distance of each evaluation object from the positive and negative ideal solutions.

$$D_i^{+} = \sqrt{\sum_{j=1}^{m} w_j (Z_j^{+} - z_{ij})^2} \tag{19}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{m} w_j (Z_j^{-} - z_{ij})^2} \tag{20}$$

Calculate the closeness coefficient of each evaluation object to the positive ideal solution ($0 \leq C_i \leq 1$), where a larger C_i value indicates a better evaluation object.

$$C_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \tag{21}$$

3.4. Step 4: Implementation and Validation of Product Opportunities

To verify the effectiveness of the proposed solution, the optimal design scheme is evaluated by selecting existing smart healthcare products available on the market. Relevant users are then chosen to experience these products, followed by a comparative analysis of the related products to test the suitability of the proposed solution. This process provides support for subsequent development efforts.

4. Case Study

4.1. Step 1: Identifying Product Opportunity Gaps

As the first step of the INPD method, it is crucial to identify the product opportunity gap by pinpointing the pain points or opportunities faced by elderly users during smart healthcare interactions. This step guides the subsequent product development and improvements. It is important to note that identifying product opportunity gaps requires a multidisciplinary approach that incorporates engineering, art, and market analysis. This study utilizes SET analysis, examining factors from three perspectives: social change (S), economic trends (E), and technological innovation (T) [63], as shown in Figure 3.

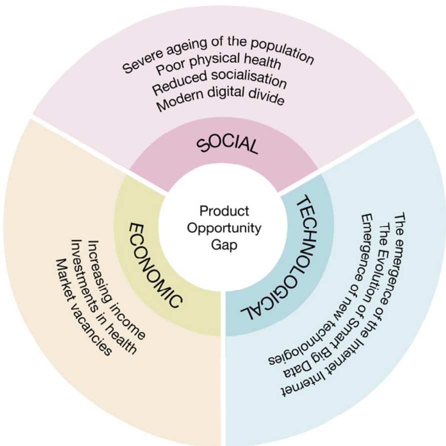

Figure 3. SET factors for elderly users' smart healthcare interaction experience.

Through a comprehensive review of the literature, news, and other sources, the analysis reveals the following. In social aspects, the rapidly growing elderly population is driving increased demand for healthcare services. Due to factors such as poor physical health, reduced social activities, and the modern digital divide, elderly individuals often experience loneliness and anxiety. This heightens their need for intuitive, user-friendly, and accessible interfaces [76,77]. In economic aspects, accelerating aging has led to a steady increase in healthcare consumption, with the elderly's demand for medical services becoming stronger [78]. The growing need for health services among the elderly and the unbalanced and insufficient development of the healthcare industry highlight the necessity to improve smart healthcare services. In technological aspects, the elderly have lower acceptance and learning capabilities for new technologies. The complexity of existing smart healthcare services makes it challenging for them to navigate, causing confusion and anxiety [79,80]. Additionally, these technologies often overlook the psychological and physiological characteristics of the elderly in their design, leading to poor user experiences [2,81].

4.2. Step 2: Identifying Product Opportunity Value

As the second step of the INPD method, qualitative and quantitative approaches were used to transform user needs into product opportunity value [82]. Through interviews and questionnaires, we identified user pain points and needs. Due to the complexity and numerous evaluation criteria of user needs, this study combines AHP and EWM to assign weights, complementing each method's strengths, reducing the impact of subjective factors in the design process, and enhancing the accuracy and rationality of user need extraction.

4.2.1. User Needs Research

To ensure the accuracy of information and the representativeness of the sample, 23 elderly users aged 60–89 were randomly selected from several hospitals in Hunan Province, China, as interview subjects. The sample included 10 males and 13 females (as shown in Table 2). The interviews were conducted one-on-one, and the interview content was discussed and developed in advance by two professors and three PhD students in relevant fields (as shown in Table 3). Each interview lasted approximately 30 min, and the entire process was audio-recorded to ensure no information was overlooked.

Table 2. Basic user information.

Category	Item	Frequency	Rate
Gender	Male	10	43.5%
	Female	13	56.5%
Age	60–69	12	52.2%
	70–79	8	34.8%
	80+	3	13.0%
Health status	Good	5	21.7%
	Average	17	73.9%
	Poor	1	4.4%
Experience with smart healthcare products	Used	19	82.6%
	Never used	4	17.4%

Table 3. Interview outline.

Category	Questions
Basic information	1. What is your gender/age? 2. How is your health condition? How frequently do you visit the hospital? 3. Have you used any related smart healthcare products?
Functional needs	1. Which smart healthcare platforms have you used? 2. Which functions of these smart healthcare platforms have you utilized? 3. Do you find the information elements displayed on existing platforms to be complex? 4. Are you able to quickly understand the purpose of these functions? 5. What do you think are the functional shortcomings? What additional features would you like to see?
Operational needs	1. Do you find the existing platforms easy to use in terms of operation? 2. Could you quickly understand how to operate them on your first use? 3. Have you ever experienced accidental touches during operation? 4. What are your usual operating habits? 5. What do you think are the operational shortcomings? What improvements would you like to see in the operation methods?
Visual needs	1. Do you find the interface of existing platforms easy to use? 2. Do you prefer large and clear fonts or icons? 3. Do you prefer a dense or simplified interface? 4. Would you like to see animation effects on the page? 5. What do you think are the visual shortcomings? What visual conditions would you like to improve?
Security needs	1. Are you concerned about the security of your personal information on smart healthcare platforms? 2. Do you find identity verification inconvenient? 3. Do you have concerns when making payments on the platform? 4. What do you think are the security shortcomings? What security elements would you like to enhance?

Based on the interview content, respondents expressed their experiences and expectations regarding functionality, operation, visuals, and security. We organized the valid information and compiled a series of user needs. However, due to limitations in the interview sample, we used stratified sampling to expand the sample size and better understand the actual needs of elderly users at different stages [83,84]. Since hospitals are places where elderly patients with medical needs are concentrated, we were able to collect data from individuals directly involved in medical services. Therefore, we invited elderly individuals over the age of 60 in several hospitals in Hunan Province to fill out paper questionnaires (participation was voluntary, and there were no conflicts of interest throughout the process). To ensure the sample's representativeness, we divided elderly users into different age groups and ensured an adequate number of participants in each group.

A total of 140 questionnaires were distributed, and after careful review by the researchers, 18 were confirmed to be invalid. The number of valid questionnaires collected was 122, with an effective rate of 87.14%. The gender distribution was 40.16% male and 59.84% female, with a slightly higher number of female participants. In terms of age distribution, the majority were in the 60-69 age group, accounting for 56%, followed by the 70–79 age group, accounting for 34%.

We then verified and filtered the needs points from the data of the 122 samples. The analysis of the results revealed that some needs had widespread consensus, reflecting common pain points among elderly users, while other less frequent and niche needs were excluded. The original needs of elderly users are presented in Table 4.

Table 4. User original needs.

User Original Needs	
A1 Simplified operation process	A2 Fewer information levels
A3 Larger text display	A4 Voice assistance function
A5 Easy-to-understand operation guidance	A6 Clear display of medical information
A7 Timely reminders and notifications	A8 Simple identity verification
A9 Long-term monitoring and feedback	A10 Convenient payment methods
A11 Consistent operation across devices	A12 Emergency call and location tracking function
A13 Timely haptic feedback	A14 Graphical health reports
A15 Simple animation effects	A16 Simplified academic terminology
A17 Intuitive interaction methods	A18 Unified and harmonious colors
A19 Clearly defined icons	A20 Secure personal privacy
A21 Increased operation fault tolerance	A22 Popularization of health knowledge
A23 Collaborative management with family members	A24 Cross-institutional data sharing
A25 Remote consultation	A26 Humanized guidance service

4.2.2. AHP Determination of Subjective Weights

(1) Establishing the Hierarchical Model and Constructing the Judgment Matrix

Based on user experience theory and "Ergonomics of Human-system interaction—Part 201: Human-Centered Design for interactive Systems" (ISO 9241-210) [85], we summarized and refined the relevant literature [86–88]. For example, Zhu et al. categorized the user experience framework into security, data requirements, and functional needs [89]; other scholars divided it into functional and non-functional aspects [90,91]; Liu et al., based on affordance theory, categorized it into physical affordance, cognitive affordance, and functional affordance [92]; Xu divided user needs into visualization needs, usability needs, and basic functional needs [93]. These studies emphasize similar categorization approaches [88,94,95]; therefore, the user needs identified above were classified, and an AHP model was established to calculate the subjective weights. The goal layer is the interactive design of smart healthcare for the elderly. The criteria layer consists of four factors: functional needs (H1), operational needs (H2), visual needs (H3), and safety needs (H4). The alternative layer extends from the four directions of the criteria layer, comprising 26 identified needs points (as shown in Table 5).

Table 5. Construction and classification of need hierarchies.

Objective Layer	Guideline Layer	Program layer
H Interactive design of smart healthcare for the elderly	H1 Functional needs	H11 Fewer information levels H12 Voice assistance function H13 Clear display of medical information H14 Timely reminders and notifications H15 Convenient payment methods H16 Emergency call and location tracking H17 Simple academic terminology H18 Popularization of health knowledge H19 Collaborative management with family members H110 Cross-institutional data sharing H111 Remote consultation H112 Humanized navigation
	H2 Operational needs	H21 Simplified operation process H22 Easy-to-understand operation guide H23 Cross-device operational consistency H24 Timely haptic feedback H25 Intuitive interaction methods H26 Increased fault tolerance
	H3 Visual needs	H31 Larger text display H32 Graphical health reports H33 Simple animation effects H34 Unified and harmonious colors H35 Clearly defined icons
	H4 Security needs	H41 Simplified identity verification H42 Long-term monitoring and feedback H43 Secure personal privacy

(2) Calculating Relative Weights and Consistency Check

At this stage, we invited sixteen experts (including three doctoral supervisors in relevant fields, four user experience designers, two hospital staff, and seven PhD students). First, before conducting the evaluation, we clearly required and confirmed that all participants had prior experience using smart healthcare applications. This ensured that they were not only theoretical professionals but also had practical product experience, allowing them to better understand the needs of elderly users when using smart healthcare products. Second, we provided the experts with a detailed introduction to the background, objectives, and content of the research. During this process, the experts were informed that we had already preliminarily identified the needs of elderly users through previous interviews and surveys regarding their use of smart healthcare applications. Lastly, to ensure that the experts could accurately understand the meaning and hierarchy of each need during the evaluation, we provided detailed explanations, giving them enough reference points when weighing the importance of various needs.

We asked the experts to use the Saaty scale to compare the importance levels of the five criteria-level indicators and construct pairwise comparison matrices, with scale options ranging from 1 to 9 and their corresponding non-zero reciprocal values. Each participant took approximately 30 min to complete the evaluation and scoring, which involved ranking the importance of needs at both the criteria and solution levels. The numerical values of the criteria layer and alternative layer judgment matrices were substituted into the mathematical Formula (1) as shown in Section 3.2.2 to calculate the normalized values of the indicators. These were then substituted into Formula (2) to obtain the weight values (ω_i) of the indicators. The normalized weight values were determined, and Formula (3) was used to find the maximum eigenvalue (λ_{max}). The value of λ_{max} was then substituted into Formula (4) to calculate the Consistency Index (CI), and the Random Consistency Index (RI) was obtained from the reference table. By substituting CI and RI into Formula (5), the

Consistency Ratio (CR) was calculated. When CR < 0.1, the judgment matrix is deemed to have passed the consistency check, and the weights are considered valid. If CR $\geq$ 0.1, the judgment matrix needs to be adjusted. Finally, the indicators with higher weight values were identified, where higher weights indicate higher credibility, and the weights of the criteria layer and alternative layer indicators were sorted in descending order of their values.

First, we constructed the judgment matrix for H, the interactive experience of smart healthcare for the elderly, with the calculated scores as follows:

$$H = \begin{bmatrix} 0.2899 & 0.2713 & 0.3125 & 0.3871 \\ 0.5797 & 0.5426 & 0.4375 & 0.4839 \\ 0.0580 & 0.0776 & 0.0625 & 0.0322 \\ 0.0725 & 0.1085 & 0.1875 & 0.0968 \end{bmatrix}$$

Second, we constructed the judgment matrix for H1, where functional needs, with the calculated scores as follows:

$$H1 = \begin{bmatrix} 0.0388 & 0.0733 & 0.0496 & 0.0259 & 0.0688 & 0.0264 & 0.0373 & 0.0820 & 0.0808 & 0.0297 & 0.0773 & 0.0195 \\ 0.0194 & 0.0367 & 0.0496 & 0.0259 & 0.0688 & 0.0264 & 0.0373 & 0.0820 & 0.0808 & 0.0297 & 0.0773 & 0.0195 \\ 0.2327 & 0.2199 & 0.2974 & 0.2593 & 0.2063 & 0.3170 & 0.3726 & 0.1475 & 0.1616 & 0.3560 & 0.1803 & 0.2921 \\ 0.0776 & 0.0733 & 0.0595 & 0.0519 & 0.0688 & 0.0396 & 0.0466 & 0.0820 & 0.0808 & 0.0396 & 0.0773 & 0.0292 \\ 0.0194 & 0.0183 & 0.0496 & 0.0259 & 0.0344 & 0.0264 & 0.0373 & 0.0656 & 0.0606 & 0.0297 & 0.0515 & 0.0195 \\ 0.1164 & 0.1100 & 0.0744 & 0.1037 & 0.1032 & 0.0793 & 0.0621 & 0.0984 & 0.1010 & 0.0593 & 0.1030 & 0.1168 \\ 0.1939 & 0.1833 & 0.1487 & 0.2074 & 0.1719 & 0.2378 & 0.1863 & 0.1311 & 0.1414 & 0.2374 & 0.1545 & 0.2337 \\ 0.0078 & 0.0073 & 0.0330 & 0.0104 & 0.0086 & 0.0132 & 0.0233 & 0.0164 & 0.0101 & 0.0170 & 0.0086 & 0.0097 \\ 0.0097 & 0.0092 & 0.0372 & 0.0130 & 0.0115 & 0.0159 & 0.0266 & 0.0328 & 0.0202 & 0.0198 & 0.0129 & 0.0117 \\ 0.1551 & 0.1466 & 0.0991 & 0.1556 & 0.1375 & 0.1585 & 0.0931 & 0.1148 & 0.1212 & 0.1187 & 0.1288 & 0.1753 \\ 0.0129 & 0.0122 & 0.0425 & 0.0173 & 0.0172 & 0.0198 & 0.0311 & 0.0492 & 0.0404 & 0.0237 & 0.0258 & 0.0146 \\ 0.1164 & 0.1100 & 0.0595 & 0.1037 & 0.1032 & 0.0396 & 0.0466 & 0.0984 & 0.1010 & 0.0396 & 0.1030 & 0.0584 \end{bmatrix}$$

Third, we constructed the judgment matrix for H2, where operational needs, with the calculated scores as follows:

$$H2 = \begin{bmatrix} 0.4537 & 0.4610 & 0.3281 & 0.2813 & 0.5229 & 0.3390 \\ 0.1134 & 0.1153 & 0.2344 & 0.2188 & 0.0871 & 0.2034 \\ 0.0648 & 0.0231 & 0.0469 & 0.0938 & 0.0436 & 0.0339 \\ 0.0504 & 0.0165 & 0.0156 & 0.0313 & 0.0327 & 0.0169 \\ 0.2269 & 0.3458 & 0.2813 & 0.2500 & 0.2614 & 0.3390 \\ 0.0907 & 0.0384 & 0.0938 & 0.1250 & 0.0523 & 0.0678 \end{bmatrix}$$

Fourth, we constructed the judgment matrix for H3, where visual needs, with the calculated scores as follows:

$$H3 = \begin{bmatrix} 0.5595 & 0.5245 & 0.3600 & 0.4286 & 0.6415 \\ 0.1119 & 0.1049 & 0.2000 & 0.1837 & 0.0713 \\ 0.0622 & 0.0210 & 0.0400 & 0.0204 & 0.0306 \\ 0.0800 & 0.0350 & 0.1200 & 0.0612 & 0.0428 \\ 0.1865 & 0.3147 & 0.2800 & 0.3061 & 0.2138 \end{bmatrix}$$

Fifth, we constructed the judgment matrix for H4, where safety needs, with the calculated scores as follows:

$$H4 = \begin{bmatrix} 0.2308 & 0.3333 & 0.2174 \\ 0.0769 & 0.1111 & 0.1304 \\ 0.6923 & 0.5556 & 0.6522 \end{bmatrix}$$

To determine the importance ranking, we calculated the weights of each indicator (to avoid data redundancy, the data were rounded to four decimal places) and determined the ranking and importance of each need based on their scores, as shown in Table 6. From the table, it can be seen that in the criteria layer, H2, H1, and H4 have higher weights; in the sub-layer under H1, H13, H17, and H110 have higher weights; in the sub-layer under H2, H21, H25, and H22 have higher weights; in the sub-layer under H3, H31 and H35 have higher weights; in the sub-layer under H4, H43 and H41 have higher weights.

Table 6. AHP weightings at various levels.

Item	Weight	Sequence	Consistency Test	Item	Weight	Sequence	Consistency Test
H1	0.3152	2	λ_{max} = 4.1072 CI = 0.0357 CR = 0.0401	H11	0.0508	7	λ_{max} = 12.7595 CI = 0.0690 CR = 0.0448
				H12	0.0461	8	
				H13	0.2536	1	
				H14	0.0605	6	
				H15	0.0365	9	
				H16	0.0940	4	
				H17	0.1856	2	
				H18	0.0138	12	
				H19	0.0183	11	
				H110	0.1337	3	
				H111	0.0255	10	
				H112	0.0816	5	
H2	0.5109	1		H21	0.3977	1	λ_{max} = 6.3070 CI = 0.0614 CR = 0.0487
				H22	0.1621	3	
				H23	0.0510	5	
				H24	0.0272	6	
				H25	0.2840	2	
				H26	0.0780	4	
H3	0.0576	4		H31	0.5028	1	λ_{max} = 5.2375 CI = 0.0594 CR = 0.0530
				H32	0.1344	3	
				H33	0.0348	5	
				H34	0.0678	4	
				H35	0.2602	2	
H4	0.1163	3		H41	0.2605	2	λ_{max} = 3.0385 CI = 0.0193 CR = 0.0371
				H42	0.1061	3	
				H43	0.6334	1	

Finally, the weights of the criteria layer were assigned to the sub-layer to make the indicator scales consistent, resulting in the subjective comprehensive weights of the sub-layer indicators, as shown in Table 7. The weight results indicate that, from the expert's perspective, the ranking of interactive experience needs for elderly smart healthcare is as follows: H2 (0.5109) > H1 (0.3152) > H4 (0.1163) > H3 (0.0576). The results show that experts tend to believe that factors related to H2 (such as simple operation, intuitive interaction, etc.) play the most critical role in improving the smart healthcare interactive experience for elderly users. Therefore, these factors should be prioritized in system design optimization. In the sub-layer, the indicators with the highest weights are H21 (0.2032), H25 (0.1451), H22 (0.0828), H13 (0.0799), and H43 (0.0737). From the specific weight values, it can be seen that H21, H25, and H22 (sub-factors related to H2, such as simplified operations and intuitive interactions) received higher weights, indicating that these sub-factors have the most significant impact on enhancing elderly users' interactive experience. H13 (a sub-factor related to H1, such as information visualization) ranks second, but its sub-factors still play an important role in improving user experience.

Table 7. AHP-derived comprehensive subjective weights.

Item	H1	H2	H3	H4	Comprehensive Weight	Sequence
H11	0.0508				0.0160	15
H12	0.0461				0.0145	17
H13	0.2536				0.0799	4
H14	0.0605				0.0191	14
H15	0.0365				0.0115	20
H16	0.0940				0.0296	10
H17	0.1856				0.0585	6
H18	0.0138				0.0044	24
H19	0.0183				0.0058	23
H110	0.1337				0.0421	7
H111	0.0255				0.0080	21
H112	0.0816				0.0257	13
H21		0.3977			0.2032	1
H22		0.1621			0.0828	3
H23		0.0510			0.0261	12
H24		0.0272			0.0139	18
H25		0.2840			0.1451	2
H26		0.0780			0.0399	8
H31			0.5028		0.0290	11
H32			0.1344		0.0077	22
H33			0.0348		0.0020	26
H34			0.0678		0.0039	25
H35			0.2602		0.0150	16
H41				0.2605	0.0303	9
H42				0.1061	0.0123	19
H43				0.6334	0.0737	5

4.2.3. EWM Determination of Objective Weights

During the data collection process, we used Questionnaire Star (https://www.wjx.cn/ (accessed on 4 September 2024)), a professional online survey platform in China, to create online survey links and QR codes. To expand the sample size and cover a broader range of elderly populations, we employed snowball sampling, wherein community staff distributed the survey through resident groups, inviting elderly users aged 60 and above to voluntarily complete the questionnaire (with no conflict of interest throughout the process), and collected the data. This approach helped us reach more elderly users dispersed throughout the community. The snowball sampling method enabled us to gather a large number of samples in a relatively short time, ensuring diversity and broad coverage in the questionnaire data [96,97].

A total of 320 open-ended questionnaires were distributed, and 307 valid responses were collected, resulting in an efficiency rate of 95.93%. The gender ratio of respondents was 47.56% male and 52.44% female, indicating a relatively balanced gender distribution with a slightly higher number of females. In terms of age distribution, the largest group was aged 60–69, accounting for 57% of the total, followed by those aged 70–79, making up 32.9%. The data from these 307 questionnaires were analyzed using a combination of the AHP and EWM to determine the comprehensive weights of each indicator, followed by a consistency check.

(1) Reliability and Validity

Reliability indicates the stability and consistency of the questionnaire results, reflecting the dependability of the measured data [98]. Validity measures the degree to which the research accurately reflects the concept it aims to measure. Validity is assessed through factor analysis, where the closer the results align with the examined content, the higher the validity index [99].

The Cronbach's alpha (α) coefficient was used to evaluate the internal consistency of factors, and a value of $\alpha \geq 0.70$ indicates high reliability of the data. The KMO value measures sampling adequacy, with values between 0.8~1.0 indicating sufficient sampling, and values between 0.7~0.8 indicating relatively sufficient sampling [100]. Bartlett's test of sphericity's *p*-value indicates suitability for factor analysis, with $p < 0.05$ suggesting that the data is appropriate for this method [101].

The survey data were imported into SPSS 26.0 for factor analysis and reliability and validity tests. The results showed that the questionnaire data had high reliability, with a Cronbach's alpha value of 0.924. The data passed the validity test, satisfying the conditions for factor analysis, with a KMO value of 0.918, a degree of freedom (df) of 325, and a *p*-value less than 0.05. Reliability and validity tests were conducted across different dimensions, as shown in Table 8.

Table 8. Reliability and validity testing.

	H	H1	H2	H3	H4
Cronbach's α	0.924	0.896	0.884	0.856	0.821
KMO	0.918	0.929	0.868	0.800	0.639
Bartlett	0.000	0.000	0.000	0.000	0.000

(2) Calculating Objective Weights

To minimize subjective influence in the data, this phase involved 307 relevant users to compute the information dispersion of the indicators in the questionnaire to obtain objective weights. The values from the matrix were substituted into the mathematical Formulas (6) and (7) shown in Section 3.2.3 for calculation, resulting in normalized values of the indicators. These were then used in mathematical Formulas (8) and (9) to compute the entropy values e_j. The entropy redundancy (difference) d_j was subsequently calculated using Formula (10). Finally, the weight values w_j for each indicator were determined using Formula (11). The higher the weight value, the greater the data's significance. The indicator weights at the scheme level were then ranked.

To determine the importance ranking, we calculated the weights for each indicator (to avoid data duplication, values were precise to four decimal places) and used these scores to establish the ranking and importance of each requirement, as shown in Table 9. According to the results of the weight indicators, from the users' perspective, the interactive experience of smart medical care for the elderly shows that indicators H13, H18, H35, H31, and H41 have relatively high weight values. From the specific weight values, it can be seen that H13 and H18 (sub-factors related to H1, such as information visualization and knowledge dissemination) received higher weights, suggesting that these sub-factors will significantly influence their interactive experience. H35 and H31 (sub-factors related to H3, such as clear icon meaning and extra-large fonts) follow, and their sub-factors also play an important role.

Table 9. EWM-derived comprehensive objective weights.

Item	Information Entropy Value	Information Utility Value	Comprehensive Weight	Sequence
H11	0.9373	0.0627	0.0335	25
H12	0.9254	0.0746	0.0399	8
H13	0.9183	0.0817	0.0437	1
H14	0.9393	0.0607	0.0325	26
H15	0.9264	0.0736	0.0393	12
H16	0.9282	0.0718	0.0384	14
H17	0.9320	0.0680	0.0363	21
H18	0.9201	0.0799	0.0427	2
H19	0.9300	0.0700	0.0374	17
H110	0.9304	0.0696	0.0372	20
H111	0.9256	0.0744	0.0397	9

Table 9. *Cont.*

Item	Information Entropy Value	Information Utility Value	Comprehensive Weight	Sequence
H112	0.9266	0.0734	0.0392	13
H21	0.9247	0.0753	0.0402	6
H22	0.9331	0.0669	0.0358	22
H23	0.9252	0.0748	0.0400	7
H24	0.9284	0.0716	0.0383	15
H25	0.9372	0.0628	0.0336	24
H26	0.9288	0.0712	0.0380	16
H31	0.9223	0.0777	0.0416	4
H32	0.9258	0.0742	0.0397	10
H33	0.9259	0.0741	0.0396	11
H34	0.9342	0.0658	0.0352	23
H35	0.9207	0.0793	0.0424	3
H41	0.9230	0.0770	0.0411	5
H42	0.9300	0.0700	0.0374	18
H43	0.9303	0.0697	0.0373	19

4.2.4. Determining the Comprehensive Weight

To ensure that the combined weights of the indicators are more scientific, the AHP and EWM were used together. This approach controls subjective randomness within a certain range and reflects fairness in comprehensive weighting. By combining both subjective and objective analyses, this method results in more authentic, scientific, and reliable evaluation outcomes. Therefore, when assigning weights to indicators, it is necessary to consider the intrinsic statistical patterns and authoritative values among the indicators. In other words, a combined weighting method that integrates two analytical approaches was used to perform comprehensive weight calculations, addressing the shortcomings of single-method weighting (as shown in Table 10).

Table 10. AHP-EWM combined weights.

Item	AHP Weight	EWM Weight	Comprehensive Weight	Sequence
H11	0.0160	0.0335	0.0247	20
H12	0.0145	0.0399	0.0272	15
H13	0.0799	0.0437	0.0618	3
H14	0.0191	0.0325	0.0258	17
H15	0.0115	0.0393	0.0254	18
H16	0.0296	0.0384	0.0340	11
H17	0.0585	0.0363	0.0474	6
H18	0.0044	0.0427	0.0235	23
H19	0.0058	0.0374	0.0216	24
H110	0.0421	0.0372	0.0396	7
H111	0.0080	0.0397	0.0238	21
H112	0.0257	0.0392	0.0325	13
H21	0.2032	0.0402	0.1217	1
H22	0.0828	0.0358	0.0593	4
H23	0.0261	0.0400	0.0331	12
H24	0.0139	0.0383	0.0261	16
H25	0.1451	0.0336	0.0893	2
H26	0.0399	0.0380	0.0390	8
H31	0.0290	0.0416	0.0353	10
H32	0.0077	0.0397	0.0237	22
H33	0.0020	0.0396	0.0208	25
H34	0.0039	0.0352	0.0196	26
H35	0.0150	0.0424	0.0287	14
H41	0.0303	0.0411	0.0357	9
H42	0.0123	0.0374	0.0249	19
H43	0.0737	0.0373	0.0555	5

4.2.5. Results Analysis

The results of the weight indicators show that H21 (0.1217), H25 (0.0893), H13 (0.0618), H22 (0.0593), H43 (0.0555), and H17 (0.0474) have higher weight values. This indicates that in the interactive experience of smart medical care for the elderly, the following factors need to be comprehensively considered:

In terms of functionality, the key design elements should focus on H13 (clear medical information display), H17 (simple academic terminology), H110 (cross-institution data sharing), H112 (user-friendly guidance), and H12 (voice assistance). Thus, the design should emphasize clear information to facilitate user understanding.

In terms of operational, the important design elements include H21 (simplified operational processes), H25 (intuitive interaction methods), and H22 (easy-to-understand operation instructions). The design should employ straightforward and easy-to-understand operation methods that align with user habits.

In terms of visuals, the critical elements are H31 (larger text display), H35 (clearly meaningful icons), and H32 (graphical health reports). The design should use easily readable and understandable text or icons to prevent misunderstandings.

In terms of safety, the management platform should enhance the protection of users' personal information and data. Therefore, in the design process of the interactive experience for smart medical care for the elderly, incorporating intuitive operation methods, clear information display, and easily understandable language can provide elderly users with a better experience and increase their satisfaction.

4.3. Step 3: Define Functions and Output the Product

As the third step of the INPD method, user needs are transformed into design requirements to proceed with solution design. Using the TOPSIS method, three design solutions were evaluated to select the smart healthcare interaction product that best meets the needs of elderly users.

4.3.1. Define Design Requirements

Based on the comprehensive weights obtained in Section 4.2.4, the core user needs were translated into design requirements. This process was carried out by ten experts, including two professors specialized in the relevant field, three user experience designers, and five doctoral students, who collaboratively refined the elements. This led to the identification of 4 primary design requirements and 17 secondary design requirements (as shown in Table 11).

Table 11. Mapping the relationship between user needs and design requirements.

Primary Design Requirements	Secondary User Needs	Secondary Design Requirements	Specific Content
Function design	H11 Fewer information levels H13 Clear display of medical information	I1 Optimized information design	Design a simple navigation structure that prioritizes core information and commonly used operations.
	H12 Voice assistance function H15 Convenient payment methods H112 Humanized guidance	I2 Convenience service design	Control operations via voice recognition. Integrate multiple methods. Provide convenient registration, navigation services, and real-time updates.
	H14 Timely reminders and notifications H16 Emergency call and location tracking	I3 Information transmission design	Real-time reminders through pop-ups, vibrations, and sounds. Design prominent buttons and integrate GPS location functionality.
	H17 Simplified academic terminology H18 Popularization of health knowledge	I4 Educational function	Simplified terminology explanations and translation functions, with regular updates on relevant health knowledge.
	H19 Coordination between family members H110 Cross-institutional data sharing	I5 Data management	Account linking, supporting data sharing, and management.
	H111 Remote consultation	I6 Social function	Provide video call and online chat functions for communication with doctors at any time.

Table 11. *Cont.*

Primary Design Requirements	Secondary User Needs	Secondary Design Requirements	Specific Content
Operation design	H21 Simplified operation process H22 Easy-to-understand operation guidance	I7 Optimized operation Guide	Reduce operation steps, provide concise and clear operation prompts and guidance.
	H23 Consistency of cross-device operations	I8 Consistent operations	Unify operation logic across different devices, eliminating the need for relearning when switching devices.
	H24 Timely tactile feedback	I9 Feedback design	Provide timely tactile feedback through vibrations during click and swipe operations.
	H25 Intuitive interaction methods	I10 Interaction design	Vertical swipe for page scrolling, horizontal swipe for forward or back navigation. Must conform to logical operations.
	H26 Increased error tolerance	I11 Undo operation	Provide reminders for undoing deletions, error handling, and recovery prompts.
Visual design	H31 Larger text display	I12 Font design	Offer adjustments for font size, font style, and font color.
	H32 Graphical health reports	I13 Data design	Display data through charts and graphics.
	H33 Meaningful icons	I14 Icon design	Adjust icon size, ensuring icons are simple and easy to understand.
	H34 Unified colors	I15 Color design	Adjust the overall color tone, contrast, and balance of the interface.
	H35 Simple animation	I16 Animation design	Use subtle and slow animations to enhance screen effects.
Security design	H41 Simplified identity verification H42 Long-term monitoring and feedback H43 Secure personal privacy	I17 Management and security design	Use fingerprint or facial recognition for one-click login, store data with encryption, and synchronize backups. Regularly maintain and monitor the system.

4.3.2. TOPSIS Evaluation of the Optimal Solution

(1) Solution Provision

Through user research, weight calculation, and design requirement analysis, combined with the actual usage scenarios and common challenges faced by elderly users, we proposed different design directions. First, during the user needs research phase, we found through data analysis that elderly users encountered unmet needs in areas such as complex operations, unclear information, and the lack of personalized, convenient services. Second, in further research and data analysis, we identified significant differences in elderly users' ability to accept technology and their usage purposes. For example, some users preferred simple, easy-to-use interfaces (I7 optimized operation guide), while others focused more on the need for diverse functionality and personalized, convenient services (I2 convenient service design). Another group of users was particularly concerned with the intuitive presentation and comprehensibility of medical data (I1 optimized information design). Therefore, in collaboration with user experience designers and doctoral students, we developed three solutions, each with different focuses and advantages, to meet various usage scenarios (as shown in Figures 4–6).

Solution A focuses on the intuitiveness of the interface layout, using large fonts and icons. The streamlined design reduces complexity, ensuring that key functions are easily accessible, with an emphasis on usability rather than additional features. Solution B offers more extensive functionality, including a wider range of personalized services and convenient features to meet users' individualized needs. The interface is more complex than the other solutions, but the additional services provide users with a richer experience. Solution C emphasizes the clarity and comprehensibility of information data through a visual, data-driven approach. The page layout is simplified to highlight core functions, reducing the number of operational layers and enhancing usage efficiency. The specific design details are shown in Table 12.

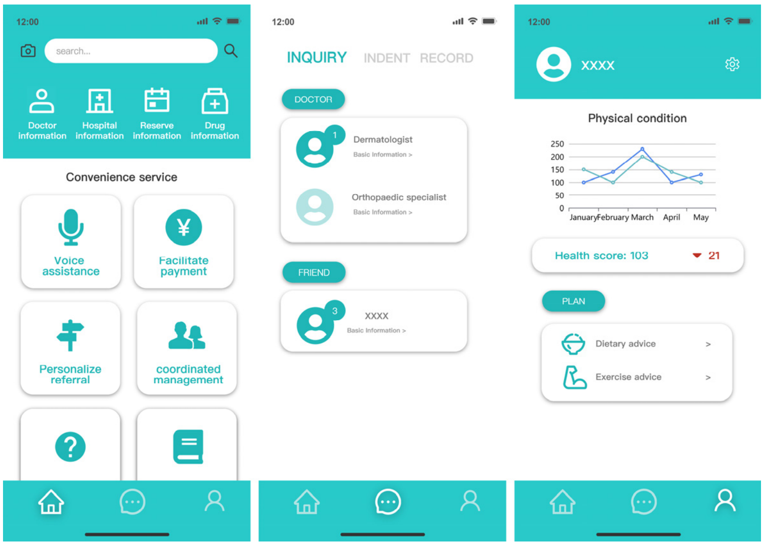

Figure 4. High-fidelity prototype of smart healthcare interaction application for the elderly (Scheme A).

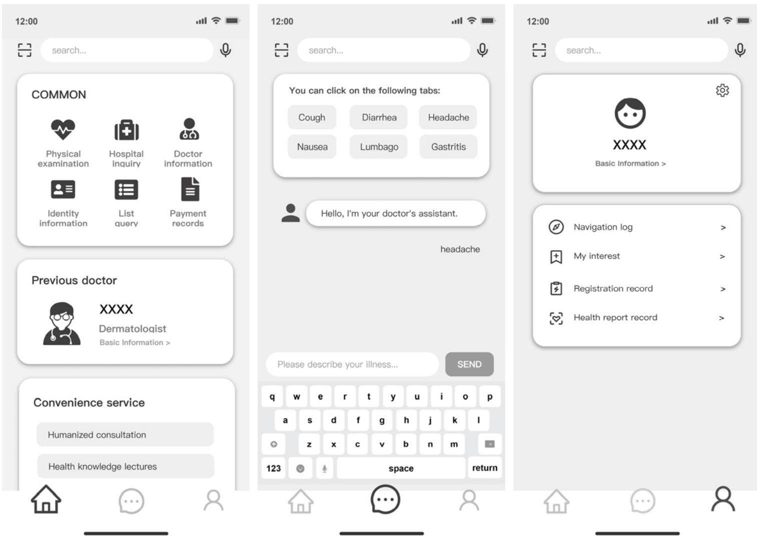

Figure 5. High-fidelity prototype of smart healthcare interaction application for the elderly (Scheme B).

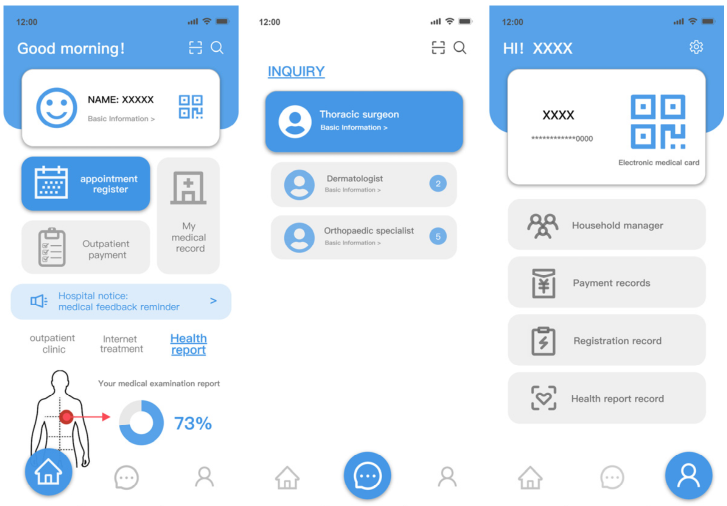

Figure 6. High-fidelity prototype of smart healthcare interaction application for the elderly (Scheme C).

Table 12. Design details of Schemes A–C.

	Scheme A	Scheme B	Scheme C
Design focus	Emphasizes intuitive interface layout and ease of use.	Highlights diverse functionality and enhances convenience and fast services.	Stresses intuitive presentation and comprehensibility of information and data.
Function design	Uses large icons and fonts to highlight key information. Organizes modules to make the page tidier.	Increases contrast to emphasize key information. Arranges information sequentially for more content display.	Highlights key information through staggered and highlighted modules, making the page more flexible.
Operation design	Interactions are completed through conventional methods like clicking and swiping.	Interactions are completed through conventional methods like clicking and swiping.	Interactions are completed through conventional methods like clicking and swiping.
Visual design	Uses teal as the main color tone, symbolizing health, calm, and trust. Utilizes colorful large fonts and larger icons.	Uses gray as the main color tone, symbolizing simplicity and neutrality. Utilizes black standard fonts and graphical icons.	Uses blue as the main color tone, symbolizing reliability, calm, and professionalism. Utilizes colorful standard fonts and highlights key sections with bright colors.
Security design	Password login.	Password and fingerprint login.	Password and facial recognition login.

(2) Solution Evaluation

The purpose of this test was to evaluate the adaptability of the designed solutions for elderly users in terms of functionality, operability, visual appeal, and security. The test invited three elderly users aged between 60 and 75, representing different genders and levels of technological proficiency. Each user participated in a system operation test lasting approximately 40 min, covering aspects such as function identification, operation, and interface interaction experience. The test data were collected using a combination of quantitative and qualitative methods. After completing each task, participants were asked to rate the 17 secondary design requirements (I1–I17) using a five-point Likert scale.

The users' ratings were then input into the mathematical formulas shown in Section 3.3.2 to calculate the normalized values of the indicators, which were substituted into Formulas (15) and (16) to compute the positive and negative indicator values. Formulas (17) and (18) were used to obtain the positive ideal solution Z^+ and the negative ideal solution Z^- for the indicators. Finally, Formulas (19) and (20) were applied to calculate the distances between the object and the positive ideal solution D^+ and the negative ideal solution D^-. The comprehensive score C_i for each solution was calculated using Formula (21), with higher C_i values indicating better performance of the evaluated object, and the solutions were ranked accordingly.

According to the data, elderly users rated Scheme C the highest, with a comprehensive score of 0.7483. Users expressed satisfaction with the solution's intuitiveness in information display and ease of interaction. Scheme A received a comprehensive score of 0.4090, and Scheme B scored 0.3832. Observation revealed that users encountered some difficulties during use, such as repeatedly failing to locate certain functions, especially in tasks involving multiple steps, where additional prompts or assistance were needed (as shown in Table 13).

Table 13. TOPSIS plan evaluation.

	Positive Ideal Solution Distance (D^+)	Negative Ideal Solution Distance (D^-)	Comprehensive Score Index (C_i)	Sequence
Scheme A	0.7340	0.5080	0.4090	2
Scheme B	0.7682	0.4772	0.3832	3
Scheme C	0.2835	0.8430	0.7483	1

4.4. Step 4: Implementation and Validation of Product Opportunity

As the final step in the INPD methodology, the product opportunity is realized. Based on the analysis of elderly users' needs and expert recommendations, we conducted design practices and validation for the smart healthcare interaction experience. To verify the effectiveness and usability of the design solution, we selected two existing smart healthcare applications from the market for a comparative analysis with Design Scheme C. This evaluation aimed to assess elderly users' experience and feedback during actual use, ultimately proposing optimized design strategies.

In this phase, three elderly users aged 60–75 were invited as participants, representing different genders and varying levels of technological proficiency (basic, intermediate, and advanced technology users). Each participant was required to use all three products for approximately one hour. The test covered the use of basic functions, ease of interface interaction, and overall user enjoyment. After completing the tasks, participants were asked to rate each product using a five-point Likert scale across four dimensions: functionality, ease of use, visual appeal, and security.

The final test results indicated that Scheme C received the highest score (55.33). According to user feedback, this solution outperformed existing products in terms of ease of use, particularly simplifying navigation layers, making it less burdensome during use. Additionally, it enhanced the visibility of information, effectively improving their experience and satisfaction. (As shown in Table 14).

Table 14. Comparison and analysis of the product and the schemes.

Design Requirement		Product A	Product B	Scheme C
H1	I1	4.00	3.33	4.67
	I2	2.67	4.00	3.33
	I3	2.00	2.33	2.00
	I4	2.67	2.33	3.33
	I5	1.00	1.33	1.67
	I6	4.00	3.67	3.67
H2	I7	2.33	3.33	4.33
	I8	1.33	1.00	2.00
	I9	1.67	2.00	3.67
	I10	4.00	4.33	4.67
	I11	2.33	1.67	2.00
H3	I12	1.67	2.33	3.33
	I13	2.67	3.67	4.67
	I14	2.67	3.33	4.33
	I15	2.67	2.00	3.67
	I16	2.00	1.67	1.33
H4	I17	1.67	2.33	2.67
Total		41.33	44.67	55.33

5. Discussion

5.1. Optimization of the INPD-AHP-EWM-TOPSIS Design Method

This study is based on the INPD product research method, combined with the AHP and EWM decision matrices, integrating both qualitative and quantitative methods in user needs identification and design optimization, demonstrating multiple advantages. First, product opportunity gaps are identified through SET analysis. Second, subjective opinions and needs of elderly users are collected through observation and qualitative interviews, deeply exploring user experiences from a personal perspective. However, qualitative interviews are often subject to bias and inconsistency, so this study uses the AHP-EWM quantitative tools to process and quantify these needs. This helps to reduce the subjective bias inherent in qualitative research, ensuring the accuracy and comprehensiveness of the needs analysis. AHP is then used to convert subjective evaluations into subjective weights through judgment matrices and calculations. However, due to inherent limitations, EWM is also applied, which does not rely on subjective expert judgment and quantifies the information amount of each factor, accurately reflecting the differences and impacts of each factor to provide more objective and comprehensive weight results. Third, after transforming user needs into design requirements, scheme designs are developed, and TOPSIS is used to evaluate these solutions. Finally, the proposed solution is validated through a comparative study with existing products on the market.

This integrated optimization design approach, compared to purely qualitative methods, not only enhances the scientific rigor of the results but also improves the repeatability and generalizability of the research, making it easier to apply to other groups or different contexts. By combining the contextual insights of qualitative interviews with the objectivity of quantitative analysis, this study strikes a balance between subjective needs and scientific data. Overall, the INPD-AHP-EWM-TOPSIS method effectively integrates multi-stage qualitative and quantitative research, providing more comprehensive, scientific identification of needs, priority ranking, and decision support, thereby enhancing the reliability and external validity of the research results. This ultimately helps the design team improve product quality and user satisfaction.

5.2. Design Strategies

5.2.1. Age-Appropriate Functional Strategies

In terms of functional requirements, age-appropriate design strategies are crucial to ensure that elderly users can use the product easily and independently. Simplifying information displays reduces their cognitive load during use (I1: optimized information design). Meanwhile, during medical visits, timely notifications and alerts via pop-ups or vibrations, along with call functions, enhance their sense of security (I3: information transmission design). Voice-assisted services reduce the need for manual operations, increasing convenience (I2: convenience service design). During this research, we found that many elderly people enjoy learning new things and have a strong sense of health management (I4: educational function design). They hope to access medical services more easily, reducing the frequency and risks associated with hospital visits (I6: social function design). Due to a lack of companionship and care, the elderly also desire support and care at the family level, so strengthening functional connections with family and friends is crucial in the design (I5: data management design). Additionally, personal privacy and identity verification are essential concerns for elderly users (I17: management and security design), and features like one-click login can improve usability and convenience.

5.2.2. Human-Centered Operational Strategies

In terms of operational requirements, the focus should be on human-centered operations, considering the convenience, comfort, and intuitiveness of the elderly during use. Simplifying operational steps and providing easy-to-understand guidance will help users complete tasks effortlessly, preventing confusion and discomfort (I7: optimized operation guide). During the operation, appropriate tactile feedback should be provided promptly, allowing elderly users to know whether their actions were successful, increasing their confidence and enhancing flow (I9: feedback design). For incorrect operations, options such as undo or delete prompts should be offered, along with simple error correction methods, enabling users to return to the correct operational path (I11: undo operation). Additionally, the decline in memory among the elderly affects their ability to recall information, so maintaining consistent interfaces and operations across devices is essential to reduce learning costs and operational difficulty (I8: equivalent operation). Interaction design should follow natural interaction logic to reduce cognitive load (I10: interaction design). Through human-centered operations, elderly users can be provided with a convenient, friendly, and barrier-free experience.

5.2.3. Multi-Sensory Experience Strategies

In terms of visual requirements, it is essential to consider the special physiological and psychological characteristics of the elderly. Sensory functions degrade with age, making it difficult for them to read small text. Therefore, using larger or bold fonts to represent important information is crucial (I12: font design). Excessive color combinations can cause visual confusion and discomfort for elderly users. A unified and soft color scheme can alleviate visual fatigue, creating a comfortable visual environment (I15: color design). Clear and well-defined icons allow users to quickly understand their meaning, avoiding confusion and misunderstandings during use. Additionally, larger icons can effectively reduce operational errors for elderly users (I14: icon design). For the elderly, complex text can be confusing, so converting health data into intuitive charts enhances comprehension and reduces reliance on text, improving information visibility (I13: data design). Additionally, moderate animations can capture the user's attention but should remain simple to avoid burden and distraction (I16: animation design). These optimized designs provide elderly users with a comfortable and pleasant experience during use.

6. Conclusions

With the acceleration of societal aging and the integration of big data, the elderly population continues to face challenges in the smart healthcare process. This study focuses on Chinese elderly users and aims to enhance their interactive experience through optimized design methods. By extracting design requirements using an integrated approach, this study addresses existing pain points and improves the experience and satisfaction of elderly users.

During the research process, we found that due to the significant individual differences and uniqueness in behavior and intentions, we initially used qualitative research methods such as interviews and questionnaires to gather user feedback. Grouping users with similar needs helped address the issue of individual differences, allowing us to identify the actual needs of different elderly user groups. This provided important guidance for the development and optimization of subsequent solutions. The AHP hierarchical structure was used to break down complex decision-making problems and quantify the relative importance of each need. EWM was then used to further adjust weights based on objective data, reducing the impact of subjective bias and making the data more objective. Based on this, three alternative solutions were designed, and the optimal solution was evaluated using TOPSIS. Finally, the selected solution was compared with existing products to ensure that it meets the actual needs of elderly users, possesses strong feasibility, and effectively reduces the barriers and challenges they face when using smart products.

Therefore, this study holds both theoretical and practical significance. Its optimized design method and targeted improvement strategies can effectively support future research. At the same time, the user-driven design model promotes social sustainability. The user-centered approach enhances the acceptance of smart healthcare products among the elderly population, reduces social exclusion caused by technological barriers, and fosters inclusive development. This optimized design also improves resource allocation efficiency, contributing to economic sustainability. Furthermore, the widespread application of smart healthcare services can alleviate pressure on healthcare systems, supporting environmental sustainability. As a crucial component of future healthcare services, the sustainable development of smart healthcare relies on a deep understanding of user needs and continuous optimization. This study provides practical guidance for achieving this goal. Additionally, the optimized design methods proposed in this study offer valuable insights for other smart services.

However, this study also has certain limitations. Regarding the sample data, constraints in time and resources may affect the representativeness of the research findings. Future research should expand the sample size, including users from different regions and backgrounds, to enhance the universality and accuracy of the research. As technology continues to evolve and user needs change, the optimized design methods will also need to be updated and iterated to continuously improve the quality of life and efficient healthcare experience for elderly users.

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