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UI Design and Optimization Research for a Dual-Interface Mobile App for Elderly Health and Safety Management Based on the AHP-FCE Model

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Abstract: *This study designs and optimizes the Jiuban APP, a dual-interface mobile app, to enhance elderly health and safety management for both elderly users and their children. Using the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE), a scientific UI evaluation framework is established. AHP identifies key functional priorities—health monitoring, emergency assistance, and interface layout—while FCE resolves ambiguity in user feedback. The elderly-side interface prioritizes simplicity with large fonts, oversized buttons, high-contrast colors, and intuitive health data visualization. The child-side interface emphasizes functionality, offering remote monitoring, health reminders, and quick consultations. Results show that integrating AHP and FCE enhances user satisfaction and functional adaptability, meeting both elderly users' needs and their caregivers' expectations. Future research could explore AI and IoT integration for further personalization in health management.*

Keywords: *Elderly Health, Mobile Interface, UI Design, Optimization Design, Fuzzy Comprehensive Evaluation Method*

1. Introduction

The global aging population is accelerating, significantly impacting various aspects of society[1]. Statistics show that as of 2023, individuals aged 65 and above account for 19.2% of the global population, a figure projected to rise to 22.3% by 2030[2]. With age, the gradual decline in physical functions among the elderly has led to increasing demands for health monitoring and safety management [3]. Addressing how to enhance elderly individuals' health management capabilities and emergency response efficiency through digital means has become a pressing societal challenge [20]. Simultaneously, advancements in mobile internet technology have offered new solutions for elderly health and safety management [4]. Mobile applications (apps) enable real-time health monitoring for the elderly, providing them and their families with convenient data access and health management functions [5]. However, despite the availability of several health management apps targeting the elderly, existing products often suffer from significant shortcomings in user experience, interface accessibility, and functional adaptability, failing to adequately meet the actual needs of elderly users [6].

In response to this issue, this study introduces the "Jiuban APP" .The Jiuban APP offers elderly users a simple and intuitive interface to enhance autonomy and convenience in health management, while providing a monitoring interface for children to enable real-time health data tracking and support remote care and intervention.

To guide the app's interface design and optimization, this study integrates the Analytic Hierarchy Process (AHP) [7] and Fuzzy Comprehensive Evaluation (FCE) [8] methods to establish a systematic and scientific UI evaluation framework. AHP decomposes user requirements and design elements into hierarchical levels, quantifying the importance of various indicators[9] ,thereby providing clear directions for interface optimization. FCE effectively handles ambiguity and uncertainty in subjective user feedback, ensuring objectivity and accuracy in evaluation results [10].

Additionally, this study emphasizes a needs-driven dual-interface design concept, thoroughly exploring the differing requirements of elderly users and their children to create differentiated app interfaces. The elderly interface prioritizes age-friendly features such as large fonts, oversized buttons, and voice assistance, while the children's interface emphasizes comprehensive functionality and data

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completeness, achieving differentiated yet coordinated interactive experiences. Through user feedback and data-driven analysis, this study proposes targeted UI design optimization solutions, enhancing the applicability and usability of the Jiuban APP among elderly users and promoting the digitalization of health management services.

Thus, this study aims to address the following key questions:

- How can the app's design be optimized to address elderly users' physiological and psychological needs, simplifying operations and improving accuracy?
- How can interface layouts and visual elements enhance readability and usability?
- How can age-friendly features be improved with personalized settings, optimized voice assistance, and enhanced remote interaction to improve the user experience for both elderly users and their children?

2. Literature Review

2.1. Design Principles for Elderly Interfaces and Analysis of User Characteristics

With the accelerating pace of global aging, the elderly population has become a significant user group for technological products. To better serve this demographic, interface design must consider physiological, cognitive, and emotional characteristics, ensuring usability and acceptability [11]. Elderly users face unique challenges when interacting with digital interfaces, stemming not only from physiological changes but also from evolving psychological needs. Therefore, interface design for the elderly must adhere to principles aimed at enhancing operational convenience, fostering user-friendly interactions, and reducing confusion and frustration during usage.

Age-related declines in vision, hearing, memory, and dexterity significantly impact the user experience [3]. For instance, vision impairment is one of the most common issues among the elderly [6]. Studies indicate that individuals over 60 often experience nearsightedness, color perception difficulties, and blurred vision. Consequently, interface design should incorporate larger fonts, increased contrast, and avoid overly complex patterns or backgrounds to improve readability [12]. For example, many elderly users prefer black text on a white background, a high-contrast design that enhances legibility. Moreover, adjustable volume and voice prompt features are crucial for users with hearing impairments [22], as they effectively improve information reception.

Declining tactile and motor skills also pose challenges for elderly users when interacting with digital devices [13].Reduced hand dexterity makes precise touchscreen operations difficult, particularly when high accuracy is required. To address this, interface designs should enlarge button sizes, optimize touch response areas, and ensure sufficient spacing between buttons to minimize accidental touches.

Cognitive decline is another critical factor in elderly interface design [16].Therefore, interface designs should avoid complex workflows and information overload. Designers should simplify interfaces, use intuitive icons, and include concise text to help elderly users quickly understand and operate the application. For example, simplified icons and streamlined workflows have proven effective in smartphone interface design [17]. Apple’s iPhone user interface adopts a minimalistic design, with simple icons and clear guidance to help elderly users quickly grasp basic operations.

Elderly users not only focus on practicality but also have high demands for emotionally resonant designs. Interface designs should consider this need by employing gentle colors, friendly language, and personalized interactions to convey care and support. Studies have shown that soft colors and gentle design elements can significantly enhance elderly users’ comfort and trust [19].

Health monitoring apps often use warm interface designs and positive language to encourage elderly users to persist in using the application [20]. These apps might include motivational messages such as, “Great job on your steps today! Keep it up!” emphasizing both functionality and emotional interaction. Additionally, elderly users prefer interfaces with humanized features, such as large fonts, clear voice feedback, and emotionally engaging animations, to build emotional connections and increase willingness to use the application.

Numerous studies highlight that well-designed interfaces are critical to the acceptance and efficiency of use among elderly users. For instance, Holliday et al. (2021) found that simple and easy-to-operate interfaces significantly enhance elderly user satisfaction and usage frequency [21]. Meanwhile, Chen et al.

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(2020) demonstrated that emotional design and personalized settings improve elderly users' reliance on and loyalty to applications [20].

In summary, effective interface design for the elderly should consider physiological, cognitive, and emotional dimensions comprehensively, employing multiple design strategies to enhance acceptance and user experience.

2.2 Application of Analytic Hierarchy Process (AHP) in Design

The Analytic Hierarchy Process (AHP), proposed by Saaty (1980) [7], is a multi-criteria decision-making method widely used to address complex, multi-layered, and multi-factor problems. For elderly interface design, AHP quantifies and compares the importance of various design requirements, providing scientific guidance for optimization.For example, Kumar et al. (2019) used AHP to quantify key design factors for elderly interfaces [23], revealing that font size and button dimensions carried significantly higher weights than color schemes and animations, providing clear priorities for interface design. Wang et al. (2021) used AHP to prioritize usability, accessibility, and emotional design for an elderly health management app [24], finding usability to have the highest weight, reflecting elderly users' preference for simple and intuitive interfaces.

2.3 Application of Fuzzy Comprehensive Evaluation (FCE) in Design

Fuzzy Comprehensive Evaluation (FCE) is a multi-criteria decision-making method based on fuzzy mathematics [8], widely used for complex problems with high uncertainty and ambiguity. FCE's primary advantage lies in its ability to handle vague information. For elderly users, preferences for interface operation ease or visual comfort often vary widely, presenting significant ambiguity. FCE effectively integrates diverse evaluations using fuzzy logic, producing rational design decisions.

3. Research Methodology

In this study, the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) methods were chosen as core methodologies for UI design optimization. This decision was based on the complexity of the optimization needs for Jiuban APP and the inherent ambiguity in user evaluations. The UI design of elderly health management apps involves multiple dimensions, such as functional layout, operational convenience, and visual presentation, which are interrelated and differ in importance [16]. The integration of AHP and FCE further enhances the systematic and reliable nature of the research. In practical application, AHP builds hierarchical models and judgment matrices to quantify evaluation criteria, calculating the weights of each factor and scientifically ranking their importance [24]. FCE then processes user feedback, transforming complex subjective perceptions into intuitive evaluation results [28]. This synergy not only reduces subjective bias during evaluation but also ensures that optimization plans genuinely align with user needs, achieving refined and user-centered UI design. As shown in Figure 1, the diagram illustrates the research process employed in this study.

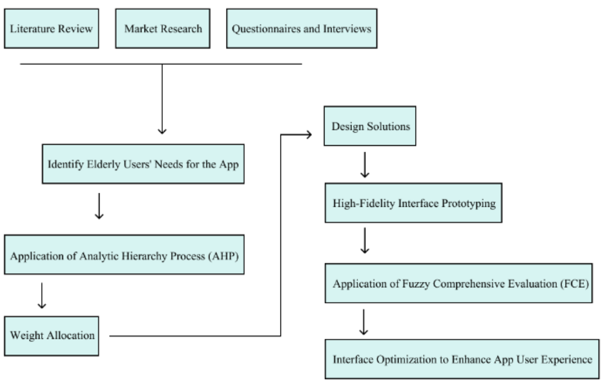

Figure 1 Research Process Flow

Moreover, AHP includes a consistency check for judgment matrices, ensuring logical coherence in expert and user evaluations, thereby enhancing the credibility and stability of the evaluation system [15].

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This consistency mechanism is particularly crucial for optimizing apps for elderly users, as their operational needs and cognitive characteristics vary.

FCE complements AHP by addressing its limitations in dealing with ambiguity and subjectivity [29]. For instance, in optimizing details like font size, button layout, and color contrast, FCE reflects elderly users' perceived comfort levels, enabling more targeted adjustments [29].

In summary, this study establishes a systematic UI evaluation framework tailored to optimizing the dual-interface mobile app for elderly health and safety management, Jiuban APP. By employing AHP and FCE, the research provides a scientific and rational basis for UI design optimization, enhancing the user experience for elderly users and facilitating remote monitoring for their children.

3.1. Research Subjects

This study employs the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) methods to evaluate the performance of a dual-interface mobile app for elderly health and safety management from the perspectives of quantitative analysis and comprehensive evaluation. The research recruited a panel of 10 professionals specializing in elderly health and mobile UI design to form an expert group. Additionally, 162 valid questionnaires were collected through both online and offline public surveys. Table 1 presents the information of the expert panel invited to participate in this study.

Table 1 Expert panel information

S/N	Occupation	Age	Education
1	Emily Carter	52	PhD
2	Hiroshi Tanaka	45	PhD
3	Amara Singh	48	PhD
4	Zhang Wei	50	Master’s Degree
5	Liu Fang	42	Bachelor’s Degree
6	Marco Rossi	39	Master’s Degree
7	Sarah Wilson	35	Bachelor’s Degree
8	Ahmed El-Sayed	37	Bachelor’s Degree
9	Chloe Dubois	39	Bachelor’s Degree
10	Li Ming	26	Master’s Degree

Elderly users are the core research group of this study. The age range for elderly users is 65 years and above, consistent with the definition of the aging population in China [30]. The primary needs of this group are divided into two parts: health management and safety management. In terms of health management, elderly users often use apps to record blood glucose, monitor blood pressure, and manage medications to meet their long-term health monitoring needs [18]. For example, a diabetic elderly user records blood glucose levels daily via the app and shares the data with their children [23]to adjust their lifestyle promptly. Furthermore, safety management features are particularly important for elderly users living alone or apart from their children. Functions such as one-click emergency calls, location sharing, and SOS can significantly enhance their sense of security [26]. The primary responsibilities of child users include setting reminders, monitoring health data, and checking real-time locations [25]. For instance, a child user may check their parent's step count and sleep quality through the app daily and set medication reminders for them.

Compared to elderly users who focus more on interface usability and operational convenience, child users are more concerned about the comprehensiveness of the app's functionality and the accuracy of data [27], such as the precision of health data statistics and the timeliness of abnormal alerts. Furthermore, child users generally have a higher level of technical proficiency, enabling them to provide feedback on app design from a professional perspective, such as optimizing notification functions or improving data loading speeds [6]. To accurately reflect the app's use in family scenarios, the study recruited child users in pairs with elderly users [33], allowing for the observation of potential issues and needs encountered during their interactions, thus providing a multidimensional perspective for interface optimization.

3.2. Data Collection and Analysis

Through in-depth research, user personas for elderly and child users were developed to understand their characteristics and needs. They lead regular lives, focus on health and wellness, use mobile devices infrequently but are willing to learn, value health monitoring, and desire independence, though they may

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experience anxiety [3]. Child users have diverse occupations, care deeply about their parents' health, are familiar with technology but often busy, and prefer tools for remote management and interaction [14].The results show that elderly users prioritize health management, emergency assistance, and interface design [26], while child users emphasize remote monitoring, reminder settings, and interactive features [25]. These findings provide key insights for the subsequent design of the dual-interface app [16].

4. Empirical Analysis

4.1. Weight Allocation Based on Analytic Hierarchy Process (AHP)

This study employs AHP (Analytic Hierarchy Process) to systematically analyze the design requirements of the health and safety management app, clarifying the importance of each requirement and providing a scientific basis for interface optimization. Tables 2, 3, and 4 display the results of the weight analysis performed using the Analytic Hierarchy Process (AHP) in this study, and Table 5 presents the normalization of the corresponding data.

Table 2 Judgment Matrix for Visual Design

	Clear Layout	Icon Design	Color Matching
Clear Layout	1	2	3
Icon Design	1/2	1	2
Color Matching	1/3	1/2	1

Table 3 Judgment Matrix for Functional Experience

	Function Annotation	Operational Feedback	Voice Operation
Function Annotation	1	2	4
Operational Feedback	1/2	1	3
Voice Operation	1/4	1/3	1

Table 4 Judgment Matrix for Core Functions

	Health Monitoring	Data Analysis	Social Network	Emergency Contacts
Health Monitoring	1	2	3	4
Data Analysis	1/2	1	2	3
Social Network	1/3	1/2	1	2
Emergency Contacts	1/4	1/3	1/2	1

Taking the judgment matrix under the "Visual Design" criterion as an example, the columns of the matrix are normalized:

Table 5 Normalized Matrix

	Clear Layout	Icon Design	Color Matching
Clear Layout	0.545	0.571	0.500
Icon Design	0.273	0.286	0.333
Color Matching	0.182	0.143	0.167

Calculate the average value of each row in the normalized matrix to obtain the weights of each criterion:

Clear Layout: (0.545 + 0.571 + 0.500) / 3 = **0.539**

Icon Design: (0.273 + 0.286 + 0.333) / 3 = **0.297**

Color Matching: (0.182 + 0.143 + 0.167) / 3 = **0.164**

Table 6 Comprehensive Weights of Requirements

Requirements	Weight	Priority
Clear Layout	0.20	1
Icon Design	0.15	2
Emergency Contacts	0.15	2
Operational Feedback	0.13	3
Function Annotation	0.12	4

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Health Monitoring	0.12	4
Color Matching	0.10	5
Voice Operation	0.10	5
Data Analysis	0.08	6
Social Network	0.05	7

As shown in Table 6, consistency check is used to evaluate the logical consistency of the judgment matrix and ensure the rationality of expert scoring.

Calculation of the Maximum Eigenvalue (λmax)

$$\lambda \text{max} = \frac{Sum\ of\ the\ Product\ of\ Weight\ Vector\ and\ Judgment\ Matrix}{Number\ of\ Elements\ in\ the\ Weight\ Vector}$$

Calculate the Consistency Index (CI):

$$CI = \frac{\lambda \text{max} - n}{n - 1}$$

Where n represents the dimension of the judgment matrix. For the "Visual Design" judgment matrix, n=3.

$$CI = \frac{3.052 - 3}{3 - 1} = 0.026$$

Calculate the Consistency Ratio (CR):

$$CR = \frac{CI}{RI}$$

Where RI is the Random Consistency Index, the values corresponding to the matrix dimension are as follows:

N	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

For n=3, RI=0.58.

$$CR = \frac{0.026}{0.58} = 0.045$$

If CR<0.1, the judgment matrix is considered consistent.

In this case: CR=0.045<0.1. Therefore, the judgment matrix passes the consistency check.

4.2. UI Interface Design and Development

Based on the AHP analysis results and in-depth research into the needs of elderly and child users, this study designed and developed a dual-interface health management app (Jiuban APP). The following interface design prioritizes user-friendliness and functionality, integrating the AHP weight calculation results to optimize key features, ensuring maximum user experience. As shown in Figure 2, the interface layout designed for the elderly user portal is displayed.

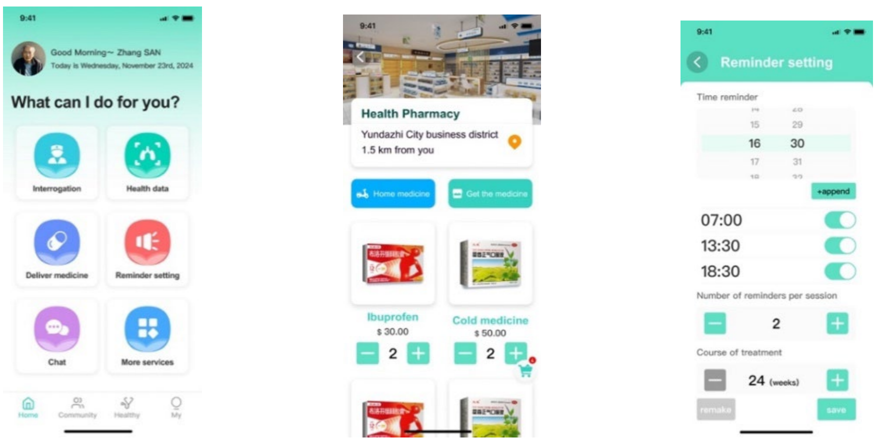

Figure 2 Parent-Side Interface

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The interface design for elderly users prioritizes simplicity, ease of use, and visual intuitiveness, focusing on practical needs. AHP analysis identifies health monitoring, emergency assistance, and operational feedback as high-priority functions. The main interface features large buttons and clear icons to display core functions, such as health data, consultations, medication delivery, and reminders, reducing complexity and aiding quick navigation. The soft green background with high-contrast text and icons enhances clarity. For health data, visualized charts present information like blood pressure, glucose, and heart rate, with color-coded alerts to highlight abnormal data. To address emergency needs, the assistance function is a prominently placed button with voice prompts, minimizing errors and improving the user experience. As shown in Figure 3, the interface accessed via the children's portal is presented.

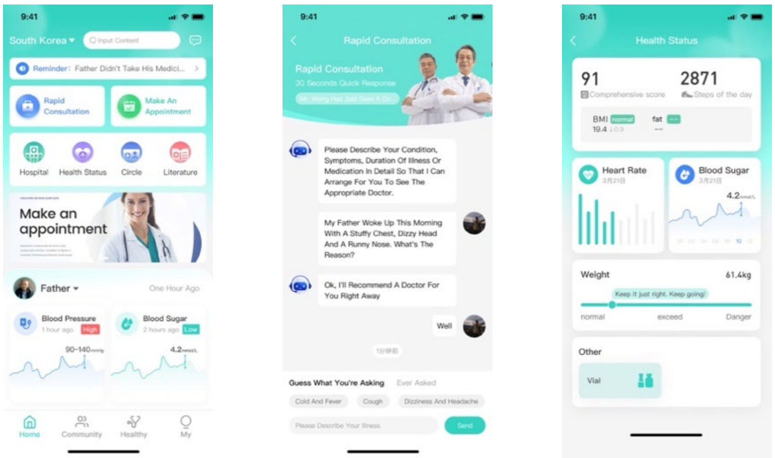

Figure 3 Child-Side Interface

The child-side interface focuses on comprehensive functionality and data visualization for remote health management. AHP analysis highlights key modules: remote monitoring, intelligent reminders, quick consultations, and medication delivery. Child users can track real-time health data, including blood pressure, glucose, step count, and sleep status, with trend charts for risk analysis. Intelligent reminders sync with the elderly-side interface to ensure medication compliance. The quick consultation module enables a 30-second rapid consultation by matching doctors based on input. Medication delivery allows direct pharmacy orders with real-time tracking. The child-side interface improves efficiency in elderly health management through streamlined and integrated features.

4.3. Consistency and Collaboration in Dual-Interface Design

The dual-interface design emphasizes collaborative functionality between elderly users and child users. For instance, medication reminders set on the child-side interface are automatically synchronized to the elderly-side interface and delivered via voice or popup notifications. Additionally, when the elderly use the emergency assistance feature, the child-side interface receives real-time notifications, including GPS location and assistance information, enabling prompt response.

5. User Feedback and Satisfaction Survey

Table 7 displays the collected user feedback on the usage experience of the system.

Table 7 Feedback Form

NO.	Feedback
01	"The numbers in the health monitoring section are a bit small. My eyesight isn’t great, and I often press the wrong button."
02	"This emergency button is quite noticeable and easy to use."
03	"The text for the schedule reminder is a bit small, making it hard to read."
04	"I don't really understand the charts in the health monitoring section. It would be great if there were some explanations."
05	"There are too many steps in the operation. My memory isn't great, so I tend to forget."
06	"The interface colors look fine, quite comfortable."

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07	"It would be better if the emergency assistance feature had a voice prompt. I'm afraid I might press the wrong button."
08	"The data updates in the health monitoring section are quite fast. I like that."
09	"The sound for the schedule reminder is a bit low; sometimes I can't hear it."
10	"The interface layout is quite clear, but some features require several steps to find."

6. Application of Fuzzy Comprehensive Evaluation (FCE) in This Study

This study utilizes Fuzzy Comprehensive Evaluation (FCE) to optimize the elderly health and safety management app by addressing ambiguity in user feedback. Elderly users often describe issues vaguely, making traditional evaluation methods insufficient. FCE quantifies subjective feedback, providing a scientific basis for UI optimization. Table 8 presents the data conclusions derived using the Fuzzy Comprehensive Evaluation (FCE) method.

Table 8 Fuzzy evaluation matrix

Requirement	Short Time (1–4 minutes)	Moderate Time (5–7 minutes)	Long Time (8 minutes or more)
Operation Time for Health Monitoring Function	0.9	0.5	0.1
Number of Misoperations in Health Monitoring Function	0.8	0.5	0.2
Time to Locate Emergency Assistance Function	0.7	0.4	0.1
Number of Misoperations in Emergency Assistance Function	0.9	0.6	0.3
Satisfaction with Schedule Reminder Function	0.8	0.6	0.3
Evaluation of Overall Interface Clarity	0.9	0.7	0.4

These fuzzy evaluation values reflect the membership degree of each design requirement at different evaluation levels, providing a foundation for subsequent comprehensive evaluation.

The comprehensive evaluation value for the "Health Monitoring Function" can be calculated using the following formula:

$$\text{Comprehensive Evaluation} = \frac{(0.9 \times 0.3 + 0.5 \times 0.5 + 0.1 \times 0.2)}{1}$$

The study results indicate that features like emergency assistance, health monitoring, and operational feedback should be prioritized for optimization, while features like social networking and data analysis can be improved in subsequent stages. Future research can validate these findings through user testing and explore ways to balance functionality and personalization across different user groups.

7. Results and Discussion

This study aligns with previous research on elderly health management apps. Zhou et al. (2020) identified health monitoring, emergency assistance, and interface simplicity as key priorities using AHP[33]. Wang et al. (2021) applied FCE to highlight emergency response and voice interaction features [24]. Li et al. (2019) confirmed the importance of health monitoring and emergency functions[34], while Chen et al. (2022) found that simplicity and emergency response significantly impact user satisfaction[35]. These findings support the optimization approach in this study.

By integrating AHP and FCE, this study optimizes the Jiuban APP, prioritizing health monitoring, emergency assistance, and operational feedback. AHP identifies core user needs, while FCE quantifies subjective feedback to refine UI design. Results show significant improvements in user satisfaction and functional adaptability, especially in emergency response and health data visualization.

However, limitations exist. The sample size (20 elderly users) is small and lacks diversity, reducing generalizability. Additionally, the study does not fully address personalized user needs. Future research should expand sample size, enhance personalization, and explore AI and IoT integration for real-time health monitoring and intelligent health recommendations.

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