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Research article

Evaluation of the elderly health examination app based on the comprehensive evaluation method of AHP-fuzzy theory

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Abstract: This research hopes to provide scientific research support for the optimization and development of the elderly health check application by studying the evaluation method of the elderly health check APP, so that the elderly users can easily enjoy the intelligent health check service. First, use the in-depth interview method and the affinity graph analysis method to extract the evaluation elements, and then use the comprehensive evaluation method that combines the analytic hierarchy process and the fuzzy theory to evaluate the health check APP for the elderly. The results show that in the evaluation research of the elderly health examination APP, the operation learning and information processing of the software are the most important. For the elderly, a health examination APP that can be used quickly and has clear and accurate information processing functions is the most satisfactory. When designing the elderly health check application program, the physical and mental factors of the elderly should be considered, taking the elderly as the center, and designing a health check application suitable for the elderly according to the characteristics of the elderly.

Keywords: AHP; fuzzy comprehensive evaluation method; elderly users; checkup APP

1. Introduction

In recent years, the mobile Internet has developed rapidly, and mobile device applications (APP) have become an indispensable tool of life for people. Health management applications, especially those developed based on the Android platform, have become the main force in mobile healthcare. A large number of Android health applications can help users manage their real-time health status. If the Internet of Things technology is combined with the medical system to realize the self-health management of the elderly, not only can the quality of life of the elderly be improved, but also the deficiencies of the existing medical system can be better compensated. Therefore, the Internet medical system has broad development prospects. With the increase of age, the perception ability, muscle control and memory ability of the elderly are greatly reduced. In addition, the negative psychological impact makes it impossible for the elderly to use APP as smoothly as younger users. Therefore, from a physical and psychological point of view, the form elements of APP should meet the interface and interaction needs of the elderly. In the research field, some scholars have begun to consider product design issues from the perspective of the elderly, and put forward a series of heuristic principles. In the field of visual perception, with age, the visual perception ability of the elderly weakens. Chan's research team found that with age, the sense of audio-visual synchronization decreases [1]. Keogh's research team found that the variability and aiming error of the absolute and relative forces of the elderly are higher than those of the young, indicating that their power control ability is significantly reduced. The weakening of the power control ability of the elderly reflects age-related differences in the distribution and connection of finger power [2]. Research results of Andréa et al.. Studies have shown that in addition to age-related cognitive decline, depression can also greatly impair memory [3]. Psychologically speaking, the mentality of the elderly tends to be conservative. Unless they understand the application, they usually don't try it. Therefore, in terms of application performance, the elderly must feel that the application is useful, easy to use and effective, and conforms to the cognitive habits of the elderly. Finally, Zhao et al. discussed the cognitive behavior of elderly people using mobile phones and concluded that the overall design should incorporate the physical, psychological and cultural factors of the elderly. Studies have found that the degradation of the elderly is provided by the icon, text, button, color, interface layout and interaction process with more systematic and targeted design principles and methods [4]. Curumsing has launched a series of devices and software for sensing, interaction, passive monitoring and emergency assistance to provide a new smart home platform for the elderly. Analysis shows that the software they successfully developed reduces the loneliness of the elderly and makes them feel safer and more caring. In addition, trial participants have a close relationship with the system, and they feel frustrated when the software fails to respond in an expected or expected manner [5]. Hussain proposed a human-centered medical perception framework for the elderly and the disabled. The platform is designed to monitor the health of the elderly and the disabled, and provide them with service-oriented emergency response in case of abnormal health conditions. The biggest feature of current work is to effectively use medical resources, provide them with real-time medical services in emergency situations, and expand the social network of the elderly at the same time. The implementation of this system shows that the proposed human-centered sensing system is both efficient and cost-effective in hygiene and first aid [6]. However, many applications currently do not consider the physical and mental differences of the elderly. In the process of use, the elderly often encounter experience obstacles. Nowadays, more and more elderly people come into contact with health check applications, so the user experience of the elderly becomes more and more important. Although some medical examination applications have begun to pay attention to the experience of the elderly, the field of evaluation and research on the application of medical examinations for the elderly is blank. The analytic hierarchy process and fuzzy set theory have been widely used in the multi-criteria decision-making process, in which fuzzy numbers are used to more truly represent human judgments. In the past few decades, many articles have been published and some algorithms have been proposed, through which the priority vector can be calculated from the fuzzy comparison matrix [7]. Fu proposed a novel comprehensive fuzzy analytic hierarchy process, fuzzy additional ratio evaluation and multi-stage target planning methods to select the best suppliers of duty-free products in the aviation industry [8]. Therefore, this research hopes to combine the analytic hierarchy process (AHP) with the fuzzy comprehensive evaluation method to evaluate the experience of the elderly health examination APP, and conduct research from the physical and mental aspects of the elderly to propose more reasonable and consistent evaluation standards. It is suitable for elderly health examination applications that most elderly people are used to. This research first understands the problems and needs of the elderly when using medical examination applications through in-depth interviews, then uses the KJ method to classify and sort the data, and finally uses the analytic hierarchy process and fuzzy theory to analyze the data. It is hoped that the conclusions of this study can provide a reference for the design of medical examination applications for the elderly.

2. Methodology

2.1. Test subject

According to international regulations, seniors over 65 are recognized as seniors. Thirty volunteers who have more than one year of experience in using the health examination application will be recruited, including 20 elderly volunteers over 65 years old and 10 volunteers who are about to enter the elderly. Among the 30 volunteers, they were between 60 and 83 years old, and 3 of them were unable to complete the entire experiment because they could not think independently or express themselves clearly. Therefore, there are 27 valid experimental cases, including 12 males and 15 females, with an average age of 66.32 years.

2.2. In-depth interviews and Kj analysis

Taking into account the health of the elderly, the interview time can be freely adjusted within the range of half an hour to two hours according to the physical condition of different interviewees. The interview consisted of interviewers, recorders and elderly volunteers. The interviewer and recorder are served by two graduate students. Interviewers and recorders are familiar with the purpose of the interview, the process and details of the interview, and have good communication skills with the elderly, maintain the normal conduct of the interview, and always discuss topics related to the elderly health examination APP. The interviewer and the elderly volunteers discussed topics related to the elderly health examination APP, and the recorder recorded and recorded the content of the interview. The process of conducting in-depth interviews is as follows [9–12]: (a) help the elderly volunteers recall their experience of using the health examination application; (b) ask the elderly about their experience in using health examination software; (c) discuss the advantages and disadvantages of using the medical examination application simultaneously; (d) consult elderly volunteers about the future prospects of health check application design. After the interview, according to the interview content, sort out the evaluation elements of the elderly physical examination application. Use KJ analysis method [13–15] to classify the obtained data hierarchically, and obtain several classifications. Use the in-depth interview method and KJ analysis method to obtain the preliminary needs of elderly users, and conduct a layered analysis of user needs. First, determine the total demand: a satisfactory evaluation of the elderly physical examination APP; second, the total demand is decomposed, and the first-level evaluation is obtained after decomposition. Finally, the multiple specific elements of elderly users obtained through in-depth interviews are regarded as secondary assessments, and the secondary assessment items are classified according to the primary assessment.

2.3. The combination of analytic hierarchy process and fuzzy comprehensive evaluation method

The Combination of Analytic Hierarchy Process [16–19] and Fuzzy Comprehensive Evaluation Method [20–23] (AHP-Fuzzy). Specifically, AHP is used when determining the factor weight method. Combine the same factors into the same level, and group them according to the affiliation and the degree of association between these factors, thus forming a disjoint multi-level structure model. The evaluation scale is shown in Table 1. The basic process is shown in Figure 1.

Table 1. Quantitative values of judgment scale.

Judgment Scale	Definition	b_{ij} Assignment
1	Indicates that the two types of factors are of equal importance.	1
3	Indicates that compared with the two types of factors, the score rate of factor i is 10% higher than factor j (i is more important than j)	3
5	Indicates that compared with the two types of factors, factor i has a 20% higher score rate than factor j (i is obviously more important than j)	5
7	Indicates that the score rate of factor i is 30% higher than factor j compared to the two types of factors (i is significantly more important than j)	7
9	Indicates that compared with the two types of factors, factor i has a 40% higher score rate than factor j (i is extremely important than j)	9
2、4、6、8	In the middle of the above two adjacent judgment scales	2、4、6、8
Reciprocal	If the ratio of importance of factor i to factor j is d_{ij}, then the ratio of importance of factor j to factor i is $d_{ij} = 1/d_{ij}$	$d_{ij} = 1/d_{ij}$

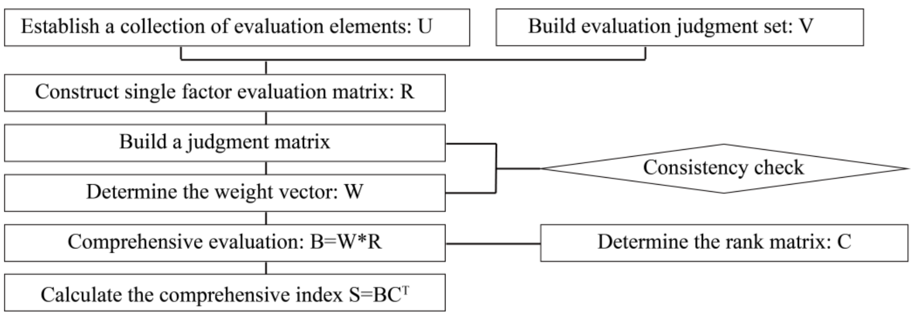

Figure 1. Evaluation method flow chart.

AHP-fuzzy evaluation method can effectively combine the advantages of AHP and fuzzy evaluation method. When the AHP method has fewer evaluation indicators, the time to obtain a consistent judgment matrix is usually shorter and easier to operate [24–26]. In the comprehensive evaluation of the entire research problem, the fuzzy evaluation method is used as the multi-level evaluation object, which can fully integrate the information contained in each level, and can better reduce the influence of subjective factors on the whole. Thereby improving the scientificity and validity of the evaluation results of research questions. The AHP can solve multi-factor problems by comparing the relative importance of two factors. It is widely used in business management, resource allocation, environment and production decision-making. Although this method is a systematic analysis and decision-making method, it is highly subjective. The fuzzy comprehensive evaluation method integrates the judgment of multiple evaluation subjects and can weaken the deficiencies of the analytic hierarchy process. Therefore, the analytic hierarchy process-fuzzy comprehensive evaluation comprehensive analysis model that combines the two methods can not only systematically consider the influencing factors of the evaluated object, but also reduce the impact of subjective assumptions on the evaluation and decision-making process. The Analytic Hierarchy Process (AHP) is to subdivide difficult decision-making problems into different levels, so as to construct an analytic hierarchy index system that combines scientific qualitative and precise quantification to obtain satisfactory decision-making. Fuzzy comprehensive evaluation method is a comprehensive evaluation method that transforms difficult to determine fuzzy problems into quantitative problems and qualitative problems into quantitative problems. This article effectively combines the analytic hierarchy process and the fuzzy comprehensive evaluation method to establish a mathematical model of comprehensive evaluation.

Weight calculation: λ_{max}—the maximum eigenvalue of the judgment matrix; M—the corresponding eigenvector. Then, the feature vector M is normalized to obtain the weight W of the importance of each index relative to the index of the previous index. Finally, perform a consistency check.

$$CI = (\lambda_{\max} - N)/(N-1) \quad (1)$$

Second, calculate the consistency check results.

$$CR = CI / RI \quad (2)$$

In the formula, λ_{max}—the maximum characteristic quantity of the judgment matrix; N—the number of factors; RI—the random consistency index. If CR < 0.1, the judgment matrix meets the consistency requirement; Once CR is greater than or equal to 0.1, the judgment matrix needs to be modified until the consistency is reached. On the basis of determining the index system, the analytic hierarchy process combined with fuzzy mathematics evaluation method is used to comprehensively evaluate the elderly physical examination APP. It mainly includes 4 steps: first, establish the index evaluation set; A = $\{B_1, B_2, ...B_N\}$ is the first-level index set, $B_i = \{B_{i1}, B_{i2}...B_{in}\}$ is the second-level index set. Then, an evaluation judgment matrix is established to determine the fuzzy judgment vector of each index through probability statistics.

$$r_{ij} = x_{ij} / N' \quad (3)$$

In the formula, N'—the number of people; x_{ij}—the frequency at which the index P_i is defined as V_j. Then construct the fuzzy judgment matrix,

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & r_{n4} & r_{n5} \end{bmatrix}$$

Finally, according to the obtained fuzzy evaluation matrix, combined with the weight W = {W_1, W_2, W_3} determined by the AHP model, the fuzzy evaluation vector is calculated.

$$Z = (W_i R)^T = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{n1} \\ r_{12} & r_{22} & \cdots & r_{n2} \\ r_{13} & r_{23} & \cdots & r_{n3} \\ r_{14} & r_{24} & \cdots & r_{n4} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_4 \end{bmatrix} = \{z_1, z_2, z_3\} \tag{4}$$

In the formula, W_i—the weight of all levels of indicators. If $\sum Zi \neq 1$ it has been normalized, a comprehensive evaluation matrix is constructed.

2.4. Experiment procedure

First, the in-depth interview method is used to conduct research, and the in-depth interview is used to collect the evaluation elements used by the elderly for physical examination applications. Secondly, the KJ analysis method is used to classify the original evaluation elements obtained from the in-depth interviews, and several evaluation indicators of the elderly physical examination APP are extracted. Then, the AHP-fuzzy comprehensive evaluation method is used to analyze and rank the existing evaluation elements. Finally, the hierarchical structure model was drawn and discussed.

3. Results

According to the in-depth interview method, 43 evaluation elements were obtained, represented by X1, X2, X3...X43, as shown in Table 2.

Using the KJ analysis method for classification, the 43 evaluation elements are divided into 10 secondary categories, and the 10 secondary categories are divided into three main categories, namely mobile phone interaction design, ease of operation and functional diversity. Based on the above data, an APP evaluation system for physical examination of the elderly was constructed, as shown in Table 3.

Table 2. Evaluation element list.

Evaluation elements	
X_1. Icon design	X_{23}. Note reminder
X_2. Can be directly checked	X_{24}. Real-time monitoring of health data
X_3. Know how to use, get started quickly	X_{25}. Clearly identify useful keys
X_4. Learn fast	X_{26}. Clear system operation buttons
X_5. There are video tutorials	X_{27}. Push information identification screening
X_6. Won’t be wrong	X_{28}. User registration is convenient
X_7. Easily return to the main interface	X_{29}. Easy to understand teaching tutorial
X_8. Full functioning	X_{30}. Voice assisted operation
X_9. Voice prompts	X_{31}. Large touch button area
X_{10}. At a glance	X_{32}. Vibration feedback when pressing keys
X_{11}. Smooth and fast operation	X_{33}. Data display logic is clear
X_{12}. Less advertising information	X_{34}. The icons are clear and easy to understand
X_{13}. Menu bar logic is clear	X_{35}. Reasonable distribution of key screen
X_{14}. Few advertisement pop-ups	X_{36}. Easy to use and operate
X_{15}. Big font	X_{37}. Interact with children
X_{16}. Loud volume	X_{38}. Simple operation steps
X_{17}. Information scrolling speed is appropriate	X_{39}. Expert medical examination
X_{18}. Color comfort	X_{40}. Doctor-patient interaction
X_{19}. Clear and reasonable color matching	X_{41}. Hospital check-up appointment
X_{20}. More useful functions	X_{42}. Life advice information
X_{21}. Guidance page audio-visual integration	X_{43}. Appointment for health examination in top three hospitals
X_{22}. Automatically generate medical report	

Table 3. Classification table of evaluation elements.

A: App Evaluation System for Elderly health examination		
B_1. Mobile phone interaction design	C_1. Smooth operation	X3\7\11\36\38
	C_2. Interface design	X6\10\33\34
	C_3. Easy to identify	X1\15\16\17
	C_4. Interface color	X18\19
B_2. Ease of operation	C_5. Navigation design	X9\13\21\28\30
	C_6. Operation tutorial	X4\5\29
	C_7. Touch button	X25\26\31\32\35
	C_8. Information filtering	X12\14\23\27
B_3. Functional diversity	C_9. Doctor-patient interaction	X39\40
	C_{10}. Full functioning	X2\8\22\24\37\41\42\43

Analyze the evaluation index system of the elderly physical examination APP and determine the evaluation index set. The target layer is set to A = (evaluation of physical examination for the elderly). Including 3 first-level indicators: $A = \{B_1, B_2, B_3\}$; there are 10 secondary indicators: $B_1 = \{C_1, C_2, C_3, C_4\}$; $B_2 = \{C_5, C_6, C_7, C_8\}$; $B_3 = \{C_9, C_{10}\}$; including 43 three-level indicators: $C_1 = \{X_3, X_7, X_{11}, X_{36}, X_{38}\}$; $C_2 = \{X_6, X_{10}, X_{33}, X_{34}\}$; $C_3 = \{X_1, X_{15}, X_{16}, X_{17}\}$; $C_4 = \{X_{18}, X_{19}\}$; $C_5 = \{X_9, X_{13}, X_{21}, X_{28}, X_{30}\}$; $C_6 = \{X_4, X_5, X_{29}\}$; $C_7 = \{X_{25}, X_{26}, X_{31}, X_{32}, X_{35}\}$; $C_8 = \{X_{12}, X_{14}, X_{23}, X_{27}\}$; $C_9 = \{X_{39}, X_{40}\}$; $C_{10} = \{X_2, X_8, X_{22}, X_{24}, X_{37}, X_{41}, X_{42}, X_{43}\}$. First, perform a hierarchical analysis of the first-level indicators to determine the judgment matrix P of the first-level indicator layer Pi relative to the evaluation target A, as shown in Table 4.

Table 4. Judgment matrix for the weights of first-level indicators.

Project	B_1	B_2	B_3	Weight Value W	Feature Vector
B_1	1	3	3	0.2605	0.781
B_2	3	1	5	0.63335	1.9
B_3	1/3	1/5	1	0.10616	0.318
Consistency Check	CR = 0.037 ＜ 0.1			Pass	

According to Table 4, the weight value W = {0.63335, 0.2605, 0.10616}, W—the weight of the first level indicator relative to the target level A. Similarly, you can calculate the weight of the second-level indicator layer, as shown in Tables 5–7.

Table 5. Weights of secondary indicators of mobile interaction design.

Project	C_1	C_2	C_3	C_4	Weight Value W	Feature Vector
C_1	1	1/5	1/3	3	0.14137	0.565
C_2	5	1	1	5	0.43601	1.744
C_3	3	1	1	3	0.34077	1.363
C_4	1/3	1/5	1/3	1	0.08185	0.327
Consistency Check	CR = 0.072 ＜ 0.1				Pass	

Table 6. Weight values of secondary indicators of ease of operation.

Project	C_5	C_6	C_7	C_8	Weight Value W	Feature Vector
C_5	1	1/3	5	3	0.29135	1.165
C_6	3	1	5	3	0.49093	1.964
C_7	1/5	1/5	1	1/3	0.06704	0.268
C_8	1/3	1/3	3	1	0.15069	0.603
Consistency Check	CR = 0.075 ＜ 0.1				Pass	

Table 7. Weights of secondary indicators of functional diversity.

Project	C_9	C_{10}	Weight Value W	Feature Vector
C_9	1	5	0.83333	1.667
C_{10}	1/5	1	0.16667	0.333
Consistency Check	CR = 0		Pass	

4. Discussion

The reliability analysis of the above evaluation system shows that Cronbach's α coefficient [27] is 0.833, which means that the reliability meets the requirements. Therefore, the evaluation system is correct and reliable, and can be used for the design and evaluation of the elderly physical examination APP. Use the analytic hierarchy process to calculate the weight, calculate the weight value of the 10 evaluation elements relative to the first-level indicator, and calculate the weight of each indicator relative to the target layer A. The results are shown in Table 8.

Table 8. Comprehensive table of index weight values.

Criterion layer	Index layer	Secondary Indicator Layer Weight	The Weight of Secondary Indicators Relative to the Overall Goal	The Weight of the First Level Indicator Relative to the Overall Goal
B_1. Mobile phone interaction design	C_1. Smooth operation	0.14137	0.04	0.2605
	C_2. Interface design	0.43601	0.11	
	C_3. Easy to identify	0.34077	0.09	
	C_4. Interface color	0.08185	0.02	
B_2. Ease of operation	C_5. Navigation design	0.29135	0.18	0.63335
	C_6. Operation tutorial	0.49093	0.31	
	C_7. Touch button	0.06704	0.04	
	C_8. Information filtering	0.15069	0.1	
B_3. Functional diversity	C_9. Doctor-patient interaction	0.83333	0.09	0.10616
	C_{10}. Full functioning	0.16667	0.02	

According to Table 8, the weight value of each major index and minor index relative to the overall target can be obtained. Figure 2 shows the ranking of secondary indicators relative to the weight value of the overall goal.

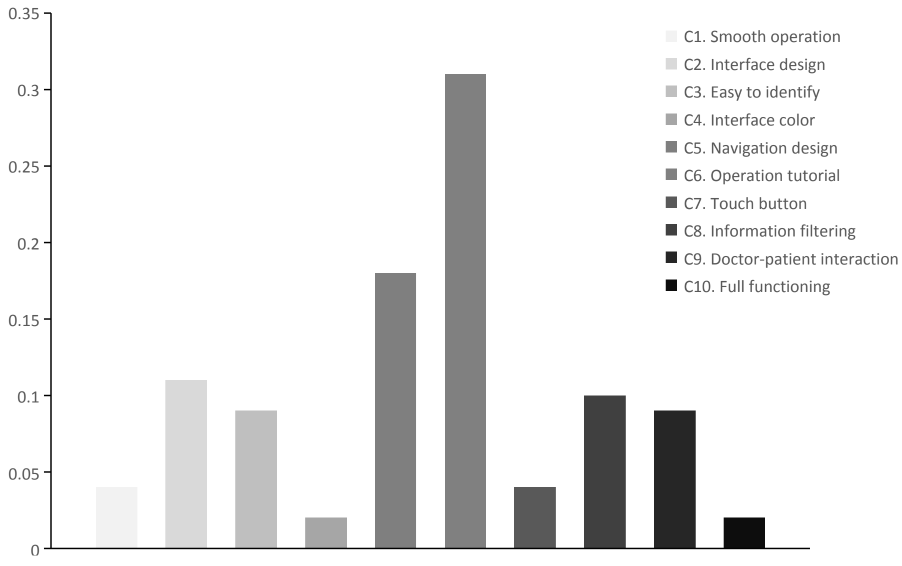

Figure 2. The weight ranking chart of secondary indicators relative to the overall goal.

As shown in Figure 2, the weight ranking of the secondary indicators relative to the target layer A is C_6, C_5, C_2, C_8, C_9, C_3, C_1, C_7, C_4, C_{10}. The most important thing in the secondary index layer is the operation tutorial and navigation design. The weights are 0.31 and 0.18, which are far ahead of other indicators. These two indicators belong to the classification of ease of operation, which may be due to the contact of the elderly. The ability to learn new things is poor. Therefore, in the design of the physical examination APP for the elderly, the elderly need the APP to help and guide users to use the physical examination function correctly. Due to the decline in memory and other physiological functions of the elderly, it may be necessary to repeat learning or guidance many times during the use of APP in order to use APP proficiently. Therefore, the navigation function needs to be considered in the design of the software to facilitate the operation of the elderly. There are four auxiliary indicators in the range of 0.05–0.15, namely interface design, easy identification, information filtering and doctor-patient interaction. Among them, interface design, easy identification and information filtering are all due to the degradation of the elderly's sensory system. When the elderly use APP, they need a clear and easy-to-understand interface, a high degree of information recognition ability and fast practical information. Due to the poor discrimination ability of the elderly, it is necessary to consider the function of advertisement filtering in the design of the APP to avoid unnecessary advertisements or pop-up windows causing misoperation by the elderly. At the same time, the elderly pay more attention to their physical health and will often consult and consult health information, so necessary doctor-patient interaction is required. At the same time, smooth operation, interface colors, touch buttons and complete functions are all less than 0.05. This may be due to the slow reaction speed and long thinking time of the elderly when using APP, so indicators such as smooth operation are not easy to use. Since the elderly use mobile devices and do not use too many functions, they do not need too many functions on the APP. There are only 27 topics in this study. The data and information come from senior citizens who have experience using medical examination applications. Old users who have never used the relevant application are not included in the study. Therefore, we need to focus on this category in our follow-up work in order to start studying the needs of the elderly. At the same time, the elderly subjects in this study are all elderly users with normal physical and psychological functions, but do not include elderly users with special physical or psychological symptoms (such as Alzheimer’s disease and sensory disorders). Such groups have certain individual differences. These people will need different requirements when using the physical examination application and need to conduct more in-depth research in subsequent work.

5. Conclusions

In summary, first, through in-depth interviews, subjective data on medical examination applications for the elderly were obtained, and 43 evaluation indicators for medical examination applications for the elderly were extracted. Then use the KJ method to classify the information obtained from the interview. The 43 evaluation elements are divided into 10 sub-categories. These 10 sub-categories are divided into 3 main categories, namely mobile phone interaction design and ease of operation, as well as diversification of usability and functions. Finally, the analytic hierarchy process and the fuzzy comprehensive evaluation method are combined to classify and analyze the obtained evaluation indicators, and calculate the weight value of each indicator. Combined with the results of this evaluation study, the design of the elderly physical examination APP should first consider the operation tutorial and navigation design, and combine the navigation function design of video or audiovisual teaching for guidance. Older users perform the operation. Combined with voice prompts to assist operation, with operation guidance video, so that the elderly can quickly master the use of APP skills. Record the operation method of each functional module in the video, so that the elderly can learn how to operate, or in the system navigation design, intelligent assistants and other methods can be used to actively guide the elderly to operate. Secondly, interface design should be considered in the design, easy to identify, information filtering and doctor-patient interaction. These four indicators belong to the scope of the elderly to obtain information, because the elderly are exposed to smart devices for a short time, so they cannot recognize too much information flow. Therefore, the interface design should be concise, clear and easy to identify, and false fraudulent information should be filtered out in advertisements to prevent the elderly from being deceived. Design a clear, easy-to-identify operation interface, filter useless or false information, and communicate effectively with doctors. Let the elderly identify useful information, filter out useless false information and obtain useful information at any time. Finally, there are indicators such as smooth operation, interface colors, touch buttons, and full functions. Considering these conditions in the design of the APP can improve the user experience of the APP.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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