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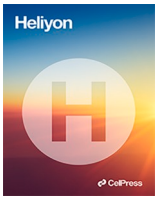

Research article

A humanistic-care factors application hierarchical design-model for intelligent elderly products

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ABSTRACT

At present, many countries and regions around the world have entered an aging society, so the demand intelligent elderly product has begun to double. However, in the design process of intelligent elderly products, there is a lack of a set of perfect method model and evaluation criteria for the application of humanistic care factors in intelligent elderly products. To standardize the use of humanistic care factors in the design of intelligent elderly products. Firstly, this study uses grounded theory to code and analyze the humanistic care factors. Secondly, the analytic hierarchy process (AHP) and analytic network process (ANP) are used for comparative study to obtain the sensitivity priority of the application of humanistic care factors, and a new design method model is proposed. Finally, the fuzzy evaluation method is used to verify the rationality of the design method model. The study shows that the use of humanistic care factors has the greatest impact on emotion, especially in the consideration of Interactivity, followed by Color mildness and Companionship. The results are divided in the form of a hierarchical demand tower, to establish a new Humanistic-care Factors Application Hierarchical Design-model (HFAHD) for intelligent elderly products. The HFAHD can not only help designers to improve the design efficiency in the design of intelligent elderly products, but also further standardize the use of humanistic care factors in the design of intelligent elderly products. Through the combination of quantitative research and qualitative research, it is proposed to divide the use of humanistic care factors into hierarchical models to help designers better use the HFAHD. This study not only improves the design standards of intelligent elderly products, but also extends to other design fields in further research, and promotes the more rational use of humanistic care factors in design.

1. Introduction

According to the latest report of the United Nations in 2022, the global population has reached 8 billion, and the aging of society will continue to accelerate. Due to the increasingly serious situation of population aging worldwide, some developed countries and regions, such as Japan and Europe, have entered a severe aging society, and developing countries have also joined the list, and having an accelerating trend [1]. As a special group, the elderly need more attention in psychology and physiology, especially in psychology. For designers, the use of humanistic care factors is particularly important. “Humanistic care” mainly focuses on the psychological characteristics of the elderly in design, and combines with the physiological characteristics of the elderly group, through the design means to give the elderly group psychological affirmation. For the elderly, it can better meet the spiritual and psychological needs of

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the elderly, make the products more comfortable and easier to use, and help the elderly to better accept and use related products [2]. On the contrary, the inappropriate use of humanistic care factors can easily create an unacceptable illusion for the elderly, who gradually deny themselves in the process, and eventually give up to accept new things.

Today, with the rapid development of science and technology, intelligent elderly products have gradually become an important part of their lives. Whether in daily life or rehabilitation medicine, intelligent elderly products can better improve the quality of elderly life and meet their diverse needs. In the design of intelligent elderly products, the concept of humanized design is the core of design [3]. It should be given more consideration to the psychological needs of the elderly based on humanized design. Therefore, the application of humanistic care factors in the design is the core of the whole design process of intelligent elderly products.

Compared with the traditional elderly product design, the application of humanistic care factors is based on humanized design, inclusive design, and emotional design. For example, Z. Bai et al. proposed to integrate the inclusive design concept into the service design to help improve the service experience of the elderly, and it can be applied to the medical service design process [4]. W. S. W. Tseng et al. studied emotional support and parent-child interaction for the elderly and analyzed family interaction behaviors between the elderly and other family members through a four-stage service design process. Then they explored the invisible needs of interaction between the elderly and family members by the previous analysis and guided relevant design practices [5]. X. Xu et al. mainly studied the "tolerance" and "sense of experience" in the design of future community public facilities suitable for aging, and put forward an innovative construction mode of "future community" which combines aging and inclusiveness [6]. Through the research themes of these scholars, it can be found that although the theme has a certain relationship with humanistic care, it focuses more on how to optimize the user experience. What's more, it is result-oriented and lacks systematic analysis of the application of humanistic care factors in the design process.

With the continuous improvement of the quality of elderly life, designers also need more reasonable consideration in the design criteria of intelligent elderly products. In traditional design methods, the application of humanistic care factors is usually completed by designers according to their design experience. Therefore, there is a lot of room for improvement in process specifications and standards. At present, all kinds of optimization design processes and methods are committed to helping designers improve the design efficiency and design specifications. For example, C. Zhao studied the problems faced by the elderly in the use of intelligent technology products and service systems and proposed an age-appropriate design method model based on the double helix structure, which was used to guide the design of age-appropriate intelligent furniture [7]. Although the application of humanistic care factors is the key to the design of intelligent elderly products, there are still some gaps in the research on the applicable standards of humanistic care factors in the design process. As a result, there are great differences in the use of humanistic care factors in the design process of intelligent elderly products due to different experiences or levels of designers, which affects the acceptance of intelligent elderly products.

Therefore, this paper takes the application of humanistic care factors in the design of intelligent elderly products as the research theme, combines qualitative and quantitative research methods, and summarizes and analyzes the priority of the application of humanistic care factors in the design of intelligent elderly products. Finally, the paper puts forward the HFAHD for intelligent elderly products. The HFAHD proposed in this study, can not only help designers to improve the design efficiency of intelligent elderly products, but also better standardize the use of humanistic care factors in the design, and help the elderly to better accept and use intelligent elderly products. The main contribution and research value of this study are to improve the design process of intelligent elderly products and propose the HFAHD for intelligent elderly products, which can avoid the subjective decision-making of designers, affecting the use of humanistic care factors in the design of intelligent elderly products. And this study can also be extended to other areas of design to promote the important development of humanistic care factors in design.

This paper is divided into several parts. The second section reviews and discusses the literature review of the research on design theory and method related to the elderly, the related research to different design fields and humanistic care, and the application of quantitative research methods in the design field. The third section makes a specific research analysis of humanistic care factors. Firstly, the specific categories of humanistic care factors are obtained by grounded theory analysis, and then the sensitivity ranking of humanistic care factors is obtained by the comparative study of AHP and ANP. Section four constructs the HFAHD for intelligent elderly products based on the importance ranking of humanistic care factors obtained in the previous section. In addition, three popular intelligent elderly products are selected to use the fuzzy evaluation method to evaluate the rationality of the HFAHD. Section five is for discussion, and section six is for the conclusion.

2. Literature review

Reviewing the relevant research in the design field, the elderly has always been the focus of many design researchers. Generally speaking, it is mainly divided into design theory method and design practice guidance related research. In addition, many scholars are also constantly exploring the methods of quantitative research in order to analyze and design problems more intuitively and accurately. This paper mainly reviews the design theory and method research related to the elderly group, the related research of different design fields and humanistic care, and the application of quantitative research methods in the design field. The purpose is to have a more comprehensive and in-depth understanding of the research status and future development direction of the design field for the elderly group. And this also can provide strong support and guidance for this study.

2.1. Research on design theory and method

Many scholars' exploration of design theory and method is constantly expanding. For example, some scholars focused on exploring inclusive design methods for elderly and proposed inclusive design methods for the elderly by analyzing their physiological functions

and other characteristics [8]. Based on inclusive design, some scholars considered that users with special needs make the design process more challenging, so they put forward a new design method to guide the process of requirement identification [9]. And some scholars put forward the user-centered design method for the design of smart clothing for the elderly and suggested that the user's evaluation tendency of smart clothing should be involved in the design process [10]. Some scholars used Quality Function Development (QFD) to study the relationship between universal design criteria and usability principles to establish a usability evaluation method for intelligent elderly vehicles [11]. To reduce the subjectivity of choosing the design scheme of intelligent elderly accompanying products, some scholars put forward an evaluation method of the design scheme of healthy elderly accompanying products [12].

By reviewing the research on design methods and theories of relevant scholars in the design field, as shown in Table 1, it can be found that both new design methods and evaluation methods are proposed to make the design process simpler or the evaluation method more accurate. And the aim is also to reduce the impact of designers and objective environment on the design process or design evaluation to meet the real needs of users to the greatest extent.

2.2. The related research of different design fields and humanistic care

In different design research fields of design, humanistic care has always been one of the research priorities in various fields, especially design for the elderly. In terms of product design, some scholars have proposed to enhance the psychological experience and emotional satisfaction of special user groups through sensory compensation, to reflect the humanistic care for special groups and apply it to product design for the blind [13]. As for the research on the emotional design of furniture for the elderly, some scholars have pointed out that compared with the design of furniture for children and middle-aged and young people, it is more necessary to inject humanistic care and emotional design concept into the design, and it needs to pay more attention to the practical function of furniture [14]. In addition, some scholars have discussed the design strategy of elderly products from the perspective of barrier-free design and proposed that consideration of improving the design from an emotional perspective in the later stage of design [15]. In the relevant research of wisdom and health care, some scholars emphasized that the elderly should not be treated specially. What's more, they put forward the "integration of the old and the young" as contemporary Chinese-style wisdom and health design strategy [16]. In terms of interaction design, some scholars have the view that the design strategy of intelligent product apps should be based on the mental characteristics and usage habits of the elderly [17]. Some scholars mainly discussed the issues related to the design of mobile smart home interaction systems for the elderly. They analyzed the interaction behavior of the elderly on the smart furniture system, and the research results will help to improve the interaction between the elderly and the smart home system [18]. In terms of environmental design, and medical environmental design, some scholars have pointed out that environmental factors such as noise, lighting, color, landscape, temperature, and comfort can be designed to reflect the needs of humanized design and reduce psychological fear for patients [19]. For the home environment, some scholars have pointed out that the design of the home environment will be directly related to the physical and elderly mental health, and the design should be improved according to the elderly psychological needs [20].

By reviewing some studies related to humanistic care in different design fields, as shown in Table 2, most scholars try to enhance user care through psychological or behavioral analysis of users. And they have put forward corresponding design countermeasures, which to a certain extent enhance the user's emotions and experience. Especially in the elderly product design field, scholars almost unanimously put forward that more care should be given to the elderly psychology and emotions. They also emphasize that the elderly should not be treated specially and designers should help the elderly regain confidence and meet their real needs.

2.3. The application of quantitative research methods in the design field

As for the research methods used in the design field, by reviewing some relevant literature, many scholars also combine some research methods used in other fields with design research methods including qualitative research and quantitative research methods. For example, in the application of quantitative research methods, some scholars used the knowledge of fuzzy mathematics and analyzed the data of the design scheme by using the fuzzy evaluation method to verify the rationality of the design scheme [21]. Some scholars used the AHP to develop a scheme evaluation and decision-making system and determined the reliability of multiple design schemes through weight priority [22]. And some scholars used a Fuzzy-AHP to analyze the priority of product form elements and

Table 1
Research on design theory and methods.

Author (s)	Conclusion	Article characteristics	Sort
L. Yin et al.	Put forward an inclusive design method for the elderly	Design method innovation	Theoretical methods
R. Blasco et al.	Put forward a method of requirement identification based on inclusive design	Demand analysis method based on design theory	Theoretical methods
S. Imbesi et al.	Put forward a user-centered intelligent clothing design method for the elderly	Design methods for clothing design	Practical guidance
I. K. Choi et al.	Propose the usability evaluation method of intelligent elderly vehicle based on QFD	Design scheme evaluation method	Practical guidance
S. Hu et al.	Propose an evaluation method for the design of healthy elderly companion products	Design scheme evaluation method	Practical guidance

Table 2
Research on different design fields and humanistic care.

Author (s)	Conclusion	Article characteristics	Sort
Q. Wang et al.	Through sensory compensation, it reflects the humanistic care for special groups	Research on product design for special groups	Practical guidance
R. Fu et al.	Inject humanistic care and emotional design concept into the design	Research on the design of elderly products	Theoretical methods
D. Liu	Put forward the design strategy of elderly products from the perspective of barrier free design	Research on the design of elderly products	Theoretical methods
F. Wang	Put forward "integration of the old and the young" as the contemporary Chinese intelligent health care design strategy	Smart health care design strategy	Theoretical methods
J. Li et al.	App should be based on the mental characteristics and usage habits of the elderly	Interactive design in intelligent elderly products	Theoretical methods
M. D. Tsuchiya et al.	Improve the elderly emotional cognition by optimizing their interactive experience of smart home system	Interactive design in intelligent elderly products	Practical guidance
D. K. Fontaine et al.	Medical environment design can reflect the humanized design needs	Environmental design and humanistic care	Practical guidance
X. Yan et al.	The design of home environment should consider the psychological needs of the elderly	Environmental design and humanistic care	Practical guidance

proposed a product form design and evaluation model [23]. And some scholars used the AHP to analyze the importance of design elements in the design of elderly care products to help designers make better design decisions [24]. In addition, some scholars used grounded theory to explore the key dimensions of design analysis to increase the sustainable competitive advantage of product design [25].

By reviewing the research methods used in the design fields above, as shown in Table 3, it can be found that in the later stage of the study, most scholars used some quantitative research tools to digitalize the research results to better help designers make more intuitive and accurate evaluation and reference. Of course, some scholars have adopted the method of qualitative research in the main research and analysis, but it lacks certain persuasion compared with the way of using intuitive data comparison to solve the problem. Generally speaking, it can not ignore the subjective feelings of users in the selection of research methods, because the design is associated with users. Therefore, in the relevant research in the design field, it is necessary to properly use qualitative research methods to help researchers better understand the relevant user groups. And it also needs to use quantitative research methods to help researchers provide objective data analysis in the research results to ensure the rigor of the whole research process.

3. Summary of the literature review

Through reviewing the literature review of the three aspects above, most scholars are committed to optimizing the design process and focusing on the study of user care in the literature research on design theories and methods. However, most of them lack a more intuitive design method model, which affects the application of designers at different levels in design practice. In the literature review of humanistic care in various fields, especially in product design, most of them pay more attention to users themselves but ignore the importance of the design process, and fail to provide designers with a design model that can be used as a reference in the whole process of design. As for research methods, quantitative research and qualitative research have their obvious advantages. But in the research of design decision-making, some studies tend to ignore the subjective feelings of users themselves and usually use data analysis to infer research conclusions. In general, by reviewing the relevant literature, it can not only avoid some shortcomings of previous scholars and researchers, but also learn and innovate the advantages of their research.

Table 3
Application and analysis of quantitative research methods in the design field.

Author (s)	Research method (s)	Article characteristics
D. Yang et al.	Use the fuzzy evaluation method to verify rationality of the design scheme	Application of quantitative research in design scheme evaluation
A. A. Saggaf et al.	Use the AHP to develop design scheme evaluation system using	Use quantitative research and analysis to design evaluation system
P. Lu et al.	Use the Fuzzy-AHP to propose the evaluation model of product form design	Adopt quantitative research and analysis to design evaluation model
Z. Zhou et al.	Use the AHP to determine the priority of the design elements of elderly care products	Application of quantitative research in design scheme
C. H. Noble et al.	Use the grounded theory to mine the key dimensions of design so as to increase the sustainable competitive advantage of product design	Combination of qualitative research and quantitative research

4. Research design

4.1. Research methods

This paper uses the combination of qualitative research and quantitative research to study the application strategy of humanistic care factors in the intelligent elderly products design, as shown in Fig. 1. Grounded theory is a qualitative research method, which was put forward by Strauss and Glassell in 1967 [26], it is a "discovery method" that decomposes the collected data, identifies the phenomenon, conceptualizes the phenomenon, and then appropriately re-abstracts the concept to refine the category [27]. The grounded theory consists of four steps: the first level coding (open coding), the second level coding (axial coding), the third level coding (selective coding), and the theoretical saturation test. In this paper, the core of the grounded theory method is to code the data to extract the keywords of humanistic care factors of intelligent elderly products.

AHP was proposed by American operational research scientists in the 1970s. By layering the complex decision-making system, it transforms the multi-factor decision-making problem into a multi-level single-factor problem [28]. Because AHP is a relatively simple and fast decision-making method, its hierarchical structure is relatively simple, and it is vulnerable to the inherent subjectivity of decision-makers in comparison, which has a certain impact on the results of the study. ANP is a decision-making method suitable for complex structures proposed by Professor T. L. Saaty in the 1990s, which is a decision-making method gradually developed based on AHP [29]. Compared with AHP, the network hierarchy of ANP is more complex. There are not only the hierarchical structure but also the hierarchical structure of internal circulation that govern each other, and also dependence and feedback in the hierarchical structure [30]. Therefore, to make a more objective evaluation and analysis of the complex system, this study will use AHP and ANP to compare, and analyze the keywords of the humanistic care factors derived from the grounded theory and obtain the weight and priority of the humanistic care factors at all levels. And on this basis, propose the HFAHD for intelligent elderly products.

The fuzzy comprehensive evaluation method, proposed by cybernetics expert Zadeh, is a comprehensive evaluation method based on fuzzy mathematics, which transforms qualitative evaluation into quantitative analysis by using precise mathematical methods to deal with things with fuzzy subjective judgment. The method has the characteristics of clear results and strong systematicness, and can better solve problems that are fuzzy and difficult to quantify [31]. By combining with the AHP and ANP, it objectively evaluates and analyzes the priority of the application of humanistic care factors, and verifies the rationality of establishing a new theoretical model. The application of research methods in this paper is shown in Fig. 1. In addition, the ethical approval about this study was approved from the Human Subjects Ethical Committee of University of Science and Technology Liaoning, and confirmed that all participants were informed and agreed to the relevant experiments of this study.

4.2. Grounded theory

This study took the elderly intelligent products as an example and used the method of combining primary interview data with secondary case data to collect and analyze the data, to ensure the reliability and validity of the obtained data. The original data were collected through user interviews, and in-depth interviews were conducted around semi-structured interviews. A total of 40 elderly users were interviewed, including 27 males and 13 females, aged between 60 and 75. Their pre-retirement occupations included

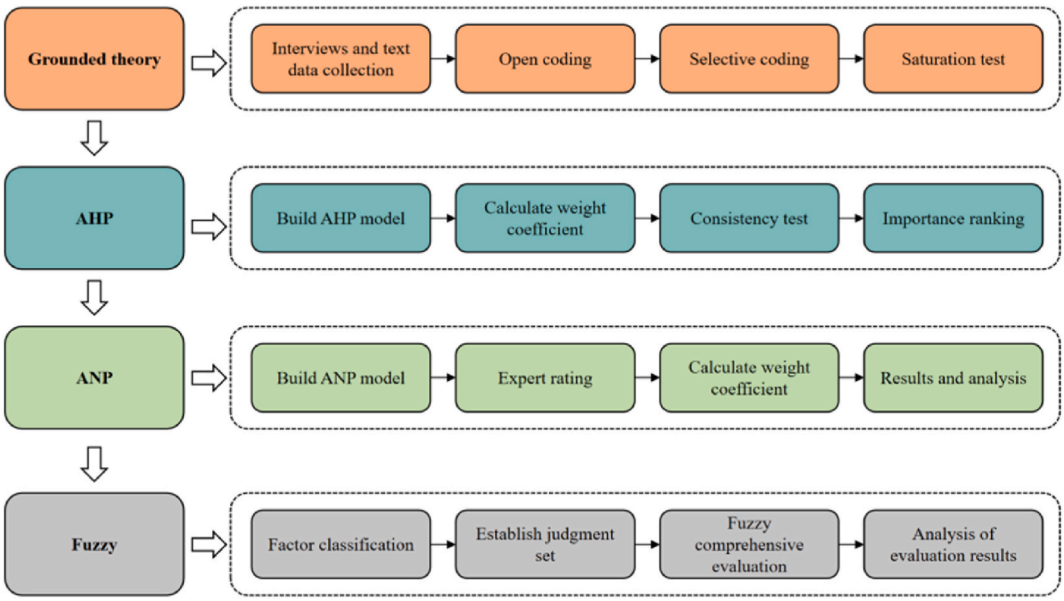

Fig. 1. Research flow chart.

university teachers, civil servants, freelancers, company employees, and so on. The interviewees in this article were highly involved in the interviews, which were mostly face-to-face and video links, lasting 15–30 min (Table 4). The formal interview outline for this paper is shown in Table 5. The outline of the interview played a guiding role in the actual interview and guided the interviewees to gradually complete the process of expressing their opinions based on their answers [32]. Through in-depth interviews, the qualitative thinking mode of researchers was overcome, and the interview content was transformed into text data as the theoretical basis of decoding. In addition, to ensure the reliability of the research results, 80% of the interview records (the first 32 interview records) were selected for coding according to the theoretical saturation test requirements, and the remaining 8 were used for the saturation test.

In addition to the interview data, the triangulation method was used to collect case data [33]. The relevant contents of humanistic care design and application of intelligent elderly products were extracted and summarized into text form, which provided the original data for the coding and analysis process of grounded theory, and provided the basic support for the application of the hierarchical model of overall humanistic care factors. To ensure the reliability of the study, multiple types of data sources were obtained through the two channels above. Finally, qualitative analysis software Nvivo 11 was used to decode and analyze the interview data and second-hand case text data.

4.2.1. Open coding

The purpose of open coding is to analyze the original data, break up the collected original data, summarize the phenomena, define the concepts and discover the categories, and then recombine them in a new way and operationalize them [34]. In the process, researchers are required to have an open mind, put aside personal prejudices and existing research opinions, comprehensively capture the key information in the data, constantly compare the phenomena in the data, and gradually abstract and name some common phenomena [35].

Firstly, the interview results of 40 elderly users were sorted, the answers that do not meet the purpose of the interview were removed, and the original text with humanistic care factors of intelligent elderly products was retained. Eight interview samples and five product case samples were set aside for later analysis of theoretical saturation. Then, through the labeling of the original materials, the continuous cycle of investigation between the original materials and concepts and categories, as well as the continuous revision and verification with experts with the title of associate professor and above in industrial design, the logical relationship between them was repeatedly demonstrated, and finally, 179 primary codes were obtained. Finally, these primary codes were sorted out and summarized, and 72 concepts were summarized. The concepts with the same essential attributes were further clustered and named, and finally, 38 initial categories were obtained, which are represented by F (Table 6).

4.2.2. Axial coding

Axial coding is a complex process of linking approximate codes together through continuous comparison based on open coding [36]. Its main purpose is to select and construct the main purpose content, and to relate the main concept categories to the secondary concept categories to reorganize the data. Based on the in-depth study of the intelligent elderly product design factors, according to the logic and operation of axial coding, this paper found that there were certain categories of classification and causality through analysis. The 38 initial categories formed by open coding can be further summarized into 4 main categories and 16 sub-categories, including the Application of humanistic care factors in function, Application of humanistic care factors in modeling, Application of humanistic care factors in CMF, and Application of humanistic care factors in emotion. See Table 7 for the scope and connotation of each category.

4.2.3. Selective coding

Selective coding is to select a "core category" from the categories found in the main axis coding after systematic analysis, to systematically link the core category with other categories, and to describe phenomena, behaviors, and context conditions in a "story line" way, to develop a new substantive theoretical framework [37]. The analytic story formed in this way should be coherent, which can conceptualize the form of relationship between categories and make the analytic story theoretical.

As mentioned above, Nvivo 11 qualitative analysis software is used in this study, which has a good model construction function and provides the expression function of the logical relationship between concepts. The specific operation is to establish a logical relationship between the concepts with obvious directivity in the original materials and refine the logical relationship structure between the categories according to the categories to which the concepts belong (Table 8).

4.2.4. Theoretical saturation test

To ensure the reliability of the final demand analysis model, the theoretical saturation must be tested. According to Gleiser and Strauss, theoretical saturation occurs when repeating the analysis above on the data set aside no longer allows data to be extracted from the data to further develop the characteristics of a category [38]. After coding the eight reserved interview text categories and five

Table 4
User composition of semi-structured in-depth interview.

Pre-retirement occupation	Age	Gender	Education level
College teacher	65–73	Male 9 Female 5	Undergraduate 10 Master 4
Civil servant	60–71	Male 7 Female 3	College 3 Undergraduate 6 Master 1
Enterprise staff	63–75	Male 6 Female 3	Senior school 2 College 4 Undergraduate 3
Professional	66–75	Male 5 Female 2	Senior school 3 College 3 Undergraduate 1

Table 5
Semi structured interview outline.

No	Summary of questions that can be raised
1	Personal information (including name, gender, age and occupation)
2	Do you know, buy and use smart products for the elderly?
3	When you use smart products, do you feel that they bring convenience to your life?
4	What problems are you likely to encounter when using smart products?
5	Do you feel the design application of humanistic care factors in the use process?
6	What factors do you pay more attention to when purchasing relevant elderly intelligent products?

Table 6
Open coding categorization (partial examples).

Original statement text data	Include concepts	Initial category
Generally, intelligent products can download a lot of software and realize many functions.	Realize multiple functions	F1Diversified functions
When buying smart products, we usually consider buying the ones that are useful to us.	Useful to myself	F2 Practicability
You can make video calls with your family at any time and see a doctor online.	Use at any time without restriction	F3 Convenience
I like the light color, but I don't like the dark or bright color.	Comfortable color, avoid exaggeration	F4 Mild color
Follow the trend of the times and keep a young mind.	Follow the trend of the times	F5 Stylish
I like things that look good. They can look good at home.	As an ornament	F6 Beautiful appearance
The materials should be comfortable to the touch and not inferior.	The material feels comfortable	F7 Comfortable material
It feels very suitable to use, just like a customized one.	Suitable size, tailored	F8 Reasonable ergonomics
I like to buy something that can be used for a long time, but good quality ones can be used for a long time.	Long service life	F9 Durability
Some corners are sharp, so you need to be very careful when handling.	Avoid sharp shapes	F10 Round and soft
There are many operation modes, including voice and key pressing.	Various operation modes	F11 Various interaction modes
There is a first aid setting that can work in some emergencies.	Can be rescued in case of emergency	F12 Safety protection
It's inconvenient to move, so it's convenient to clean up.	Convenient cleaning	F13 Easy to clean
The font should be large, and it can be seen clearly at a conspicuous position.	The display is clear and can be seen clearly	F14 Easy to view
It's not easy to lose a rope that can be hung on your body.	It's not easy to lose it	F15 Anti theft
It is very troublesome to take it out and put it away when it is used up. It is seldom used.	It is easy to collect	F16 Storage
I can't take it. It's just for the Spring Festival. My son helps me move it out for use.	The item is too heavy to carry	F17 Save labour
I also like to participate in some recreational activities, and my life is boring.	Rich entertainment activities	F18 Entertainment
Usually I want to talk to my family more, but my son and daughter are too busy.	Lack of communication opportunities	F19 Spiritual care
The memory has deteriorated a little. I can't remember many things.	Inconvenient life and memory loss	F20 Living Care
The operation is too complicated for us old people to understand.	Complex use process	F21 Easy operation
Presbyopia is easy to lose sight of things and identify wrong things.	Difficult to identify and identify errors	F22 Easy to recognize
I don't know how to put it back when it is used.	Inconvenient to take	F23 Easy to take
The direction cannot be rotated. It needs to be operated back and forth.	The position can be changed at any time	F24 Flexibility
You can select a suitable gear according to your needs.	Adjust to the proper position	F25 Adjustability
Don't use too hard, for fear of falling or directly damaging.	Not easy to damage and fall	F26 Stable structure
I like the things that are natural in person. I feel relieved about the things that are natural and environmentally friendly.	Natural and environmental protection	F27 Natural material
It's convenient to take when going out. It's not troublesome.	Can be taken out	F28 Portability
Sometimes the user's operation is slow, and needs to be restarted after waiting too long.	Fast response and support of AI	F29 Intelligence
It can save a lot of effort when you go out and take it with you.	Save energy consumption	F30 Assistive
It's interesting. I like to play when I'm bored.	Create fun and relieve boredom	F31 Interesting
It's good for the body. Exercising muscles and bones can prevent senile dementia.	Rehabilitation treatment	F32 Rehabilitation physiotherapy
Not willing to be treated specially. People are old but still young.	Refuse special treatment	F33 Equality
Taking it out is like wearing a piece of jewelry, which is very fashionable.	Increase wearing aesthetics	F34 Decorative
The tradition of the older generation should not be forgotten and should be passed down from generation to generation.	Inheritance of traditional culture	F35 Traditional culture
No one chats at ordinary times. I have to endure many things myself.	Alleviate loneliness	F36 Spiritual Companion
I don't know how to operate. I can't return to the initial state after random operation.	Operation error, one click restore	F37 Anti misoperation
The appearance should not be too complicated, and the operation should not be complicated.	Avoid complex shapes	F38 Simple modeling

Table 7
Categorization of spindle codes.

Main category	Sub-category	Initial Category	Connotation
Application of humanistic care factors in function	Intelligence	F1Diversified functions	Meet the needs of different elderly people through functional diversification
		F24 Flexibility	It can be applied to different scenarios through the versatility function
		F25 Adjustability	Multi gear adjustment can meet the needs of the elderly in different situations
		F29 Intelligence	Highly intelligent can reduce the difficulty of the elderly
	Practicability	F2 Practicability	Try to focus on practical functions
		F9 Durability	It can be used for a long time and can solve certain problems
	Suitable for aging	F3 Convenience	Assisting daily life is more convenient
		F20 Living Care	Solve some problems often encountered by the elderly in the field of daily life
	Safety	F12 Safety protection	Add emergency rescue settings to ensure safety
		F15 Anti theft	Increase anti-theft settings to reduce loss
		F32 Rehabilitation physiotherapy	Some rehabilitation physiotherapy functions can be added as appropriate
		F37 Anti misoperation	Prevent accidental operation
Application of humanistic care factors in modeling	Decorative	F34 Decorative	It can be worn as a certain ornament
	Succinct	F10 Round and soft	Round and soft shape, avoid sharp shape
		F38 Simple modeling	The modeling is simple, avoiding complex modeling
	Identifiability	F14 Easy to view	The font should be adjusted for the elderly to avoid confusion
		F22 Easy to recognize	The appearance shall be recognizable to avoid confusion with other products
	Fashion	F5 Stylish	Keep up with the trend of the times and avoid old-fashioned modeling
		F6 Beautiful appearance	The shape conforms to the aesthetic taste of the elderly
Application of humanistic care factors in CMF	Material comfort	F7 Comfortable material	The material feels comfortable and avoids inferior materials
		F27 Natural material	Use natural materials as much as possible to avoid harmful materials
	Color mildness	F4 Mild color	Use soft colors to avoid stimulating colors
	Structure and process	F16 Storage	Convenient storage, avoid bulky
		F26 Stable structure	Stable structure to avoid external damage
	Lightweight	F17 Save labour	Minimize physical consumption when using
		F28 Portability	Delicate and compact, easy to carry
		F30 Assistive	It can give the elderly some strength support when using
Application of humanistic care factors in emotion	Interactivity	F8 Reasonable ergonomics	Reasonable size, convenient for the elderly
		F11 Various interaction modes	Various interaction methods are available for different scenarios
		F13 Easy to clean	It doesn't need too much trouble to clean
		F21 Easy operation	Easy to use, no need for complex learning
		F23 Easy to take	Easy to take, avoid taking out and placing too complex
	Interest	F18 Entertainment	It is entertaining and creates a relaxed atmosphere
		F31 Interesting	It can bring a little fun to the boring life
	Cultural	F35 Traditional culture	Avoid full high-tech and have certain cultural heritage
	Companionship	F19 Spiritual care	Give more spiritual support and care
		F33 Equality	Avoid too special setting, causing psychological damage to the elderly
		F36 Spiritual Companion	Avoid loneliness and enhance sociability

Table 8
Selective coding.

Typical paradigm	Connotation of relationship structure	Main category
Causal condition	Designers should design a product based on the realization of the main functions	Application of humanistic care factors in function
Phenomenon	Designers convey special care for users through modeling and appearance	Application of humanistic care factors in modeling
Intermediary conditions	In production, designers further convey special care for the elderly through the design of CMF	Application of humanistic care factors in CMF
Strategy	In terms of design strategy, it gives users a sense of high quality through CMF processing	
Result	Finally, when users use it, the designer's emotional care for users is conveyed through a good user experience	Application of humanistic care factors in emotion

humanistic care designs of intelligent elderly products, no new concepts were generated, which indicated that the platform demand model constructed through the coding text process had been saturated.

4.3. Analytic hierarchy process (AHP)

4.3.1. Creation of ladder hierarchical model

It is difficult to directly quantify the evaluation of design schemes according to the evaluation categories of human factors of intelligent elderly products extracted above. Therefore, combining the coding results of the application of humanistic care factors of intelligent elderly products with the grounded theory and the AHP, and then draw a preliminary ranking of the importance of the application of humanistic care factors [39]. The target layer C is based on the analysis of the application of humanistic care factors in the design of intelligent elderly products. The criterion layer is based on four types of design index: Application of humanistic care factors in function, Application of humanistic care factors in modeling, Application of humanistic care factors in CMF and Application of humanistic care factors in emotion; and the 16 sub-categories summarized and sorted out in the early stage are used as the sub-criterion layer, as shown in Fig. 2.

4.3.2. Construction of judgment matrix and determination of weight

The construction method of the judgment matrix is shown in Table 9. To quantify the importance of each element, a nine-point scale is used for comparison, as shown in Table 10.

To meet the design needs of the target layer and pass the consistency test, first of all, 30 people are randomly selected to score the demand level, including 10 elderly, 12 product designers, and 8 design teachers. Second, they are assigned a value according to the matrix scale table in Table 10. Finally, the eigenvector and weight value are calculated by constructing the comparison matrix model. The weight value is represented by W. In this study, the software Yaahp is used to calculate the weight value. The specific steps are as follows.

(1) Firstly, establish an AHP hierarchical graph according to a first-level evaluation index and a second-level evaluation index.
(2) Carry out data entry. The data comes from expert scoring and is compared with the 9-point scale. The consistency is required to be less than 0.1 during data entry. If it is not met, the data will be readjusted.
(3) Click to calculate the result.

4.3.3. Consistency check

To ensure the scientificity and standardization of the evaluation, it is necessary to check the consistency of the evaluation results. See Eq. (1) for calculating the consistency index and Eq. (2) for calculating the consistency ratio:

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

$$CR = \frac{CI}{RI} \tag{2}$$

Find the average random consistency index RI, and the specific values are shown in Table 11. When $CR \leq 0.1$, the consistency test is acceptable, otherwise the judgment matrix needs to be modified [40]. Through the analytic hierarchy process calculation, $CR \leq 0.1$, and the consistency test is passed.

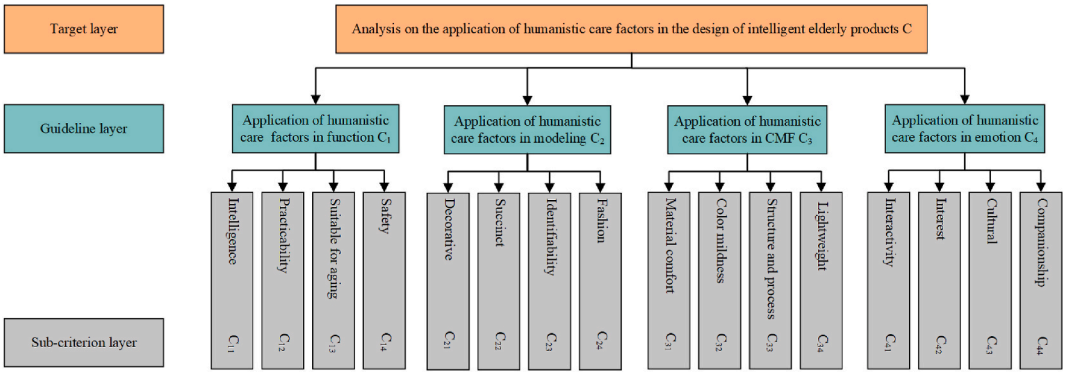

Fig. 2. AHP model of application of humanistic care factors.

Table 9
Construction of judgment matrix.

X	Y_1	Y_2	…	Y_n
Y_1	Y_{11}	Y_{12}	…	Y_{1n}
Y_2	Y_{21}	Y_{22}	…	Y_{2n}
…	…	…		…
Y_n	Y_{n1}	Y_{n2}	…	Y_{nn}

Table 10
Judgment matrix scale table.

Scale	Meaning
1	Indicates that two factors are equally important compared to each other
3	Indicates that the former is slightly more important than the latter when compared to the two factors
5	Indicates that the former is significantly more important than the latter when compared to the two factors
7	Indicates that the former is more strongly important than the latter when compared to the two factors
9	Indicates that the former is more extremely important than the latter when compared to the two factors
2, 4, 6, 8	Median of the above two adjacent judgments
Inverse	Judgment Y_{ij} for comparison of factor i with j, then judgment $Y_{ji} = 1/Y_{ij}$ for comparison of factor j with i

Table 11
Consistency index of average random number.

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.52	0.89	1.12	1.26	1.26	1.41	1.46	1.49	1.52	1.54

4.4. Analytic network process (ANP)

4.4.1. Construct the ANP model

Considering the singleness of the AHP, this study will combine the ANP for further comparative analysis. ANP constructs a judgment matrix according to the relationship between the elements, generates a "limiting super-matrix" through multiple calculations, and then obtains the mixed weight by comprehensive analysis of the factors that interact with each other. Therefore, the

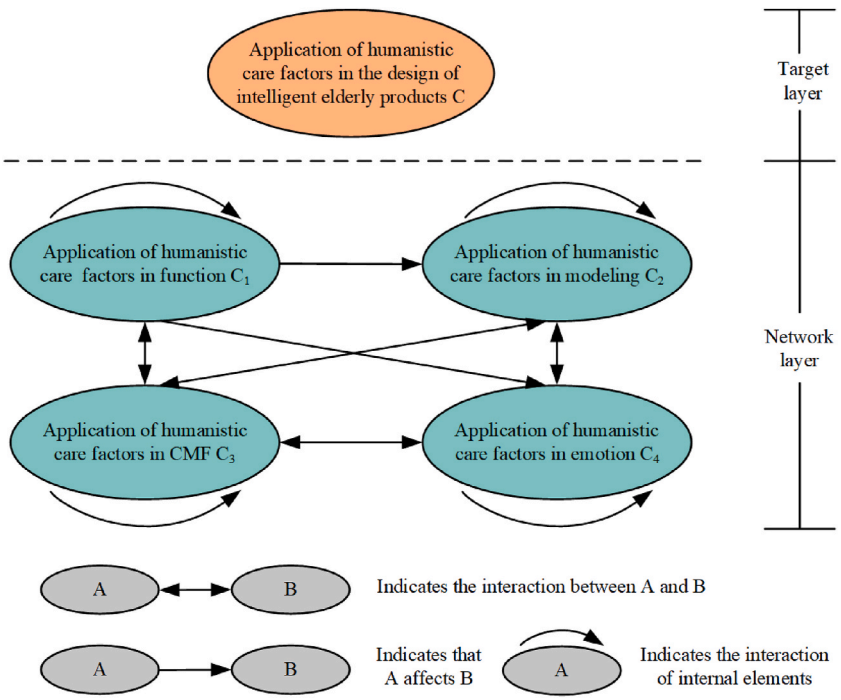

Fig. 3. ANP model of application of humanistic care factors.

relationship between the specific indicators within each criterion layer is no longer independent but has a dependence and feedback relationship with each other [41]. In this study, based on the grounded theory, the application of humanistic care factors of intelligent elderly products is divided into four criteria layers, namely, Application of humanistic care factors in function, Application of humanistic care factors in modeling, Application of humanistic care factors in CMF and Application of humanistic care factors in emotion, and an ANP model is established (Fig. 3).

Due to the complexity of the relationship diagram between the specific indicators within the criteria layer, it is not listed here. And in the analysis part of the AHP, relevant experts have been invited to score, and this step will not be repeated here.

4.4.2. ANP weight calculation

Suppose the control layer in the ANP model is P, and the network layer has C_i, where C_i has elements C_{ij} ($i = 1, 2, \ldots, n$), the calculation of the weight of each element has the following four steps.

(1) Calculate a normalized eigenvector of each C_{ij} judgment matrix. The judgment matrix in this step takes C_i as the criterion and C_{ij} as the sub-criterion, and the ${W_{ij}}^T$ ($i = 1,2, \ldots,n$) is calculated by the eigenvalue method.
(2) Compute the unweighted super matrix. All eigenvectors ${W_{ij}}^T$ are summed into an unweighted super matrix W_{ij}. If one of the elements C_{ij} has no judgment matrix, $W_{ij} = 0$. Summing up all W_{ij} results in the super matrix W. Carry out consistency inspection on the super matrix, $CR < 0.1$ indicates that the consistency inspection is qualified, and if the consistency inspection is not qualified, the super-matrix is reconstructed.
(3) Compute the weighted super-matrix W. The unweighted super-matrix only reflects the relative importance of the secondary indicators, and the judgment matrix needs to be constructed under the control level criterion. The normalized eigenvector a_{ij} is obtained by calculating the first-level index, the a_{ij} is summarized to obtain the weighted matrix A, and the weighted super-matrix $W = A \bullet W = a_{ij} \bullet W_{ij}$ is calculated.
(4) Compute the limit matrix W^{∞} of the weighting matrix, as shown in Eq. (3). The global and local weights of each level are generated by the stability processing of the weighted super-matrix through the limit relative ranking vector.

$$W^{\infty} = \lim_{k \to \infty} \left(\frac{1}{R} \right) \sum_{k=1}^{R} W^k \tag{3}$$

(Note: R is the weighted super-matrix, and W is the cycle period).

In view of the fact that the calculation process above is rather tedious, this paper uses Super Decisions 3.2 software to calculate the scoring results of each expert for each judgment matrix. All results were $CR < 0.1$, indicating that the consistency test was passed. By calculating the super-matrix and the limiting super-matrix, the weight of each index of the application of humanistic care factors of intelligent elderly products is obtained.

4.5. The comparative analysis of AHP and ANP and the prioritization of the application of humanistic care factors

4.5.1. The weight results and comparative analysis of AHP and ANP

Through calculating the weight values of each level by AHP and ANP methods, the AHP method obtains the ranking of the criteria level as follows: Application of humanistic care factors in emotion > Application of humanistic care factors in function > Application of humanistic care factors in CMF > Application of humanistic care factors in modeling, which shows that the application of humanistic care factors is more important in emotion and function. The importance ranking of Application of humanistic care in emotion is: Interactivity > Companionship > Interest > Cultural, which shows that it is more important to consider Interactivity and Companionship. The importance ranking of the Application of humanistic care factors in function is: Safety > Practicability > Intelligence > Suitable for aging, which shows that it is more important to consider Safety and Practicability. The importance ranking of Application of humanistic care factors in CMF is as follows: Color mildness > Structure and process > Material comfort > Lightweight, which shows that Color mildness and Structure and process are more important. The importance ranking of the Application of humanistic care factors in modeling is: Identifiability > Fashion > Succinct > Decorative, indicating that Identifiability and Fashion are more important.

The importance ranking of ANP method is as follows: Application of humanistic care factors in emotion > Application of humanistic care factors in CMF > Application of humanistic care factors in modeling > Application of humanistic care factors in function. It is concluded that the Application of humanistic care factors in emotion is more important. In the importance ranking of each sub-level, only the sub-level ranking of humanistic care factors in function is different from the importance ranking obtained by AHP

Table 12
Comparison of guideline layer results based on AHP and ANP.

Guideline layer (C)	Weight of AHP	Sort	Weight of ANP	Sort
Application of humanistic care factors in function (C_1)	0.3212	2	0.1134	4
Application of humanistic care factors in modeling (C_2)	0.0939	4	0.1319	3
Application of humanistic care factors in CMF (C_3)	0.1834	3	0.2397	2
Application of humanistic care factors in emotion (C_4)	0.4015	1	0.5150	1

Table 13
Comparison of sub-criterion layer of AHP and ANP.

Guideline layer (C)	Sub-criterion layer	Weight of AHP	Sort	Weight of ANP	Sort
Application of humanistic care factors in function (C_1)	Intelligence (C_{11})	0.0505	8	0.0191	12
	Practicability (C_{12})	0.0946	4	0.0100	14
	Suitable for aging (C_{13})	0.0432	9	0.0181	13
	Safety (C_{14})	0.1328	2	0.0662	6
Application of humanistic care factors in modeling (C_2)	Decorative (C_{21})	0.0101	16	0.0099	15
	Succinct (C_{22})	0.0178	15	0.0241	11
	Identifiability (C_{23})	0.0418	10	0.0682	5
	Fashion (C_{24})	0.0242	13	0.0297	10
Application of humanistic care factors in CMF (C_3)	Material comfort (C_{31})	0.0339	12	0.0453	9
	Color mildness (C_{32})	0.0762	5	0.1354	2
	Structure and process (C_{33})	0.0537	7	0.0498	8
	Lightweight (C_{34})	0.0196	14	0.0092	16
Application of humanistic care factors in emotion (C_4)	Interactivity (C_{41})	0.1876	1	0.2237	1
	Interest (C_{42})	0.0643	6	0.1093	4
	Cultural (C_{43})	0.0383	11	0.0613	7
	Companionship C_{44})	0.1113	3	0.1207	3

method. The importance ranking of the Application of humanistic care factors in function calculated by ANP is Safety > Intelligence > Suitable for aging > Practicability. Specific hierarchical weight sorting and comparison are shown in Table 12 and Table 13.

The main differences between the importance ranking of humanistic care factors at all levels obtained by ANP method and the importance ranking of humanistic care factors at all levels obtained by AHP method are as follows: First, in the criterion level, the weight of Application of humanistic care factors in CMF has increased, and the importance ranking has risen to the second place, and the Application of humanistic care factors in modeling has also risen to the third place. While the Application of humanistic care factors in function dropped from second place to fourth place. Considering the particularity of the elderly group, the design criteria of elderly products should pay more attention to the psychological feelings of the elderly group. And in terms of CMF and modeling, it can give the elderly more psychological comfort in cognitive aspects. While in terms of function, the pursuit of functionality by the elderly group is not like that of the young group, they will be happy as long as it can meet their needs of use. Therefore, in contrast, the weights and rankings obtained by ANP are more reasonable and in line with the design criteria of elderly products. Second, in the sub-level, for example, the Color mildness rises from fifth place to second place, while the Safety decreases from second place to sixth place. In terms of brain cognition, for example, visual cognition directly conveyed by color is more easily perceived by the elderly than deep cognition conveyed by function. Therefore, it is reasonable that the order of importance of Color mildness rises. In addition, there are more hierarchical factors in the sub-level, which have been improved in weight and importance ranking, such as Decorative, Succinct, Identifiability and Fashion in the use of humanistic care factors.

4.5.2. Prioritization of the application of humanistic care factors

Through the AHP and ANP, the paper makes an in-depth comparative analysis of the application of humanistic care factors in the intelligent elderly products design, which shows that the ANP method is more reasonable than the AHP method in terms of the weight

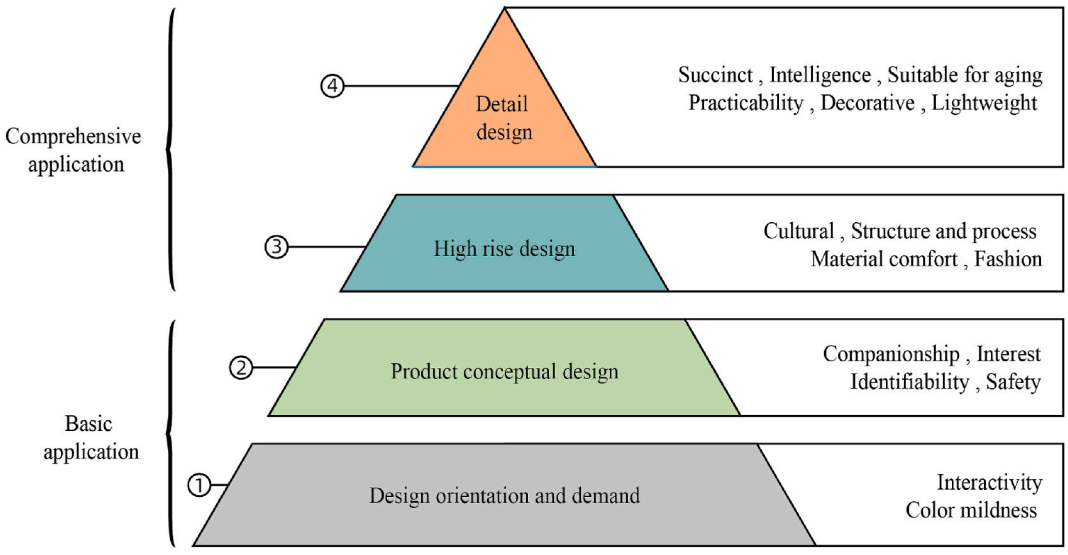

Fig. 4. The hierarchical demand design method model of humanistic care for intelligent elderly products.

proportion and importance ranking of each level. So it can be concluded that the Application of humanistic care factors in emotion had the greatest impact, and the weight value is 0.5150, and then the weight values of the Application of humanistic care factors in CMF, modeling, and function are arranged in turn. In the sub-criteria level, $C_{41} > C_{32} > C_{44} > C_{42} > C_{23} > C_{14} > C_{43} > C_{33} > C_{31} > C_{24} > C_{22} > C_{11} > C_{13} > C_{12} > C_{21} > C_{34}$. Under the objective guidance of data analysis, the application of humanistic care factors in the design of intelligent elderly products should focus on the use of humanistic care factors in emotion, especially in the Interactivity, followed by Color mildness and Companionship.

5. Results analysis

5.1. Construction of a theoretical model

First of all, based on the research results of the grounded theory, the key direction of the application of humanistic care factors in the design of intelligent elderly products was obtained. Then, with the help of the comparative analysis of AHP and ANP, the importance ranking of the application humanistic care factors in the design of intelligent elderly products is obtained. Finally, the hierarchical division was summarized by the Delphi method, and the HFAHD for intelligent elderly products based on hierarchical demand theory and humanistic design concept was constructed (Fig. 4). Hierarchical priorities were reflected in the form of graphs (Fig. 5) to help interdisciplinary design teams put humanistic care needs and design needs at the core of design, and achieve continuous transformation between research on design problems and exploration of solutions.

According to the HFAHD in intelligent elderly products, the application of humanistic care factors in intelligent elderly products is divided into four levels according to their importance, which are design orientation and demand, product conceptual design, high rise design, and detail design from bottom to top. For elderly users, the basic requirement of a good elderly product is to make it easy for the elderly to use. In addition, designers also need to consider the psychological cognitive problems of the elderly, and the rational use of color can give the elderly a more basic cognition. Therefore, in the design of intelligent elderly products, Interactivity and Color mildness are included in the first level, that is, the stage of design orientation and demand. In the second level, that is, the stage of product conceptual design, designers need to further tap the psychological needs of elderly users, so Companionship, Interest, Identifiability, and Safety are included in the second level. In the third and fourth levels, namely the high rise design and detail design stages, designers are required to explore the potential needs of users and create more meticulous humanistic care for users, so as to enhance user satisfaction. Therefore, according to the important relationship of various levels in the hierarchical demand model, the application of humanistic care factors in the design of intelligent elderly products should be based on the protection of the first and second levels. On this basis, designers should try the best to meet the application of the third level factors, and further meet the application of the fourth level factors if conditions permit. In the case that most of the humanistic care factors cannot be used, the humanistic factors under the same level are selected according to the type of products.

5.2. Fuzzy evaluation method

5.2.1. Establish a set of judgments

To verify the effectiveness of the HFAHD, it is necessary to select intelligent elderly products with large coverage of elderly users on the market and verify them with the help of the fuzzy evaluation method [42]. Among many intelligent elderly products, smartwatches

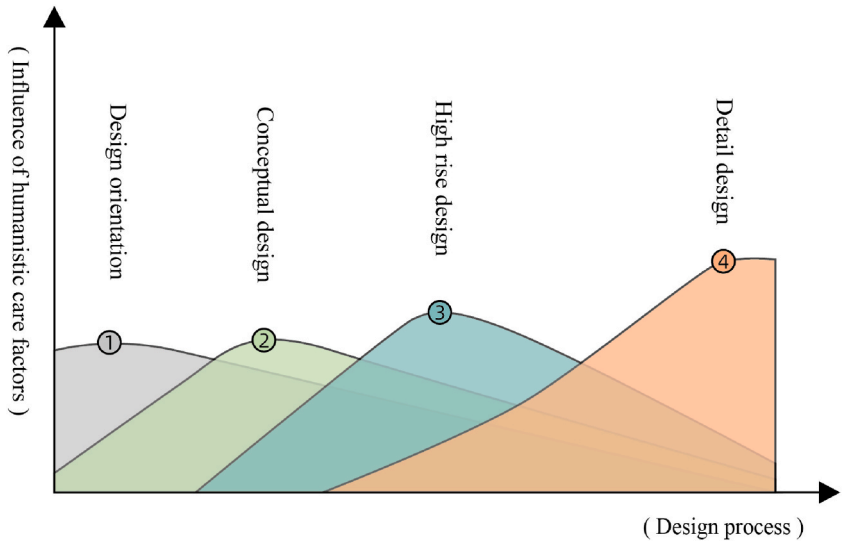

Fig. 5. Level demand curve of humanistic care.

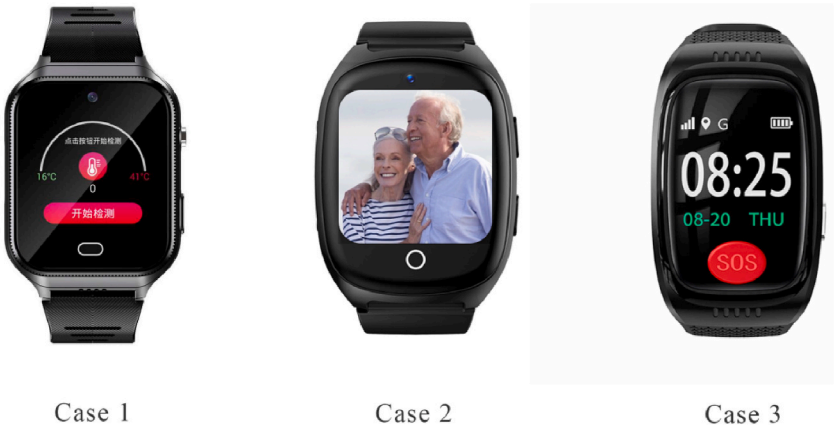

Fig. 6. Evaluation Cases 1, 2, and 3 for the elderly smart watch.

Table 14
Details of elderly smartwatches.

	Interaction mode	Material	Color	Feature highlights
Case 1	Touch screen and buttons	Metal and plastic	Black	Large image, remote positioning, and health detection
Case 2	Touch screen, buttons and face recognition	Plastic and rubber	Black	Ergonomics, voice mode, face recognition, and health housekeeper
Case 3	Touch screen, buttons and voice	Plastic and cloth	Black and red	Continuous health testing, multiple warning methods, locate find, and one click for help

for the elderly have been well-developed and are suitable for the majority of elderly users. Because of its diversified functions, relatively low price, and portable and compact design, it is loved and used by many elderly people. Therefore, the user coverage of smart aged watches is large, which meets the requirements of verifying the HFAHD. To better verify the rationality of the HFAHD, this study selects three smartwatches for the elderly with high market sales as the scheme to be evaluated, as shown in Fig. 6, and the product details are shown in Table 14.

In order to conduct a comprehensive evaluation of the case products, 9 product designers from relevant enterprises, 5 experts in geriatric psychology and 6 experts in products for the elderly were invited. A total of 20 evaluators scored and evaluated in the form of questionnaires. The following is the specific evaluation process.

(1) Firstly, experts give evaluation opinions to determine evaluation elements, which are represented by $y = \{y_1, y_2, y_3, y_4\}$, representing the application of humanistic care factors in function, modeling, CMF, and emotion respectively. The evaluation element set is determined as $y_i = \{y_{ij}\}$ $(i,j = 1, 2, 3, 4)$.
(2) Determine the evaluation grade and its corresponding standard. Set the evaluation set as $V = (v_1, v_2, v_3, v_4, v_5)$, corresponding to $V =$ (very excellent, excellent, general, poor, very poor) respectively. The corresponding scores are: very excellent is 95 points, excellent is 85 points, the general is 70 points, qualified is 60 points, and poor is 50 points.
(3) To make the evaluation results comparable, the data need to be normalized to obtain a comprehensive evaluation matrix.

For example, in Case 1, the fuzzy evaluation matrix R_{X1}, as shown in Eq. (4), has used the application of humanistic care factors in function:

$$R_{X1} = \begin{bmatrix} 0.30 & 0.35 & 0.20 & 0.10 & 0.05 \\ 0.20 & 0.30 & 0.30 & 0.15 & 0.05 \\ 0.15 & 0.20 & 0.35 & 0.20 & 0.10 \\ 0.10 & 0.20 & 0.30 & 0.30 & 0.10 \end{bmatrix} \tag{4}$$

5.2.2. Fuzzy evaluation operation

Carry out a comprehensive evaluation by using a mathematical model, respectively carry out comprehensive evaluation calculation on the weight vector W calculated by the analytic hierarchy process and the corresponding fuzzy evaluation matrix R to obtain a comprehensive evaluation vector B, and marking the single-factor evaluation vectors as B_{X1}, B_{X2}, B_{X3}, B_{X4}:

$$B = W \circ R = (B_{X1}, B_{X2}, B_{X3}, B_{X4}) \tag{5}$$

In the same way, the fuzzy evaluation matrixes of Application of humanistic care factors in modeling, Application of humanistic

care factors in CMF, and Application of humanistic care factors in emotion are calculated, and then the evaluation vectors are calculated by Eq. (5). For example, from the weight vector $W_1 = (0.1684, 0.0884, 0.1599, 0.5833)$ of the Application of humanistic care factors in function, the evaluation vector of the Application of humanistic care factors in function in Case 1 can be obtained:

$B_{X1} = W_1^{\circ} R_{X1} = (0.1676, 0.2530, 0.2910, 0.2109, 0.0774)$

In Case 1, the evaluation vectors of R_{X2} in the application of humanistic care factors in modeling, R_{X3} in the application of humanistic care factors in CMF, and R_{X4} in the application of humanistic care factors in emotion are also obtained:

$B_{X2} = W_2^{\circ} R_{X2} = (0.2246, 0.2720, 0.3034, 0.1650, 0.0350)$

$B_{X3} = W_3^{\circ} R_{X3} = (0.2152, 0.2426, 0.3555, 0.1669, 0.0198)$

$B_{X4} = W_4^{\circ} R_{X4} = (0.2433, 0.2492, 0.2718, 0.1896, 0.0461)$

Then from $W = (0.1134, 0.1319, 0.2397, 0.5150)$, the comprehensive evaluation vector of Case 1 is obtained:

$B = W^{\circ} R = (0.2236, 0.2489, 0.2982, 0.1863, 0.0430)$

Finally, the scores of each level and the comprehensive score are calculated by Eq. (6), and the scores of Case 2 and Case 3 are calculated by the same method. The specific results are shown in Table 15.

$$U = B \cdot V \tag{6}$$

5.2.3. Analysis of fuzzy evaluation result

In the beginning, the evaluation set $V =$ (very excellent, excellent, average, qualified, and poor) was set. Through calculation, it is known that the weighted average scores of the three elderly smartwatches are all between 75 and 80. By comparing the scores with the evaluation set, it is concluded that the three products are all at the "average" level. According to the scoring rules, Case 2 had the highest score of 78.26 among the three products. In the analysis of the detailed rules for the application of humanistic care factors in each case, Case 1 scored 77.35 for the Application of humanistic care factors in modeling. According to the HFAHD, the application of humanistic care factors can be more considered in emotion and CMF. Case 2 has the highest score of 79.10 in the Application of humanistic care factors in emotion, and the scores of the other three aspects are roughly consistent with the HFAHD, so the scheme also has the highest score among the three products. Case 3 has the highest score of 79.01 for the Application of humanistic care factors in function. Combined with the design position of Case 3, its advantages mainly lie in functionality. However, according to the HFAHD, the product needs to consider more about the Application of humanistic care factors in CMF and modeling in the future. On the whole, Case 2 not only has the highest comprehensive score, but also its scores at all levels are roughly consistent with the HFAHD. Therefore, Case 2 is more reasonable in the use of humanistic care factors than the other two products. Through the analysis of the comprehensive scores and the scores of each level of the three intelligent elderly products, it can be seen that the HFAHD for intelligent elderly products is suitable for guiding the design of intelligent elderly products and the evaluation of design schemes.

6. Discussion

Under the background of global aging, it is particularly important to reflect the humanistic care for elderly in product design. The core idea of this study is to build the HFAHD through the research and analysis of the application of humanistic care factors in the design of intelligent elderly products, to provide a new design idea for the design and development of intelligent elderly products and a more standardized design process reference for the application of humanistic care factors. Throughout the academic circle. Some scholars consider the intelligent elderly products design from the perspective of interaction design, and they point out that interaction design can make products more humane, and good interaction design can be more in line with the psychological and physiological needs of the elderly [43]. Some scholars study the design of intelligent elderly products from the perspective of Kansei Engineering and evaluate the usability of products, which can help developers and designers understand the current situation and improvement direction of product usability [44]. Most scholars consider a specific aspect in the study of intelligent elderly products, and they optimize a certain aspect of intelligent elderly products or make a certain stage of design simpler from different perspectives. However, there is little consideration for the use of humanistic care factors in the whole design process, and there is a lack of a common reference design model for designers at different levels. Therefore, this study takes humanistic care as the breakthrough point and summarizes the concerns of the elderly on the application of humanistic care factors through in-depth interviews with grounded theory. What's more, this study uses rigorous mathematical methods to obtain the important levels of the use of humanistic care factors in intelligent elderly products to establish the HFAHD. The aim is to improve the efficiency and standard of the application of humanistic care factors in the design process of intelligent elderly products.

In the HFAHD, the design process is mainly divided into four stages with pyramidal distribution, which are design orientation and demand, product conceptual design, high rise design, and detail design. It corresponds to four different levels, among which the bottom is the most important level. The factors of humanistic care at each level are divided according to the results of the ANP and expert opinions. The first level is the design orientation and demand stage, in which Interaction and Color mildness are the key points of the

Table 15
Summary of fuzzy evaluation scores of three elderly smartwatches.

Brand	Model	Product pictures	U_1	U_2	U_3	U_4	Comprehensive score U
DBT	GTW13		73.16	77.35	76.95	77.00	76.60
OEM	FA66		76.84	77.84	77.37	79.10	78.26
Thinkrace	L001		79.01	76.88	74.75	78.92	77.66

application of humanistic care factors that designers need to pay the most attention to. In the stage of product conceptual design, designers can focus on Companionship and Interest, and so on. In terms of top-level design details, designers can focus on different humanistic care factors at the highest level according to product positioning. Finally, this paper also uses the fuzzy evaluation method to verify the rationality of the HFAHD, and through the case product evaluation score, it can see that the HFAHD has a certain scientific nature.

Because of the particularity of the elderly group, the key to the design of intelligent elderly products is to meet the psychological needs of the elderly group. Considering the cognitive ability of the elderly group, designers need to focus on the specific application of different humanistic care factors in different design stages. According to the HFAHD, the key points of the intelligent elderly products design are as follows: First of all, the basic cognitive ability of the elderly should be considered in the design orientation and demand stage. For example, Interactivity and Color mildness convey the friendliness of an intelligent elderly product, which is also the basic design principle of intelligent elderly products. Then in the product conceptual design stage, designers need to further tap into the actual needs of the elderly group. Designers should focus on the basic characteristics of the elderly group, and meet the actual needs of the elderly through design means, such as Companionship and Interest, and so on. Finally, in the stage of high rise design and detail design, designers can dig deep into the potential needs of the elderly group according to different product types and actively convey the charm attributes of intelligent elderly products, to better attract the elderly group.

The research results show that the application of humanistic care factors of intelligent elderly product design, the weight of Application of humanistic care factors in emotion is as high as 52%, followed by the weight of CMF as high as 24%, followed by modeling and function. At the sub-level, the weight of Interactivity and Color mildness is the highest 22% and 14% respectively. However, due to the particularity of the elderly group, many intelligent elderly products have little difference in Interactivity and Color mildness, and there is little room for designers to improve. The HFAHD in the actual design application, designers should take the first level as the basic requirement. The focus of the whole design should be on other levels with more room for improvement. Through the evaluation of the case, although the comprehensive evaluation score of Case 3 is second only to the highest score of Case 2, the specific analysis shows that the highest score of Case 3 in the sub-level is the Application of humanistic care factors in function. This is just the opposite of the lowest weight of the Application of humanistic care factors in function in the research results. Through specific analysis, the biggest highlight of Case 3 compared with the other two products is the particularity of its function, which also explains that Case 3 has the highest score in function. At the same time, it also shows that the HFAHD also has some defects, for the intelligent elderly products focusing on a special aspect, the use of the HFAHD needs more specific analysis. Generally speaking, the HFAHD can provide effective guidance for the design of ordinary intelligent elderly products, but for some special products or special elderly groups, the specific application also needs to consider the actual application. In addition, there is a small amount of subjectivity due to the inclusion of qualitative research methods in the research process.

For the development of intelligent elderly product, the HFAHD has injected new blood into the theory and method of intelligent elderly product design, and also provided some reference for designers at different levels to use humanistic care factors in the design process of intelligent elderly products. And because the core of the HFAHD is to pay attention to the psychological needs of users, in further research in the future, the HFAHD can also be applied to other product designs that pay attention to the psychological needs of users, such as children product design, medical and health product design, etc. In this kind of research field, the psychological needs of users are the focus that designers need to pay attention to. Therefore, designers can use the HFAHD to analyze the psychological needs

of users and their importance ranking for different user groups, and build a hierarchical design method model that can be applied to this field.

7. Conclusion

In this paper, based on the background of global aging, through the grounded theory and ANP, the HFAHD for intelligent elderly products is proposed, which enriches the theory and method of intelligent elderly product design. And it provides a more standardized application standard for different levels of designers to use humanistic care factors in the design process of intelligent elderly products. Through the evaluation of the HFAHD by the fuzzy evaluation method, It proves that the HFAHD has certainly practical guiding significance for the design of intelligent elderly products. And compared with the traditional research methods of intelligent elderly product design, this study takes humanistic care as the core throughout the design stage and makes a comprehensive study from the aspects of function, modeling, CMF, and emotion. Based on the rigorous mathematical model analysis, the HFAHD is proposed. It makes the application of humanistic care factors in the design process of intelligent elderly products simpler, and also standardizes the application standards of humanistic care factors for designers at different levels. It helps designers to design more humanized intelligent elderly products in modern society. The aim is to promote the elderly to be more integrated into modern social life and promote the social development of active aging to a certain extent, and it can also extend this method to other similar product design-related processes. In general, although this study has certain guiding significance for the application of humanistic care factors in the design of intelligent elderly products, there are also some limitations. So to enhance the science of the HFAHD, it needs to further study and continuously optimize the HFAHD with the change of the needs of elderly users.

Although this research can improve and standardize the application of humanistic care factors in the design of intelligent elderly products, several limitations also apply. First, due to the development of new materials and new technologies, the iterative speed of intelligent product update is fast. The HFAHD proposed in this study may not be able to keep up with the development of intelligent elderly products on the market in the future. Therefore, in future work, it is necessary to understand the development and application of new materials and new technologies in time, to integrate new elements into the HFAHD. Second, with the development of the times, the elderly needs for humanistic care will also change over time. Therefore, in future work, it is necessary to regularly understand the changes in the elderly psychological needs and make timely adjustments to the HFAHD. Lastly, in the research related to product design, limited data were found in the literature on humanistic care, and more people tend to focus on nursing and environment fields. Therefore, a more comprehensive comparative analysis cannot be carried out. This, from another point of view, highlights the importance of this pioneering research.

Author contribution statement

Zhengjun Zhou: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ling Wang: Performed the experiments.

Runhan Ye: Analyzed and interpreted the data.

Han Yue: Performed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

No data was used for the research described in the article.

Declaration of interest's statement

The authors declare no conflict of interest.

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