Integrating Kansei Engineering, Analytic Hierarchy Process, and Quality Function Development in Elderly-Oriented Seating Design

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To deeply understand the psychological and emotional needs of the elderly population, this study proposes a seat design method combining Kansei engineering (KE), analytic hierarchy process (AHP), and quality function development (QFD). The method aims to fulfill the functional needs of the seat and focuses on capturing the emotional imagery of the elderly group, thus enhancing the emotional experience of the users. Factor analysis (FA) was used to conceptualize the user's perceptual vocabulary data, AHP to assess the relative importance of these perceptual words, and morphological analysis to deconstruct the characteristics of the seat components. Finally, the mapping relationship between user perceptual data and design features was established through QFD. The FA and AHP results showed that the emotional needs of the elderly for seating are primarily focused on the sense of lightness (32.5%), simplicity (45.7%), and sophistication (21.8%); and QFD analysis results show that among seating components, the No. 6 seat back, No. 1 seat cushion, No. 2 door post, and No. 2 seat leg have the highest importance and can best meet the emotional needs of elderly users. This design method effectively improves the product's suitability for the elderly and provides a valuable reference for related product design.

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INTRODUCTION

With the increasing trend of global population aging, there is a growing demand for comfortable, safe, and convenient furniture for the elderly. Elderly-oriented seating design has received widespread attention as an essential tool to enhance the quality of life of older adults (Zhou *et al.* 2020). Existing elderly-oriented seating designs mainly focus on ergonomic optimization to meet the diverse needs of the elderly in terms of health functions, such as how to alleviate the discomfort caused by rheumatism, arthritis, *etc*., as well as providing additional support for obese users, or even providing a convenient transition design for those who rely on walkers or wheelchairs. Although functional design can meet the physiological needs of some older people, purely functional solutions often ignore the unique emotional and psychological needs of the elderly, resulting in products lack of attraction and emotional resonance during use. Therefore, how to achieve a balance between functional and emotional design remains a challenge in elderly-oriented design.

Although some progress has been made in the elderly-oriented product design in recent years, for example, Zhang *et al.* (2023) deeply analyzed the design characteristics of seats for the elderly, applied the analytic hierarchy process (AHP), the quality function development (QFD), and the axiomatic design (AD) method, and verified the validity of these methods in the optimization design, which provided a solid theoretical foundation for the development of future elderly-oriented seats. Juliá *et al.* (2020) introduced multi-sensory experiences in design, showing that appropriate materials and shapes could evoke emotional resonance in the elderly users. It can stimulate positive feelings about the past life of the elderly and enhance their emotional attachment to the product. These studies reveal the needs of the elderly for perceptual design elements. However, how to accurately incorporate the emotional needs of the elderly for sensory elements such as color, form, and material into the design is still a research gap that needs to be addressed. Therefore, how to build a set of scientific optimization methods based on the Kansei Engineering (KE) method to combine emotion and function for the elderly-oriented seating design has become an important entry point for this study.

Kansei engineering is an interdisciplinary approach that aims to integrate users' perceptions, emotions, and experiences into the design process of products and services (Jiao and Qu 2019), by analyzing users' emotional responses to sensory elements such as product appearance, texture, *etc.*, which helps designers to go beyond functionality to further enhance the emotional appeal and user experience of products (Hu *et al.* 2022). Wang *et al.* (2022) pointed out in their study that elderly-friendly furniture design not only needs to focus on the functional needs, but it should also focus on perceptual elements, such as color, form, and material, to enhance the emotional connection of elderly users to the furniture, thus improving the overall use experience. López *et al.* (2021) explored how to use KE methods to identify and satisfy the psychological and emotional needs of elderly users through the study of perceptual needs in the design of furniture for the elderly, which provides a strong theoretical support for the design of furniture for the elderly. The AHP is a multi-criteria decision analysis method for solving complex problems in which multiple factors and various choices need to be considered. The method was developed by Thomas L. Saaty in 1970 to help decision makers weigh and compare different factors to make the best choice (Albayrak and Erensal 2004). Li *et al.* (2024) combined AHP with QFD to explore the key factors in elderly-oriented product design. Through the hierarchical analysis of AHP, the priorities in product design were identified, which provided a systematic design process for elderly-oriented design. Chen *et al.* (2023) used the AHP method to assess the adaptive needs of smart home systems for the elderly, which provides a new idea for the development of intelligent elderly-oriented products. The QFD is a quality management tool that aims to translate customer needs into specific product or service design requirements (Andronikidis *et al.* 2009). Wang *et al.* (2023) constructed a relationship mapping model between perceptual imagery and morphological elements, which fully demonstrates the effectiveness of QFD in translating users' emotional needs. Zeng *et al.* (2024) further demonstrated the important role of QFD tools in elderly-oriented design by measuring, ranking, and selecting the perceptual elements of the elderly through QFD, and translating these elements into specific product design features to identify key elderly-oriented design elements.

This study aimed to establish a design framework for the emotional needs of elderly users by combining the design methods of KE, AHP and QFD in order to build a multidimensional and multilevel design process, which will provide a new perspective to enhance the dual appeal of emotion and function of the elderly-oriented seats. The innovations of this paper include: 1) Introducing KE into the elderly-oriented seating design to build emotional connection and enhance the user acceptance and satisfaction of the product; 2) Proposing the method combining KE-AHP-QFD to realize the multilevel design optimization from perceptual to functional; 3) Expanding the scope of the design of elderly-oriented products, and enlarging the focus from pure functionality to the aesthetic sense of the product, psychological comfort, and adaptability of the home. The construction of this framework not only helps to improve the quality of daily life for the elderly, but also provides scientific and humanized guidance for the future elderly-oriented product design, thus positively promoting the field of furniture design for the elderly.

EXPERIMENTAL

Experimental Processes

To systematically explore and resolve the multidimensional needs of the elderly in seating design, this paper proposes a design framework that combines KE, AHP, and QFD. The framework aims to optimize the elderly-oriented seating design from perceptual to functional requirements through a scientific and comprehensive approach. Finally, QFD, as a systematic design tool, can transform user needs into specific design features.

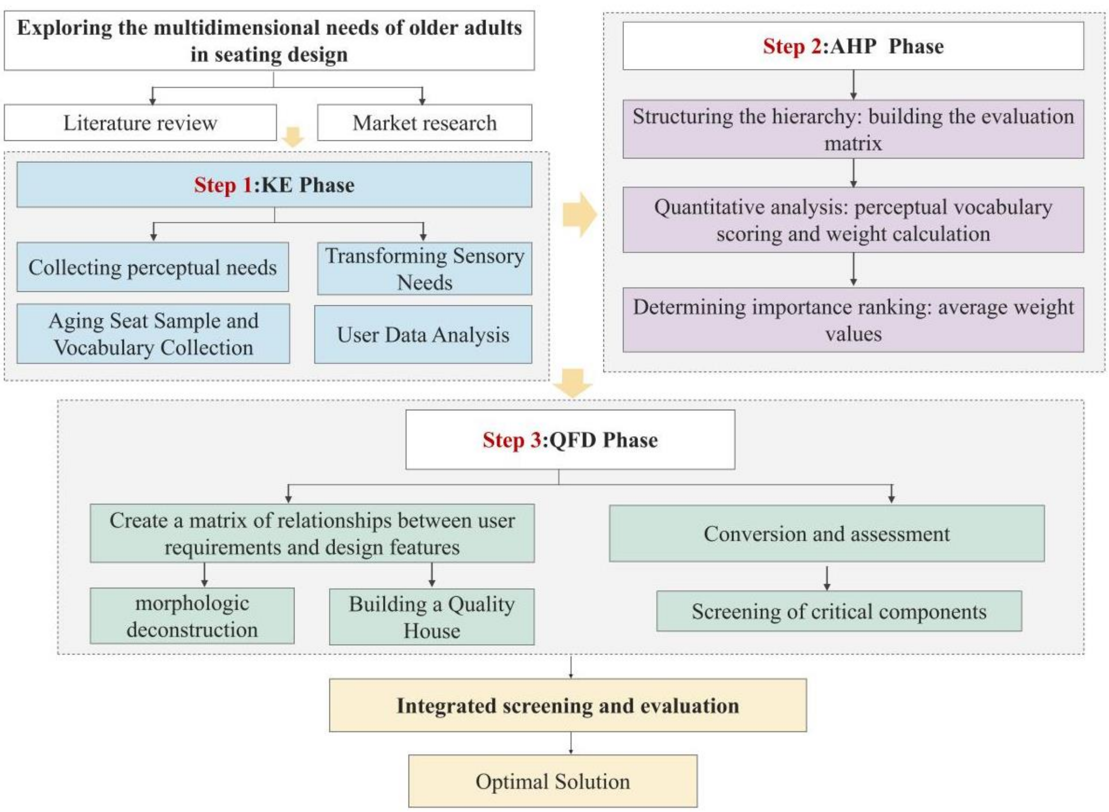

Fig. 1. Flowchart of experimental process

Firstly, Kansei Engineering, as an interdisciplinary design approach, provided guidance for seating design based on user experience by studying users' emotional responses and perceived preferences (Wang *et al.* 2024). In this study, KE was used to collect the emotional needs of elderly users for seating design and translate these perceptual needs into specific design elements. Secondly, analytic hierarchy process was used to determine the relative importance of each design element. In the framework of this study, AHP helps in quantitatively analyzing the perceptual needs and functional needs so as to ensure that the weights of each factor in the design are reasonably distributed, thus achieving the optimization of the design solution. Through QFD, the authors were able to correspond the perceptual needs of elderly users to the product form elements to ensure that the seating design not only met the ergonomic requirements, but also satisfied the psychological and emotional needs of elderly users (Wang *et al.* 2022).

In summary, the research framework proposed in this paper forms a bottom-up design process by combining three methods: KE, AHP, and QFD. Under this framework, the emotional and functional needs of elderly users are fully considered and integrated, which provides a practical and innovative theoretical support for the elderly-oriented seating design, as shown in Fig. 1.

Collection of Elderly-oriented Seat Samples and Vocabulary

An extensive collection of elderly-oriented seats was conducted through age-appropriate websites, furniture websites, and Google search engine's image gallery to establish a sample library of elderly-oriented seats. To prevent visual fatigue caused by many samples, which in turn affects the accuracy of the test results, it is necessary to select and optimize the sample set of the elderly-oriented seats, including removing samples with unclear pixels and background interference, to reduce the interference with the visual perception of the test subjects. In terms of sample selection criteria, this study identified three core criteria of simplicity, comfort, and ease of use for selecting a sample of elderly-oriented seats based on a literature review.

Fig. 2. Seat modeling sample library

Next, a group of focus groups consisting of elderly user representatives, design experts and researchers were convened to conduct in-depth discussions and evaluations around these criteria. Focus group members selected 16 images of seat shapes suitable for this study from the initial sample set, which were able to represent, to some extent, the main trends and characteristics of elderly-oriented seating design, and thus constructed a library of seat shape samples that met the needs of the study, as shown in Fig. 2.

User Research on Elderly-Oriented Seats

User research on elderly-oriented seating design is a critical step to ensure that the design can truly meet the needs and expectations of elderly users. In this study, through a synthesized research methodology, the design team can more comprehensively and accurately understand the needs and use scenarios of the elderly users, and thus effectively guide the design process of the elderly-oriented seat. The research was separated into three main objectives.

1. The target user group is clear: The target user group of elderly-oriented seats includes specific age groups, health conditions and lifestyle characteristics, in order to more effectively identify their needs and design products that meet the actual situation. The target group of this study was set to be elderly people over 50 years old, and the specific demographic characteristics are shown in Fig. 3. The source of data was the questionnaire survey of the target user group, which covered the information of gender, age distribution, and health status, *etc*. In terms of gender distribution, females accounted for 64% and males 36%; in terms of age distribution, people aged 50 to 60 accounted for 17%, 60 to 70 accounted for 36%, 70 to 80 accounted for 31%, and over 80 accounted for 16%. These data provided strong support for understanding the needs and preferences of the elderly in different age groups.

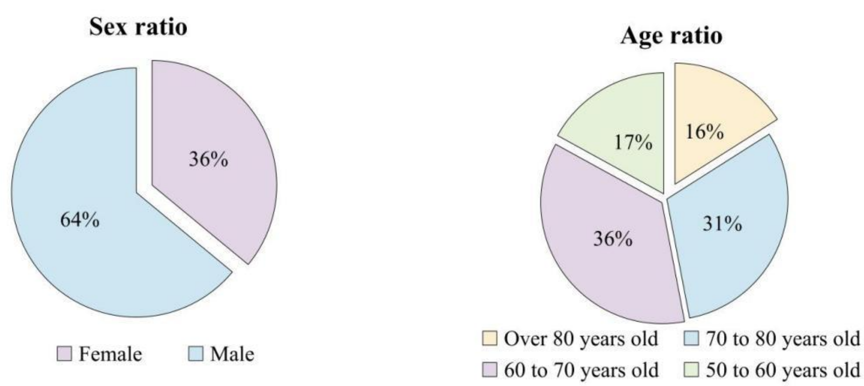

Fig. 3. Demographic characteristics

2. In-depth understanding of user needs: Conduct in-depth research on user needs, including seating use scenarios, use frequency, use duration, seating function needs, and other aspects. Through face-to-face interviews, questionnaire surveys, or participatory observation, the lifestyles and seating usage habits of elderly users can be understood.

3. Kansei Engineering Research: The seating design research was conducted to understand elderly users' perceptions, emotions, and experiences of seating design. The process identified their preferences for seating appearance, touch, and color, as well as the emotional connections associated with the seats. In this paper, the perceptual imagery

research on elderly users was conducted with the primary objective of collecting users' imagery vocabulary for this type of product, thus providing important implications for the subsequent collection of perceptual vocabulary. Through identifying key perceptual vocabulary, enriching the perceptual vocabulary base, guiding the collection methodology, and optimizing the choices, design creators could better understand and satisfy the perceptual needs of users, thus improving the quality of the design and enhancing user satisfaction.

Data Analysis of Elderly-oriented Seating Users

Through user research and group discussion, 28 sensory vocabularies were collected describing the elderly-oriented seats from the user research of the elderly-oriented seats. At the same time, 15 design creators with relevant elderly-oriented design background were invited to conduct a secondary selection of these perceptual words, removing meaningless vocabularies and terms with similar meanings, and finally selecting the 8 most representative perceptual terms for elderly-oriented seats (simplicity, vintage, neatness, lightness, freshness, elegance, comfort, and agility), as shown in Table 1.

Table 1. Perceptual Vocabulary of Elderly-Oriented Seating Design

Simplicity	Vintage	Neatness	Lightness
Freshness	Elegance	Comfort	Agility

Table 2. Matrix of Perceptual Imagery for Elderly-Oriented Seating Design

	Simplicity	Vintage	Neatness	Lightness	Freshness	Elegance	Comfort	Agility
1	3.82	1.87	3.92	3.65	2.23	4.56	3.97	2.87
2	4.02	2.24	3.67	3.66	2.89	2.45	3.56	1.87
3	2.56	4.15	3.89	3.78	3.67	4.02	4.12	4.45
4	3.78	1.87	4.21	3.78	3.98	3.35	3.98	3.78
5	2.32	4.02	2.92	2.76	1.77	1.78	3.78	3.32
6	3.98	2.78	4.56	2.63	3.23	4.02	4.07	1.78
7	3.04	2.34	3.75	3.95	2.76	3.32	4.02	4.25
8	3.44	4.06	3.89	2.89	2.97	3.67	2.34	3.91
9	3.73	3.79	4.35	4.45	4.06	3.45	2.84	3.02
10	3.25	3.84	3.78	2.85	3.05	3.56	2.98	3.93
11	3.97	1.86	4.43	4.45	3.78	2.45	1.78	3.71
12	3.67	2.45	2.67	2.32	2.26	3.35	4.34	1.84
13	3.45	4.47	3.67	2.45	2.21	2.16	3.02	3.56
14	1.56	4.58	2.65	2.52	2.56	2.67	2.77	3.67
15	3.32	3.37	3.67	2.76	2.17	1.76	3.79	2.29
16	3.78	3.82	3.02	4.62	4.02	3.59	3.06	4.59

In order to ensure the representativeness of the sample data and the robustness of the findings, 70 questionnaires were publicly distributed in the form of the 5-point Likert scale and evaluated 8 vocabularies and 16 samples of elderly-oriented seats selected. Among them, 1 term did not match the sample, 3 terms matched the sample, and 5 terms strongly matched the sample. Finally, 67 valid questionnaires were collected, and accordingly, the average score of the perceptual vocabulary corresponding to each seat sample was calculated to construct the evaluation matrix of user perceptual imagery, which is shown in Table 2.

To remove the information load caused by too much data and ensure the efficiency of the subsequent design research, the data analysis software SPSS (IBM Corp, version 25.0.0.0, Armonk, NY, USA) was adopted to process the user data and used factor analysis to downscale the user perceptual vocabulary. The "Kaiser-Meyer-Olkin" (KMO) measure and Bartlett's test of sphericity showed (Table 3) that the score of the KMO sampling aptness measure was 0.631 > 0.5, and the significance was 0.033 < 0.05, which indicates that the data can be analyzed by factor analysis.

Table 3. KMO and Bartlett's Test of Sphericity

KMO Sample Suitability Quantity		0.631
Bartlett's test of sphericity	Chi-square approximations	43.235
	Degrees of freedom	28
	Significance	0.033

The factor fragmentation diagram (Fig. 4) analyzed by SPSS showed that the component eigenvalue of factor 1 was the largest, and 1 had the highest contribution to the interpretation of the original variables, followed by component 2 and component 3. The fold trend in the fragmentation diagram was gradually flattening from the 4th factor eigenpoint, which indicated that the eigenvalues of the factors thereafter were gradually becoming smaller. It also indicated that all factors from the 4th factor onwards contributed less to the overall variable in the fragmentation diagram, suggesting that it is more appropriate to extract 3 male factors. In the total variance explained (Table 4), there were 3 factors with a cumulative contribution of 77.09%, which shows that it is possible to downsize this dataset into 3 perceptual vocabulary factors.

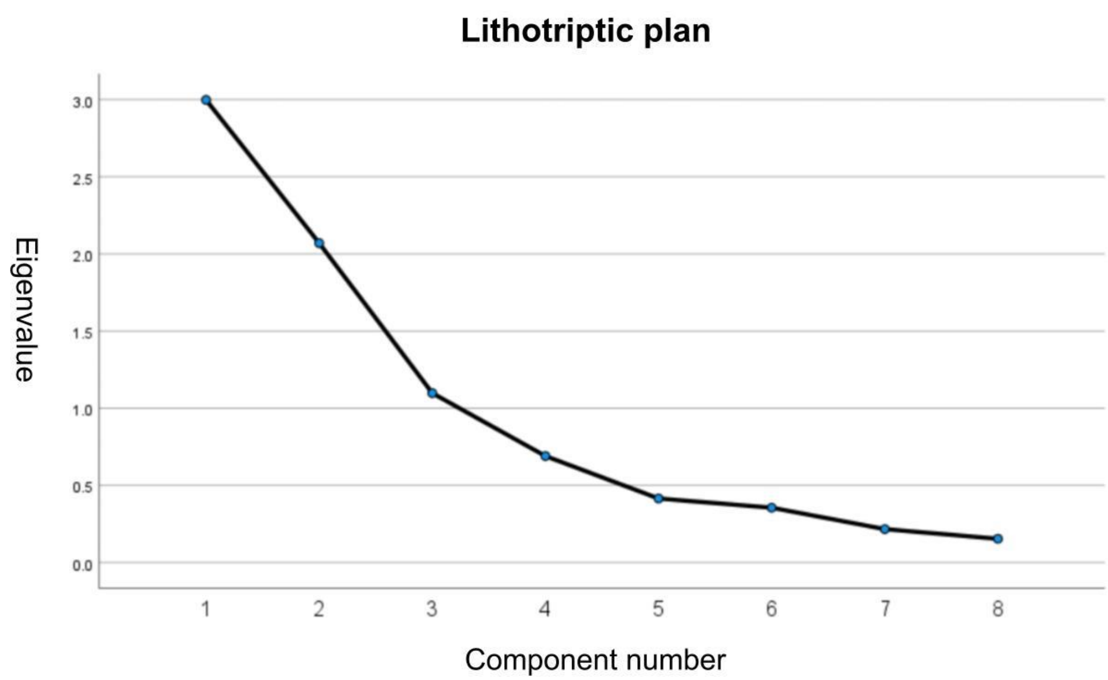

Fig. 4. Factor fragmentation diagram

Table 4. Total Variance Explained

	Initial Eigenvalue			Extract the Sum of Squares			Rotational Load Sum of Squares		
Element	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	2.998	37.479	37.479	2.998	37.479	37.479	2.601	32.517	32.517
2	2.070	25.880	63.360	2.070	25.880	25.880	2.308	28.850	61.367
3	1.098	13.728	77.087	1.098	13.728	13.728	1.258	15.720	77.087
4	0.691	8.633	85.720						
5	0.415	5.193	90.913						
6	0.356	4.446	95.359						
7	0.217	2.712	98.071						
8	0.154	1.929	10.000						

The Kaiser variance maximization method was applied to orthogonal rotation of the user data, and the calculated results are displayed in Table 5. To simplify the visual presentation, factors with absolute values less than 0.5 were left blank. The authors extracted 3 factors with the largest contribution. The first type of factor consisted of lightness, freshness, and agility, the second type of factor consisted of vintage, neatness, and simplicity, and the third type of factor consisted of elegance and comfort. The first type of factor represents a sense of lightness with the name of lightness; the second type of factor represents a sense of simplicity with the name of simplicity; and the third type of factor represents a sense of exquisite with the name of exquisite.

Table 5. Component Matrix After Rotation

	1	2	3
Vintage		-0.802	
Neatness		0.626	
Lightness	0.813		
Freshness	0.883		
Elegance			0.730
Comfort			0.805
Agility	0.683	-0.604	
Simplicity		0.882	

Weight Calculation of Perceptual Vocabularies for Elderly-oriented Seats

According to the results of the factor analysis method, the eight vocabularies of user perceptual imagery were downscaled to three perceptual factors, and the AHP hierarchical model of the elderly-oriented seats was constructed (Fig. 5). The AHP method was used to establish an importance evaluation matrix for the perceptual vocabulary of the users of elderly-oriented seating design. Within each level, decision makers need to compare the relative importance between different factors. This is usually accomplished by completing a comparison matrix in which each factor is compared with the others one-by-one and a scale (usually with a number from 1 to 9) is used to indicate the relative importance between them. Five furniture design creators were invited with experience in furniture design to evaluate user perceptual needs according to the scale in Table 6.

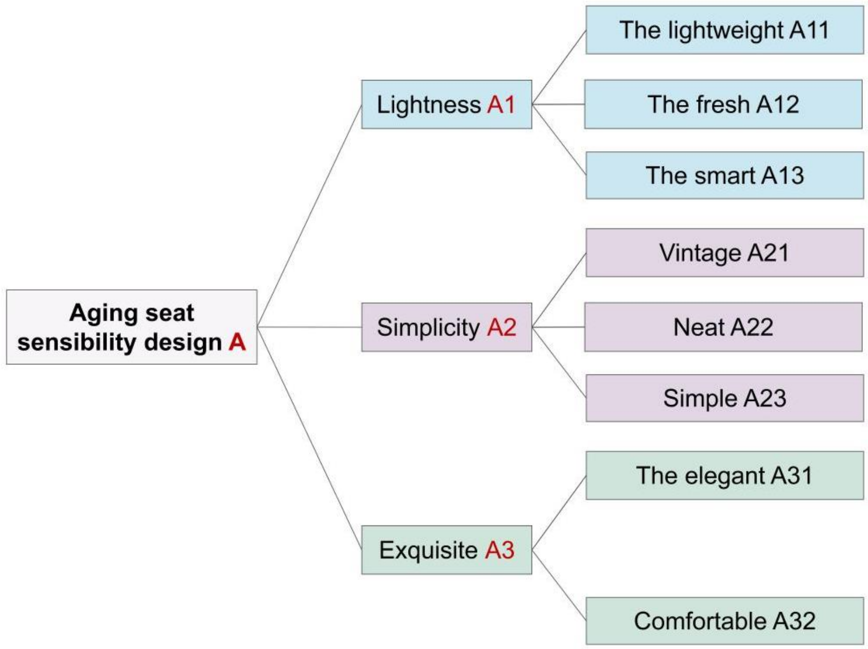

Fig. 5. AHP hierarchy table for elderly-oriented seats

Table 6. 1 to 9-point Scale Method

Scale	Connotation
1	The former is as important as the latter
3	The former is slightly more important than the latter
5	The former is clearly more important than the latter
7	The former is strongly more important than the latter
9	The former is extremely more important than the latter
2, 4, 6, 8	The median of two adjacent factor judgments
Inverse of the above value	The inverse comparison of the two factors is the reciprocal of the original comparison value

To ensure the consistency of the matrix, a consistency test (Eqs. 1 through 3) is also necessary to evaluate the relative importance of the perceptual vocabulary of the elderly-oriented seats. If the consistency test fails, the decision maker needs to re-evaluate and revise the comparison.

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nw_i} \tag{1}$$

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

$$CR = \frac{CI}{RI} \tag{3}$$

In the consistency assessment process of judgment matrix, *n* denotes the order of the judgment matrix, AW is the product of the judgment matrix and the weight vector, 'max' denotes the maximum eigenvalue, *CI* stands for consistency index, *RI* is random consistency index (see Table 7), and *CR* is random consistency ratio. If the *CR* value of the judgment matrix is less than 0.1, this indicates that the judgment matrix satisfies the consistency requirement, thus indicating that the data are valid. AHP has been widely used in multiple fields, including engineering, economics, environmental management, and healthcare. It provides a systematic approach to help decision makers consider multiple factors and complex issues to make more accurate and rational decisions.

Table 7. Random Consistency Indicators

Matrix Order	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

To reduce the complexity of evaluation and improve the efficiency of decision-making, the furniture design experts were mainly invited to evaluate the importance of the perceptual vocabulary after the second level of dimensionality reduction. The scores and weight calculations of each perceptual vocabulary of elderly-oriented seating design by the five design creators are shown in Tables 8 through 12.

Table 8. Designer 1 Scoring and Weighting

A	A1	A2	A3	Weight (w)%
A1	1	1/2	4	33.394
A2	2	1	5	56.787
A3	1/4	1/5	1	9.819

Based on the calculations, the consistency test was passed with *CI* = 0.012 and *CR* = 0.023 < 0.1.

Table 9. Designer 2 Scoring and Weighting

A	A1	A2	A3	Weight (w)%
A1	1	1/3	1/3	14.156
A2	3	1	1/2	33.377
A3	3	2	1	52.468

Based on the calculations, it can be seen that the consistency test was passed with *CI* = 0.027 and *CR* = 0.051 < 0.1.

Table 10. Designer 3 Scoring and Weighting

A	A1	A2	A3	Weight (w)%
A1	1	1/5	2	19.25
A2	5	1	4	67.677
A3	1/2	1/4	1	13.073

Based on the calculations, it can be seen that the consistency test was passed with *CI* = 0.047 and *CR* = 0.09 < 0.1.

Table 11. Designer 4 Scoring and Weighting

A	A1	A2	A3	Weight (w)%
A1	1	2	4	57.937
A2	1/2	1	1	23.413
A3	1/4	1	1	18.651

Based on the calculations, it can be seen that the consistency test was passed with *CI* = 0.027 and *CR* = 0.051 < 0.1.

Table 12. Designer 5 Scoring and Weighting

A	A1	A2	A3	Weight (w)%
A1	1	1	2	37.672
A2	1	1	4	47.196
A3	1/2	1/4	1	15.132

Based on the calculations, it can be seen that the consistency test was passed with *CI* = 0.027 and *CR* = 0.051 < 0.1.

The authors sorted the weight values calculated by each expert for each indicator by mean and calculated the eigenvectors and eigenvalues using Eqs. 4 through 6 to find the evaluation weights of each indicator, which is shown in Table 13.

$$V_i = \sqrt[n]{\prod_{i}^{n} a_{ij}} \tag{4}$$

$$w_i = \frac{\sqrt[n]{\prod_{i}^{n} a_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{i}^{n} a_{ij}}} \tag{5}$$

$$W = \left(w_1 w_2, \ldots w_n\right)^T \tag{6}$$

In this formula, V_i denotes the i-th component in the eigenvector of the judgment matrix corresponding to the maximum eigenvalue λ_{max}, a_{ij} denotes the importance ratio of the factor relative to the factor, n denotes the order of the judgment matrix, W denotes the weight vector, and w_i denotes the final weight of each factor.

The eigenvectors and eigenvalues were calculated, and the evaluation weights of each index were determined. Among them, simplicity was rated as the most important design feature, with an average weight of 45.7%, indicating its central position in the elderly-oriented seating design, followed by lightness, with an average weight of 32.5%, and sophistication was given a relatively low weight of 21.8%. These weights revealed the experts' ranking of the importance of different sensory indicators in the elderly-oriented seating design, which could help to guide the direction of design optimization, as shown in Table 13.

Table 13. Average Weight Value

	Expert1	Expert2	Expert3	Expert4	Expert5	**Average Weight**
Lightness	33.394	14.156	19.25	57.937	37.672	32.48
Simplicity	56.787	33.377	67.677	23.413	47.196	45.69
Sophistication	9.819	52.468	13.073	18.651	15.132	21.83

Morphological Deconstruction of Elderly-oriented Seats

Morphological deconstruction in Kansei Engineering is an important approach that focuses on analyzing and understanding the impact of individual forms of a product on people's emotions and perceptions. This method is commonly used in the design process to enhance the aesthetic value and user experience of a product. The morphology of existing products was analyzed in detail, including the impact of their lines and shapes on users' emotions and perceptions, as shown in Fig. 6.

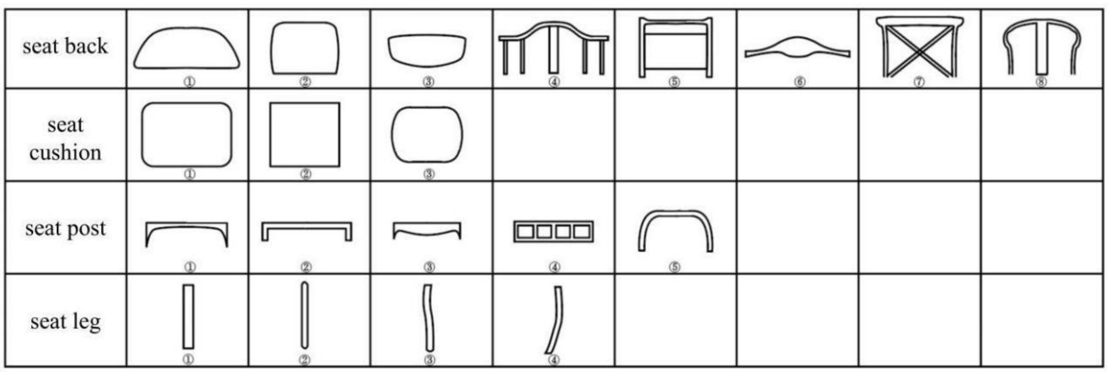

Fig. 6. Morphological deconstruction table

User Perceptual Mapping for QFD

The mapping model between users' perceptual imagery and the design form of the elderly-oriented seat was established using QFD house of quality, which can be used in the elderly-oriented seating design to better understand and integrate the users' perceptual needs and translate these needs into specific design parameters, and can also help the design creators to better understand and integrate these needs and translate them into feasible design decisions. The authors used the correlation scoring rules in Table 14 to connect user perceptual imagery with the design features of the elderly-oriented seat. In the table, the △ symbol represents a weak correlation between the design feature and the user perceptual vocabulary, the ○ symbol represents a moderate correlation between the design feature and the user perceptual vocabulary, and the ● represents a strong correlation.

Table 14. Quality House Correlation Meets Extreme Meaning

Relevant Symbol	Correlation Expression	Score
△	Weak correlation	3
○	Moderate correlation	5
●	Strong correlation	7

In this study, five elderly users were invited to discuss with five design creators who had experience in designing elderly-oriented furniture to score the degree of correlation between the constructed morphological features of elderly-oriented seats and the vocabulary of the users' perceptual imagery. Through evaluating the importance of the user's perceptual needs and design component features, the weight of each product component feature can be calculated, which helps to determine which components most symbolize the user's perceptual imagery. The constructed matrix model of quality house was based on Eqs. 8 and 9,

$$W_j = \sum_{i=1}^{q} W_i P_{ij} \tag{8}$$

$$W_K = \frac{W_j}{\sum_{i=1}^{q} W_j} \tag{9}$$

where W_j is the absolute weight value of the quality house, W_i is the perceptual semantic weight value calculated by AHP, P_{ij} is the correlation value, and W_K is the relative weight value of the quality house. QFD is commonly used in the manufacturing and service industries to ensure that the products or services are consistent with the customer's needs (Wang *et al.* 2023), which could help to improve the quality of the products or services, their reliability, and reduce the number of unnecessary design and production errors, as well as improving collaboration and communication within teams (Sohn and Choi 2001).

The weighting data of user perceptual vocabulary was transformed into weighting data of elderly-oriented seating design by constructing the HOQ quality house, as shown in Fig. 7.

	Component feature	seat back								seat cushion			seat post					seat leg			
Perceptual image weight (%)		1	2	3	4	5	6	7	8	1	2	3	1	2	3	4	5	1	2	3	4
lightness	32.48	○	△	○	△	△	●	△	●	○	△	●	●	△	●	△	●	●	○	●	●
Sense of simplicity	45.69	○	●	△	△	△	●	△	△	●	●	○	○	●	△	△	○	○	●	○	○
refinement	21.83	○	○	○	●	●	○	△	○	●	○	○	○	●	○	●	△	○	●	○	○
Absolute weight		500	526.4	408.6	387.3	387.3	656.3	300	473.6	635	526.4	564.9	564.9	570	473.6	387.3	521.3	564.9	635	564.9	564.9
Relative weight (%)		4.9	5.2	4	3.8	3.8	6.4	2.9	4.6	6.2	5.2	5.5	5.5	5.6	4.6	3.8	5.1	5.5	6.2	5.5	5.5

Fig. 7. Kansei imagery transformation for quality house users

Through the weight calculation of the quality house, it could help the designer to filter the important parts and improve the science and rationality of decision-making. As can be seen from Fig. 6, among the morphological components of seat back, No. 6 had the highest weight value of seat back (6.4%), among the morphological components of seat cushion, No. 1 had the highest weight value (6.2%), among the morphological components of seat post, No. 2 has the highest weight value (5.6%), and among the morphological components of seat leg, No. 2 had the highest weight value of seat leg (6.2%).

DESIGN PRACTICE AND DISCUSSION

Design Results

The elderly-oriented seating design focused on the multi-level needs of the elderly group, with detailed considerations from physiological to psychological and functional to emotional aspects. To ensure comfort and practicality, the overall appearance of the seat was designed with warm wood materials and soft padding, which not only meets the aesthetic preferences of elderly users, but also optimizes safety and ease of use.

The design features of the seat included a thicker backrest, armrests and seat cushion, all padded to provide better support and comfort. These features emphasized the key principles of the design: providing the user with sufficient security to ensure adaptability in different physical conditions. At the same time, the design has taken into account the need to reduce the weight of the seat, making it easier for elderly users to move the seat when they need to, increasing their daily independence and ease of operation. Furthermore, sharp edges and corners were deliberately minimized to reduce the risk of injury from potential collisions. In addition, wood played an important emotional and functional role in this design, as its natural texture not only matched the aesthetic preferences of elderly users, but also enhanced psychological comfort and intimacy through its warm touch. The overall support of the seat was carefully designed to retain sufficient rigidity without cross-bracing to ensure a safe experience of use, as shown in Fig. 8.

Fig. 8. Aging-friendly seat design

Discussion

The design results reflect the effective integration of Kansei Engineering (KE), Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD) methods. By transforming the emotional needs of elderly users into design elements and relying on the QFD modeling system to map emotional needs to specific design features, this study makes progress in balancing the emotional and functional needs of elderly users.

1. Consistency and innovation with previous research: This study further refined the idea based on Kansei engineering, proposing to concretize the emotional needs of older adults through perceptual vocabulary (lightness, simplicity, sophistication) and mapping the emotional needs directly to the design of seating forms through QFD. This innovation is rarely mentioned in the existing literature, especially the breakthrough in the application methodology of how to refine the emotional vocabulary and map it to the design features.

2. Application and development of Kansei engineering: Kansei engineering plays a key role in understanding users' emotional responses and preferences. Specifically, this study used factor analysis to refine perceptual descriptors suitable for elderly users and to accurately portray user needs. This applied approach aligns with previous research on elderly-oriented products, which emphasizes the critical role of emotional needs in enhancing user experience. In this study, we further quantify the significance of these perceptual vocabularies by using AHP to systematically apply them to the design of seating for elderly users.

3. Use and safety of wood: This study focused on the use of wood in the elderly-oriented seating design. Wood has a high acceptance among elderly users due to its familiarity and good comfort. In addition, considering the safety of the joints, the design should focus on the dimensions of the leg supports to avoid potential chair failures. It is worth noting that the chair shown in the figure lacks cross members or diagonal supports, which are commonly used to enhance the stiffness and safety of chairs. Ensuring that the design is robust is critical to the safety of elderly users.

4. Effectiveness in the integration of multidisciplinary methods: The Analytic Hierarchy Process (AHP) in this study plays a key role in quantifying the importance of each design element, ensuring that the product meets the user's preferences while at the same time being practically feasible. By accurately mapping these emotional needs to specific design features through the QFD methodology, this study develops a systematic and user-centered approach to elderly-oriented design, which echoes the existing literature on elderly-oriented design.

This integrated approach supports the importance of balancing emotional and functional needs in elderly-oriented design. The findings suggest that focusing on the balance between these two aspects can lead to the design of elderly-oriented products that are both functional and emotionally appealing, providing new perspectives to further enhance the quality of life of older adults. Future research could reapply this analysis after interviewing more than 25 or 30 older adults and explore the diversity of chair designs for different sizes of older adults. By setting an older minimum age, it ensures that the design meets the specific needs of different elderly users and further explores the application of this design framework to other ageing-friendly products and its long-term impact on users' quality.

CONCLUSIONS

1. *Refinement of perceptual vocabulary:* The data on perceptual vocabulary were downgraded through factor analysis, and three core perceptual descriptors in the design of elderly-oriented seats were finally refined: lightness, simplicity, and sophistication. These descriptors not only accurately reflect the main emotional responses of elderly users when using the seats, but they also provide clear emotional guidance for design optimization. This finding helps designers to more effectively incorporate users' emotional needs into specific design features, laying a solid foundation for the development of elderly-oriented products.
2. *Weighting analysis of emotional features:* The identified core emotional descriptors were quantitatively analyzed for their relative importance through the analytic hierarchy process (AHP). The results show that simplicity was rated as the most important emotional feature with a weight of 45.7%, reflecting that elderly users have a high preference for the simplicity in seating design. The lightness followed with a weight of 32.5%, showing its secondary position in the emotional needs. And although the sophistication has some emotional appeal, its importance is relatively low, with a weight of only 21.8%.
3. *Morphological deconstruction and emotional matching:* Through the morphological deconstruction method, the morphological features of the elderly-oriented seats were analyzed and decomposed in depth. This process effectively identified key design

elements that are highly compatible with the emotional preferences of elderly users, providing a scientific basis for designers to establish a closer connection between the function of the seats and the emotional needs.

4. *QFD perceptual mapping analysis:* Through the Quality Function Deployment (QFD) method, users' perceptual cognition was accurately mapped to specific design features. The results show that the backrest of Model 6, the seat cushion of Model 1, as well as the armrests and legs of Model 2 received the highest weights in their respective categories, reflecting the consistency of these design elements with the perceptual expectations of elderly users. Based on this analysis, an optimized design solution for the elderly-oriented seat is proposed, which achieves a coordinated balance between functionality and emotional needs, and further enhances the applicability and user satisfaction of the product.

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