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Research on Human-Computer Interaction Interface Design of Electric Vehicles for Elderly Users

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Abstract. With the aggravation of population ageing in China, the elderly have become an important potential user group for intelligent transport products. As a green and low-carbon travelling mode, the aging-friendly design of human-machine interface (HMI) of electric vehicles needs to be solved urgently. This paper identifies the core needs of elderly users based on the KANO model, combines the AHP hierarchical analysis method to rank their needs, innovatively constructs a combined KANO-AHP evaluation method, and proposes a scientific and systematic optimisation path for the interaction interface. Through the combination of questionnaire research and expert evaluation, the study extracts design suggestions in four dimensions: interface information presentation, operation flow, feedback mechanism and emotional experience. The results of the study show that the interface design based on the user needs hierarchy can effectively improve the operation satisfaction, safety and sense of belonging of the elderly users, and provide a theoretical basis and practical reference for the interaction system of the ageing-adapted intelligent vehicle.

Keywords: Electric vehicles; Elderly users; Human-computer interface; KANO model; AHP; Ageing-friendly design

1. Introduction

China is accelerating into a deeply aging society, and according to the data of the seventh national census, as of 2021, the population aged 60 and above has reached 264 million, accounting for 18.7%. Under the trend of the elderly gradually becoming important transport participants, the interface design of intelligent travel products shows problems such as complex structure, heavy operation burden and weak feedback mechanism, which seriously affects the willingness of elderly users to use them and their safety and security. Electric vehicles are known for their high degree of intelligence and strong integration of interface interaction, but their operating systems are often designed to focus on young and middle-aged digital users, without fully taking into account the decline in visual perception, information recognition, hand dexterity, and cognitive memory of elderly users. Therefore, exploring a set of interface aging design paths based on users' real needs has become an important issue in industrial design and human factors engineering.

In recent years, the application of KANO model and AHP method in product demand identification and interface optimisation has gradually matured. For example, Jingyin et al[1]. constructed a model for the use of elderly electric vehicles on the basis of ‘driven by user demand’; Yan Shengzan successfully applied the KANO-AHP method to the design of service system for Alzheimer's patients, which showed that the integration of the dual-model for the special user groups is of great practical value; Han Liduo et al[2]. successfully applied the KANO-AHP-FCE method to the design of interface for college and university. -FCE method was successfully applied to the design and evaluation of modular desks and chairs for smart classrooms in universities, constructing a systematic path from user demand acquisition, attribute classification, weight ranking to comprehensive evaluation, fully reflecting the comprehensive decision-making advantages of the model in multi-scene, multi-role participatory design, and providing quantifiable and verifiable theoretical and practical support for educational furniture design.

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To sum up, this paper takes 'the interaction interface of electric vehicle for elderly users' as the research object, adopts KANO to identify the types of user needs, combines AHP to calculate the relative weights of various types of needs, puts forward the innovative application path of the KANO-AHP model in the interface of the elderly-friendly interface, and puts forward a set of implementable interface design suggestions on the basis of this. interface design suggestions.

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2. Theoretical Approach

2.1 Section KANO Model

The Kano model is a systematic product requirement analysis method proposed by Professor Noriaki Kano of Tokyo University of Technology in the 1980s, which aims to reveal the non-linear relationship between user satisfaction and product attributes. The model breaks the traditional linear perception of 'the better the function, the higher the satisfaction' and points out that user satisfaction and dissatisfaction are not opposites[3], but two relatively independent dimensions. That is to say, even if a product removes the factors that lead to user dissatisfaction, it may not significantly increase their satisfaction; similarly, enhancing certain satisfying features may have a limited impact on reducing dissatisfaction, as shown in Figure 1.

Kano model emphasises that in the process of actual use, users compare the functional performance of a product or service with their own expectations, thus forming a psychological reaction of satisfaction or dissatisfaction, which is often not absolute, but is the result of the joint action of many factors. In order to better guide the design and improvement of the product, the Kano model divides the user requirements into five types:

Must- be Requirements: This is the product's ability to meet the user's needs. Must- be Requirements: These are basic functions that exist by default, and their absence will cause strong dissatisfaction, but their existence will not significantly increase satisfaction;

One-dimensional Requirements: The more complete these functions are, the higher the user satisfaction, and vice versa, leading to dissatisfaction, with a linear positive correlation;

Attractive Requirements: These are functions that can be used to improve product design and improvement, and they can be used to improve product design and improvement. Attractive Requirements: those features that are beyond users' expectations and unexpected, if they are available, they will significantly increase satisfaction, while their absence will not lead to dissatisfaction;

Indifferent Requirements: no matter whether the feature exists or not, it will have little effect on user satisfaction;

Reverse Requirements: some features will significantly increase user satisfaction, while their absence will not lead to dissatisfaction. Reverse Requirements: the presence of certain features may reduce satisfaction, possibly due to the variability of user needs or inconsistencies in the context of use.

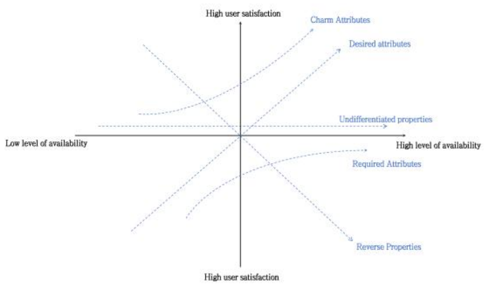

Fig. 1 Kano model

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2.2 AHP Hierarchical Analysis

Analysis of Hierarchy (AHP) is a multi-criteria decision-making tool proposed by Thomas Saaty, an American operations research expert, in the 1970s, aiming to effectively deal with multi-objective and complex structure decision-making problems[4]. The method combines the advantages of qualitative judgement and quantitative analysis, and is able to improve the scientificity and precision of overall decision-making through structured modelling and systematic evaluation. Usually through the construction of a multi-level structural model, the complex problem is decomposed into a number of manageable components, forming a three-layer decision-making architecture consisting of the goal layer, criterion layer and solution layer. During the analysis process, the decision-maker needs to establish a pairwise comparative judgement matrix, score the relative importance of each evaluation factor, and use mathematical methods to calculate the weight values, and ultimately ensure that the judgement is logically reasonable through the consistency test[5].

2.3 An Innovative Application of the Combined KANO-AHP Methodology

KANO model and AHP method have a solid theoretical foundation in the field of user needs identification and multi-criteria decision analysis. KANO model helps to reveal the non-linear influence mechanism of user satisfaction and deeply understand the complexity of the demand hierarchy by classifying user needs into essential, desired and charismatic, while AHP method takes hierarchical modelling as the core and calculates the weights of indicators by pairwise comparison to provide a scientific quantitative analysis framework for multi-dimensional problems. index weights with the help of pairwise comparison, providing a scientific quantitative analysis framework for multidimensional problems. The innovation of this study is to combine the KANO model with the AHP method and systematically apply it to the demand analysis and design optimisation of the human-machine interaction interface of electric vehicles for elderly users, which is still rare in the current relevant research. The study firstly used the KANO model to identify the key requirements of the elderly in EV interaction[6], and then structured the ranking of these requirements with the help of the AHP method to quantify their relative weights in user satisfaction. This integration process not only achieves the identification of requirements, but also enhances the precision of decision-making and operational guidance in the design process.

The main contribution of this study is to construct a more detailed and systematic user requirement modelling path, which effectively improves the scientific and practicality of ageing-friendly interactive interface design. Meanwhile, it also provides a strong empirical reference for the application of KANO-AHP method in complex interactive systems. Future research can further extend the versatility of the method in different socio-cultural contexts, or explore its potential in dynamic user behaviour modelling and real-time optimisation by combining artificial intelligence and big data technologies, so as to promote the continuous evolution of user-centred design methods[7].

3. Designing the Research Process

3.1 Preliminary Analysis of the KANO Model

3.1.1 User Requirements Acquisition

The acquisition of human-computer interaction interface requirements for elderly electric vehicles is an important prerequisite to ensure that the design results are representative and diverse. In this study, elderly people who are over 65 years old, in good physical condition, and have some experience in driving cars or have used electric cars are the main target of the survey, and the form of the questionnaire is shown in Table 1. Through a variety of methods such as literature combing, on-site interviews and expert consultation, 40 eligible respondents were finally selected for the

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study, of which half were male and half were female, and the age distribution ranged from 65 to 80 years old[8].

The survey covered four dimensions: interface information presentation, operation process, feedback mechanism and emotional experience, aiming at a comprehensive understanding of the pain points and needs of elderly users in the process of actual use. After summarisation, 10 demands closely related to the interactive interface were finally extracted, the details are shown in Table 2, which lays the data foundation for the subsequent KANO classification and AHP ranking analysis.

Tab. 1 Example of questionnaire

Setup issues	Content of the question				
forward-looking issue	How do you feel when you have ‘User Interface Design for Elderly Electric Vehicles’?				
	dissatisfied	should have	not matter	barely	unsatisfactory
inverse problem	How do you feel when you don't have ‘User Interface Design for Senior Electric Vehicles’?				
	dissatisfied	should have	not matter	barely	unsatisfactory

Tab. 2 Evaluation indicators

latitude of demand		Programme elements	Corresponding function description
Basic Needs A	A1	Adjustable font size/icon	Meeting reading needs after visual deterioration
	A2	High Contrast Visual Mode	Adaptation of colour vision degradation to improve recognition efficiency
	A3	Fixed display of frequently used functions on the homepage	Reduce search costs and improve operational efficiency
	A4	Clear error indication	Reduce barriers to use and increase operational fault tolerance
Expected demand B	B1	Voice prompts throughout	Confirmation voice feedback after each step
	B2	Operation can be cancelled/corrected by false touch	Enhanced sense of control and reduced risk of misuse
	B3	Simple operation process	Short processes and clear pathways reduce cognitive burden
Glamour demand C	C1	Safe Driving Mode	Switch to a clean, secure interface with one click
	C2	Personalised welcome message	Emotionally caring features to enhance a sense of belonging
	C3	Affinity Voice Assistant	Supports daily interactions such as small talk and reminders

3.1.2 KANO questionnaire analysis

The Better-Worse Coefficient is a quantitative method for evaluating the impact of a user's needs on satisfaction[9], and consists of two indicators: the satisfaction coefficient (B) and the dissatisfaction coefficient (W); the closer the B coefficient is to 1, the more the need will significantly increase user satisfaction once it is met; and the closer the W coefficient is to -1, the more dissatisfied the user will be if the need is not met. The closer the B coefficient is to 1, it means that once the demand is satisfied, the user satisfaction will be significantly increased; while the closer the W coefficient is to -1, it means that if the demand is not satisfied, the user dissatisfaction will be significantly increased. In this study, SPSS and other statistical tools were used to process the proportion of options in the KANO questionnaire, and the B and W values of each demand were

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calculated according to equations (1) and (2), respectively. Where A represents the proportion of users choosing the ‘glamour type’, M is the ‘expectation type’, O is the ‘basic type’, I is the ‘no difference type’, R is the ‘no difference type’, and W is the ‘no difference type’. M is ‘Desired’, O is “Basic”, I is ‘No Difference’, and R is ‘Reverse’. Through these results, the value position of each function in the user's psychology can be clarified, thus providing scientific data support for interface optimisation. After data collation and analysis, the KANO classification of 10 preliminary user requirements and their corresponding Better-Worse coefficients are finally obtained, and the specific results are summarised in Table 3.

$$Better = \frac{A' + O'}{A' + O' + M' + I'} \tag{1}$$

$$Worse = -\frac{M' + O'}{A' + O' + M' + I'} \tag{2}$$

As can be seen from Table 3, a total of 10 KANO types of demand indicator items are obtained through analysis and calculation. Among them, there are 3 essential demand indicators, namely: A3-fixed display on the homepage of frequently used functions; B2-operation revocable/mis-touch correction; C3-affinity voice assistant. There are 2 desired demand indicators, namely: B1 - full voice prompts; C1 - safe driving mode. Attractive demand indicators 3, respectively: A1 - font size / icon can be adjusted; A4 - clear error prompts; B3 - concise operation process. There are 2 indicators of undifferentiated needs, which will not be considered.

Tab. 3 Results of KANO analysis for 10 preliminary user needs

Elements of User Requirements (No.)	A/%	O/%	M/%	I/%	R/%	Q/%	Better-Worse Classification	Better/%	Worse/%
(A1)	37.89%	10.65%	6.39%	23.62%	9.44%	10.32%	A	69.71%	-9.94%
(A2)	12.70%	3.00%	9.44%	43.55%	20.70%	2.61%	I	30.21%	-13.57%
(A3)	16.05%	16.88%	47.19%	15.10%	19.48%	2.31%	M	28.70%	-59.26%
(A4)	45.67%	3.61%	21.05%	40.23%	1.31%	8.13%	A	45.00%	-27.32%
(B1)	13.18%	25.19%	10.36%	16.49%	3.31%	9.48%	O	42.77%	-38.89%
(B2)	13.05%	10.88%	42.19%	23.10%	10.48%	6.31%	M	30.70%	-55.26%
(B3)	48.18%	12.92%	26.70%	28.28%	2.44%	4.48%	A	31.19%	-28.44%
(C1)	23.88%	43.66%	23.53%	13.49%	15.74%	13.70%	O	58.31%	-51.56%
(C2)	21.62%	25.01%	16.62%	48.10%	1.00%	7.65%	I	45.38%	-45.38%
(C3)	11.44%	12.44%	28.67%	36.36%	21.44%	1.65%	M	16.36%	-51.82%

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3.2 In-Depth Analysis of AHP Models

3.2.1 Building an evaluation system for demand indicators

Based on the preliminary user requirements analysis table, combined with expert interviews, a requirements hierarchy analysis framework for the design of human-computer interaction interfaces for electric vehicles for elderly users was constructed, covering the target, guideline and programme layers, as shown in Figure 2.

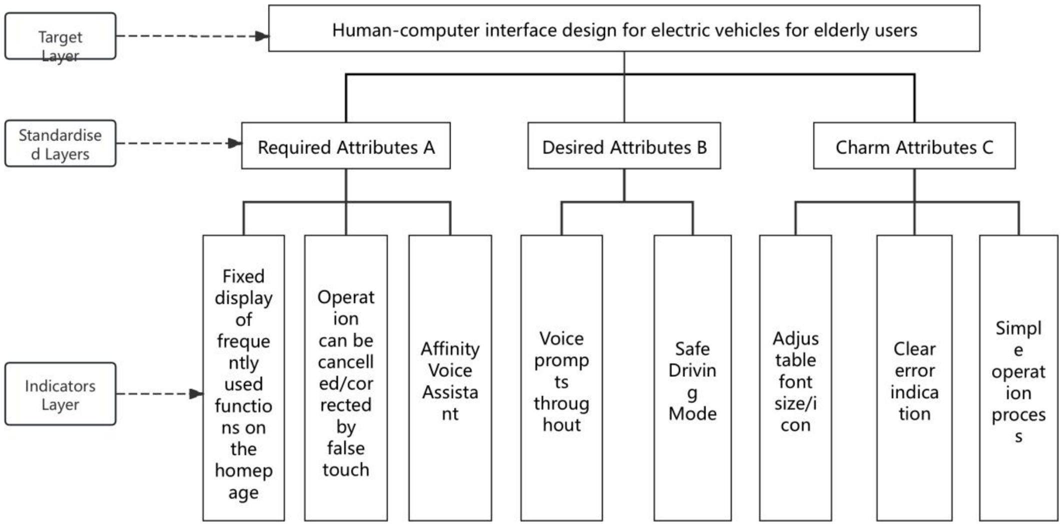

Fig. 2 Hierarchical Requirements Structure of Human-Computer Interface for Electric Vehicles for Elderly Users

3.2.2 AHP Demand Attribute Questionnaire and Weighting Analysis

In order to scientifically define the relative importance of the design elements of the human-computer interaction interface of electric vehicles for elderly users, this study adopts the 1-9 scale proposed by Saaty to construct a pairwise comparison questionnaire and form a quantitative judgement matrix[10]. Eleven evaluation subjects were invited to participate in the scoring during the research process, including seven professionals with industrial design, human factors engineering, or intelligent interaction backgrounds, and four elderly users with EV experience. In order to enhance the appropriateness and practicality of the evaluation system for the target population, four of the panelists are close to 65 years old and can provide a judgement basis that is more suitable for the characteristics of elderly users[11].

In the process of weight solving, this study adopts the sum-product method (also known as the eigenroot method) to process the judgement matrix, calculate its maximum eigenvalues and solve the corresponding eigenvectors, so as to obtain the relative weights of each criterion dimension, and the eigenvectors are used as the final weight coefficients of each element of the criterion layer in the target layer after the normalisation process. Specific scale meanings and scoring references are shown in Table 4, which provides a unified judgement basis and operation specification for expert scoring.

Table 4. Needs hierarchy analysis

normative layer	Sub-normative level indicators	Sub-criteria layer weights	Combined weights of indicators	weighting
Required Attribute M	Z3 Fixed display of frequently used functions on the homepage	0.1592	0.0418	5

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	Z2 Operation can be cancelled/corrected by false touch	0.5888	0.1537	2
	Z3 Affinity Voice Assistant	0.2518	0.0658	6
Desired Attribute O	Z4 Voice prompts throughout	0.7500	0.3083	1
	Z5 Safe Driving Mode	0.2500	0.1028	4
Charming Attribute A	Z6 Adjustable font size/icon	0.1492	0.0489	8
	Z7 Clear error indication	0.1948	0.0639	7
	Z8 Simple operation process	0.4254	0.1295	3

4. Design Methodology

Under the theoretical guidance of KANO-AHP composite model, this study proposes human-computer interaction interface design strategies for the characteristics of elderly users, focusing on the four core dimensions of information presentation, operation path, interaction feedback and emotional experience, combined with the weighted data of users' needs obtained from the preliminary questionnaire survey and expert interviews.

In terms of interface information presentation, based on the higher weighted essential and glamour requirements such as ‘adjustable font size/icon’ and ‘high contrast visual mode’, the interface should support customised adjustment of font size to ensure the readability of the text, and set a high contrast theme (e.g. white text on a black background) to enhance the readability of the text. The interface should support customised font size adjustment to ensure text readability, and set high-contrast themes (e.g. white text on a black background) to enhance visual clarity. In addition, function icons should be paired with clear Chinese labels to avoid understanding difficulties caused by purely graphical information.

In terms of operation flow optimisation, in order to meet the expectations and essential requirements such as ‘fixed display of frequently used functions on the homepage’, ‘false touch correction’ and ‘simple operation flow’, the interface should be set up for frequently used operations (For example, navigation, power, return trip) should be set up in the interface to reduce the level of jumping. At the same time, functions such as ‘operation undo’ and ‘return to previous step’ are added to build a fault-tolerant mechanism and enhance the sense of control and security of elderly users.

In terms of feedback mechanism, the design emphasises the functions of ‘full voice prompts’ and ‘error message correction’ to ensure that each operation has a clear feedback path, including text, voice and tactile feedback and other multi-channel information prompts, so as to make it easy for users to confirm the current state and the direction of the next step. The user can easily confirm the current status and the direction of the next operation.

In terms of emotional interaction, based on indicators such as ‘affinity voice assistant’, ‘safe driving mode’ and ‘personalised welcome message’, the interface can introduce voice interaction assistants with personality characteristics, supporting daily greetings, weather announcements, and so on. The interface can introduce voice interaction assistants with personalised features, supporting functions such as daily greetings, weather forecasts and medication reminders. At the same time, we

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provide a switching portal for ‘Safe Driving Mode’ to simplify the interface information and improve the confidence of elderly users in complex traffic situations.

In conclusion, the design method follows the principles of ‘functional accessibility, friendly interaction, clear information, and emotional accompaniment’, establishes an interface optimisation system based on the boundaries of elderly users' abilities, and provides a clear direction and systematic path for the construction of ageing-adapted interfaces for electric vehicles.

5. Conclusion

With the continuous advancement of the aging society, the elderly, as an important user group of intelligent transport products, need to pay great attention to their experience and safety. This paper focuses on the human-computer interaction problems of the elderly in the process of using electric vehicles, identifies the demand attributes based on the KANO model, and then quantitatively ranks the functional requirements with the help of the AHP method, so as to construct a set of scientific user demand assessment and functional priority judgement system. The study finally puts forward operational design suggestions in terms of interface visual presentation, interaction process simplification, clear feedback mechanism and emotional experience.

The main contribution of this study is that the KANO and AHP models are systematically applied to the design of the ageing-friendly interface of electric vehicles for the first time, and a demand-oriented, clear hierarchical, and reasonably weighted interaction design decision-making path is constructed, which effectively improves the scientificity and practicability of the design. Meanwhile, through the two-dimensional verification mechanism of user questionnaire data and expert scoring, the final design weighting structure has strong practical reference value.

Future research can further combine eye tracking, use of context simulation, multimodal interaction and other technical means to collect and verify the behavioural data of the elderly in real driving situations, so as to achieve the transformation of the interface design from ‘static adaptation’ to ‘dynamic perception’, and to promote the design of smart electric vehicles to be more inclusive. In this way, the interface design can be transformed from ‘static adaptation’ to ‘dynamic perception’, which will promote the development of intelligent electric vehicles in the direction of more inclusiveness and human-oriented care.

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