Research on Function-Interface Design of Old and Antique Hongmu Furniture E-commerce Platform in the Second-hand Economy Environment

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To optimize the user experience of an e-commerce platform for old and antique hongmu furniture, this study explored the functional design and interface elements of such platforms within the context of the second-hand economy. First, through qualitative research, the general needs of users were identified. Then, using the Analytic Hierarchy Process (AHP), the priorities of different types of needs were ranked. After expanding the functional indicators for each type, the Kano model was used to identify the specific attributes of these indicators. Then the results were combined with the AHP study to determine the core functions that the e-commerce platform should possess. Eye-tracking (ET) technology helped to understand users' visual preferences and identify their focus on interface layout, color, and other aspects. These findings suggest that the functional framework should include 24 features, such as expert authentication and institutional certification; in terms of interface design, multiple layout options should be provided for users to choose from, while balancing color schemes and text-to-image ratios. This study provides theoretical guidance for designing an e-commerce platform for old and antique hongmu furniture, enabling to identify user needs and enhance user satisfaction.

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Keywords: E-commerce platform; Old and antique hongmu furniture; Analytic hierarchy process; Kano model; Eye-tracking technology

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INTRODUCTION

The history of traditional Chinese furniture is long and rich, providing not only a material foundation for daily life but also embodying the spiritual and aesthetic values of ancient Chinese people. Hongmu furniture typically refers to furniture made using traditional craftsmanship and traditional mortise-and-tenon joints, with the primary materials being 29 types of wood from five genera and eight categories listed in the Chinese national standard GB/T 18107-2017 "Hongmu," including *Pterocarpus santalinus*, *Dalbergia odorifera*, and other species from the *Pterocarpus*, *Dalbergia*, *Millettia, Mesua,* and *Diospyros* genera. Hongmu furniture gained popularity during the mid-to-late Ming Dynasty, and it has remained popular to this day, representing a valuable cultural heritage of China and an important component of the Chinese furniture market (Fu *et al*. 2024). Old and antique hongmu furniture refers to pieces crafted during the Ming and Qing dynasties, rather than modern-day productions. As such, it not only embodies the cultural significance and artistic value of hongmu furniture but also possesses significant collectible value due to its age and historical context.

Driven by policies to improve resource efficiency and promote a circular economy, as well as the digital economy, the second-hand goods economy has been boosted, and second-hand e-commerce platforms have gradually emerged. Due to the growth in cultural demand consumption and trade treaty restrictions, the price of rosewood furniture has continued to rise (Siriwat and Nijman 2018), and the market for old and antique hongmu furniture has shown a growth trend.

Current research on old and antique hongmu furniture primarily focuses on several areas: cultural value and heritage (Zhu 2020), artistic style and craftsmanship (Sun *et al*. 2016), and modern design applications (Chen 2022). While these studies provide a solid foundation for further research on old and antique hongmu furniture, there has been little systematic exploration of the e-commerce platform for old and antique hongmu furniture—a critical link between culture and contemporary consumers that addresses core pain points. To address this critical research gap, this study focuses on the core interactive interface of old and antique hongmu furniture e-commerce platforms—specifically, functional design and interface design—with an emphasis on resolving market pain points and enhancing user experience. The quality of functional and interface design directly impacts users' operational fluency, information retrieval efficiency, and overall purchasing decision-making experience. From multiple perspectives including market demand, cultural heritage, and user needs, this study not only captures user needs and market pain points from both economic and humanistic angles, providing a platform to disseminate China's traditional culture and artistic value, but also systematically distills the core functional modules and interface design elements required for constructing similar vertical e-commerce platforms, laying a solid foundation for the platform's actual usability and user appeal.

LITERATURE REVIEW

Hongmu Furniture and the Hongmu Furniture Market

Regarding hongmu furniture, Gustav Ecke classified hongmu furniture according to its morphological structure in *Chinese Domestic Furniture* (Ecke 2013), and explored issues such as the materials, decorative techniques, and dating of hongmu furniture, as well as the exquisite craftsmanship in its structure and production techniques; Shixiang Wang, in *Connoisseurship of Chinese Furniture: Ming and Early Qing Dynasties* (Wang 1990), provides a detailed analysis of the types and forms of Ming-style Chinese furniture, traces the evolution of craftsmanship and functionality, and establishes a rigorous and scientific system for naming and evaluating furniture.

Regarding the hongmu furniture market, Wang *et al*. (2024) argue that China currently lacks a mature secondary market for hongmu furniture, with offline transactions being more common. However, issues such as material quality, form, and dating persist, necessitating the establishment of a hongmu furniture valuation system centered on wood origin, craftsmanship, and historical value. Chen (2015) found through research that the hongmu furniture industry suffers from issues such as price chaos, substandard products being passed off as genuine, and new items being made to look old, leading to unmet consumer demands and chaotic market management, with a lack of specific regulations to enforce standards.

Second-hand Market

Wang *et al*. (2022) analyzed the motivations and obstacles of Chinese consumers in purchasing second-hand goods, using second-hand clothing as an example. The overwhelming majority of consumers are motivated to purchase second-hand goods for the fun of treasure hunting, while "ineffective industry regulation," "misleading labeling," and "hygiene issues" are the most frequently mentioned problems in China's second-hand clothing market. Huang (2023) found that Chinese consumers currently hold a positive attitude toward second-hand consumption, which is not influenced by gender, education level, or urban tier. However, when categorized by age group, younger generations are more inclined toward second-hand consumption. Yan *et al*. (2024) used second-hand luxury goods as an example and found that the social value, emotional value, and quality of products have a positive impact on consumers, purchasing intentions, while the cost-effectiveness of products and consumers' recycling awareness also enhance purchasing intentions. Gong *et al*. (2021) took the Chinese second-hand trading app "Idle Fish" as their research object and found that consumers' innovation, participation, and economic benefits, as well as the convenience, security, and interactivity of second-hand trading platforms, all have a positive impact on the usability of the platform, and the usability of the platform also has a positive impact on users' intention to continue using it. Sun and Choo (2023) found that consumers' use of second-hand platforms is influenced by hedonic characteristics, price, platform technology, and consumption habits, and suggested that second-hand trading platforms should enhance user experience and provide various discounts and benefits to promote user willingness to use the platform.

Furniture E-commerce Platform Functionality and Interface Design

In terms of functionality and interface design, Luo *et al*. (2021) proposed an internet-based physical furniture customization and delivery system that maximizes seller benefits through mathematical modeling and algorithm design. Comparisons revealed that this system is more suitable for situations in which buyers are geographically dispersed. Yang and Chiu (2023) found that vertical layout achieves a higher target reach rate than horizontal layout, meaning users obtain information more efficiently in a vertical layout. Wang *et al*. (2021) demonstrated that text aesthetics in shopping platform interface design have a U-shaped relationship with user bounce rates, while image aesthetics show no significant correlation with bounce rates. Gong *et al*. (2009) analyzed use cases to identify functional requirements related to sensory, needs, and interaction aspects, and referenced user online shopping needs research and prototype design to complete the website's user functionality and interface design. Zhang *et al*. (2023) found that users prioritize product trial experiences, compatibility, delivery, and after-sales return services, and adopted a low-information-density layout to divide modules and used high-saturation colors to emphasize key information in interface design.

In terms of user research, Gu *et al*. (2021) conducted a survey of the e-commerce furniture market and found that, in terms of gender, women's total furniture purchases were always higher than men's, with male consumers focusing more on quality and female consumers prioritizing low prices and cost-effectiveness; in terms of age, the 26 to 35 age group had the largest customer base and highest transaction volume, while those over 45 had the highest average order value. Arghashi and Arsun Yuksel (2022) studied the impact of Augmented Reality (AR) applications on consumer engagement, concluding that AR applications are an effective tool for inducing optimal flow experiences and increasing consumer engagement in online retail environments. Yu *et al*. (2023) used Analytic

Hierarchy Process (AHP) to study the factors influencing online furniture purchasing behavior, concluding that when purchasing furniture online, users prioritize price factors. Aldosari (2024) compared AR mobile e-commerce with 3D mobile e-commerce interfaces, finding that compared to 3D product displays, AR significantly enhanced consumers' perceived enjoyment and perceived product quality, positively influencing their willingness to pay.

In summary, current research on old and antique hongmu furniture primarily has focused on aspects such as the management of hongmu and hongmu furniture market, furniture authentication, and the development of standardized production systems. However, amid the current research boom on second-hand goods and antique markets, existing studies mainly analyze the current state of second-hand markets, consumer behavior and influencing factors, as well as consumer characteristics, with limited specific research on the old and antique hongmu furniture market. In terms of research on the functionalities and interface design of furniture e-commerce platforms, studies have primarily focused on platform functionalities, interface construction, logistics and transportation, consumer needs, and user experience. However, there have been few publicly available reports specifically addressing the functionalities and interface design of e-commerce platforms for old and antique hongmu furniture.

Therefore, this study addressed market demand and research gaps by proposing a design concept for old and antique hongmu furniture platforms. The research focuses on meeting consumer and market needs and optimizing the online consumption experience design for old and antique hongmu furniture platforms. The AHP-Kano model method was adopted to analyze consumers' dissatisfaction and needs regarding platform functions and interfaces from a subjective perspective during the shopping process. Secondly, Eye-Tracking (ET) technology was employed to objectively analyze users' priorities regarding platform functions and interfaces. Ultimately, the study aimed to uncover consumers' genuine needs, summarize the design elements of the platform's functional layers, and optimize the platform's interface layout.

METHODS AND MATERIALS

This study aimed to explore the functional and interface design elements of an e-commerce platform for old and antique hongmu furniture. It combined the advantages of qualitative and quantitative methods, utilizing user interviews, questionnaires, the AHP, the Kano model, and ET technology to conduct user interface design for the e-commerce platform. First, qualitative methods such as interviews and observations were used to identify user needs. Second, questionnaires were used to collect real-user data, which was then subjected to quantitative analysis. Third, AHP was employed to establish functional priorities, and the Kano model was applied to classify functional requirements. Finally, ET experiments were conducted to collect objective user gaze data, which guided the optimization of interface design. The obtained user requirements were ranked, a user requirement list was compiled, and the design requirements for platform functionality and interface layers were summarized. The research process flowchart is shown in Fig. 1.

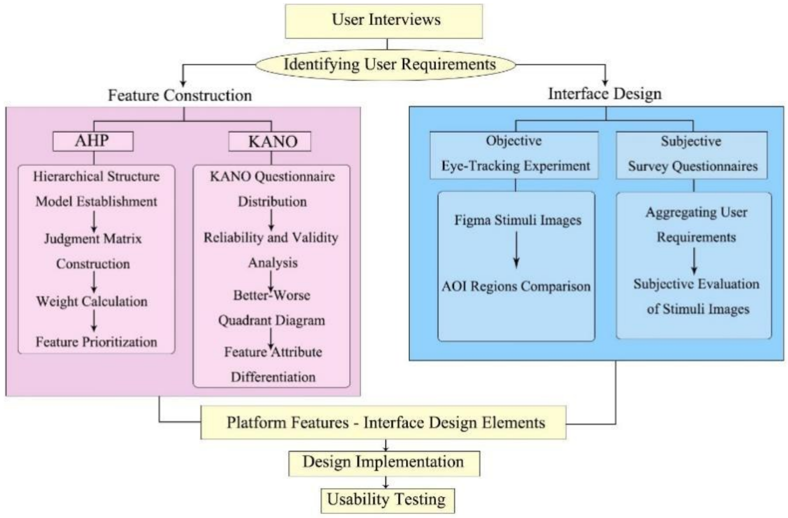

Fig. 1. Research framework

Qualitative Research

In the initial data collection and market research phase of this study, the current state and future trends of the old and antique hongmu furniture market were analyzed to gain an initial understanding of existing issues. Based on this, a representative group of target users were selected, and interviews were used to further explore their needs and pain points. The primary purpose of the interviews was to explore the decision-making challenges users face when purchasing old and antique hongmu furniture, including authenticity verification, quality assessment, logistics risks, and value matching; the user experience on e-commerce platforms, covering information transparency, seller credibility, platform protection mechanisms, and after-sales support. There was further attention to specific demands during platform use, such as customized service requirements, professional knowledge support, and community interaction mechanisms. Interviews were typically conducted in quiet, distraction-free environments. The researchers used open-ended questions to guide participants in expressing their personal views and avoided interrupting participants' narratives during the interviews. All interview content was recorded using audio equipment and subsequently organized and analyzed.

Quantitative Research

The quantitative research in this paper was mainly conducted through questionnaire surveys and ET experiments to understand users' needs, preferences, and usage behaviors from both subjective and objective perspectives. Based on preliminary qualitative analysis and statistical analysis, three questionnaires were designed and distributed, each combined with AHP, Kano model, and ET for research.

AHP

The AHP combines qualitative and quantitative analysis to calculate decision weights for multi-objective complex problems. This method breaks down the problem into different components and organizes them into hierarchical levels based on the degree of mutual influence and subordination among the factors, forming a multi-level analytical structure model. The relative order of superiority and inferiority is then quantified through comparison (Miao *et al*. 2024).

AHP typically uses a 1–9 point scale for scoring, as shown in Table 1. The measurement scale is based on nine levels, where the values 9, 7, 5, 3, and 1 correspond to absolutely important, very important, relatively important, slightly important, and equally important, respectively. The values 8, 6, 4, and 2 indicate importance levels between adjacent levels.

Table 1. Meaning of the Scale Method

Scale	Meaning
1	Indicates that the two factors are equally important
3	Indicates that the former is slightly more important than the latter
5	Indicates that the former is more important than the latter
7	Indicates that the former is much more important than the latter
9	Indicates that the former is very important or extremely important
2/4/6/8	Indicates the intermediate value between the above adjacent judgments
Reciprocal	Indicates the importance of continuing the comparison by swapping the two factors

The calculation process for AHP evaluation indicator weights is shown in Fig. 2. First, the weight vectors of the judgment matrices for each expert are calculated separately. After passing the consistency test, the ranking weight values that can be used for the indicators are obtained. The average of the ranking weights calculated by each expert is then used as the final ranking weight value.

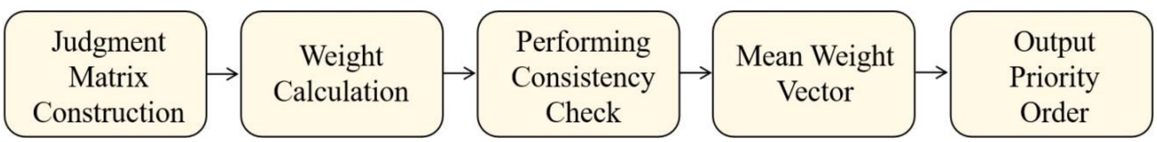

Fig. 2. Evaluation Indicator Weighting Flowchart

The specific calculation steps are as follows:

Step 1: As shown in Eq. 1, a judgment matrix was established. Here, parameter a_{ij} is the result of comparing parameters a_i and a_j, and n is the number of parameters to be compared. The formula satisfies $a_{ij} > 0$, $a_{ij} = 1/a_{ji}$, and $a_{ii} = 1$.

$$A = (a_{\mathrm{ij}})_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

Step 2: The weight vector was calculated next. The judgment matrix was normalized, the weight values were calculated, and the maximum eigenvalue was determined. The specific calculations are shown in Eqs. 2 to 4.

$$\overline{\alpha_{ij}} = \frac{\alpha_{ij}}{\sum_{j=1}^{n} \alpha_{ij}} (i, j = 1,2,\ldots,n) \tag{2}$$

$$W_i = \sum_{j=1}^{n} \frac{\overline{a_{ij}}}{n} (i, j = 1,2,\ldots,n) \tag{3}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{[AW]_i}{nW_i} \tag{4}$$

Step 3: A consistency test was conducted. The consistency index *CI* was calculated using Eq. 5. *CI* = 0 indicates complete consistency in the judgment matrix, the larger the *CI* value is, the more severe the inconsistency will be found in the judgment matrix.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{5}$$

The consistency ratio *CR* for consistency testing was used, as shown in Eq. 6. The consistency testing standard *RI* is referred to as the average random consistency index as shown in Table 2.

When $CR < 0.1$, it indicates good consistency or that the degree of inconsistency is acceptable; otherwise, adjustments must be made until the consistency meets the requirement of being less than or equal to 0.1.

$$CR = \frac{CI}{RI} \tag{6}$$

Table 2. Random Consistency Index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Step 4: Hierarchical total ranking and output: Under the premise of satisfying consistency testing, the weight of the relative importance of all factors at a certain level to the highest level was calculated, which is referred to as hierarchical total ranking. This process was carried out sequentially from the highest level to the lowest level. The specific formula for the hierarchical total ranking of Level B relative to the upper level (Level A) is given in Eq. 7, where Level A includes m factors with hierarchical single-ranking weights a_1, a_2, ..., a_m; Level B includes n factors with hierarchical single-ranking weights b_{11}, b_{12}, ..., b_{nn}, and the hierarchical total ranking weight of Level B is b_i.

$$b_i = \sum_{j=1}^{m} a_j b_{ij} \tag{7}$$

Kano model

The Kano model is a tool invented by Noriaki Kano for classifying and prioritizing user needs. It analyzes the impact of user needs on user satisfaction and reflects the nonlinear relationship between product functionality and user satisfaction (Liang and Chen 2024). Currently, Kano has been widely used in home furnishings, industrial design, and other fields (Li *et al*. 2024). In the Kano model, based on the relationship between different types of needs and user satisfaction, the needs that affect user satisfaction can be divided into five categories, as shown in Table 3.

Table 3. Classification of User Satisfaction Requirements

Requirement Type	Repre-sentative Letter	Meaning
Essential Requirements	M	When these requirements are met, user satisfaction does not increase significantly; when they are not met, user satisfaction decreases significantly.
Expected Requirements	O	The higher the degree of fulfillment, the higher the user satisfaction; Conversely, the lower the degree of fulfillment, the lower the user satisfaction.
Attractive Requirements	A	The absence of this attribute does not cause user dissatisfaction, but its presence significantly enhances user satisfaction.
Indifferent Type Requirements	I	Satisfaction is unrelated to whether this attribute is present.
Reverse Type Requirements	R	Satisfaction is inversely proportional to the fulfillment of this attribute.
Questionable Type Requirements	Q	Requirements where users may misunderstand the meaning of the question.

For each feature, two questions were designed—one positive and one negative—to test users' attitudes toward the provision or non-provision of that feature. The positive question is "How would you feel if this feature were provided?", The negative question is "How would you feel if this feature were not provided?". The questionnaire uses a 5-point Likert scale, with users selecting from five options: "Satisfied," "As expected," "Indifferent," "Tolerable," and "Dissatisfied." The classification comparison table for the results is shown in Table 4.

Table 4. Comparison of Kano Model Results

Function/Requirement		Negative Question				
		Dissatisfied	Tolerable	Indifferent	As Expected	Satisfied
Positive Question	Dissatisfied	Q	R	R	R	R
	Tolerable	M	I	I	I	R
	Indifferent	M	I	I	I	R
	As expected	M	I	I	I	R
	Satisfied	O	A	A	A	Q

The Better-Worse coefficients are introduced into the questionnaire results to quantify the extent to which customer needs influence satisfaction. The Better coefficient and the Worse coefficient, respectively, indicate the extent to which a particular feature can increase satisfaction or eliminate dissatisfaction. For a given better value, the larger the value, the greater is the impact of that need on user satisfaction; for a given Worse value, the larger the value, the greater the change in user dissatisfaction when that attribute is absent. The specific calculation methods are shown in Eqs. 8 and 9.

$$Better = \frac{A+O}{A+O+M+I} \tag{8}$$

$$Worse = -\frac{O+M}{A+O+M+I} \tag{9}$$

A Better-Worse coefficient quadrant diagram is constructed with the absolute value of the Worse coefficient as the X-axis and the absolute value of the Better coefficient as the Y-axis.

Eye-tracking Experiment

In addition to subjective evaluation methods, this study also employed objective evaluation using ET technology to accurately reflect the feelings and choices of target users. ET can better identify interface design issues through the detection of physiological indicators and visual data analysis, optimize the design of user attention areas, and enhance the user experience (Zhu and Lv 2023).

Participants and stimuli

The experiment recruited 30 participants, with a balanced gender distribution, all of whom had experience using e-commerce platforms. All participants had normal vision, no color blindness or color weakness, and were right-handed.

Based on prior research, the interfaces of currently common e-commerce platforms were summarized and analyzed, and Figma software was used to simulate the platform interfaces. All product materials used were identical. The e-commerce platform interface was divided into five sections: Home Screen, Search Screen, Details Screen, Categories Screen, and Account Screen. Each section had three or more different designs, and images of the same size were output. The experiment was divided into five groups, with each group corresponding to one section, and each viewing one design at a time. There was a 5-second rest period between each group to alleviate visual fatigue and allow the eyes to refocus. To facilitate subsequent result processing and analysis, areas of interest (AOI) were marked on each interface, as shown in Fig. 3.

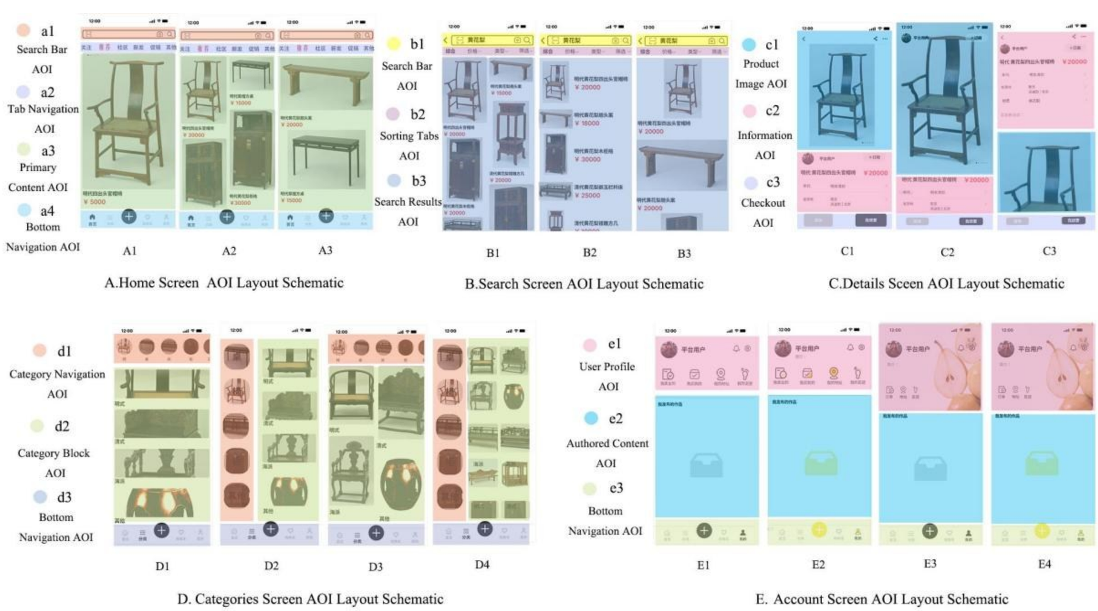

Fig. 3. Exciting AOI partitioning diagram

Experimental facilities

The entire experiment was conducted at the Human Factors Laboratory of Nanjing Forestry University. The experiment was carried out in a quiet and comfortable indoor environment with sufficient soft lighting. The Tobii Pro Fusion telemetric eye tracker was used as the experimental instrument, and the sampling rate was set to 250 Hz to ensure that the instrument could collect real-time gaze data from users. The ErgOLAB 3.17.8 software, which has functions such as experimental design and data statistics, was used in conjunction with the eye tracker to export the final user data.

Experimental design

The experiment employed a parallel scoring method. Before the experiment, participants were instructed to observe the stimulus images based on their personal preferences and were introduced to the scoring criteria, emphasizing the need to score each stimulus image and verbally inform the nearby recorder. Participants were then asked to maintain an upright sitting posture, place their right hand on the mouse, keep their eyes at a distance of 60 to 65 cm from the screen, complete the vision calibration task required by the equipment, and begin the experiment. During the experiment, stimulus images were displayed in a specific order, and participants were required to click the mouse to switch between stimulus images. The experiment concluded after all stimulus images had been observed and rated. All participants were seeing the stimulus images for the first time during the experiment. The experimental procedure is illustrated in Fig. 4.

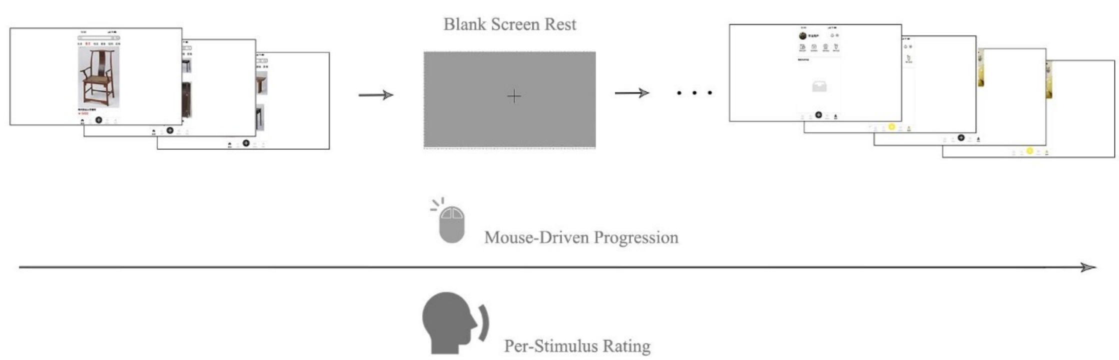

Fig. 4. Eye-tracking experiment flowchart

Usability Testing

Product usability is an important dimension of user experience. The System Usability Scale (SUS) was used to evaluate the learnability and usability of the product. The questionnaire used a 5-point Likert scale for quantitative assessment. A score of 1 represents strongly disagree, while a score of 5 represents strongly agree. The evaluation indicators based on the SUS are shown in Table 5.

Table 5. System Usability Scale

Number	Evaluation Indicator	Number	Evaluation Indicator
1	I think that I would like to use this system frequently.	6	I thought there was too much inconsistency in this system.
2	I found the system unnecessarily complex.	7	I would imagine that most people would learn to use this system very quickly.
3	I thought the system was easy to use.	8	I found the system very cumbersome to use.
4	I think that I would need the support of a technical person to be able to use this system.	9	I felt very confident using the system.
5	I found that the various functions in this system were well integrated.	10	I needed to learn a lot of things before I could get going with this system.

Let the raw score for item *i* on the questionnaire be *X*, the converted score for item *i* be X_i, and the total score for the questionnaire be *S*. Equation 10 is the formula for odd terms, and Eq. 11 is the formula for even terms, and the total score for the questionnaire using Eq. 12 was calculated.

$$X_i = X - 1 \tag{10}$$

$$X_i = 5 - X \tag{11}$$

$$S = 2.5\sum_{i=1}^{10} X_i \tag{12}$$

EXPERIMENTAL RESULTS

When selecting research subjects, the uniqueness was considered of old and antique hongmu furniture and the representativeness of the target audience. Due to the uniqueness of old and antique hongmu furniture, to ensure that the sample effectively reflects the characteristics and needs of the target audience, offline visits were combined with online recruitment based on dimensions such as occupation, age, gender, economic status, and purchasing needs for old and antique hongmu furniture. A total of 150 respondents were identified through this process. This included key groups such as industry experts, furniture collectors, sellers of old and antique hongmu furniture, professional scholars, and potential buyers. All respondents had a certain level of understanding and purchasing intent regarding old and antique hongmu furniture, with a balanced gender ratio and ages ranging from 25 to 60. To obtain in-depth information, six respondents with higher professional qualifications and experience were selected for user interviews, and 10 experts were selected for AHP indicator scoring; Additionally, to conduct objective data measurement, 30 respondents were randomly selected for ET experiments. Furthermore, all 150 respondents completed a questionnaire survey. After designing prototypes based on research conclusions, 14 respondents were randomly selected to assess product usability using SUS.

User Interview Results

After screening the respondents' professional backgrounds, basic knowledge, and industries, six respondents with high levels of expertise were selected for user interviews. Among them, two were furniture design students, two were practitioners in the old and antique hongmu furniture industry, and two were experts and professors with professional backgrounds. Their ages ranged from 25 to 60, and the male-to-female ratio was 1:1.

The interview outline consisted of four main parts: (1) Their purchasing channels and decision-making factors for old and antique hongmu furniture; (2) Their understanding of the current old and antique hongmu furniture market; (3) Their use of and specific evaluations of related platforms; and (4) Their functional requirements and expectations for old and antique hongmu furniture e-commerce platforms. After conducting the interviews in a conversational format, the identified needs are extracted, condensed, and analyzed from everyday language and sentences. The data collected from the previous survey is then summarized and organized alongside the data from this interview to derive user needs, which can be broadly categorized into four sections: user trust and protection, product quality and price, platform experience and functionality, and service and after-sales support.

AHP Analysis Results

The hierarchical structure model is shown in Fig. 5. Based on the results of the previous research and interviews, this study sets "factors for improving user satisfaction with e-commerce platforms for old and antique hongmu furniture" as the target layer; four indicators—User Trust Assurance, Product Quality and Price, Platform Experience and Functionality, and Service and Post-purchase Support—are set as the first-level criteria layer, represented by B1, B2, B3, and B4, respectively. Under each primary criterion, secondary criteria layers are established, including Professional Appraisal, Transaction Security, User Interaction, Quality Threshold, Pricing Transparency, Fair Pricing, Product Display, Additional Features, intelligent interaction, Logistics Assurance, After-Sales Service, and Professional Consultation, totaling 12 secondary criteria, denoted as C1 to C12. The specific explanations of each criterion are shown in Table 6.

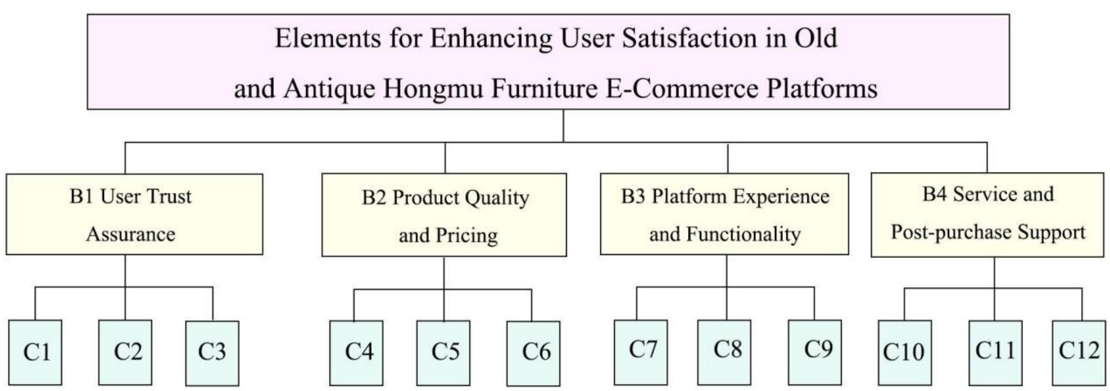

Fig. 5. Hierarchical structure model diagram

Table 6. Specific Explanation of Secondary Indicators

Primary Indicators	Secondary Indicators	Explanation of Secondary Indicators
B1 User Trust Assurance	C1 Professional Appraisal	The platform provides free expert appraisal and valuation services, as well as professional certification from accredited institutions.
	C2 Transaction Security	Funds are held in escrow to ensure security, and counterfeit goods are subject to penalties such as "ten times compensation for one counterfeit item." Seller credit is publicly disclosed.
	C3 User Interaction	Users are provided with interaction channels such as user communities, live streaming, and offline exhibitions.
B2 Product Quality and Pricing	C4 Quality Threshold	The platform evaluates merchants and products to raise quality standards and organizes products into different sections based on quality tiers.
	C5 Pricing Transparency	The goal is to prevent merchants from engaging in self-selling and self-purchasing behavior and introduce fixed-price products.
	C6 Fair Pricing	The goal is to establish a consultation section to promptly introduce price fluctuations within the industry and provide auction services.
B3 Platform Experience and Functionality	C7 Product Display	AR is used to display products, providing detailed information such as specific dimensions, patterns, and the condition of each part.
	C8 Additional Features	Repair and maintenance services are provided, as well as buyback and consignment services.
	C9 Intelligent Interaction	AI is integrated to offer smart scene pairing and recommended product suggestions.
B4 Services and Post-purchase Support	C10 Logistics Assurance	Professional and secure logistics transportation services are provided.
	C11 After-Sales Service	Product status and transaction details are monitored throughout the process, offering quality assurance and free repair/maintenance services within a specified timeframe.
	C12 Professional Consultation	There are 24/7 free consultation services provided by professionals and expert Q&A services.

After completing the hierarchical structure model, to ensure the scientific and objective nature of the data, 10 relevant industry experts or scholars were selected to conduct pairwise comparisons of indicators at the same level, using a 1-9 scale to reflect the differences in the importance of the two indicators. After constructing the judgment matrix for the first-level indicators and each second-level indicator, the maximum eigenvalue of each matrix was calculated. The consistency test table is shown in Table 7.

Table 7. Consistency Check Table

	λ_{max}	*CI*	*RI*	*CR*
Primary Indicators	4.0103	0.034	0.90	0.0038
Secondary indicators under level B1	3.0258	0.0129	0.58	0.0222
Secondary indicators under level B2	3.0010	0.0005	0.58	0.0009
Secondary indicators under level B3	3.0300	0.0150	0.58	0.0258
Secondary indicators under level B4	3.0640	0.0320	0.58	0.0551

The final *CR* values of each matrix all satisfied *CR*<0.1, thereby passing the consistency test. After calculating the comprehensive weights, the overall hierarchical ranking is shown in Table 8.

Table 8. Total Sorting by Level

Primary Indicator	Weight Value	Secondary Indicator	Relative Weight Value	Comprehensive Weight Value	**Ranking**
B1	0.2977	C1	0.4845	0.14423565	**1**
		C2	0.4035	0.12012195	**5**
		C3	0.1119	0.03331263	**10**
B2	0.3735	C4	0.3828	0.1429758	**2**
		C5	0.3369	0.12583215	**3**
		C6	0.2803	0.10469205	**6**
B3	0.1042	C7	0.4534	0.04724428	**9**
		C8	0.2959	0.03083278	**11**
		C9	0.2506	0.02611252	**12**
B4	0.2246	C10	0.2285	0.0513211	**8**
		C11	0.5383	0.12090218	**4**
		C12	0.2331	0.05235426	**7**

According to the calculation results, the importance of the first-level indicators was B2 > B1 > B4 > B3; the importance of the second-level indicators is C1 > C4 > C5 > C11 > C2 > C6 > C12 > C10 > C7 > C3 > C8 > C9.

Kano Model Analysis Results

After prioritizing functional indicators using AHP, an in-depth analysis of each secondary indicator based on user interview results and market research pain points was conducted. For example, indicator C1 was expanded to yield functions 1, 2, and 3; indicator C2 was expanded to yield functions 4, 5, and 6; and indicator C3 was expanded to yield functions 7, 8, and 9. Ultimately, the 12 secondary indicators were expanded to yield a total of 28 specific functions.

A Kano model questionnaire was designed and distributed for the specific functions identified. The sample size for this analysis was 150, totaling 56 items. The results of the questionnaire's reliability and validity analysis are shown in Table 9. In terms of reliability analysis, if the reliability coefficient is above 0.8, it indicates high reliability. In this data analysis, the Cronbach's α was 0.916 > 0.8, indicating that the reliability quality of the research data was high and suitable for further analysis. In terms of validity analysis, the KMO and Bartlett's sphericity test were used to validate the scale's validity. When the KMO value is between 0.7 and 0.8, it indicates that the research data is suitable for information extraction. In this data analysis, the KMO value was 0.792, and the *P*-value was less than 0.05, indicating that the Bartlett's sphericity test was passed, indicating that the scale had good validity and could be used for analysis and research.

Table 9. Kano Model Reliability and Validity Analysis

Cronbach's α		0.916
KMO		0.792
Bartlett's sphericity test	Approx. Chi Square	2690.729
	df	630
	P	0.000

The questionnaire data was imported into SPSS for statistical analysis, the functional indicators were classified according to the evaluation table and the classification results are shown in Table 10.

Table 10. Kano Model Classification Results

Serial Number	Function	A	O	M	I	R	Q
1	Expert Authentication Services	7.04%	25.35%	33.80%	28.17%	2.82%	2.82%
2	Authorized Institution Certification	4.23%	30.99%	33.80%	28.17%	0.00%	2.82%
3	Free Appraisal Services	18.31%	19.72%	19.72%	38.03%	1.41%	2.82%
4	Escrow Payment Protection	9.86%	29.58%	29.58%	25.35%	2.82%	2.82%
5	10x Refund Guarantee for Counterfeits	14.08%	30.99%	22.54%	29.58%	1.41%	1.41%
6	Transparent Seller Credit Ratings	8.45%	45.07%	23.94%	21.13%	0.00%	1.41%
7	User Community Building	12.68%	16.90%	12.68%	53.52%	1.41%	2.82%
8	Interactive Live Streaming	19.72%	9.86%	7.04%	60.56%	1.41%	1.41%
9	Offline Exhibition Events	32.39%	22.54%	5.63%	38.03%	0.00%	1.41%
10	Quality Standards for Listings	14.08%	35.21%	22.54%	25.35%	1.41%	1.41%
11	Themed Categories by Product Features	26.76%	23.94%	12.68%	35.21%	0.00%	1.41%
12	Shill Bidding Prevention	8.45%	33.80%	22.54%	33.80%	0.00%	1.41%
13	Fixed-Price Listings	19.72%	9.86%	14.08%	49.30%	5.63%	1.41%
14	Industry Insider Insights	22.54%	22.54%	11.27%	42.25%	0.00%	1.41%
15	Auction Platform Integration	23.94%	15.49%	11.27%	45.07%	2.82%	1.41%
16	AR Product Viewing	38.03%	18.31%	11.27%	30.99%	1.41%	0.00%
17	Detailed Item Specifications	8.45%	49.30%	22.54%	18.31%	0.00%	1.41%
18	Multi-Angle Condition Reports	9.86%	42.25%	26.76%	19.72%	0.00%	1.41%
19	Restoration & Maintenance	19.72%	40.85%	16.90%	21.13%	0.00%	1.41%
20	Resale & Consignment Programs	25.35%	30.99%	11.27%	30.99%	0.00%	1.41%
21	Smart Styling Solutions	25.35%	18.31%	11.27%	42.25%	0.00%	2.82%
22	AI-Powered Matching Recommendations	23.94%	22.54%	8.45%	43.66%	0.00%	1.41%
23	Dedicated Logistics Network	15.49%	43.66%	19.72%	19.72%	0.00%	1.41%
24	End-to-End Transaction Tracking	14.08%	43.66%	21.13%	18.31%	1.41%	1.41%

25	Post-Sale Quality Guarantee	4.23%	54.93%	26.76%	12.68%	0.00%	1.41%
26	Complimentary Maintenance Period	16.90%	45.07%	18.31%	18.31%	0.00%	1.41%
27	Professional Support Hotline	21.13%	32.39%	15.49%	29.58%	0.00%	1.41%
28	Expert Q&A Sessions	25.35%	32.39%	11.27%	29.58%	0.00%	1.41%

Based on the calculations, the Better-Worse coefficients were derived, and a Better-Worse quadrant diagram was created, as shown in Fig. 6. The first quadrant represents desired attributes, whose functions should be prioritized; the second quadrant represents attractive attributes, whose functions should also be prioritized; the third quadrant represents indifferent attributes, whose functions are typically not provided; and the fourth quadrant represents essential attributes, whose functions must be satisfied.

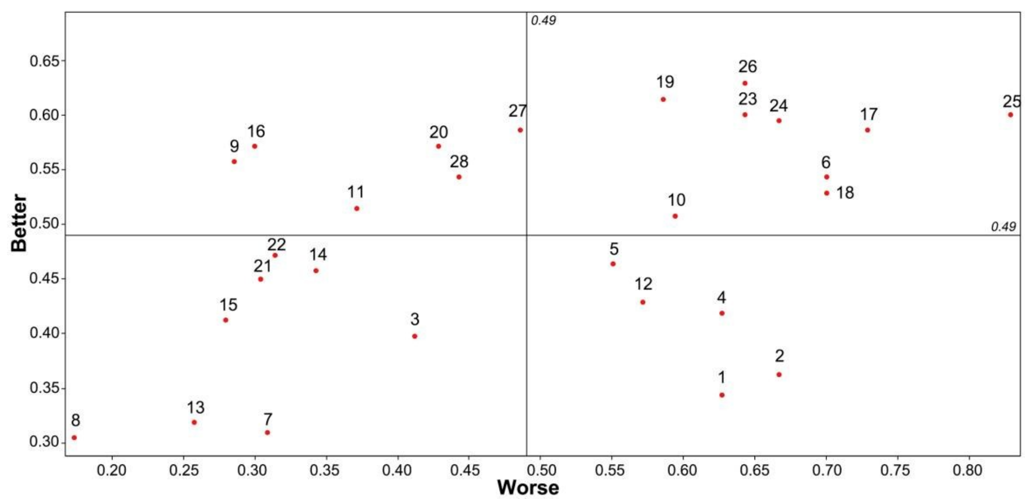

Fig. 6. Better-worse quadrant chart

According to the Better-Worse Quadrant Chart, the following features were categorized under the Essential Attributes Quadrant: items 1, 2, 4, 5, and 12; under the Expected Attributes Quadrant: items 6, 10, 17, 18, 19, 23, 24, 25, and 26; and under the Delightful Attributes Quadrant: items 9, 11, 16, 20, 27, and 28. When designing the platform, it is vital to first meet the essential and desired requirements. Then, the desirable requirements were developed to provide users with a surprising and enjoyable experience, thereby enhancing user satisfaction. The non-differentiating requirements should be considered last.

Eye-tracking Experiment Analysis

The data collected from the ET experiment included heat maps, trajectory maps, *etc*. Here, the indicators shown in Table 11 were selected for data analysis.

Table 11. Meaning of Eye Tracking Indicators

Index Name	Indicator Meaning	Significance
AOI Time to First Fixation (TTFF)	Count the time (s) from the start of the stimulus or segment to the subject's first gaze at the AOI.	Indicates the subject's tendency to focus attention when first exposed to the stimulus.
AOI Total Fixation Duration (TFD)	The total duration of the visit to the interest area.	Indicates the degree of interest or importance of the area to the subject.
AOI Percentage of Total Fixation Du-ration (TFD%)	The total duration of fixation on the specified AOI as a percentage of the total duration of fixation during the entire experiment.	Indicates information about the allocation of visual attention by subjects in the experiment.
AOI Average Fixation Duration (AFD)	Average time spent looking at each designated AOI	Indicates the degree to which the subject processes information in this area.
AOI Fixation Count (FC)	Total number of times the specified AOI was viewed.	Reflect the importance of different regions.

Experimental results

The results of the ET experiment are shown in Table 12. As can be seen from the table, in the "Home Screen" section, a3 was the most prominent area for TTFF, TFD, and FC; in the "Search Screen" section, b3 was the most prominent area for TTFF, TFD, and FC; in the "Details Screen" section, the most prominent areas for TTFF, TFD, and FC are all located at the top of the interface; In the "Categories Screen" section, the most prominent area for TTFF, TFD, and FC is d2; in the "Account Screen" section, the most prominent area for TTFF, TFD, and FC is e1.

Table 12. Eye Tracking Experiment Indicator Data

Stimulation	AOI	TTFF(s)	TFD(s)	TFD%(%)	AFD(s)	FC(n)
A1	a1	4.10	0.21	3.37	0.11	1
	a2	1.77	1.00	15.60	0.22	4
	a3	**0.11**	**3.67**	**70.87**	**0.24**	**16**
	a4	3.87	0.18	2.72	0.09	1
A2	a1	2.40	0.05	0.91	0.03	0
	a2	2.67	0.45	7.70	0.18	2
	a3	**0.23**	**4.80**	**86.41**	**0.25**	**19**
	a4	5.94	0.17	2.20	0.04	1
A3	a1	3.05	0.05	1.28	0.03	0
	a2	1.43	0.47	9.13	0.11	2
	a3	**0.07**	**3.32**	**86.02**	**0.23**	**15**
	a4	6.14	0.10	1.56	0.03	1
B1	b1	2.97	0.37	6.51	0.18	1
	b2	1.98	0.48	8.82	0.13	2
	b3	**0.20**	**4.23**	**82.31**	**0.23**	**18**
B2	b1	1.79	0.17	3.96	0.09	1
	b2	1.32	0.26	5.94	0.11	1

	b3	**0.13**	**4.00**	**88.88**	**0.24**	**17**
B3	b1	2.57	0.10	2.78	0.10	0
	b3	1.71	0.31	8.54	0.13	1
	b3	**0.15**	**3.02**	**86.98**	**0.23**	**13**
C1	**c1**	**0.02**	**2.07**	**51.49**	**0.23**	**9**
	c2	1.24	1.69	42.04	0.21	8
	c3	3.90	0.26	6.47	0.11	1
C2	**c1**	**0.26**	**2.90**	**65.99**	**0.23**	**12**
	c2	1.23	1.18	27.81	0.20	6
	c3	3.85	0.16	4.00	0.09	1
C3	c1	1.22	0.74	18.78	0.18	3
	c2	**0.15**	**3.04**	**77.16**	**0.21**	**14**
	c3	4.68	0.16	4.06	0.08	1
D1	d1	1.35	1.21	22.53	0.22	4
	d2	**0.15**	**3.41**	**71.85**	**0.22**	**16**
	d3	5.01	0.20	3.13	0.07	1
D2	d1	0.50	1.90	39.43	0.23	8
	d2	**0.25**	**2.58**	**57.87**	**0.23**	**12**
	d3	4.51	0.10	1.84	0.05	1
D3	d1	1.51	0.74	15.44	0.22	3
	d2	**0.14**	**3.60**	**80.03**	**0.23**	**15**
	d3	4.16	0.10	1.67	0.04	0
D4	d1	1.14	1.12	25.20	0.22	5
	d2	**0.17**	**3.35**	**71.81**	**0.23**	**14**
	d3	5.86	0.13	2.28	0.03	1
E1	**e1**	**0.31**	**2.70**	**65.14**	**0.22**	**11**
	e2	0.95	1.12	26.93	0.21	5
	e3	3.83	0.19	3.87	0.08	1
E2	**e1**	**0.33**	**2.33**	**66.27**	**0.19**	**9**
	e2	0.93	0.89	25.42	0.25	4
	e3	2.43	0.25	5.24	0.09	1
E3	**e1**	**0.04**	**2.87**	**87.40**	**0.23**	**13**
	e2	1.94	0.35	8.95	0.15	2
	e3	3.64	0.06	1.45	0.02	0
E4	**e1**	**0.28**	**1.57**	**57.89**	**0.24**	**6**
	e2	0.44	1.06	35.37	0.24	4
	e3	2.11	0.23	6.11	0.10	1

Based on the participants' ratings of the stimulus images during the experiment, as shown in Table 13, the highest-rated sample in the "Home Screen" section was A3; in the "Search Screen" section, the highest-rated sample was B2; in the "Details Screen" section, the highest-rated sample was C1; and in the "Categories Screen" section, the highest-rated sample was D3. In the "Account Screen" section, the highest-rated sample was E2.

Table 13. Subject Stimulus Rating Scale

Stimulation	Mean	SD	Cronbach's α
A1	2.87	0.86	0.725
A2	2.97	0.89	
A3	**3.27**	0.94	
B1	3.03	1.03	
B2	**3.20**	1.03	
B3	2.43	0.68	
C1	**3.73**	0.91	
C2	3.37	0.89	
C3	3.10	1.06	
D1	3.43	1.48	
D2	3.40	1.19	
D3	**3.53**	0.73	
D4	2.63	0.96	
E1	3.23	1.10	
E2	**3.57**	0.86	
E3	3.13	1.14	
E4	3.17	0.91	

According to the questionnaire survey data, the importance of visual factors in platform interface design is shown in Fig. 7. The results indicate that seven factors should be given priority consideration in platform interface design: overall style comfort, content layout, highlighting of important parts, complementary use of images and text, icon aesthetics, and color consistency.

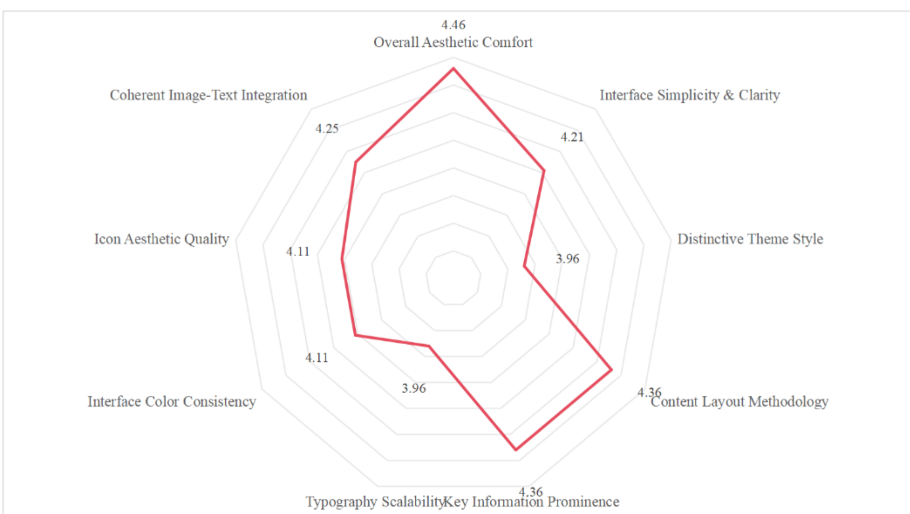

Fig. 7. The importance of visual factors in platform interfaces

In summary, within a single stimulus image, the areas that receive the most attention are typically those located in the central region, which occupy a larger area and contain more information. The least attention-grabbing position is at the bottom of the interface. This result aligns with the characteristics of visual attention and is consistent with the findings of Sulikowski and Zdziebko (2020). Since most people read from top to bottom, in situations where information density is similar, users typically notice the upper regions of the interface first, which is also consistent with the experimental results of the "Details Screen" section. In the "Home Screen" and "Search Screen" sections, although the ET experiment data showed that the A2 and B1 samples using the waterfall layout had more prominent TTFF, TFD%, and FC data, users tended to prefer the A3 and B2 samples in the subjective questionnaire. In the "Categories Screen" section, the waterfall layout of the D3 sample had more outstanding TTFF, TFD%, and FC data than the other three samples, and users also tended to choose the D3 sample in the subjective questionnaire. Such inconsistencies and irregularities between objective and subjective data are also common in interface layout surveys. Luan *et al*. (2016) noted that longer gaze times indicate a longer process of information extraction in the designated area, which, to some extent, suggests the difficulty of information extraction. However, it also indicates greater user interest. For example, while the waterfall layout can trigger exploratory gazes, its visual elements may increase the difficulty of information integration, leading to higher cognitive load and thereby reducing the operational efficiency and satisfaction of users' subjective evaluations. The study found that there is no single, definitive, optimal layout form for interface design. Due to differences in information type, user aesthetics, and habits, satisfaction with interface layout varies. According to the findings of Lee *et al.* (2024), if a platform aims to convey primarily textual information to consumers, a list-based design is recommended to facilitate users' processing of textual information; if the platform aims to convey primarily image-based information to consumers, a waterfall layout is more suitable for user browsing.

In the "Account Screen" section, due to the minimal differences in the layout of the stimulus images, the main distinctions lie in the colors and patterns of the icons and backgrounds. ET data shows that areas with richer colors and more prominent hues have shorter first fixation times compared to areas with simpler colors and hues, indicating that regions with more vibrant colors and hues are more effective at capturing attention. However, it is important to note that a higher richness of colors and hues does not necessarily lead to greater user satisfaction with the interface. Balance, centrality, and density are important factors influencing users' aesthetic preferences for interface design (Xiao and Wang 2023). Similar to color, when selecting the size of text and images in an interface, overall coordination should be prioritized to avoid falling into the trap of solely focusing on attracting users' attention. Imbalances in text and image formats may evoke negative emotions such as anxiety or aversion in users, reducing the likelihood of platform usage. Therefore, final design decisions should not be based solely on ET data but should instead involve a comprehensive evaluation incorporating additional theoretical considerations.

DESIGN PRACTICE

Based on the functional priorities determined by AHP and the user demand attributes classified by Kano, the platform prototype was designed. The structural layer design of the platform is shown in Fig. 8.

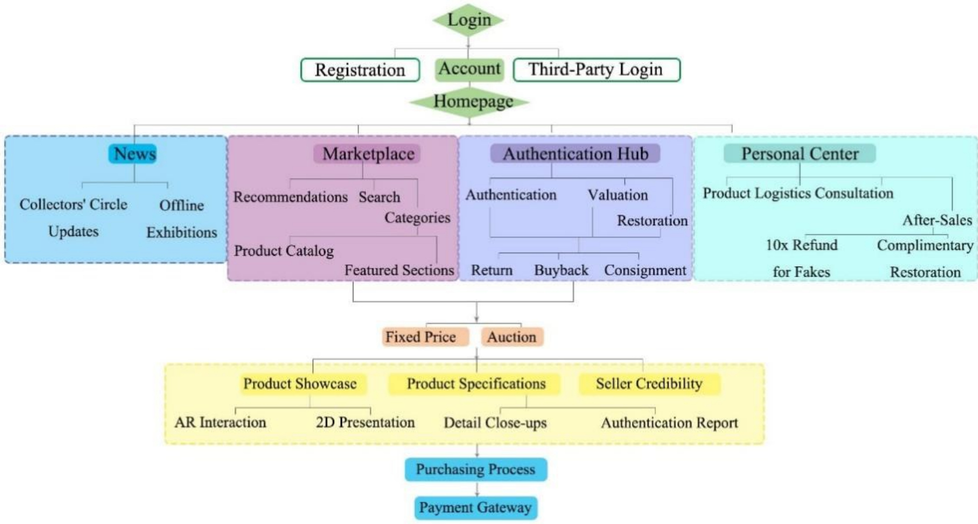

Fig. 8. Platform structure layer design diagram

The platform's functional design is structured around four main sections: “News,” “Marketplace,” “Authentication Hub,” and “Personal Center.” “News” provides updates on industry trends and exhibition content (corresponding to Kano Function 9); “Marketplace” focuses on the most important product quality and price dimensions (AHP B2), offering a “Recommendations” feature based on personalized recommendation principles, as well as “Search” and “Categories” functions. The “Categories” feature, in addition to standard product category classifications, includes a “Featured Sections” function, enabling the creation of specialized modules based on product characteristics (Kano Function 11) and enforcing quality thresholds (AHP C4), thereby grouping products with common features together; “Authentication Hub” is a platform-specific feature zone that addresses the highest-priority user trust assurance requirement (AHP B1) and its core sub-item “professional authentication” (AHP C1), providing users with product authentication, valuation, repair, and maintenance services (Kano functions 1-3, 19). Users can retrieve products after these services or store them in the platform's designated warehouse for sale (Kano function 20); “Personal Center” is the user's personal information zone, integrating service and after-sales support services (AHP B4). Users can post product sales information in this area, view logistics and after-sales status of purchased products, and seek professional consultation (Kano functions 23-28).

The platform interface layout design was based on the results of ET experiments. Drawing inspiration from the style and characteristics of old and antique hongmu furniture, the design incorporates “Chinese-style” aesthetics, resulting in a clean and elegant overall appearance, while also offering layout customization options. In terms of information layout, sections containing important information are prioritized and placed in the upper-middle area of the interface. Key information such as product prices is highlighted with prominent colors. While using color to attract attention, the design also emphasizes the balance, centrality, and density of interface elements to avoid causing user discomfort due to excessive stimulation.

Based on the functional architecture of AHP/Kano and the interface design principles of ET experiments, a high-fidelity interface design for the platform has been completed, as shown in Fig. 9.

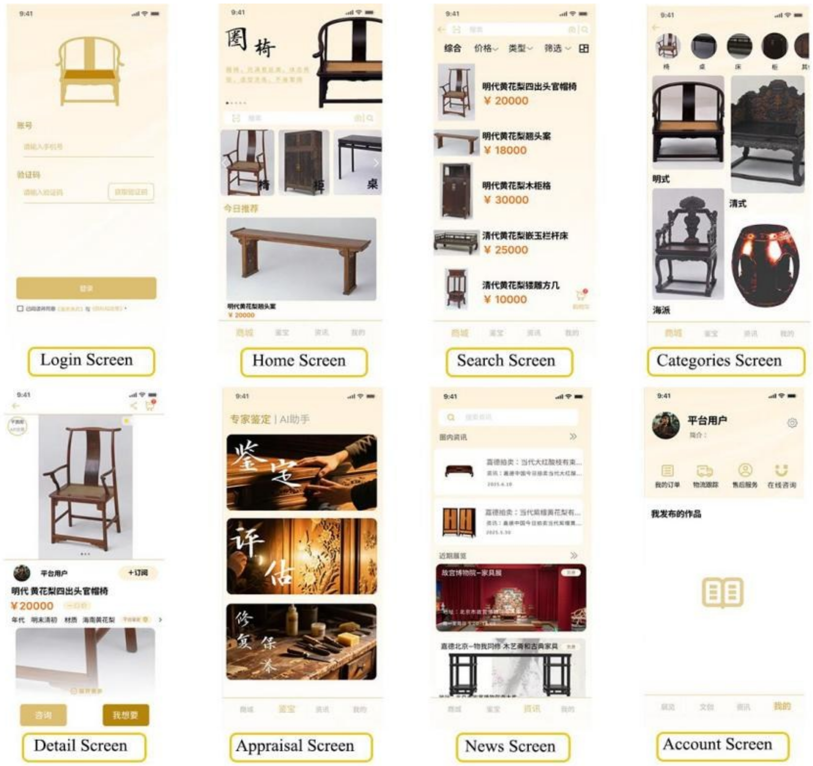

Fig. 9. High-fidelity design drawings

Usability Testing

To validate the usability and learnability of the design scheme, 14 respondents were randomly selected and asked to use SUS to measure their overall perception of the product's usability. According to the formula, the average score of the 14 users was 81.25. This indicates that users have a good user experience when using the platform and are satisfied with the overall design of the old and antique hongmu furniture e-commerce platform.

DISCUSSION

This study uses research methods such as AHP-Kano and ET to consider the functional construction and interface design of e-commerce platforms for old and antique hongmu furniture. In terms of functional construction, the AHP results show that the following six indicators should be considered first: professional authentication, quality thresholds, transparent pricing, after-sales service, transaction security, and fair pricing—that is, the indicators with a composite weight value greater than 0.1. Among these, the two indicators with the highest composite weight values, "professional authentication" (weight value 14.42%) and "quality thresholds" (weight value 14.30%), can be regarded as the highest priority functions. In the Kano model, the analysis results of the Better-Worse diagram indicate that the 20 functions located in the essential attributes quadrant, expected attributes quadrant, and charm attributes quadrant should be prioritized for development. Among these, users classify the return of consigned goods as a charm attribute, while logistics and after-sales functions are categorized as expected attributes, confirming the significant issues currently present in China's second-hand market in these areas (Liu and Wan 2023). Users categorized "professional authentication" as a must-have attribute, while "smart matching recommendations" are classified as a non-differentiating attribute. This aligns with the findings of Lei *et al*. (2024), who noted that the collection-oriented nature of the platform weakens the practical utility demands familiar to artificial intelligence, thereby increasing reliance on human-operated systems.

Combining the results of AHP and Kano, in addition to the above-mentioned functions, the priority results from the AHP should also be considered, incorporating the functions in the non-differentiating attribute quadrant (items 3, 13, 14, and 15) to address users' potential needs.

In terms of interface design, the ET experiment revealed users' attention focus, gaze trajectories, and layout preferences when using online shopping platforms, while also collecting users' evaluations of the importance of interface design factors through subjective questionnaires. While some experimental results differ from subjective evaluations, research on such phenomena indicates that discrepancies between attention allocation and subjective evaluations are normal. For such results, the platform can offer multiple layout options for users to choose from, as platforms such as JD and Taobao do. Regarding other interface design elements, important information should be placed in the upper-middle position based on users' gaze trajectories and ET habits and highlighted using methods such as color and size. Information should be presented in a combination of text and images, but the ratio between images and text should be balanced. The overall style of the interface should be simple and elegant, with consistent colors, to avoid causing information overload and negative emotions such as aversion or avoidance.

However, this study still had some shortcomings. In terms of respondent selection, it did not cover all age groups and relevant industries, while the actual user group was more extensive. Secondly, in terms of physiological measurement technology, this study only used eye-tracking technology. Future studies can combine multimodal fusion methods such as EEG technology, increase sample data, and expand the scope of respondents to improve the accuracy of demand forecasting.

CONCLUSIONS

This study employed a combination of qualitative, quantitative, and psycho-physiological methods to investigate the functional construction and interface design of an e-commerce platform for old and antique hongmu furniture. The research focused on aspects such as user needs acquisition, prioritization of needs, specific needs ranking, and physiological indicator measurement.

1. In terms of functional development, the analytic hierarchy process (AHP) identified the following priority functional indicators: professional certification, quality thresholds, pricing transparency, after-sales service, transaction security, and fair pricing. Kano identified a total of 24 specific functions that needed to be implemented.
2. In terms of interface design, it can be an advantage for the platform to provide multiple layout options for users to choose from. Important information should be placed in the visual center, *i.e*., the upper-middle position, and highlighted in terms of color and size. However, color saturation and text-to-image ratios should be controlled to ensure concise information delivery and reduce cognitive load.

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