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Contemporary Expression of Artistic Genes in Henan Bian Embroidery

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ABSTRACT

Henan Bian embroidery, a national-level intangible cultural heritage rooted in Northern Song court embroidery, is celebrated for its continuous grayscale transition, low-saturation tonal values, and realistic stitching, yet it increasingly struggles with mismatches between traditional craftsmanship and contemporary tastes, weak emotional resonance among younger consumers, and the declining transmission of core techniques. Guided by cultural gene theory, this study decodes the artistic "genes" of Bian embroidery and evaluates how gene fidelity and design innovation shape public acceptance of contemporary expressions. Using a mixed-method design, we collected 168 classical embroidery works and 96 contemporary product samples through literature review and fieldwork, then extracted gene features with an information-entropy model to construct a structured gene map. A stratified questionnaire survey yielded 486 valid responses, and SPSS 26.0 was used for factor analysis and multiple regression to test the driving factors. The results identify a two-level gene system (dominant vs. recessive), organized into four categories and sixteen elements. Regression shows that color gene fidelity (β=0.328), design innovation (β=0.312), morphological gene fidelity (β=0.256), and technique gene fidelity (β=0.215) each exert significant positive effects on acceptance, with strong explanatory power (R^2=0.624). Age-group comparisons further reveal divergent preference structures: Generation Z demonstrates the strongest purchase intention, whereas traditional collectors exhibit the highest cultural identity. Overall, designs that simultaneously maintain high gene fidelity and achieve high innovation receive the greatest approval, supporting a "heritage-preserving yet future-oriented" transformation pathway.

KEYWORDS

Henan Bian embroidery, artistic genes, contemporary expression, cultural symbols, design reconstruction

INTRODUCTION

Henan Bian embroidery originated from Northern Song Dynasty court embroidery, with a thousand years of inheritance, renowned worldwide for its unique ink wash painting style and exquisite realistic embroidery

techniques, hailed as a treasure of Chinese embroidery art [1]. As a cultural symbol of Kaifeng city, Bian embroidery was inscribed on the national intangible cultural heritage list in 2008, with its artistic value and historical status officially recognized [2,3]. The aesthetic characteristics of Bian embroidery are deeply rooted in Song Dynasty court aesthetic traditions, emphasizing elegance, subtlety, and fine delicacy, particularly excelling in reproducing Song Dynasty academy-style paintings [4,5]. Representative works such as the embroidered 'Along the River During the Qingming Festival' recreate Zhang Zeduan's prosperous Bianjing using distinctive stitch techniques like rolling stitch and water ripple stitch, with stitches as fine as hair strands and naturally flowing color transitions, representing an artistic paradigm of using needles as brushes and threads as ink [6].

However, in the contemporary social context, Bian embroidery is facing severe survival challenges. Traditional Bian embroidery products mostly exist as collectibles and gifts, with high prices and weak practicality, gradually drifting away from people's daily lives, showing obvious museumification tendencies [7]. Pattern subjects mostly follow classical painting motifs such as peony, court ladies, and landscapes, lacking response to contemporary aesthetic preferences, making it difficult for young consumer groups to generate emotional resonance [8]. In terms of technique inheritance, older generation embroiderers are gradually retiring, the number of young practitioners is sharply declining, and core techniques face the risk of being lost. Market research shows that fewer than thirty Bian embroidery enterprises remain in Kaifeng, with annual output value shrinking year by year, and the industry overall is in a development bottleneck period [9]. How to realize contemporary value transformation while maintaining the authenticity of Bian embroidery art has become an urgent practical issue to be addressed.

Cultural gene theory provides a new analytical perspective to solve this dilemma. Drawing on the concept of biological genes, cultural genes refer to the smallest information units with heredity, variability, and adaptability in cultural systems, carrying the core characteristics and value connotations of specific cultures [10]. Viewing Bian embroidery as a complex cultural organism, its artistic genes include two levels: dominant genes and recessive genes [11]. Dominant genes are directly observable formal elements, such as color configuration, composition rules, and stitch techniques; recessive genes are the spiritual core hidden beneath the form, such as Song Dynasty aesthetic conception, regional cultural identity, and craftsman spirit inheritance [12]. Through systematic decoding and scientific reconstruction of Bian embroidery artistic genes, formal

innovation can be achieved while preserving cultural roots, organically integrating traditional techniques with contemporary life aesthetics.

Based on the above background, this study proposes the following core questions: How to extract and classify the artistic genes of Bian embroidery? What are the differences in the effects of different types of artistic genes in contemporary expression? How to balance gene fidelity and design innovation to obtain optimal market feedback? The research hypothesizes that scientific extraction and innovative reconstruction of Bian embroidery artistic genes can significantly enhance contemporary expression acceptance, thereby promoting dual enhancement of cultural identity and market economic value [13]. This study aims to construct an operable methodology for the contemporary expression of Bian embroidery artistic genes, providing theoretical support and practical reference for the revitalized inheritance of Henan Bian embroidery and similar intangible cultural heritage projects.

The structure of this paper is arranged as follows: the 2nd section reviews the research status of Bian embroidery techniques, cultural gene theory, and contemporary transformation of traditional handicrafts; the 3rd section elaborates on research design, gene map construction methods, and questionnaire analysis framework; the 4th section presents reliability and validity testing, factor analysis, regression analysis, and group difference comparison results; the 5th section summarizes main findings, proposes practical recommendations, and discusses research limitations and future directions.

LITERATURE REVIEW

Research on Bian Embroidery Techniques and Aesthetic Characteristics

Research on Bian embroidery can be traced back to the textual research and compilation of Song embroidery during the Republican era. In recent years, with the advancement of the intangible cultural heritage protection movement, academic attention to Bian embroidery has significantly increased [14]. Existing research mainly focuses on three aspects: first, historical origin research, tracing the evolution of Bian embroidery from Song Dynasty court embroidery to folk embroidery workshops to modern arts and crafts; second, technique system documentation, classifying and describing characteristic stitch techniques such as rolling stitch embroidery, covering stitch embroidery, and long-and-short stitch embroidery with illustrated analysis; third, aesthetic characteristic interpretation, analyzing the artistic style of Bian embroidery from perspectives of painterliness, color concept, and artistic conception creation [15,16]. However, existing research is mostly qualitative

description, lacking quantitative analysis of the Bian embroidery formal elements, and has not established a gene database for design transformation reference.

Application of Cultural Gene Theory in Design Studies

The concept of cultural genes was first proposed by Dawkins in 'The Selfish Gene' and later developed into the cultural memetics theory system through multidisciplinary development [17]. The design field applies cultural gene theory to research on the modern transformation of traditional culture, forming operational concepts such as cultural DNA and design genes [18]. Researchers extract visual genes from traditional crafts such as paper cutting, shadow puppetry, and blue-and-white porcelain, establishing morphological grammar rules to guide cultural creative product development [19]. The international academic community has made progress in cultural heritage digitization and intelligent design systems, using machine learning technology to achieve automatic recognition and generation of traditional patterns [20, 21]. However, gene research on embroidery-type intangible cultural heritage is currently limited, mostly staying at the pattern level, with gene encoding of craft characteristics such as stitch techniques and textures still lacking.

Research on Contemporary Design Transformation of Traditional Handicrafts

Contemporary transformation of traditional handicrafts is a hot intersection of design studies and cultural heritage studies [22]. Research paths include: symbol extraction and redesign, simplifying traditional elements into visual symbols for application in modern products; material and craft innovation, reinterpreting traditional craftsmanship with new materials and technologies; cross-boundary integration design, combining handicrafts with fashion, technology, art, and other fields [23]. At the practical level, domestic and international brands such as Hermès, Shang Xia, and Exception have accumulated rich experience in modernizing traditional crafts. At the academic level, researchers use tools such as Kansei engineering and semantic differential methods to evaluate consumer cognition and preferences for traditional elements [24, 25]. However, most research focuses on case analysis, lacking empirical testing of the balance between gene fidelity and design innovation, making it difficult to provide quantitative guidance for design practice [26].

In summary, research on contemporary expression of Bian embroidery has three gaps: first, the lack of systematic and structured artistic gene extraction methods; second, the lack of empirical comparison of expression effects of different gene elements in contemporary carriers; third, the optimization rules for gene fidelity and design innovation have not yet been revealed. This study will explore these gaps, constructing a Bian embroidery artistic gene map and validating its contemporary expression effects.

RESEARCH METHODS

Research Design and Approach

This study employs a mixed research methodology, combining qualitative and quantitative analysis. The research is divided into four stages: the first stage is the gene extraction stage, collecting Bian embroidery sample materials through literature analysis and field investigation, extracting artistic genes using the information entropy model and constructing a gene map; the second stage is the design transformation stage, designing contemporary carrier product schemes according to three expression modes; the third stage is the effect evaluation stage, collecting consumer perception data through questionnaire surveys; the fourth stage is the model validation stage, using statistical analysis to test research hypotheses. The research framework follows the closed-loop logic of gene extraction, design reconstruction, carrier application, and value feedback, as shown in Figure 1.

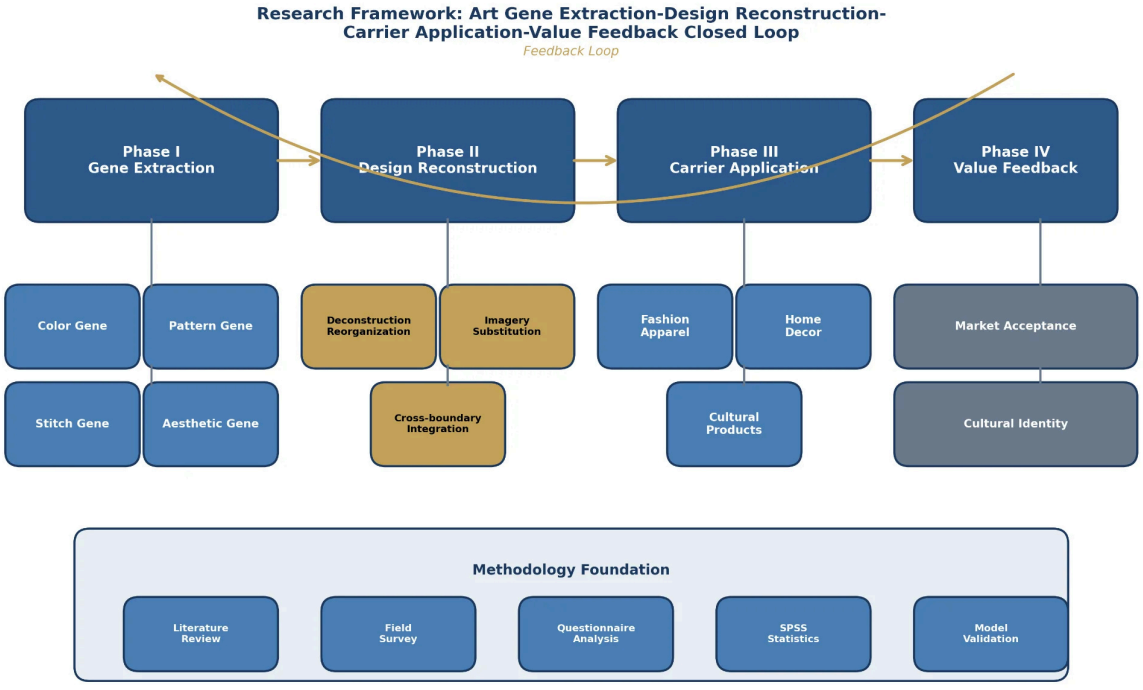

Figure 1. Research Framework for Contemporary Expression of Bian Embroidery Artistic Genes

Data Sources and Samples

Research data sources include three channels: first, museum collection image data, collecting 168 high-definition images of classic Bian embroidery works from institutions such as Henan Museum, Kaifeng Museum, and China National Silk Museum, covering subject types including flowers and birds, figures, landscapes,

and animals; second, Kaifeng Bian embroidery enterprise survey data, conducting field visits to 12 major enterprises including Bian Embroidery Factory and Kaifeng Bian Embroidery Research Institute, interviewing 18 intangible cultural heritage inheritors, and collecting 96 contemporary Bian embroidery product samples; third, consumer Kansei engineering questionnaire data, distributing questionnaires among three groups of design students, intangible cultural heritage inheritors, and ordinary consumers using stratified sampling methods.

The questionnaire survey was conducted from March to May 2024, using a combination of online and offline methods. Online distribution was conducted through the Wenjuanxing platform with targeted delivery, while offline intercept interviews were conducted at venues such as Kaifeng Bian Embroidery Exhibition Center and Zhengzhou Cultural Creative Market. A total of 550 questionnaires were distributed, with 486 valid questionnaires recovered, achieving an effective recovery rate of 88.36%. In sample composition, design students accounted for 32.10%, intangible cultural heritage inheritors and practitioners for 12.35%, and ordinary consumers for 55.55%. Age distribution covered the 18 to 65 age range, with Generation Z respondents accounting for 32.10%, Millennials for 29.22%, Generation X for 22.22%, and traditional collector groups for 16.46%.

Construction of Bian Embroidery Artistic Gene Map

The construction of the Bian embroidery artistic gene map follows the dual-layer structure of dominant genes and recessive genes[27]. Specifically, this ink-wash gradient is not merely a poetic aesthetic imagery; at the digital encoding level intended for design, it strictly manifests as the continuous progression of grayscale values and the precise mapping of low-saturation color parameters; morphological genes cover four subcategories: realistic reproduction, symmetrical balance, figure-ground relationship, and decorative rhythm. It should be particularly noted that, as a quintessential three-dimensional physical art form, the dominant manifestation of Bian embroidery is by no means limited to two-dimensional visual patterns; the indispensable “tactile and texture characteristics” constitute its core distinction from flat painting. This encompasses the inherent optical refractive luster of silk threads, the 3D undulating tactile sensation created by the intertwining of different stitch techniques (such as the raised feel of rolling stitches versus the smoothness of flat stitches), and the micro-physical topological structure imparted to the fabric surface by the embroidery process. Within the gene map framework of this study, this 3D tactile texture is not isolated as an independent category, but is rather treated as a cross-dimensional physical attribute, organically internalized within the synergistic interaction between the dominant “morphological genes” and the recessive “technique genes” discussed

below. Recessive genes include technique genes and artistic conception genes, with technique genes covering four core stitch techniques: rolling stitch, water ripple stitch, flat stitch, and blending stitch; artistic conception genes cover four dimensions: poetic-pictorial conception, cultural symbols, emotional resonance, and historical memory.

Gene extraction employs the information entropy model for quantitative analysis. Let the Bian embroidery sample set S contain n samples, with each sample containing m gene features. The information entropy calculation formula for the j-th gene feature is: $jH(j)$

$$H(j) = -\sum_{i=1}^{n} p(i,j) \times \log_2 p(i,j) \tag{1}$$

Where $p(i,j)$ represents the probability distribution of the i sample on the j gene feature. The larger the information entropy, the richer the information content of that gene feature, and the stronger its representation capability for Bian embroidery artistic characteristics. Based on the information entropy calculation results, the weight of each gene feature is determined: $w(j)$

$$w(j) = \frac{H(j)}{\sum_{k=1}^{m} H(k)} \tag{2}$$

Based on the above information and entropy analysis results, this study constructed the Bian embroidery artistic gene map (Figure 2). The map is presented in a tree structure, containing two major branches of dominant genes and recessive genes, four gene types, and sixteen gene elements, systematically displaying the hierarchical relationships and internal structure of Bian embroidery artistic characteristics. It must be emphasized that the information entropy model and the subsequent multiple regression analysis serve distinct and complementary methodological functions in this study. The information entropy model quantifies the historical information content and typicality of artistic genes based on the physical feature distribution of objective samples, addressing the foundational question of “what to extract.” In contrast, the multiple regression analysis relies on subjective questionnaire surveys to evaluate the market acceptance of these extracted genes after contemporary design transformation, addressing the question of “how to express and transform.” The combination of the two achieves a logical closed-loop from objective physical characteristics to subjective perceived value.

Contemporary Expression Mode Design

According to the transformation rules of cultural genes, this study designs three contemporary expression modes: deconstruction-reconstruction mode, imagery substitution mode, and cross-boundary integration mode. The deconstruction-reconstruction mode refers to extracting the core visual elements of Bian embroidery, breaking the original combination relationships, and rearranging according to modern design principles, suitable for carriers such as clothing and home furnishings; the imagery substitution mode refers to retaining the technique characteristics and artistic conception atmosphere of Bian embroidery while replacing specific expression objects, interpreting traditional crafts with contemporary themes; the cross-boundary integration mode refers to combining Bian embroidery crafts with modern technology, fashion trends, digital art, and other fields, expanding its expression boundaries and application scenarios.

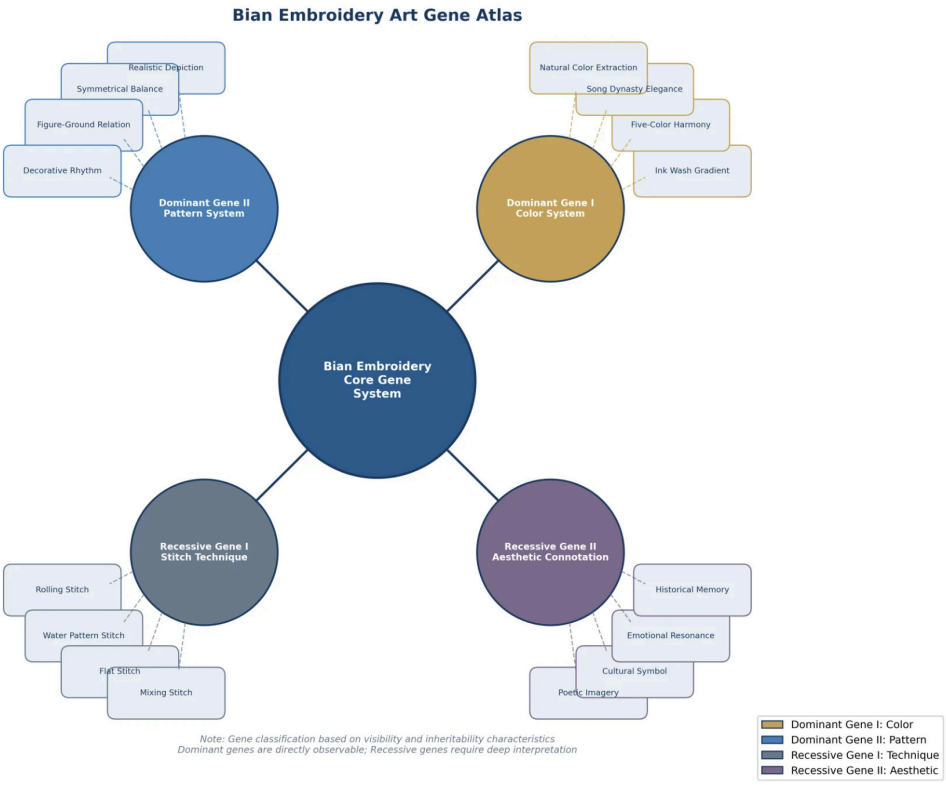

Figure 2. Artistic Gene Map of Henan Bian Embroidery

The evaluation model for the integration degree of traditional genes and modern design is constructed as follows. Let gene fidelity be G, with a value range of 0 to 1, where larger values indicate higher retention of traditional genes; let design innovation be I, with a value range of 0 to 1, where larger values indicate higher innovation in modern design. The calculation formula for the integration degree F is:

$$F = \alpha G + \beta I + \gamma G \times I \tag{3}$$

Where α , β , and γ are parameters to be estimated, α + β =1, and γ is the interaction effect coefficient. This model considers both the linear contributions of fidelity and innovation and incorporates the synergistic effect of both, capable of revealing the optimal ratio rules for combining traditional methods with modern aesthetics. The encoding-decoding bidirectional pathway mechanism for transforming Bian embroidery artistic genes from traditional form to contemporary expression is shown in Figure 3.

Questionnaire Design and Data Analysis

The questionnaire was designed using a five-point Likert scale, containing four measurement dimensions: aesthetic compatibility, cultural identity, functional practicality, and market premium capability[5]. Each dimension contains 4 to 6 measurement items, totaling 22 items. Questionnaire pre-testing was conducted among 50 respondents, and items with insufficient discrimination were eliminated based on item analysis results before formal distribution after revision.

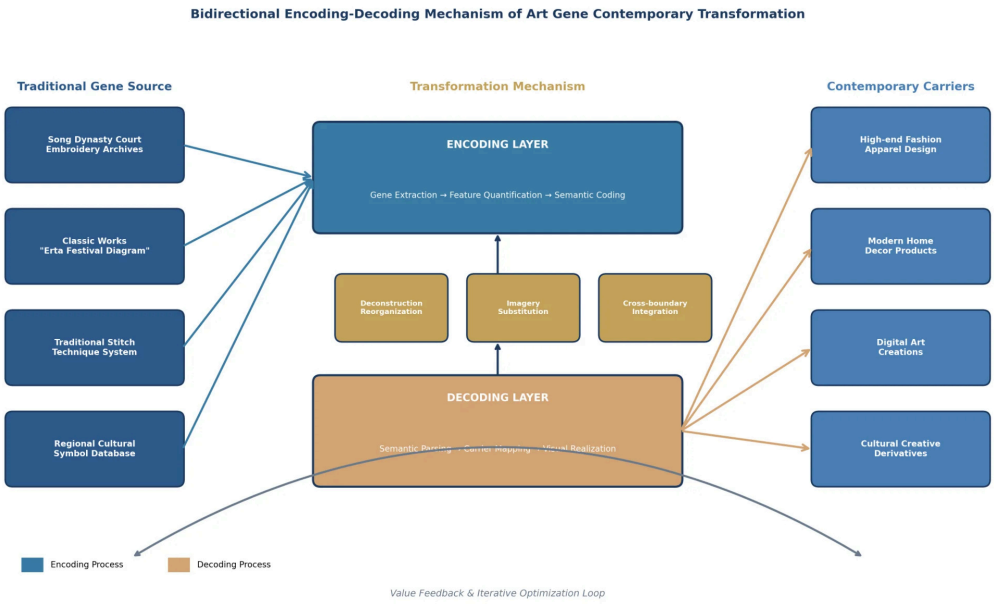

Figure 3. Encoding-Decoding Bidirectional Pathway Mechanism of Bian Embroidery Artistic Genes

Data analysis was completed using SPSS 26.0 software. First, reliability and validity testing were conducted, using Cronbach's α coefficient to assess internal consistency reliability and exploratory factor analysis to assess construct validity. Second, descriptive statistics and correlation analysis were conducted to reveal association patterns between variables. Then, multiple regression analysis was conducted to test the influence of gene

fidelity and design innovation on contemporary expression acceptance. Finally, analysis of variance and post-hoc comparisons were conducted to explore aesthetic preference differences among different groups. The regression model for the market value conversion rate of contemporary expression is set as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \quad (4)$$

Where Y is contemporary expression acceptance, X_1 is color gene fidelity, X_2 is morphological gene fidelity, X_3 is technique gene fidelity, X_4 is design innovation, β_0 is the constant term, β_1 to β_4 are regression coefficients, and ε is the random error term. Through model estimation, the relative importance of each factor and the optimal combination scheme can be determined.

RESULTS AND DISCUSSION

Sample Characteristics Description

The demographic characteristics distribution of the valid samples is shown in Table 1. The gender structure of the sample indicates that female respondents accounted for a slightly higher proportion at 56.38%, with males at 43.62%, which basically matches the gender structure of the Bian embroidery consumer groups. From the perspective of age cohorts, the Generation Z group aged 18-25 accounted for 32.10%, Millennials aged 26-40 for 29.22%, Generation X aged 41-55 for 22.22%, and traditional collectors over 56 for 16.46%, with the sample covering the main age segments of potential Bian embroidery consumers. In terms of education distribution, bachelor's degree and above accounted for 72.43%, indicating an overall high educational level of the sample. The occupational composition characteristics demonstrate that design students accounted for 32.10%, intangible cultural heritage practitioners for 12.35%, and ordinary consumers for 55.55%, forming an effective contrast between professional and general public groups.

Table 1. Demographic Characteristics of Respondents

Category	Option	Number	Percentage	Cumulative Percentage
Gender	Male	212	43.62%	43.62%
	Female	274	56.38%	100.00%
Age	18-25 years	156	32.10%	32.10%
	26-40 years	142	29.22%	61.32%
	41-55 years	108	22.22%	83.54%
	56 years and above	80	16.46%	100.00%

Category	Option	Number	Percentage	Cumulative Percentage
Education	High school and below	68	13.99%	13.99%
	Associate degree	66	13.58%	27.57%
	Bachelor's degree	248	51.03%	78.60%
	Master's degree and above	104	21.40%	100.00%

To gain an in-depth understanding of different consumer groups' preference levels for various Bian embroidery gene elements, this study created a user preference heat map (Figure 4). The horizontal axis of the heat map represents six product carrier categories (clothing, home furnishings, cultural creative products, digital products, artworks, and collectibles), the vertical axis represents eight core gene elements, and color intensity represents preference level. It can be observed that color genes have the highest preference in clothing and home furnishing categories, technique genes receive more attention in artworks and collectibles, and artistic conception genes perform prominently in cultural creative products.

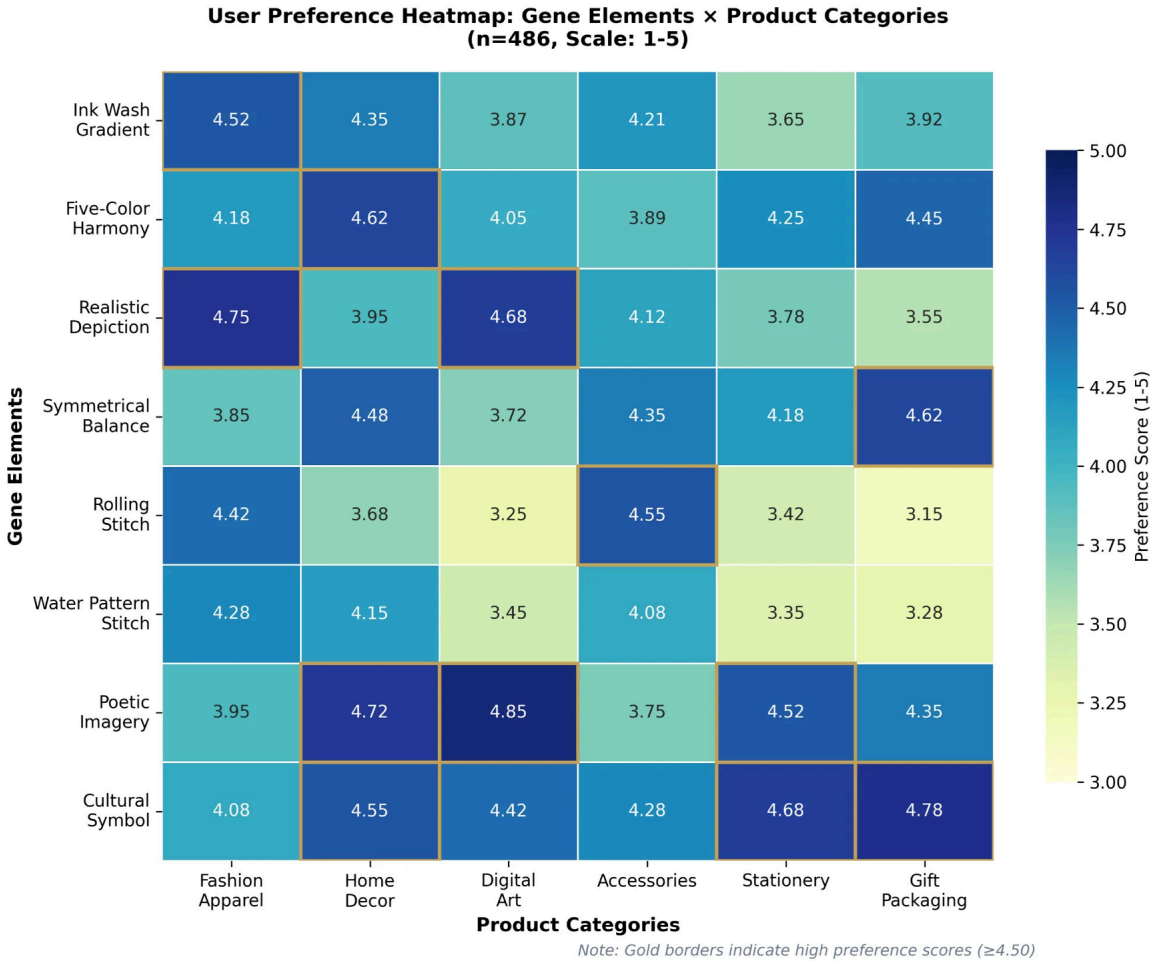

Figure 4. User Preference Heat Map of Bian Embroidery Artistic Genes

Reliability and Validity Testing

Reliability testing used Cronbach's α coefficient to assess the internal consistency of the questionnaire. Results showed that the aesthetic compatibility dimension α=0.892, cultural identity dimension α=0.878, functional practicality dimension α=0.865, market premium capability dimension α=0.851, and total scale α=0.924. The α coefficients of all dimensions and the total scale exceeded the high reliability standard of 0.85, indicating that the questionnaire has good measurement stability.

Validity testing used exploratory factor analysis to assess construct validity. The KMO value was 0.912, exceeding the excellent standard of 0.9; Bartlett's test of sphericity χ^2=5862.47, df=231, p<0.001, reaching significance level, indicating that the data is suitable for factor analysis. Principal component analysis was used to extract factors, with eigenvalue greater than 1 as the criterion, extracting 4 common factors with cumulative variance explained of 77.23%. Factor loadings of all items on corresponding factors exceeded 0.6, cross-loadings were all less than 0.4, and factor structure was clear, consistent with theoretical conception.

Table 2. Coding Table of Henan Bian Embroidery Artistic Genes

Gene Level	Gene Type	Gene Element	Feature Description
Dominant Genes	Color Genes	Ink wash gradation	Natural transition of black, white, and gray gradients
		Five-color harmony	Traditional color scheme of blue, red, yellow, white, and black
		Song's elegant color palette	Elegant and subtle court color tones
		Nature-derived colors	Nature-inspired color selection
	Morphological Genes	Realistic reproduction	Pursuing realistic effects with both form and spirit
		Symmetrical balance	Central axis symmetry and visual balance
		Figure-ground relationship	Solid and void treatment of the subject and background
		Decorative rhythm	Rhythmic sense of repetition and variation
Recessive Genes	Technique Genes	Rolling stitch embroidery	Stitches interlacing and rolling into lines
		Water ripple stitch	Stitch technique simulating water wave flow
		Flat stitch embroidery	Basic straightforward stitch technique
		Blending stitch embroidery	Gradient effect of blending colored threads
		Poetic-pictorial conception	Poetry in painting and painting in poetry
	Artisti Conception Genes	Cultural symbols	Auspicious implications and symbolic expression
		Emotional resonance	Triggering the emotional experience of viewers
		Historical memory	Carrying regional historical context

Factor Analysis Results

Exploratory factor analysis employed principal component analysis with Varimax orthogonal rotation, extracting common factors with eigenvalues greater than 1. The scree plot shows that the eigenvalues of the first four factors are 4.856, 2.347, 1.892, and 1.245, respectively, with the fifth factor eigenvalue dropping to 0.876, showing an obvious inflection point. According to the Kaiser criterion, four factors were retained. The four factors cumulatively explain 77.23% of total variance, with variance contribution rates of 35.42%, 17.12%, 13.80%, and 10.89%, respectively. Factor analysis results are shown in Figure 5.

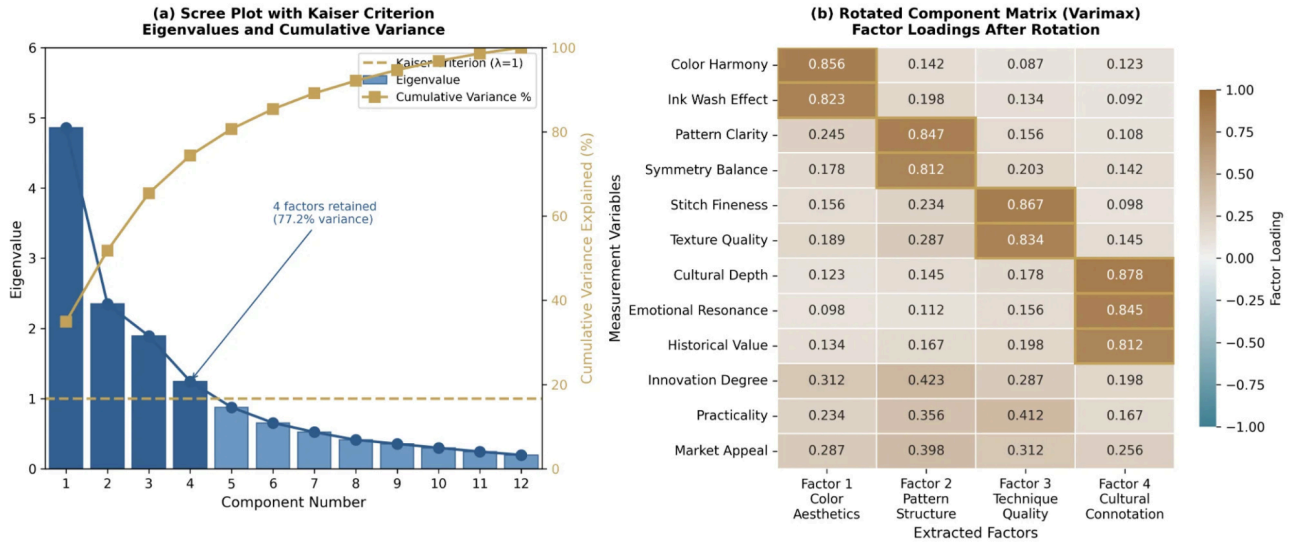

Figure 5. Factor Analysis Scree Plot and Rotated Component Matrix

The rotated component matrix shows a clear factor structure. Factor one is named the color aesthetics factor, containing items such as color harmony and ink wash effect, with main loadings ranging from 0.823 to 0.856; factor two is named the morphological structure factor, containing items such as pattern clarity and symmetrical balance, with main loadings ranging from 0.812 to 0.847; factor three is named the technique quality factor, containing items such as stitch fineness and texture quality, with main loadings ranging from 0.834 to 0.867; factor four is named the cultural connotation factor, containing items such as cultural depth, emotional resonance, and historical value, with main loadings ranging from 0.812 to 0.878. The factor structure highly matches the theoretical classification of Bian embroidery artistic genes, validating the construct validity of the gene map.

Table 3. Weight Table of Contemporary Expression Evaluation Index System for Artistic Genes

Primary Indicator	Secondary Indicator	Information Entropy	Weight	Rank
Aesthetic Compatibility	Color harmony	0.856	0.142	2
	Pattern aesthetics	0.824	0.135	4
	Overall coordination	0.812	0.128	5
Cultural Identity	Cultural recognition	0.867	0.148	1
	Emotional resonance	0.798	0.118	6
	Historical value perception	0.845	0.138	3
Functional Practicality	Ease of use	0.756	0.098	7
	Scenario adaptability	0.723	0.093	8

Regression Analysis Results

Multiple linear regression analysis was conducted with contemporary expression acceptance as the dependent variable and color gene fidelity, morphological gene fidelity, technique gene fidelity, and design innovation as independent variables [28]. The model R^2 value is 0.624, adjusted R^2 is 0.619, F=132.45, p<0.001, indicating that the model is overall significant, with the four independent variables jointly explaining 62.4% of the dependent variable variance, showing strong explanatory power. The structural equation model and path coefficients for the contemporary expression of Bian embroidery artistic genes are shown in Figure 6.

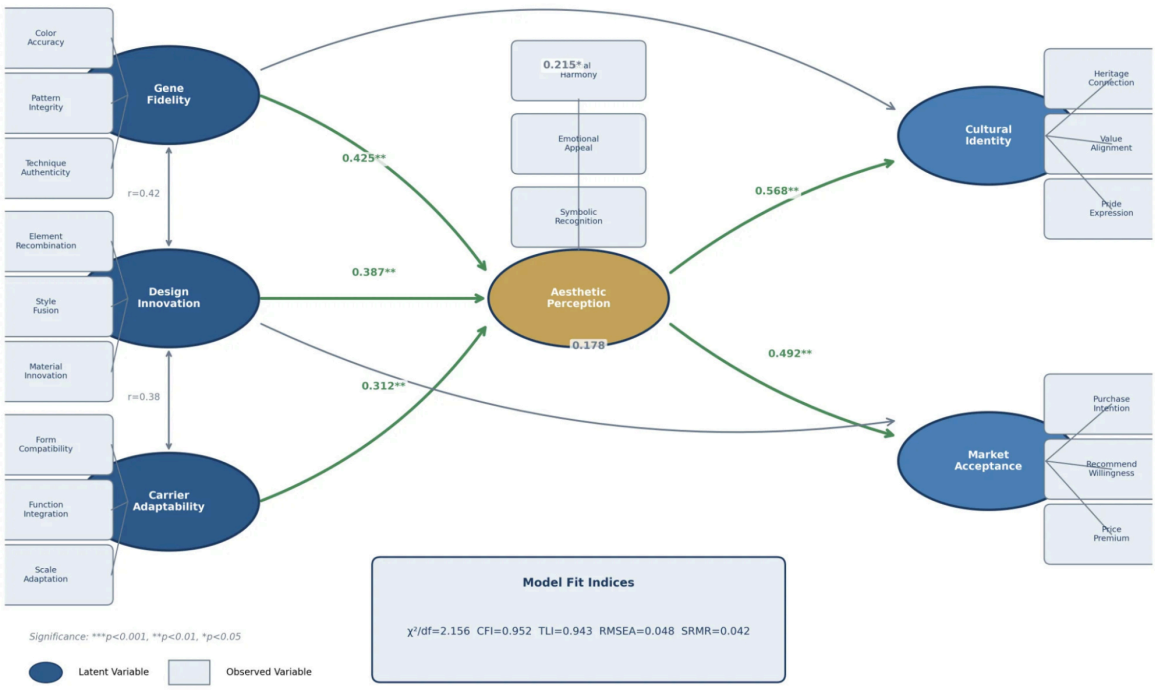

Figure 6. Structural Equation Model of Contemporary Expression of Bian Embroidery Artistic Genes

Table 4. Multiple Regression Analysis Coefficient Table

Variable	B	SE	β	t	Sig.
Constant	0.526	0.142	-	3.704	<0.001
Color Gene Fidelity	0.425	0.052	0.328	8.173	<0.001
Morphological Gene Fidelity	0.312	0.048	0.256	6.500	<0.001
Technique Gene Fidelity	0.287	0.055	0.215	5.218	<0.001
Design Innovation	0.398	0.058	0.312	6.862	<0.001

Note: R^2=0.624, Adjusted R^2=0.619, F=132.45, p<0.001

Visualization of regression analysis results is shown in Figure 7. Regression coefficients show that all four independent variables have significant positive effects on contemporary expression acceptance. Standardized regression coefficients in descending order are: color gene fidelity β=0.328, design innovation β=0.312, morphological gene fidelity β=0.256, technique gene fidelity β=0.215. This indicates that in contemporary expression of Bian embroidery, faithful inheritance of color genes is most critical, followed by innovative breakthroughs at the design level, while the influence of morphological genes and technique genes is relatively weaker but still significant.

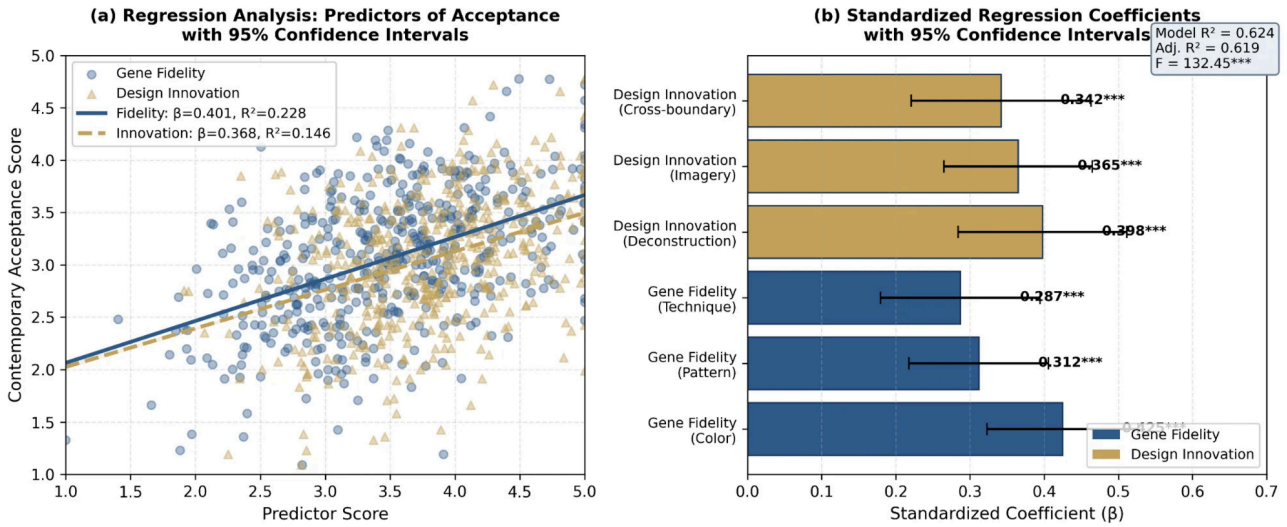

Figure 7. Regression Analysis, Scatter Plot, and Coefficient

The interaction effect between gene fidelity and design innovation was further tested. Including the product term of gene fidelity and design innovation in the regression model, results show that the interaction term coefficient γ=0.12, t=3.42, p<0.01, with a significant interaction effect. This means that the synergistic combination of high fidelity and high innovation can produce additional gain effects, validating the theoretical

hypothesis of the integration model. Although this interaction coefficient is relatively low compared to the main effects, indicating it is not the absolute dominant factor driving acceptance, it objectively confirms a crucial boundary condition statistically: radical innovation devoid of gene fidelity, or pure replication lacking modern design transformation, cannot maximize market value. Optimal design schemes should pursue a dynamic balance between traditional methods and modern aesthetics, rather than simple traditional replication or radical innovation.

Aesthetic Preference Differences Among Different Groups

One-way analysis of variance was conducted with age groups as the independent variable and scores on each evaluation dimension as the dependent variables. Results show that the four age groups have significant differences on four dimensions of aesthetic appreciation, cultural identity, purchase intention, and innovation acceptance, with F values of 12.35, 18.72, 15.48, and 28.63, respectively, all $p<0.001$.

Table 5. Aesthetic Preference Differences Among Different Age Groups

Evaluation Dimension	Generation Z	Millennials	Generation X	Traditional Collectors	F-value
Aesthetic Appreciation	4.35	4.42	4.58	4.25	12.35***
Cultural Identity	3.68	4.15	4.72	4.85	18.72***
Purchase intention	4.52	4.28	3.95	3.42	15.48***
Innovation Acceptance	4.78	4.35	3.52	2.85	28.63***

Note: ***$p<0.001$

The aesthetic preference characteristics of each generational group can be clearly observed (Figure 8): Generation Z performs prominently on purchase intention and innovation acceptance dimensions, traditional collectors have advantages on cultural identity and aesthetic appreciation dimensions, while Millennials and Generation X show relatively balanced evaluation patterns. Post-hoc multiple comparisons used the LSD method for pairwise contrasts. On the aesthetic appreciation dimension, Generation X scored highest, significantly higher than Generation Z and traditional collectors, indicating that middle-aged groups have a stronger aesthetic appreciation ability for Bian embroidery. On the cultural identity dimension, traditional collectors and Generation X scored significantly higher than younger groups, reflecting differences in cultural memory between generations. On the purchase intention dimension, Generation Z scored highest, significantly higher than the other three groups, reflecting young consumers' enthusiasm for guochao products. Specific to Bian

embroidery, Generation Z's high purchase intention is not merely based on generalized trend-following of the 'Guochao' movement, but stems from the specific visual reconstruction potential of the craft. In open-ended questionnaire feedback, this group clearly indicated that the cross-boundary integration strategy of Bian embroidery—which combines traditional 'flat stitch' and 'rolling stitch' textures with modern digital art or ACG (Anime, Comic, and Games) IPs—breaks the antiquated feel of traditional intangible cultural heritage. This collision of high-density traditional handcrafted textures with avant-garde cyberpunk or minimalist visual contexts provides them with a unique identity symbol that simultaneously embodies deep historical heritage and aggressive personalized expression. On the innovation acceptance dimension, age showed a significant negative correlation, with Generation Z's acceptance of innovative design far higher than that of traditional collectors.

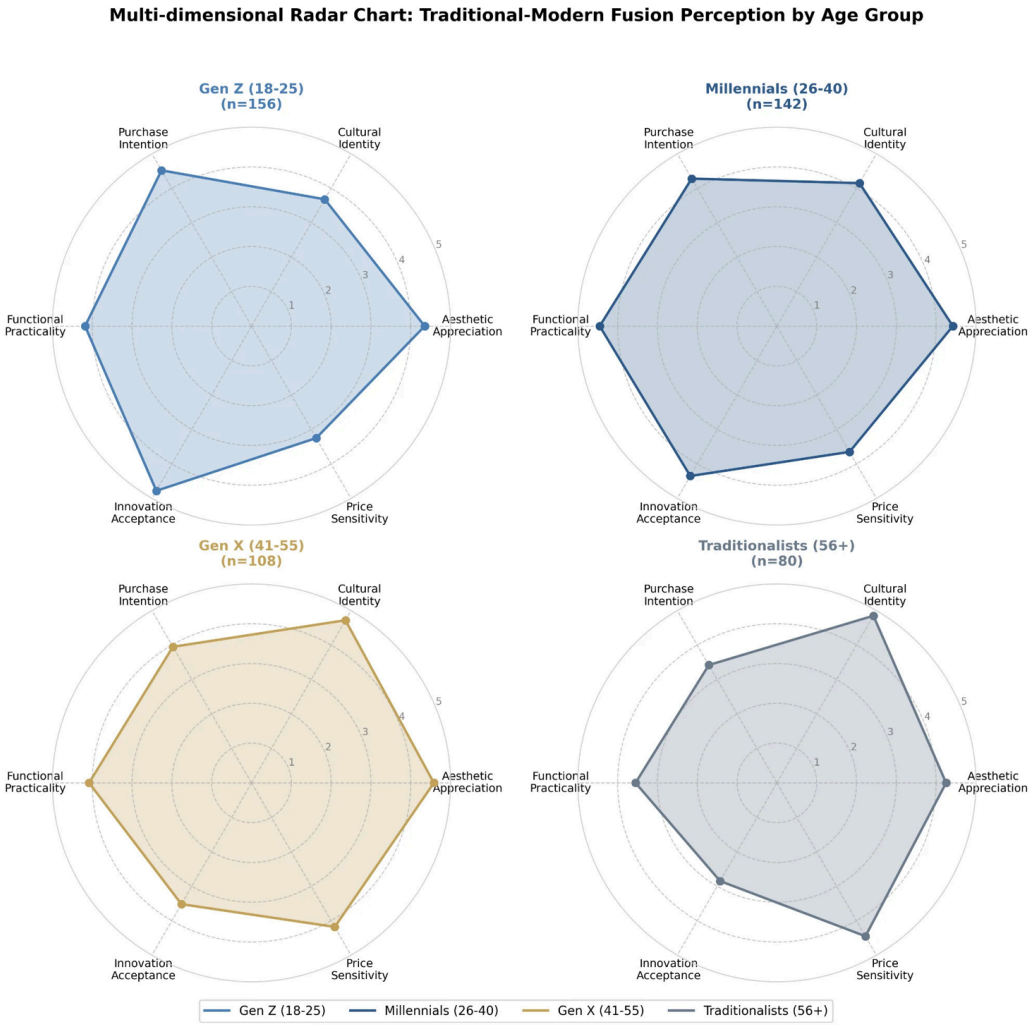

Figure 8. Multi-dimensional Radar Chart of Aesthetic Preferences Among Four Generational Groups

The above differences provide important implications for Bian's contemporary expression strategies. Product design targeting Generation Z can increase innovation intensity, adopting a cross-boundary integration mode to combine Bian embroidery elements with trend culture and digital art; products targeting traditional collectors should focus on gene fidelity, adopting an imagery substitution mode to interpret classic techniques with contemporary themes. Differentiated product strategies help cover broader consumer groups and maximize market value.

Market Acceptance Comparison of Design Strategies

Comparative analysis was conducted on the market acceptance of four design strategies, including deconstruction-reconstruction, imagery substitution, cross-boundary integration, and traditional replication. Respondents evaluated design schemes of the four strategies, with results shown in Table 6.

Table 6. Market Acceptance Comparison Under Different Design Strategies

Design Strategy	Aesthetic Appeal	Cultural Identity	Purchase intention	Price Premium
Deconstruction-Reconstruction	4.25±0.68	3.85±0.72	4.12±0.65	3.92±0.78
Imagery Substitution	4.42±0.62	4.28±0.58	3.95±0.71	3.68±0.82
Cross-boundary Integration	4.68±0.55	3.52±0.85	4.45±0.58	4.25±0.65
Traditional Replication	3.75±0.78	4.72±0.52	3.25±0.88	3.45±0.92

Note: Values are mean±standard deviation, rating range 1-5 points

From Figure 9, it can be intuitively seen that the cross-boundary integration strategy has obvious advantages in aesthetic appeal and purchase intention, while the traditional replication strategy performs best in cultural identity. Results show that the cross-boundary integration strategy scores highest on three dimensions of aesthetic appeal, purchase intention, and price premium, but scores lower on cultural identity; the traditional replication strategy has the highest cultural identity but lower aesthetic appeal and purchase intention; the imagery substitution strategy performs relatively balanced across all dimensions; the deconstruction-reconstruction strategy scores at a medium level overall[28]. Overall, the cross-boundary integration strategy is most suitable for product development targeting young consumer markets, the imagery substitution strategy is suitable for mid-to-high-end positioning that balances tradition and modernity, and the traditional replication strategy is suitable for niche demand in the collectibles market. This simultaneously reveals an inevitable paradox in the contemporary transformation of intangible cultural heritage: the excessive pursuit of modern

practicality and cross-boundary integration inevitably dilutes its “cultural identity” as a national heritage. The key to resolving this tension lies not in the absolutization of a single strategy, but in establishing a multi-tiered product matrix: utilizing the “cross-boundary integration” strategy for entry-level practical products to expand market reach and attract younger demographics, while employing “imagery substitution” or “traditional replication” strategies to maintain the core cultural genes and identity of high-end product lines.

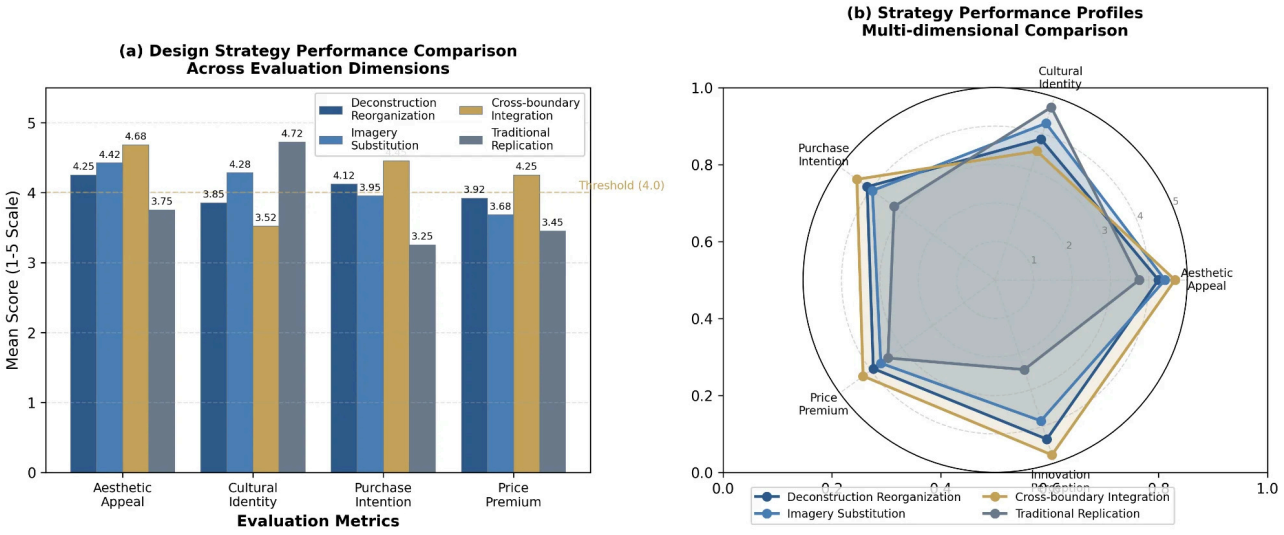

Figure 9. Multi-dimensional Comparison Chart of Market Acceptance for Four Design Strategies

CONCLUSION AND LIMITATIONS

Main Findings

This study uses cultural gene theory as an analytical framework to systematically explore the extraction methods and contemporary expression strategies of Henan Bian embroidery artistic genes, empirically validating the influence mechanism of gene fidelity and design innovation on contemporary expression acceptance. The main findings are as follows:

1), Bian embroidery artistic genes can be classified into two levels of dominant genes and recessive genes, four types of color genes, morphological genes, technique genes, and artistic conception genes, totaling sixteen gene elements. Information entropy analysis shows that rolling stitch and water ripple stitch in technique genes have the highest information content, representing the core genes that distinguish Bian embroidery from other embroidery types; ink wash gradation and Song Dynasty elegant color palette in color genes are key elements reflecting Song Dynasty court aesthetics. The construction of the gene map provides a scientific basis for digital protection and innovative design of Bian embroidery.

2), Contemporary expression strategies of Bian embroidery artistic genes can significantly enhance cultural identity and market economic value. Regression analysis results confirm that color gene fidelity, morphological gene fidelity, technique gene fidelity, and design innovation all have significant positive effects on contemporary expression acceptance, with model explanatory power reaching 62.4%. Among them, color genes have the greatest influence, followed by design innovation, indicating that retaining the color system with Song Dynasty aesthetic charm is the primary task for contemporary expression of Bian embroidery.

3), There is a significant synergistic effect between gene fidelity and design innovation. The integrated design scheme with high fidelity and high innovation achieved the highest contemporary expression acceptance, validating the effectiveness of combining traditional methods with modern aesthetics. This finding breaks the binary opposition thinking between traditional protection and modern innovation, revealing the dialectical law of cultural heritage revitalization: traditional genes are the foundation and soul of innovative design, innovative design is the contemporary interpretation and value realization of traditional genes, and the two are interdependent and mutually promoting.

4), Significant differences exist in aesthetic preferences for the contemporary expression of Bian embroidery among different age groups. Generation Z consumers have high acceptance of innovative design and strong purchase intention, but relatively weaker cultural identity; traditional collectors have low acceptance of innovative design but stronger cultural identity and aesthetic appreciation ability. Differentiated product strategies are key to covering diverse markets, with a cross-boundary integration strategy suitable for young markets, an imagery substitution strategy suitable for mid-to-high-end markets, and a traditional replication strategy suitable for collection markets.

Practical Recommendations

Based on research findings, this paper proposes the following recommendations for contemporary development of the Bian embroidery industry: establish a Bian embroidery artistic gene database, systematically encoding classic collection works and outstanding contemporary works according to the gene map constructed in this study, establishing a searchable and retrievable digital gene library; implement a minimalist transformation strategy that retains Song Dynasty aesthetic charm, prioritizing retention of color gene authenticity in product design and reinterpreting Song Dynasty aesthetic conception with modern minimalist language; implement differentiated product development and marketing strategies, developing differentiated products for different age groups; strengthen industry-academia-research collaboration and cross-boundary coopera-

tion, introducing multidisciplinary forces to participate in product development, leveraging the opportunity of guochao rise to enhance brand cultural added value.

Limitations and Future Directions

This study has the following limitations: first, samples are mainly concentrated in Henan and surrounding areas, with geographic coverage needing expansion; second, the relatively high proportion of design students in the sample (32.10%) may introduce a certain degree of "professional bias," potentially overestimating the overall acceptance of innovative designs and not fully reflecting the actual paying market for high-end embroidery. However, as the core consumers and potential driving force for future "Guochao" products, their preferences still hold significant predictive value for the contemporary transformation trends of intangible cultural heritage; third, gene extraction is mainly based on visual analysis, with insufficient attention to tactile characteristics of stitch techniques and temporal characteristics of the embroidery process; fourth, evaluation of contemporary expression effects is mainly based on subjective questionnaires, lacking validation from objective indicators such as eye tracking and physiological signals. Future research can be deepened in the following directions: first, introducing artificial intelligence technology to achieve automatic recognition and intelligent generation of Bian embroidery genes; second, conducting cross-cultural comparative research to extract universal laws for contemporary transformation of traditional embroidery; third, tracking market performance of Bian embroidery products to validate long-term benefits of contemporary expression strategies; fourth, exploring immersive inheritance models for Bian embroidery techniques, leveraging virtual reality technology to expand intangible cultural heritage dissemination pathways. In conclusion, the contemporary expression of Bian embroidery artistic genes is a systematic project involving cultural protection, design innovation, and market operation. It is hoped that this thousand-year-old craft can bloom with unique brilliance in contemporary life aesthetics.

Author Contributions

Conceptualization – Zhao L S; methodology – Zhao L S; formal analysis – Zhao L S; investigation – Zhao L S; resources – Zhao L S; writing-original draft preparation – Zhao L S; writing-review and editing – Zhao L S; visualization – Zhao L S; supervision – Zhao L S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The author declares no conflict of interest. The authors identify no personal circumstances or interests that may be perceived as inappropriately influencing the representation or interpretation of the reported research results.

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Human Research Subjects

This study involves the distribution and collection of questionnaires for primary data acquisition. The research protocols were conducted in strict accordance with the Declaration of Helsinki and relevant ethical guidelines. Prior to participation, informed consent was obtained from all subjects, who were fully briefed on the research objectives, the voluntary nature of their participation, and their right to withdraw at any time. To ensure participant confidentiality, all collected data were thoroughly anonymized, and no personally identifiable information (PII) was recorded or retained in the final dataset.

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