

Innovative Design Model for the Mortise and Tenon Structure

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The mortise and tenon structure is a pivotal component of ancient Chinese architecture and furniture, encapsulating a rich history of evolution, cultural shifts, and productivity developments. Engaging modern individuals with this historical context through innovative product design provides a way to advance the cultural and creative industries and promote the sustainable development of mortise and tenon culture. This study conducted sentiment analysis on consumer reviews of three types of mortise and tenon cultural and creative products in the Chinese market, revealing consumer needs and expectations regarding functionality, quality, and design. Utilizing Norman's Emotional Design Theory, the study analyzed the design elements of mortise and tenon cultural and creative products across the instinctive, behavioral, and reflective levels. A systematic design model was put together, providing both theoretical support and practical guidance for the future design of these products, thereby offering inspiration and aid for the modernization and transformation of traditional culture.

DOI: 10.15376/biores.19.3.5413-5434

Keywords: Mortise and tenon structure; Cultural and creative products; Sentiment analysis; Emotional design

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INTRODUCTION

The mortise and tenon structure, a fundamental component of traditional Chinese woodworking, comprises two interlocking parts: the mortise and the tenon. Functionally, it utilizes the natural friction of wood to create tight joints that prevent warping and loosening. This versatile design is widely applied in various parts of traditional furniture, such as connections between chair legs and seat surfaces, as well as between backrests and armrests, allowing for diverse shapes and extended furniture longevity (Uysal *et al.* 2015). Recognized as an intangible cultural heritage by UNESCO, the mortise and tenon structure holds significant historical and inheritance value. However, its complexity poses challenges for mass production due to the limitations of automated machine tool processing, leading to its gradual decline in modern Chinese furniture applications. Dong *et al.* (2019) modernized the structure by employing aluminum-magnesium alloy and brass at the interface, incorporating non-slip soft glue to enhance stability, thus adapting it to mechanized production and contemporary lifestyles. Wu *et al.* (2021) integrated the principle of reduction from green design into modern mortise and tenon structure, improving its shape and connections to facilitate mass production while maintaining stability, thus preserving cultural heritage within modern production contexts. Current scholarly efforts primarily focus on simplifying processing methods or introducing new materials, with an emphasis on the furniture domain.

In China, other forms of intangible cultural heritage can be preserved and promoted through cultural and creative products. He *et al.* (2024) investigated the innovative design pathways for Li brocade cultural and creative products from the perspective of emotional design, constructing an emotional design model across three levels to facilitate the modern inheritance of Li brocade. Zhu and Liu (2022) deconstructed intangible cultural heritage into three levels—material, behavioral, and spiritual—extracting the cultural attributes of each level and exploring how these attributes evolve within the current cultural context. This approach ensures that cultural and creative products not only carry the cultural connotations of intangible heritage but also align with modern lifestyles, thus expanding the design concepts for such products. Cultural and creative products present significant advantages as pathways for the inheritance of intangible cultural heritage. According to the National Bureau of Statistics of China, in the first quarter of 2024, the revenue of cultural and related industries above a designated size exceeded three trillion yuan, reflecting an 8.5% increase compared with the same period the previous year. Specifically, the revenue of cultural and creative design services reached 521.9 billion yuan, a 10.4% increase from the previous year (National Bureau of Statistics n.d.). This data highlights the rapid development of China's cultural and creative design services, providing a stable environment for transforming various types of intangible cultural heritage into cultural and creative products.

The mortise and tenon structure can be perpetuated and advanced through the development and production of cultural and creative products (Liu and Leng 2019). Liu and Zhao (2023) have investigated the application of the mortise and tenon structure, intrinsic to Dong Nationality's wood construction techniques, within the realm of cultural and creative products. By extracting the mortise and tenon features from the Dong Drum-tower architecture and integrating them into product design grounded in the theory of symbolic symbols, they effectively bridge traditional techniques with contemporary design, fostering both the inheritance and innovation of intangible cultural heritage. Yang *et al.* (2024) undertook a comprehensive study, utilizing literature review and case studies to explore the connectivity, reversibility, interactivity, aesthetics, and intelligence inherent in mortise and tenon structures. They contend that this structure holds substantial promise for the development of cultural and creative products. Collectively, these studies underscore the significance and design feasibility of integrating mortise and tenon structures into modern product design. Compared to the studies on other cultural and creative products of intangible cultural heritage mentioned earlier, the current research on cultural and creative products using mortise and tenon structures still lacks sufficient consideration of emotional design aspects. The objective of this study was to analyze consumer needs and expectations for mortise and tenon structure cultural and creative products through online comment mining and emotional analysis. By examining real market feedback, the study aimed to develop a model for mortise and tenon structure product design based on Norman's emotional design theory, thereby facilitating the modernization and inheritance of this traditional structure.

METHODOLOGY

Text Mining

Text mining is employed to extract valuable information from large volumes of textual data and is particularly prevalent in the analysis of user comments. Common

methodologies for text mining encompass word frequency statistics, text clustering, text content analysis, and sentiment analysis. These techniques facilitate an in-depth understanding of users' opinions, attitudes, and emotional tendencies. Consequently, these analyses unveil the genuine feedback and implicit needs of users regarding products.

Liu and Li (2023) utilize online reviews of silk quilts as their analysis sample, applying text mining techniques to perform sentiment analysis and co-occurrence clustering on the product reviews. Their findings inform product improvement suggestions, highlighting consumer preferences from the perspectives of industry and enterprise. Similarly, Chen *et al.* (2022) focus on household aromatherapy products, employing text mining of consumer reviews grounded in the design knowledge hierarchy. This approach aims to uncover a method for acquiring and analyzing user needs, identifying the structural relationships among these needs, and evaluating their importance. This facilitates the formulation of product improvement strategies and design positioning.

This paper seeks to support the design model of mortise and tenon structure cultural and creative products through the extraction and analysis of consumer reviews of typical products. Given that consumer reviews are expressed in natural language, key preprocessing steps such as text cleaning, word segmentation, and stop-word removal are essential. Subsequently, various text analysis methods are applied according to the specific content of the reviews.

The Three Levels in Norman's Theory of Emotional Design

In "Emotional Design," Donald Norman examines the impact of design on users' emotions and perceptions (Norman 2007). He argues that design transcends functionality, encompassing significant emotional dimensions. According to Norman, users' perceptions and reactions to products manifest on three distinct levels: visceral, behavioral, and reflective. These levels provide a framework for designers to comprehend and analyze users' emotional responses throughout their interactions with products.

Visceral Level: This level focuses on users' initial impressions and instinctive reactions, typically influenced by sensory stimuli such as sight, touch, and sound. Design at this level aims to elicit immediate, instinctual responses, leading users to either favor or reject the product instantly. Designers must prioritize aesthetics, form, and materials to cater to users' visceral needs.

Behavioral Level: This level pertains to the user experience and the product's functionality. Users assess aspects such as ease of use, practicality, and reliability at this stage. Design at the behavioral level should ensure the product is user-friendly, fully functional, and provides a seamless and enjoyable experience. Emphasis should be placed on interaction design, interface design, and functional layout to enhance user satisfaction.

Reflective Level: This level encompasses users' deeper emotional and cognitive responses, including their thoughts, evaluations, and memories after interacting with the product. The reflective level highlights how the product influences users' self-image, identity, and social status. Designers must consider the symbolic meanings and cultural connotations of the product, aiming to convey brand value and emotional resonance through design.

Norman's emotional design theory underscores that successful product design must perform effectively across all three levels to meet fundamental user needs and deliver profound emotional satisfaction and an enjoyable experience.

Overall, text mining can elucidate users' genuine needs and emotions, providing crucial insights for design and innovation. This study, therefore, incorporates Norman's

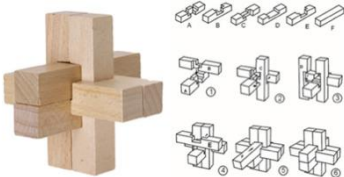


emotional design theory into the proposed design model for mortise and tenon structure cultural and creative products. By employing text mining, it captures users' needs across the visceral, behavioral, and reflective levels, thereby constructing a comprehensive design model aimed at enhancing user experience and market competitiveness.

EXPERIMENTAL

Research Sample

Mortise and tenon structure cultural and creative products are those centered on the traditional mortise and tenon joinery. These products incorporate the cultural elements and creative concepts of mortise and tenon structures through innovative design and production, offering cultural, artistic, and market value (Lin 2007). In the current Chinese consumer market, mortise and tenon structure cultural and creative products can be categorized into three types: puzzle toys, traditional architectural building blocks, and traditional furniture building blocks. Examples and descriptions of these three types can be found in Table 1.

Table 1. Three Types of Sample Illustrations and Profiles

Classification	Example	Brief Introduction
Puzzle toys		The example diagram shows a typical Luban lock product from puzzle toys, consisting of six parts. The image on the left displays the complete structure of the Luban lock, while the puzzle-solving process involves discovering the disassembly and assembly steps illustrated on the right.
Traditional architectural building blocks		The image on the left shows a complete model of a traditional Chinese four-corner pavilion made of building blocks. By assembling the components on the right using mortise and tenon joints, the structural aesthetics of traditional Chinese architecture are demonstrated.
Traditional furniture building blocks		This is a typical piece of traditional Chinese furniture called the 'official's hat chair,' named for its high back that resembles an official's hat. By creating a miniature version of the furniture, the mortise and tenon joints of traditional furniture are replicated, allowing one to experience the connection method of this structure.

Puzzle toys, exemplified by the Luban lock, are traditional Chinese brainteasers composed of interlocking wooden pieces intricately connected through mortise and tenon joints to form a cohesive whole. The design of the Luban lock showcases the precision craftsmanship and ingenuity found in ancient Chinese architecture and furniture making. It also serves as an educational tool for understanding spatial geometry and problem-solving principles. Traditional architectural building blocks draw inspiration from ancient Chinese pavilions and towers. These modern adaptations extract the shape characteristics of these structures and use a scaled-down design, typically at a 1:10 or 1:15 ratio, to create contemporary cultural and creative products featuring mortise and tenon joints. Traditional furniture building blocks, connected through precise mortise and tenon joints, display the complexity and functionality of traditional Chinese furniture design. These blocks reproduce the construction art of ancient furniture, promoting an understanding and appreciation of traditional woodworking techniques and craftsmanship.

Sample Selection

The aforementioned three types of samples are widely recognized in the current Chinese market, possessing both representativeness and research value. They provide comprehensive data support for the design model of mortise and tenon structure cultural and creative products. This study selects certain products from Tmall and Modian crowdfunding platforms as data sources for obtaining user reviews.

Tmall is a B2C one-stop retail platform under Alibaba. The primary reason for selecting product reviews from Tmall as a data source is that all brands on Tmall are officially operated by brand owners, ensuring high product quality and reliability. Tmall enjoys high consumer recognition, with data from the 2022 Tmall TopTalk merchant conference indicating that the platform has 900 million annual active consumers (Alibaba n.d.). The reviews on Tmall are not only numerous but also of high quality, providing an excellent data source for subsequent information extraction. The Luban lock is now a well-established type of puzzle toy with numerous brands and products available on Tmall, along with a wealth of consumer reviews for research. Therefore, this study selected the top four Luban lock puzzle toys on Tmall, based on sales rankings, as the research samples for the puzzle toy category.

The reason for selecting crowdfunding product reviews from the Modian platform as a data source is that traditional architectural and furniture building blocks are often launched on Modian as their initial platform. Products with successful crowdfunding campaigns on Modian have already gained some consumer recognition and support. Given that consumers on crowdfunding platforms typically possess higher levels of expertise, analyzing their reviews has potential to provide deep insights into the target users' needs and expectations. The feedback collected from this group is highly professional and valuable for reference. Although the number of reviews is not as large as on Tmall, the high quality of the data can yield high-quality insights for subsequent review analysis. Therefore, this study selected the top four traditional architectural building blocks on Modian based on sales rankings as sample products. For the traditional furniture building block category, since currently the only product with sales exceeding 500 units is the "Diary of the Grand Secretary of the Ming Dynasty" by the Puzzle Master brand, this product was chosen as the sample for traditional furniture building blocks due to its research value.

The final selection of nine products from the three categories includes: Qiaozuihou's Luban Lock, V&F's Luban Lock, Keyi Toys' Luban Lock, Fuhaier's Luban

Lock, Wanfengshuwu's Summer Palace Zhichun Pavilion Building Blocks, Wanfengshuwu's Ningxiang Pavilion Building Blocks, Chongshiyingzao's Chilai Pavilion Building Blocks, Chongshiyingzao's Zuiweng Pavilion Building Blocks, and Puzzle Master's Diary of Ming Dynasty Grand Chancellor. Each of these products has garnered over 500 reviews, reflecting current trends in mortise and tenon cultural and creative product design and consumer interests, thus providing valuable insights for research. A schematic of the nine products is shown in Fig. 1.

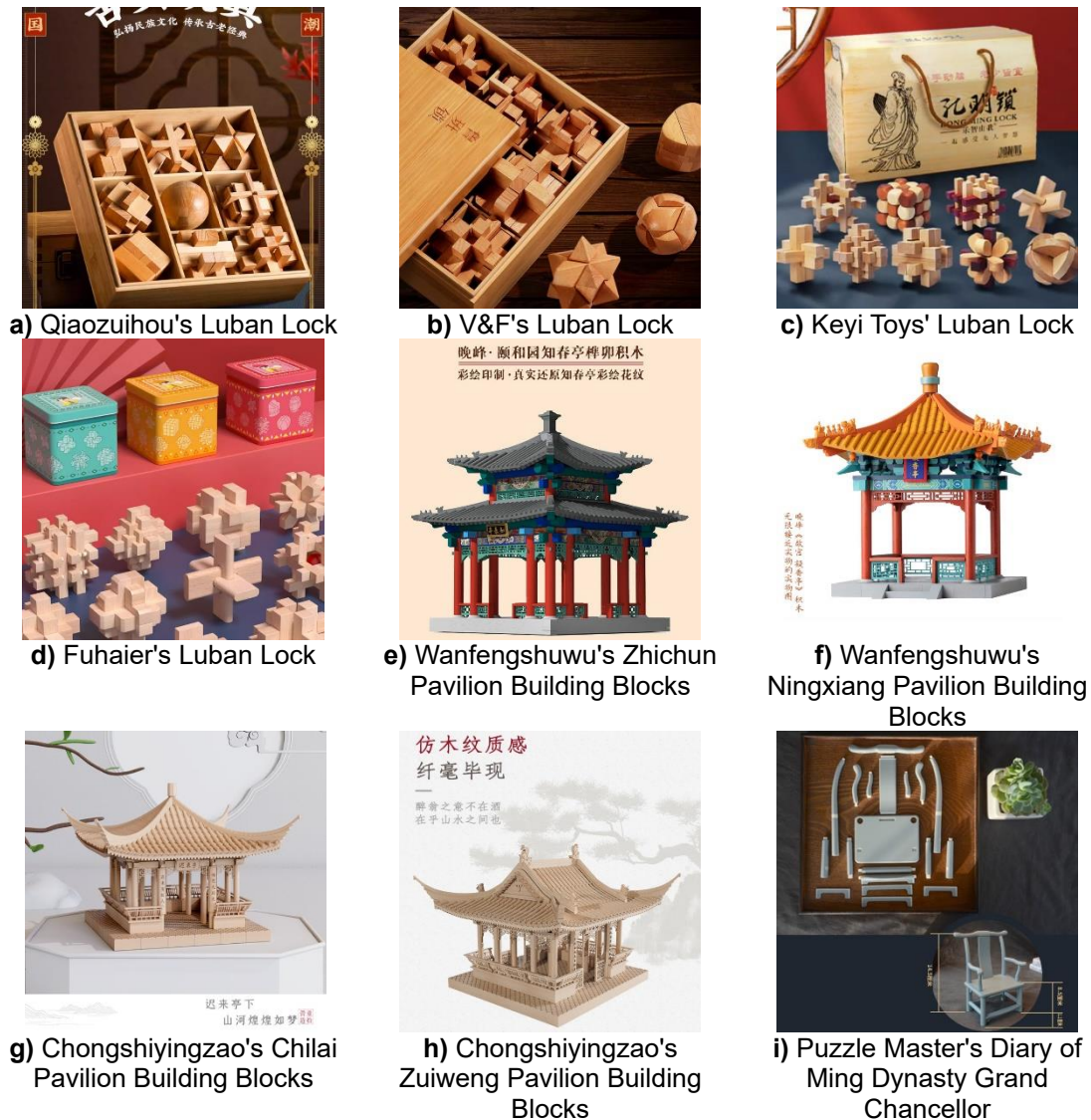


Fig. 1. Nine product schematics

Data Preparation

All review data analyzed in this study were collected using a Python 3.8.5 script. Given the vast number of reviews for high-selling products, the authors manually extracted valid reviews from the past year (up to January 2024) for the nine selected products. The two fields of first comment content and additional comment content were collected for each comment. Subsequently, the system-default product evaluations were filtered out in chronological order, and the pre-processed consumer reviews were extracted. The raw review data obtained directly from the website, which is in Chinese, often contained

irrelevant information, such as emojis and English characters, which can negatively impact text analysis. Directly analyzing such data is less feasible and yields less effective results. Therefore, it is necessary to preprocess the raw data. Using Python's Pandas library, the *drop_duplicates* function was employed to remove duplicate texts. Additionally, functions such as *str.contains* and *str.len* were used to eliminate texts that were too short, system-default positive reviews, and those containing emojis or English characters (Zhou *et al.* 2022). This preprocessing step ensures that the raw data is converted into high-quality information suitable for analysis. The efficiency of the processed reviews is shown in Table 2, and examples of the review content can be found in Table 3.

Table 2. Product Review Data Noise Reduction Variation Table

Product Category	Original Reviews	Reviews after Noise Reduction	Effectiveness of Data
Puzzle toys	4255	3672	86.29%
Traditional architecture building blocks	3129	2564	81.94%
Traditional furniture building blocks	647	532	82.22%

Table 3. Selected Product Review Contents Table

Product Category	Content of Some Reviews
Puzzle toys	Very good beech wood material, representing traditional Chinese culture with the Luban Lock, a crystallization of ancient wisdom. It can fully exercise children's thinking and hands-on abilities. It's an excellent gift. Highly recommended!
	The smell is too unpleasant. Upon opening the packaging, a strange odor hit me, making it unsuitable for children to play with. I don't know what chemicals were used, but the smell lingered for a long time, causing headaches and nausea.
Traditional architecture building blocks	Assembling it did not provide any deeper understanding of the mortise and tenon structure of beams and columns; the beams are simply stacked together. The wood grain effect described is absent, the blocks don't fit tightly, resulting in many unsightly gaps. The base blocks frequently fall off, and there is a slight odor.
	Overall, the price reflects the seller's sincerity, but the quality is much worse than the promotional photos. The instructions are clearly printed, logically organized, and easy to follow. I hope for more complex upgraded versions in the future! As an architect, I admire your company's efforts to promote ancient architectural culture!
Traditional furniture building blocks	A bit flawed. It's slightly larger than I imagined, but the texture isn't as good as expected. The color and sheen make it look somewhat cheap, and it's too light. The tightness of the joints is inconsistent. Overall, it's not bad, though I'm not sure if I assembled it correctly.
	The bookmark has a printing error with a color deviation in the middle. The surface of the chair is not smooth and has some scratches. The paper of the journal is excellent, feels comfortable, and the printing is very clear. The chair's joints are precise, and the connectors fit well. After assembly, it is very sturdy and doesn't wobble, and the shape is very accurate.

For Chinese text, word segmentation based on standard corpora and statistical data is essential, as it forms the foundation for subsequent text processing. Currently, Chinese word segmentation methods primarily include dictionary-based methods, statistical methods, and understanding-based methods. This study used Jieba, an open-source word segmentation tool in Python, known for its efficiency and accuracy (Zhang *et al.* 2021). Consequently, this tool was used for the word segmentation of the review texts. To demonstrate the effectiveness of Jieba for Chinese text segmentation, consider the following example. Given the Chinese sentence "非常好的榉木材料" (which means "Very good beech wood material"), Jieba segments it into the following words: "非常" (very), "好的" (good), "榉木" (beech wood), and "材料" (material). This segmentation accurately breaks the sentence into meaningful units, which is crucial for subsequent natural language processing tasks.

Demand Mining

Sentiment analysis studies primarily employ two methods: machine learning-based methods and semantic dictionary-based methods. Machine learning-based methods use various classification techniques to identify sentiment, while semantic dictionary-based methods first construct a dictionary or list of sentiment words and then use this dictionary to determine sentiment orientation. This study used the SnowNLP library in Python, a natural language processing component, to process the text content (Ding and Li 2023). The processing flow is as follows: 1. Text Reorganization: The results of Jieba segmentation are recombined into a single string using the `join(words)` command, with each word separated by a space. This recombined string is then passed to SnowNLP to create a SnowNLP processing object for sentiment analysis and keyword extraction. 2. Part-of-Speech Tagging: The `s.tags` command is used to perform part-of-speech tagging on each word. 3. Sentiment Analysis: The `sentiment` command is invoked to score the sentiment orientation of the reviews. The scores range from 0 to 1, with values closer to 1 indicating positive sentiment and values closer to 0 indicating negative sentiment. In this study, a score of 0.4 is used as the neutral threshold. Scores above 0.5 are considered positive reviews, scores between 0.4 and 0.5 are considered neutral, and scores below 0.4 are considered negative reviews.

When further analyzing the keywords in the review set, the results of Jieba segmentation are first cleaned by removing all single-character words to facilitate word cloud and word frequency analysis. A word cloud visually presents keywords, allowing complex text information to be displayed in a simple and intuitive manner, helping quickly understand the themes, focuses, and key concepts of the text (Wang *et al.* 2023). In this study, the Word Cloud library in Python 3.8.5 is used to generate word cloud images. By adjusting custom parameters, it is possible to modify the font, color, layout, and overall shape of the word cloud. Word frequency analysis involves counting the frequency of words to identify those that appear most frequently in the text, thereby understanding the themes and keywords of the text. After segmenting the text with Jieba, this study manually counts the highest frequency words and merges semantically similar words for the analysis.

Word cloud and word frequency charts can present the main factors that consumers focus on, but they cannot show the relationships between these factors. To explore the theme distribution more deeply, this study uses the Python Gensim library to perform co-occurrence clustering on the segmented text (Huang *et al.* 2023). The principle of this clustering is that the higher the co-occurrence frequency of two keywords, the closer their

relationship, making them more likely to be grouped into the same cluster. Subsequently, the sentiment command is also invoked to score the ‘sentiment’ orientation for each cluster theme.

RESULTS AND DISCUSSION

Comment Collection Holistic Sentiment Analysis

Through sentiment analysis, the emotional positioning of product reviews for the three sample categories was assessed, resulting in the sentiment distribution chart shown in Fig. 2. The data indicate that puzzle toys receive a higher proportion of positive and neutral reviews, with negative reviews being less frequent than neutral ones. In contrast, traditional architectural building blocks exhibit a lower proportion of positive reviews compared to puzzle toys, with negative reviews surpassing neutral ones. Traditional furniture building blocks have the lowest positive review rate among the three categories, with negative reviews constituting 29.3% of the total. Among the three samples, the Luban lock, categorized under puzzle toys, has been preserved and passed down for thousands of years, boasting a well-established industrial processing system for design and production. Various brands can achieve favorable market feedback by adjusting the materials and colors of their products to enhance craftsmanship.

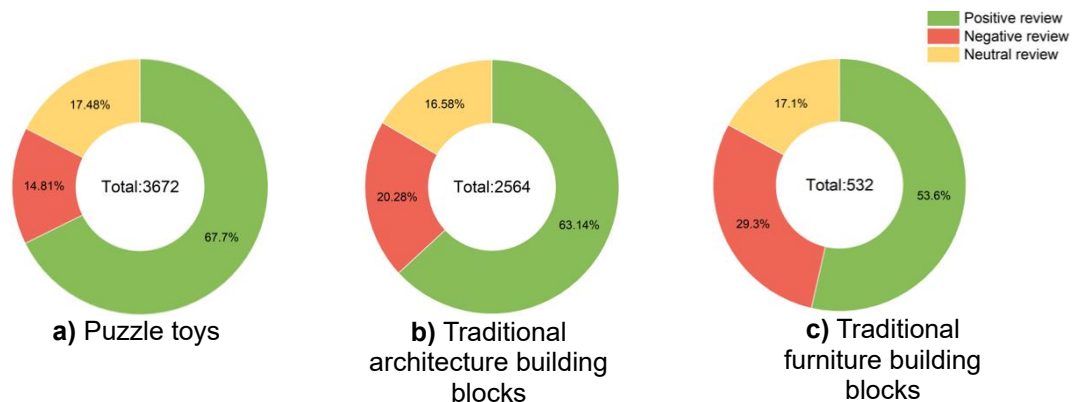
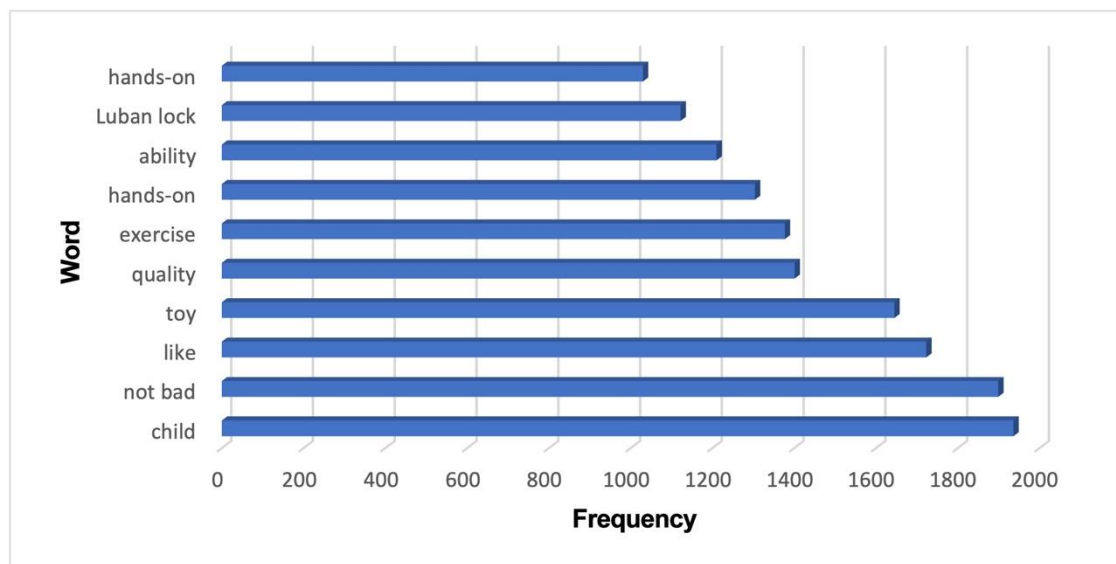


Fig. 2. Sentiment distribution chart of reviews for three product categories

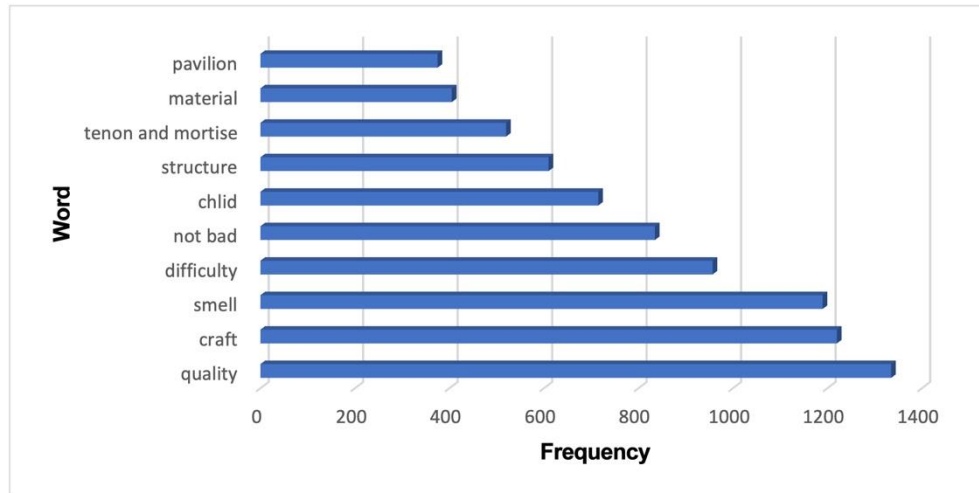
However, for the newly emerging traditional architectural and furniture building blocks, there is little prior experience to draw upon, positioning them as novel fields within mortise and tenon structure cultural and creative products. These products often rely on crowdfunding to reach the market, a commercial model that remains relatively nascent in the realm of cultural and creative products. The entire product delivery cycle, from consumer payment to final receipt, can span from a quarter to six months, posing a significant challenge in the current fast-paced consumer market. Additionally, extensive promotion during crowdfunding campaigns can elevate initial consumer expectations excessively. The long wait times may increase the likelihood of consumer disappointment with the received products, ultimately resulting in lower overall evaluations. For these innovative categories of mortise and tenon structure cultural and creative products, the initially high proportion of negative reviews can prompt timely adjustments in product design based on professional feedback from platform consumers. This can lead to market-responsive improvements and assist brands in rapidly building their reputation. However,

concerned with the quality of mortise-and-tenon cultural and creative products when making a purchase. For instance, words such as “quality,” “packaging,” and “odor” all indicate concerns related to quality. Notably, the word “quality” appeared in the reviews of the three categories of products with frequencies of 1401, 1335, and 343, respectively.

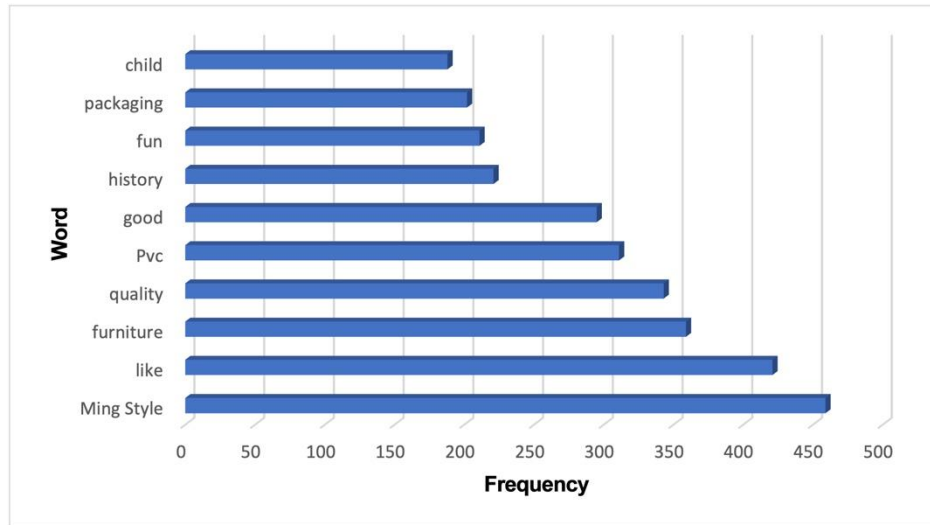
In the current field of mortise-and-tenon cultural and creative products, consumer attention to product quality is a core consideration. These cultural products not only need to convey cultural value but also must demonstrate durability and functionality in practical use. Specifically, in the development of mortise-and-tenon cultural and creative products, regardless of how the structural design is innovatively reassembled, how novel design elements are introduced, or how they integrate with modern consumption habits, the core competitiveness of the product always focuses on its intrinsic quality. Therefore, ensuring the dual advantages of cultural and quality aspects is crucial for enhancing the market competitiveness of cultural and creative products. In the case of puzzle toys, the Luban lock primarily uses beech wood, which is known for its excellent stability and hard texture. Beech wood has good wear resistance and impact resistance, making it highly durable and ensuring the quality of the finished cultural product. Due to China’s vast geographical span and significant humidity differences between the northern and southern regions, wood materials may crack when they are utilized in certain regions. Thus, the choice of raw materials directly affects the shopping experience of consumers in different areas. Additionally, the precision of processing significantly impacts the surface quality of the product, as residual burrs on the surface can negatively influence consumer perceptions of product quality.



a) Puzzle toys word frequency chart



b) Traditional architecture building blocks word frequency chart



c) Traditional furniture building blocks word frequency chart

Fig. 4. Word frequency chart of three product categories

Based on the word frequency table, it is evident that the current consumer group for mortise-and-tenon cultural and creative products primarily consists of adolescents and children, with the term “children” appearing 990, 715, and 188 times, respectively. Due to the inherent educational attributes of mortise-and-tenon structures, the derived cultural and creative products also possess functions such as intellectual development. Hence, the current consumer focus is more on enhancing youth intelligence and hands-on abilities, without broadening the age range. Currently, the younger generation in China is growing rapidly and has already occupied a significant position in the cultural and creative market. This consumer group disseminates information quickly and has a high acceptance of emerging products, thus easily driving products to become rapidly popular. Paying attention to and meeting the needs of this group not only boosts sales but also promotes the inheritance and innovation of traditional crafts. Specifically, mortise-and-tenon cultural and creative products, when combined with modern design and traditional craftsmanship, can better integrate into contemporary life and attract young consumers. Utilizing social media and e-commerce platforms for promotion can significantly enhance product

influence and recognition. Therefore, focusing on the needs of young consumers is a key strategy for market development and the inheritance of mortise-and-tenon structures, achieving a win-win situation for culture and commerce.

In terms of cultural experience and emotional resonance, the nine products selected for this study perform well in integrating mortise-and-tenon structures into their design. However, their development is limited to common mortise-and-tenon structures and lacks comprehensive educational products. Consequently, most consumers tend to focus more on the overall design rather than the mortise-and-tenon structure itself in terms of cultural experience and emotional resonance. For instance, in traditional architectural building block products, many reviews directly mention “buildings” and “pavilions.” This suggests that designers should place more emphasis on showcasing the mortise-and-tenon structure itself, making it a selling point of the product.

In recent years, cultural and creative products from museums, led by the Palace Museum, have attracted significant attention and favor from young consumers. Therefore, in product design, capturing the current consumer focus is crucial. This has a substantial positive impact on the inheritance of traditional culture, and a product prototype that aligns with contemporary trends can greatly benefit the brand.

Sentiment Analysis of Clustered Topics

The clustering themes and some keywords of the three types of product reviews are shown in Table 4. The sentiment method was again used to score the sentiment tendencies of the clustered review themes. The scoring rules were consistent with the overall sentiment analysis of the reviews mentioned above. The distribution of sentiments for the clustered themes is shown in Fig. 5. According to the vertical axis in the figure, the top three consumer concerns for puzzle toys are: experience, functionality, and quality. For traditional architectural building block products, the top three consumer concerns are: design, culture, and functionality. For traditional furniture building block products, the top three consumer concerns are: culture, quality, and packaging.

The consumer reviews can be summarized into seven main themes.

Experience: Consumers are particularly concerned with the additional experiential value of mortise-and-tenon cultural and creative products, including whether the products themselves exhibit personalization and innovation, as well as the experience gained during assembly, such as the level of difficulty, fun, and the tactile sensation of the materials. Among these, the number of positive and neutral evaluations for the "experience" of puzzle toys is the highest. This is attributed to the fact that the primary reason consumers purchase Lu Ban locks is for children's intellectual development, and sellers offer products with varying levels of difficulty based on children's age groups. Consequently, this theme represents the most well-received consumer experience for puzzle toys. The performance of the other two types of products in providing a satisfactory consumer experience requires further improvement.

Table 4. Clustering Themes and Keywords for Three Types of Product Reviews

Product Category	Cluster Themes	Some of the Keywords Under the Clustering Topic
Puzzle toys	Appearance	Mortise and tenon, Complex, Multiple
	Experience	Difficult, Solid wood, Texture, Play, Tradition
	Culture	Mortise and tenon, Classic, Luban Lock, National treasure
	Quality	Burr, Edge, Bad, Loose
	Price	Expensive, Worth buying, Discount, Cheap
	Function	Educational, Mind-engaging, Logical thinking
Traditional architecture building blocks	Experience	Easy to use, Exquisite, Interesting, Ordinary, Form
	Quality	Delicate, Odor, Plastic, Rough
	Function	Gift, Ornament, Learning
	Appearance	Ornament, Pavilion, Building
	Culture	Ancient architecture, Mortise and tenon, Ancient style, National brand
	Price	Not worth it, Expensive
Traditional furniture building blocks	Quality	Smooth, Burr, Odor, Blemish, Quality control
	Appearance	Exquisite, Restore, Furniture, Chair
	Packaging	Box, Integrity, Texture, Meticulously Designed
	Price	Acceptable, Affordable, Worth the Price
	Culture	Ming Dynasty, History, Traditional Furniture, Minister
	Function	Record, Heritage, Ornament, Diary

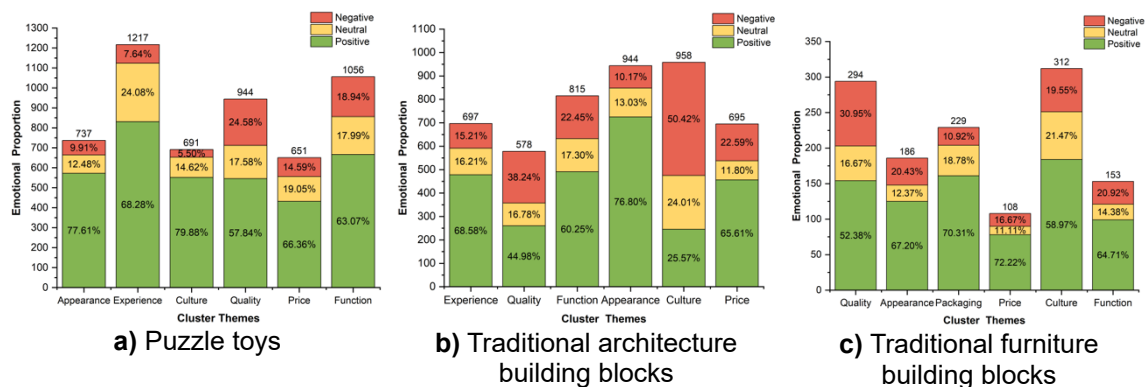


Fig. 5. Sentiment distribution chart of clustering themes

Quality: This mainly refers to the detailed handling of the product, including the tightness of component assembly, the presence of burrs on the edges of parts, and any odors from plastic materials, all of which affect consumers’ quality perception scores. As shown in the figure, the proportion of negative sentiments regarding the quality of the three sample categories is relatively high, at 24.6%, 38.2%, and 31.0%, respectively. This indicates the inconsistency in product quality in the current market, which impacts the consumer experience. The high proportion of negative quality evaluations for traditional architectural and traditional furniture building blocks is primarily due to merchants selling products through crowdfunding channels lacking mature production models. Each product undergoes fewer iterations, leading to more quality issues being exposed in the later stages of the product lifecycle.

Culture: The mortise-and-tenon structure inherently possesses a strong cultural attribute. Consumers evaluate whether they have gained a cultural experience through the complete usage of these products. Generally, consumers hold high expectations for the cultural experience provided by mortise-and-tenon cultural and creative products. In the

evaluation of traditional architectural building block products, consumers expect to gain knowledge about the mortise-and-tenon structures of ancient buildings. While the current design of these products meets the basic requirements for the average consumer, it falls short of the expectations for many enthusiasts and professionals in related fields who have a deep interest in mortise-and-tenon structures. This situation reflects a common issue in the current cultural and creative product market, where there is a tendency to sacrifice cultural depth in favor of meeting the mass market's demands, thus only pursuing superficial forms.

Functionality: The primary function of puzzle toys for consumers is to develop children's intelligence and enhance their hands-on abilities. Traditional building blocks and furniture assembly sets primarily aim to preserve and promote traditional culture. By engaging in the assembly process, users gain an understanding of the cultural significance embedded within these products. Additionally, they can serve as decorative pieces to adorn spaces or as gifts for friends and family, thereby possessing certain social attributes. Currently, consumers are relatively satisfied with the functionality and performance of the three types of samples.

Form: The form of cultural and creative products significantly influences the initial impression and favorability among consumers. While the forms of puzzle toys are generally similar, some brands have innovated upon traditional designs to create modern versions of Lu Ban locks, including heart-shaped and apple-shaped variants. The four traditional building block sets are modeled after Zhichun Pavilion in the Summer Palace, Ningxiang Pavilion in the Forbidden City, Zuiweng Pavilion, and Chilai Pavilion. The process of scaling down these large structures into miniature blocks breaks traditional thinking and is a challenging task. The creative team's effort to incorporate mortise and tenon joints into the miniature ancient architectural blocks is a valuable innovative attempt. Similarly, the representative product of traditional furniture building blocks focuses on a single piece of traditional furniture. This approach provides brands with a design direction for the future, suggesting that Chinese traditional furniture can also be miniaturized into building blocks, thus preserving cultural heritage.

Price: Consumers have different perspectives on the cost-performance ratio of the three types of products. Puzzle toys are often regarded as ordinary educational blocks, whereas traditional architectural and furniture building blocks are valued for their cultural attributes. Consumers are willing to pay a premium for the cultural value embedded in these products. Therefore, the discussion of the cost-performance ratio of mortise and tenon structured cultural products should be analyzed with respect to the consumers' purchasing motivations. Brands should align their pricing with the product's functional positioning to match consumers' psychological expectations.

Packaging: Among the clustered themes, only traditional furniture building blocks included packaging as a focus. Packaging is not only a physical barrier protecting the product but also an important medium for brand communication with consumers through its design aesthetics. An innovative and personalized packaging design can meet consumers' dual needs for aesthetics and individuality, while also enhancing their unboxing experience. This is well exemplified in traditional furniture building blocks, where the outer packaging is made of translucent PVC. The interaction between the protagonist of the product and the chair enhances consumer satisfaction with the product packaging, thereby increasing the overall positive evaluation of the product.

Design Model for Mortise and Tenon Cultural and Creative Products

To gain a deeper understanding of consumers' emotional needs and better fulfill these needs in product design, Norman's emotional design theory provides a robust framework. This theory facilitates the analysis and optimization of mortise and tenon structured cultural products across multiple dimensions, ensuring that these products resonate with consumers on visual, functional, and cultural levels. Based on Norman's emotional design theory, the seven consumer needs of the three types of mortise and tenon structured cultural products were categorized into visceral, behavioral, and reflective levels; further, it is proposed here to target optimization suggestions to construct a design model (Aftab and Rusli 2017). The visceral level encompasses form and packaging; the behavioral level includes functionality, user experience, and quality; and the reflective level involves cultural value and price.

Instinctive level: Visual and tactile design

At the visceral level, the design model for mortise and tenon structured cultural products emphasizes form and packaging design. The form design, which includes aspects such as appearance, materials, and colors, directly influences consumers' purchasing decisions. In terms of packaging design, the packaging not only protects the product but also enhances its overall attractiveness and reinforces the brand image.

Innovation is paramount in appearance design. At present, cultural and creative products employing mortise and tenon structures predominantly adhere to traditional architectural and furniture designs. Future advancements should transcend these constraints by amalgamating mortise and tenon structures with diverse fields, including modern electronic devices and fashion accessories. This strategy aims to generate novel visual experiences and reshape public perceptions of mortise and tenon structures. It is imperative for designers to account for contemporary consumers' aesthetic preferences and emotional requirements, thereby augmenting the aesthetic value of these products through interdisciplinary aesthetic integration. Such an approach will render their design more adaptable to the dynamic landscape of aesthetic trends.

In material selection, beyond the traditional use of beechwood, other high-quality and environmentally friendly materials can be considered. For example, bamboo, known for its good texture and eco-friendly properties, is well-suited for mortise and tenon structured cultural products. Bamboo is hard, possesses natural antibacterial properties, and is a renewable resource, supporting sustainable development (Yuen *et al.* 2017). To prevent wood from cracking, an eco-friendly varnish can be applied to its surface. Additionally, ABS eco-friendly material is an ideal choice, as it mitigates the cracking issues associated with wood and ensures a burr-free finish, thereby enhancing user safety and experience.

In terms of color coordination, applying principles of color psychology can help select hues that elicit positive emotional responses. Bright colors such as red and yellow can evoke feelings of joy and excitement, making them suitable for puzzle toys and children's products. For traditional architectural and furniture building blocks, designers can draw inspiration from traditional Chinese paintings, selecting historically and culturally significant color schemes such as Forbidden City Red and Imperial Yellow. These choices highlight the cultural attributes of the products while enhancing their visual appeal. Additionally, the color selection for puzzle toys should avoid monotony; a thoughtful combination of multiple colors can add visual depth and interest. Ensuring overall color harmony is crucial, and the contrast and coordination between different colors should adhere to aesthetic principles.

Packaging forms the initial impression consumers have of a product. Beyond its primary function of protecting the product from damage, packaging design can incorporate interactive elements that engage with the product itself. By integrating creativity and interactivity, packaging can become an integral part of the product, thereby enhancing the consumer's purchasing experience.

Behavioral level: Function and user experience

At the behavioral level, the design model of mortise and tenon structured cultural products emphasizes practicality and user experience. The functionality and user experience of a product directly influences consumer satisfaction and the likelihood of repeat purchases. Effective functional design and user experience can significantly enhance the product's usability and ease of use.

Regarding functionality optimization, the positioning of puzzle toys, traditional architectural building blocks, and traditional furniture building blocks has been well received by consumers. Future mortise and tenon structured cultural products can incorporate educational booklets to enhance their educational value. These booklets can provide users with insights into the historical background and cultural significance of the mortise and tenon structure, enriching their overall experience.

In the area of quality control, consumers have expressed numerous negative comments regarding the quality of the three types of products, primarily focusing on issues related to component assembly and material texture. Brands should strengthen quality control by implementing stringent quality management processes to ensure the durability and reliability of their products. For instance, the components of puzzle toys must fit precisely to avoid being either too loose or too tight. The edges of parts in traditional architectural and furniture building blocks should be finely polished to ensure they are burr-free, thereby enhancing user safety and comfort. Additionally, brands can utilize quality inspection equipment to conduct comprehensive product testing, ensuring that every product leaving the factory meets high-quality standards.

In terms of user experience, puzzle toys have received high praise for their educational function and design that caters to different age groups. To further enhance user experience, brands can improve ergonomic design to ensure ease and comfort of use. In designing puzzle toys, considerations should be made for children's hand size and strength, ensuring the assembly process is challenging yet not overly difficult (Deng and Yang 2012). For traditional architectural and furniture building blocks, the design should consider the aesthetics and usage habits of adult users, ensuring that the products are both visually appealing and easy to assemble.

Reflective level: Cultural value and price

At the reflective level, the design model of mortise and tenon structured cultural products emphasizes cultural value and cost-performance ratio. These aspects are critical factors in consumers' evaluations and can resonate emotionally with them, profoundly influencing their purchasing decisions.

In terms of integrating cultural elements, designers can enhance the cultural value of products through innovation and enriched cultural content. Traditional architectural and furniture building blocks not only can showcase the details of ancient buildings or furniture but also they can incorporate interactive elements, such as accompanying augmented reality (AR) applications. These applications can allow users to view related historical images and stories through their phones or tablets during the assembly process, thereby

increasing user immersion and interactivity.

For brand storytelling, brands can convey the historical background and cultural significance of their products through various channels, thereby increasing the emotional value of the products and enhancing users' brand recognition. By linking a QR code on the packaging to a short film about the brand's story or by sharing the design concepts and cultural background of the products on social media, users can gain a deeper understanding of the story behind the products. This approach not only enhances the cultural attributes of the products but it also fosters emotional resonance during the purchase and usage process, thereby increasing brand loyalty.

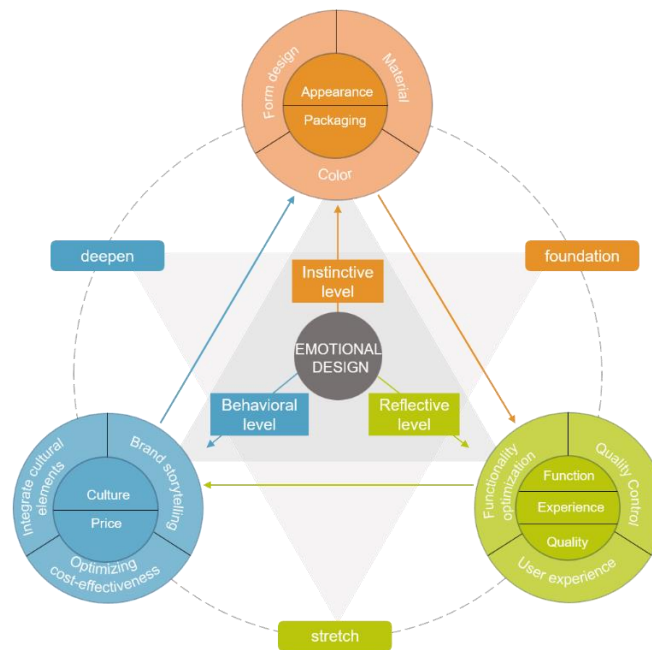


Fig. 6. Design model for mortise and tenon cultural and creative products

In optimizing prices, the current prices of mortise-and-tenon structure cultural and creative products are generally high, and some products risk failing to meet expectations due to the long delivery cycle associated with crowdfunding, extended waiting periods, and elevated consumer expectations. Brands should carefully consider the functional positioning and cultural value of the product when setting prices to ensure that the selling price aligns with consumers' psychological expectations. For products with high cultural value, additional services can be enhanced to increase their perceived value, ensuring that consumers feel they are getting value for money. Moreover, brands can expand their market coverage by developing product lines at different price points to meet the needs of various consumer segments. Implementing reasonable pricing strategies and ensuring transparent delivery times will help increase consumer satisfaction and brand trust.

Through detailed analysis and proposed optimization measures at the instinctive, behavioral, and reflective levels, these design strategies not only address the appearance and usage experience of the products but also deeply consider their cultural value and market positioning. To more intuitively demonstrate the application of these design strategies in the development of mortise-and-tenon cultural and creative products, a comprehensive design scheme was envisioned, as shown in Fig. 6. This scheme systematically integrates design elements at various levels and provides a guiding framework.

Limitations and Directions for Future Research

Despite the comprehensive analysis and detailed design model proposed in this study, certain limitations persist. Firstly, the research primarily relied on consumer reviews from online platforms, which may not fully represent the diverse perspectives of all users. Additionally, this study focused on a limited number of cases, which may not encompass the entire spectrum of mortise and tenon structured cultural products available in the market. Moreover, the proposed design model has not yet undergone extensive empirical testing in real-world scenarios, which may limit its practical applicability and effectiveness.

Future research should incorporate more diverse data sources, such as consumer interviews and surveys, to gain deeper insights into user experiences and preferences. Utilizing advanced sentiment analysis techniques, such as deep learning models, can provide a more comprehensive understanding of consumer emotions and opinions. Expanding the scope of the research to include a wider variety of products and cultural contexts will enhance the generalizability of the findings. Finally, the design model should be validated through practical applications and user testing to assess its real-world applicability and effectiveness. This can be achieved by collaborating with designers and manufacturers to develop prototypes based on the model and conducting user experience trials to optimize the design framework.

CONCLUSIONS

1. This study conducted a comprehensive sentiment analysis of consumer reviews on mortise and tenon structured cultural products, revealing that the crowdfunding sales model poses challenges related to product quality in the realm of cultural and creative products. Through word cloud and word frequency analysis, it was determined that consumers prioritize a diverse range of attributes for mortise and tenon structured cultural products, with quality being the central element. Sentiment analysis of clustered themes indicated that users have specific needs and expectations concerning the functionality, quality, form, experience, cultural value, price, and packaging of these products. This analysis provides consumer-driven data support for the development of an emotional design model for mortise and tenon structured cultural products.
2. Based on Norman's emotional design theory, this study examines the design elements of mortise and tenon structured cultural products from three perspectives: visceral, behavioral, and reflective levels. Integrating findings from sentiment analysis, the study offers a detailed evaluation of the design elements at each level. At the visceral level, considerations include form and packaging design. The behavioral level emphasizes optimizing functionality, quality, and user experience. The reflective level seeks to enhance cultural value and cost-performance ratio. Corresponding optimization suggestions are proposed for each design element, culminating in the construction of an emotional design model for mortise and tenon structured cultural products.
3. As a heritage of Chinese wooden structures, the mortise and tenon structure holds significant historical and practical value, with its profound cultural connotations enriching creative products. By integrating user needs with emotional design theory, the developed design model facilitates the incorporation of the traditional mortise and

tenon structure into modern product design. This integration enhances the market competitiveness and user satisfaction of mortise and tenon structured cultural products, promotes the modern transformation and preservation of the mortise and tenon structure, and consequently fosters product innovation and development.

ACKNOWLEDGMENTS

The authors are grateful for the support of the Youth Fund for Humanities and Social Science Research 540 of the Ministry of Education in Jiangsu Province, China, Grant Number 21YJC760017.

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Article submitted: March 17, 2024; Peer review completed: April 24, 2024; Revised version received: June 11, 2024; Further revised version received and accepted: June 16, 2024; Published: June 25, 2024.

DOI: 10.15376/biores.19.3.5413-5434