Quantitative Research on Visual Image of Tourist Souvenirs

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Abstract. We propose a research method that combines the analytic hierarchy process, Kansei, and preferences to break through the fixed thinking patterns of the "black box" in cultural and creative products and the current confusion between Kansei and preferences. Firstly, we take Dunhuang regional culture as the object and use the analytic hierarchy process to select representative visual elements as experimental objects and create graphic samples. Secondly, we use the semantic differential and pairwise comparison methods to evaluate Kansei imagery and preferences. Finally, we use correlation and regression to quantitatively analyze the relationship between Kansei and preferences. Based on the scores of each graphic sample, we provide design guidance. The use of scientific graphic representation methods can effectively avoid subjectivity and experiential bias in design, improve the objectivity of cultural image communication in cultural and creative products, quantitatively analyze the connection between visual graphics and user imagery, assist designers in design activities, provide references for cultural and creative product design, and enhance the design added value of cultural and creative products.

Keywords: Souvenirs; Analytic hierarchy process; Kansei engineering; Preference evaluation; Dunhuang regional culture

1 Introduction

Cultural and creative products are an essential component of the cultural tourism industry. Developing cultural and creative products can increase tourism revenue and promote the overall development of the tourism industry but also alleviate the human-induced damage suffered by tourist attractions during the tourism process. Furthermore, cultural and creative products extract the regional characteristics of local attractions and endow the products with richer artistic expression through creative presentation. This product is equally significant for disseminating regional culture and improving the image of tourist destinations. With the expansion of the cultural and creative product market, issues such as varying quality, high homogeneity, and lack of innovation have gradually become prominent. As a result, consumers are becoming less interested in cultural and creative products within tourist attractions. In response to the needs of China's cultural and creative industry, the development bottlenecks faced by cultural and creative products are receiving increasing attention. Designers choose unique local architectural features, artistic patterns, landscapes, and other representative cultural symbols as core elements for developing cultural and creative products.

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By integrating regional culture with the creative expressions of designers, cultural and creative products are once again brought to the forefront for people to appreciate.

However, designers often rely on a "black box" mode of personal subjective aesthetics, design abilities, and experience in the design process of cultural and creative products. There is a lack of objective and quantitative methods to guide the design process. Furthermore, there is a lack of analysis from the perspective of users' Kansei imagery, resulting in products contradictory to users' perceptions. Specifically, designers tend to focus on the visual presentation of the products without considering the cultural connotations they convey. As a result, the designed products may possess aesthetic appeal but lack an emotional connection with the users. In response, researchers have focused on the relationship between the formal characteristics of products and users' Kansei imagery. While designers can manifest creativity in a tangible form, they often lack a systematic and quantitative understanding of sensibility. On the contrary, by integrating the principles of Kansei evaluation from Kansei engineering, designers can quantitatively grasp users' Kansei needs during the design process.

References [1-2] utilize Kansei evaluation methods to analyze the relationship between experimental objects and users' Kansei imagery and extract the constituent elements that significantly impact Kansei imagery. In contrast, preference evaluation is often used to analyze the relationship between product attributes, user preferences, and purchase intentions [3]. However, researchers often focus on enhancing Kansei or preferences without studying the relationship between Kansei and preferences. Instances, where Kansei and preferences are mixed or indistinguishable are also common. Integrating multiple methods, such as Kansei and preference evaluation, is crucial to meet the needs of both users and design activities. Therefore, this study combines the analytic hierarchy process, Kansei engineering, and preference evaluation to determine the representative element weights in the target regional culture. This integration aims to increase the accuracy of Kansei and preference evaluation results, ultimately obtaining a more objective and scientific quantification of the relationship between cultural elements of souvenirs and Kansei cognition.

2 Research methods and process

2.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a decision-making method that decomposes information factors related to decision-making into multiple levels, such as objectives, criteria, and alternative solutions and combines qualitative and quantitative analysis. This method quantifies qualitative problems and enables decision-making for complex systems that are difficult to quantify using limited quantitative information. The designer used the AHP method to select design goals in previous design activities. In the context of cultural and creative product design activities, using the AHP method can help designers objectively prioritize cultural elements and assist in designing culturally distinctive products with regional characteristics. Indeed, the AHP method still has certain limitations when applied in practical design scenarios. For example, while the AHP method can help designers select the optimal solution among several design alternatives, it cannot explain the relationship between different solutions and people's Kansei. Elvin Karana et al. pointed out that products should satisfy functionality and express Kansei value, which is equally essential for enhancing the added

value of products [4]. Therefore, it is crucial to consider the expression of Kansei's values while making design decisions.

2.2 Kansei Enginering

Researchers believe the ability to evoke "emotional resonance" in users is the crucial difference between cultural and creative products and ordinary products [5], where emotions encompass sensibility. Currently, in the field of enhancing sensibility-related research, one prominent approach is Kansei Engineering. The term "Kansei Engineering" was coined by Kenichi Yamamoto, former President of Mazda [6]. As a product development method, Kansei Engineering aims to quantitatively measure the previously ambiguous and difficult-to-quantify "human sensibility" using scales, analyze it in conjunction with more easily quantifiable "product attributes," and utilize mathematical and statistical analysis methods to extract quantitative data for design guidance. Both Kansei Engineering and the AHP method are widely applied in design research.

2.3 Preference evaluation

In daily language, the term "preference" is synonymous with "liking" or "favoring" in the context of sensibility and implies a tendency toward choosing something. In some studies, terms like "cute" or other preferences specific to women can be observed [7]. However, in specific research fields, preference has a more rigorous definition. According to [8], an individual's preference is expressed as a ranking of choices in mathematical psychology. In other words, preference is defined as a relationship where someone likes option b more than option a, represented as $a < b$. Similarly, there are different methods for determining Kansei imagery and preferences. The semantic differential method, or the SD method, is commonly used in Kansei evaluation. This method involves evaluating experimental objects based on a series of adjective pairs. On the contrary, preference evaluation often utilizes pairwise comparisons. This study uses the Thurstone pairwise comparison method as an example to illustrate this approach. The Thurstone pairwise comparison method requires participants to make forced choices between two objects based on their preference, thereby determining their preference for the experimental objects. Unlike the SD method, which evaluates a single object at a time, pairwise comparison involves evaluating two objects by comparing them directly. Preference is a critical factor influencing consumers' choices or purchases of cultural and creative products. Therefore, to study consumers' decision-making behavior, it is essential first to investigate their preferences.

2.4 Research Process

As an important node along the Silk Road, Dunhuang is the Silk Road Economic Belt's core area for transportation, trade logistics, and culture. Over time and through spatial expansion, Dunhuang has developed a profound and diverse Dunhuang culture, which has significantly influenced China and even globally. In order to better convey the cultural imagery of Dunhuang and enhance the design-added value of Dunhuang's cultural and creative products, we start with the visual elements of Dunhuang culture. Figure 1 illustrates the specific research process framework. Based on this research process, we first collect visual elements of Dunhuang culture and use the AHP to calculate the weights of each element. This method helps us determine representative elements and create graphics. Next, we collect user Kansei

word and use cluster analysis to select relevant Kansei words. We then conduct Kansei evaluation and preference evaluation. Finally, we analyze the quantitative relationship between Kansei and preference, guiding Dunhuang's cultural and creative product design.

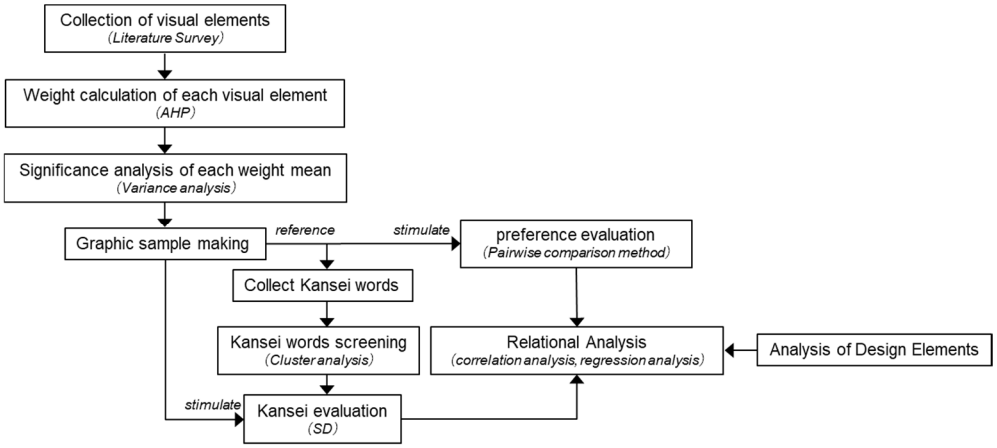

Figure. 1. Research process framework

3 Analysis of representative visual elements of dunhuang culture

3.1 Construction of Evaluation Benchmarks

In applying the analytic hierarchy process (AHP), setting the evaluation criteria is crucial as it affects the effectiveness of questionnaire distribution and the validity of the evaluation model. We have collected commonly occurring visual elements related to Dunhuang culture [9-12], and we found that these elements can be categorized into four major categories: architectural landscapes, Dunhuang art, transportation of goods, and local specialties. Subsequently, following the requirements of the AHP, we first construct a multi-level hierarchical structure model. The representative elements of Dunhuang culture are placed at the first level. In contrast, the second level includes the categories of architectural landscapes (A), Dunhuang art (B), transportation of goods (C), and local specialties (D) within Dunhuang culture. The specific element names form the third level, as shown in Figure 2.

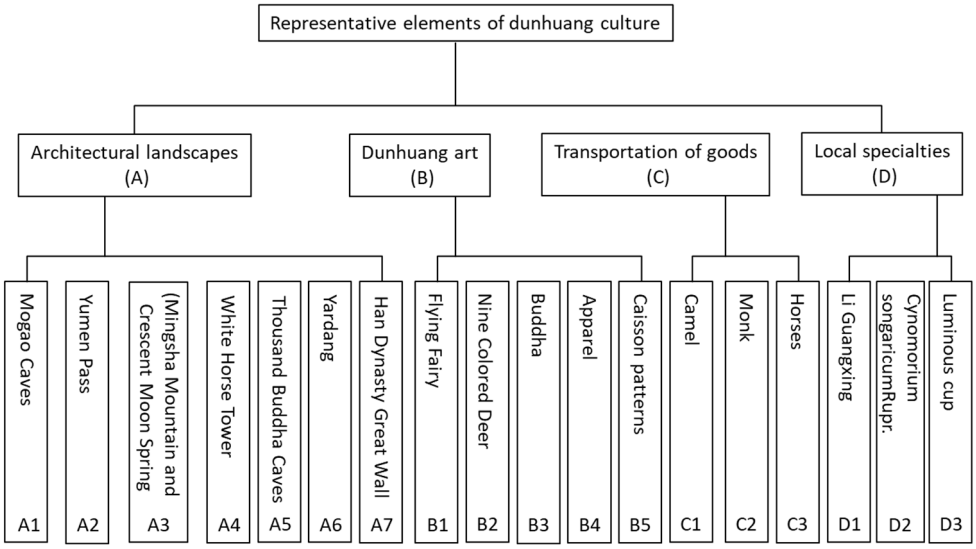

Figure. 2. Multilevel hierarchical structure of cultural elements

3.2 Evaluation process and weight analysis

After constructing the multi-level hierarchical structure diagram, we compared each element's importance regarding its impact on the overall structure. We used the scale of 1, 3, 5, 7, 9, and their reciprocals to record the importance levels (for quantitative analysis) and calculated their average values to determine the quantitative weights of each element. This experiment invited 18 participants, including design students and teachers (9 males and nine females). We asked participants to evaluate each lower-level element relative to the upper-level element as the reference. For example, we asked them to determine the influence between architectural landscapes (second level) and Dunhuang art (second level) based on the reference to the representative visual element of Dunhuang culture (first level). Each participant completed the evaluations, and the experiment took an average of 15 minutes. Subsequently, we constructed judgment matrices for each level of elements and used AHP software (such as yaahp) to obtain the weights for each level. Then, the weights of individual sub-criteria layers were synthesized, and the weights of each level and the comprehensive weights of each element are presented in Table1.

Table 1. Comprehensive weight of each element

	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3	B4	B5	C1	C2	C3	D1	D2	D3
A（0.24）	0.28	0.15	0.12	0.07	0.18	0.12	0.08											
B（0.52）								0.35	0.21	0.22	0.15	0.07						
C（0.12）													0.61	0.25	0.14			
D（0.12）																0.21	0.19	0.6
Target weight	0.07	0.04	0.03	0.02	0.04	0.03	0.02	0.18	0.11	0.12	0.08	0.04	0.07	0.03	0.02	0.03	0.02	0.07

Based on the statistical results of the comprehensive weights of each element obtained through the analytic hierarchy process, we can observe that the Flying Apsaras (B1) has the highest comprehensive weight, indicating that it is the most representative visual element of Dunhuang culture. Furthermore, we conducted a variance analysis using one-way ANOVA in SPSS software to determine the differences between each element, followed by post hoc multiple comparisons using the Least Significant Difference (LSD) method. The results of the variance analysis on the average weights of the second-level elements show a significant difference among the elements ($F(3,68) = 52.329$, $p = 0.000$). The results of the multiple comparisons indicate that there are significant differences between architectural landscapes (A) and Dunhuang art (B) compared to transportation of goods (C) and local specialties (D) ($p < 0.01$). The former two significantly influence the first-level element, suggesting that these two areas should be prioritized when designing Dunhuang cultural and creative products. The results of the variance analysis on the constituent elements of architectural landscapes (third level) show that there are significant differences among the elements ($F(6,119) = 7.857$, $p = 0.000$). The multiple comparisons revealed significant differences between Mogao Caves (A1) and other elements ($p < 0.01$), indicating that the Mogao Caves, as an architectural element, are the most representative of Dunhuang architecture. Similarly, we conducted a variance analysis on the constituent elements of Dunhuang art (third level). The results indicate significant differences among the elements of Dunhuang art ($F(4,85) = 11.705$, $p = 0.000$). The multiple comparison results show significant differences between the Flying Fairies and other elements ($p < 0.01$). Through this study, we can analyze that the Flying Fairies and the Mogao Caves, among the visual elements related to Dunhuang culture, represent Dunhuang's cultural characteristics more than other elements. Therefore, in the subsequent research, the focus will also be on analyzing the Flying Fairies and the Mogao Caves as critical objects of study.

3.3 Graphic representation

Based on the results of the AHP, we invited design students to create graphic samples of the Flying Fairies and the Mogao Caves. Using techniques such as silhouettes, line drawings, and creative interpretations, the designers produced five sets of graphic samples, as shown in Table 2. These samples will serve as experimental materials for further analysis of the relationship between graphic representations and users' sensibility and preferences.

Table 2. Visual graphic samples of dunhuang culture

Graphic samples

Sample1 Sample 2 Sample 3

Sample 4 Sample 5

4 Kansei analysis and design performance extraction and application of design

4.1 Kansei Word and Kansei Evaluation

This paper's research falls within the visual evaluation scope related to Dunhuang regional culture graphics. Due to the relatively limited research available in this field, we started by collecting Kansei word to ensure that the Kansei evaluation content can effectively reflect the participants' true feelings. We collected sensory word related to the Flying Fairies and the Mogao Caves. Through literature review, online searches, and book references, we collected and compiled reference images. Subsequently, we invited 40 participants to collect Kansei word based on the reference images using an open-ended questionnaire format. We consolidated and organized the collected adjectives and selected the top 20 adjectives with a selection rate of over 40% and best represented the sensory perception of Dunhuang regional culture. We then conducted hierarchical cluster analysis using Ward's and squared Euclidean distance methods in the statistical analysis software SPSS. By constructing a dendrogram based on the clustering coefficient, we determined that a cluster distance of 4 or above yielded stable results, indicating that 4 was an appropriate number of clusters. We further applied the K-means clustering analysis. Consequently, we obtained four groups of word categories, as shown in Table 3. From these categories, we selected four representative adjectives: Wide, Inherited, Miraculous, and Dignified. We then identified corresponding antonyms for each adjective, resulting in four sets of representative word with contrasting meanings: Wide - Narrow, Inherited - Innovative, Miraculous - Ordinary, and Dignified - Easily.

Table 3. Selection result of kansei word

Group	Adjective	Distance	Group	Adjective	Distance
1	Wide	1.00	2	Determination	2.11
1	Deserted	1.00	3	Dagical	0.71
1	Magnificent	2.00	3	Desert	1.29
2	Inherited	0.11	3	Miraculous	1.29
2	Tall	1.11	3	Historical	2.29
2	Frontier	1.11	3	Dry	2.29
2	Warm	1.89	3	Gorgeous	2.71
2	Old	1.89	3	Unique	3.71
2	Dim	2.11	4	Dignified	1.00
2	Quaint	2.11	4	Lonely	1.00

Based on the graphic samples created by the designers and the four sets of representative vocabulary obtained through screening, we designed a questionnaire using the semantic differential method to measure users' Kansei evaluations of Dunhuang regional culture graphics. We utilized a seven-point scale, ranging from 1 to 7, to represent the Kansei evaluations. For example, if a sample evoked a strong sense of "Inherited," it would be closer

to the value of 1 on the scale. Conversely, if it evoked a strong sense of "innovation," it would be closer to the value of 7. If the sample received relatively balanced evaluations for two sensory words, it would be closer to the midpoint value of 4 on the scale. We distributed 36 questionnaires to design students aged 21-25 and collected 34 valid questionnaires. The average ratings of the sensory vocabulary groups for each sample were summarized and presented in Table 4.

Table 4. Mean value of kansei word evaluation

Visual graphic samples	Kansei evaluation average			
	Wide—Narrow	Inherited—Innovative	Miraculous—Ordinary	Dignified—Easily
Sample1	3.65	3.62	3.94	4.35
Sample 2	3.15	2.09	2.88	2.68
Sample 3	4.26	4.09	3.35	4.09
Sample 4	4.09	3.21	3.79	3.06
Sample 5	3.21	2.71	2.97	3.03

4.2 Preference evaluation

In the preference evaluation experiment, we used Thurstone's pairwise comparison method. The experiment included five sets of graphic samples, and we invited 34 design students to participate in the evaluation. At the beginning of the experiment, two random images from the set would simultaneously appear on the screen (Figure 3). Participants would use their visual preference as a reference and choose their preferred image by clicking the mouse to input their selection results. "B (Sample 2)" represented a preference for the image on the top, while "D (Sample 4)" represented a preference for the image on the bottom. After making their selection, a new combination of images would appear on the screen, and the experiment continued until all combinations were evaluated. In this experiment, participants repeated this process ten times. We used the frequency of participants' choice of each sample as a criterion for preference judgments. Specifically, when a participant chose a particular sample, it was scored based on the frequency of selection (+1 for frequency). When a sample was not chosen, it was not scored (frequency: 0). Finally, the selection frequencies for each image were summed and ranked. The higher the rank, the higher the preference evaluation (Table 5).

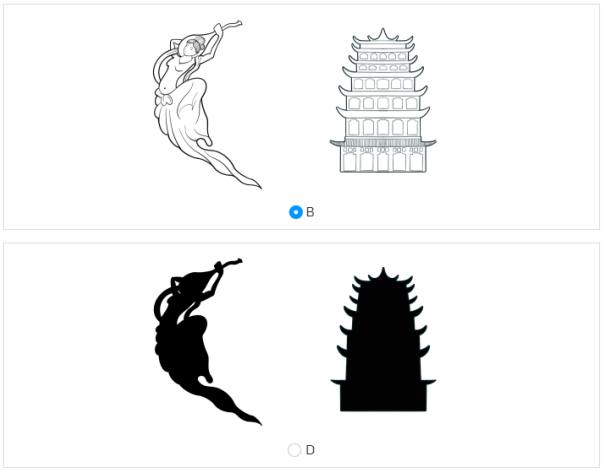

Figure. 3. Preference evaluation: “B” like the image on the top, “D” like the image on the bottom

Table 5. Preference evaluation score matrix

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Sample 1		31	25	20	33
Sample 2	3		12	5	21
Sample 3	9	22		17	25
Sample 4	14	29	17		32
Sample 5	1	13	9	2	
Total	27	111	63	44	95

Subsequently, we transformed the data from Table 5 into a preference evaluation distance coordinate graph for visualization. We used the paired samples t-test in SPSS to compare the differences between each pair of samples. As shown in Figure 4, the results indicate significant differences ($p < 0.05$) between the top two samples, Sample 2 and Sample 5, and the bottom three samples, Sample 3, Sample 4, and Sample 1. The data reflect that Sample 2 and Sample 5 are significantly preferred over the other three graphic samples. There was no significant difference ($p > 0.05$) between Sample 2 and Sample 5. Furthermore, Sample 1, which ranked last, showed significant differences ($p < 0.05$) compared to the other four samples. From the perspective of preference evaluation and sample content, Sample 1, which only had an outline, received the lowest score. This result indicates that when the contour shapes are the same, people also care about presenting internal details. Therefore, samples with relatively rich details, such as Samples 2 and 5, received higher scores.

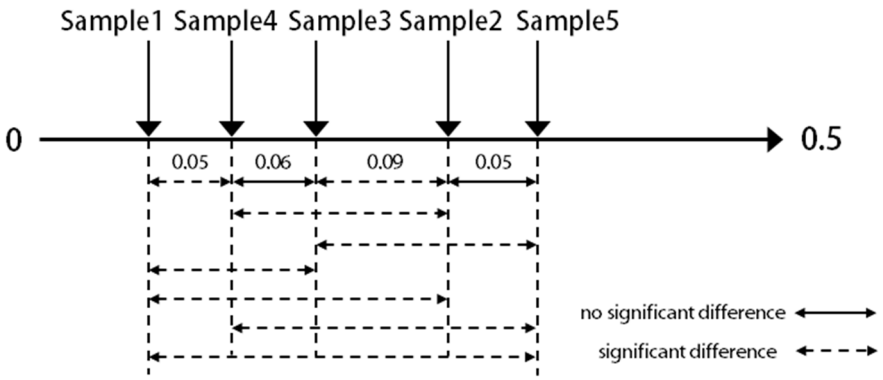

Figure. 4. Preference evaluation distance coordinate map

4.3 Kansei and Preference Relationship

We analyzed the correlation between the four sets of Kansei evaluation words and user preferences for the graphic samples using Pearson's linear correlation coefficient. The correlation coefficient matrix between the Kansei words and preferences is shown in Table 6. Specifically, the correlation coefficient between the Kansei words "Miraculous - Ordinary" and preferences is significant at 1%. In contrast, the correlations between the other three sets of sensory words and preferences are insignificant ($p > 0.05$). Therefore, we can exclude these three sets from further regression analysis.

Table 6. Correlation coefficient matrix between perceptual vocabulary and preference

	Preference score	Wide - Narrow	Inherited - Innovative	Miraculous - Ordinary	Dignified - Easily
Preference score	1.00	-0.66	-0.67	-0.99**	-0.68
Wide - Narrow	-0.66	1.00	0.85	0.62	0.54
Inherited - Innovative	-0.67	0.85	1.00	0.62	0.88*
Miraculous - Ordinary	-0.99**	0.62	0.62	1.00	0.61
Dignified - Easily	-0.68	0.54	0.88*	0.61	1.00

Next, we used " Miraculous - Ordinary " as the independent variable and preference scores as the dependent variable to conduct a simple linear regression analysis to examine the influence of the independent variable on the dependent variable. The simple linear regression analysis results are shown in Figure 5, with an R-square value of 0.97, indicating a good fit for the linear regression model. The regression coefficient of the Kansei words on the preference scores is -72.43, indicating a significant negative impact of the " Miraculous - Ordinary " Kansei words on preferences. We can interpret this as when the graphic representation tends to be more " Ordinary," user preferences score lower, and vice versa. To enhance graphic preferences, designers should pay more attention to embodying the " Miraculous " sensory aspect in the graphics.

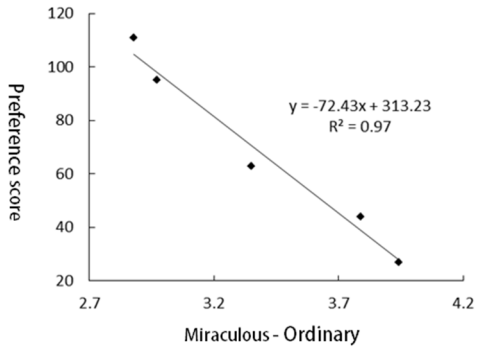

Figure. 5. Quantitative relationship between preference and perceptual words

4.4 Design performance

Based on the research findings mentioned earlier, we have selected Sample 2, which received the highest score in both preference and Kansei evaluation (Miraculous - Ordinary), as a design reference. In the specific design expression process, we have chosen a tie set with a touch of popular culture as a vehicle to integrate with Dunhuang culture. This product series includes a tie, a tie clip, and cufflinks. In the graphic treatment, we have incorporated representative elements from Dunhuang culture, such as the Mogao Caves, Mingsha Mountain and Crescent Moon Spring, White Horse Tower, Thousand Buddha Caves, Yangguan, and Yumen Pass. These elements have been extracted and transformed into usable design elements.

For the design of the tie, we have used a route map style to present the connected symbols, symbolizing the concept of moving and changing scenery. The tie clip and tie depict the prosperity of trade and commerce along the Silk Road, with the camel caravan design representing Dunhuang's significance as a critical node. The cufflinks combine multiple symbol elements, portraying a picturesque scene of the vast desert. These designs add a sense of fun and interactivity for the users and effectively promote the local culture. The design results are shown in Figure 6.

Figure. 6. Design expression (left: tie, upper right: sleeve nail, lower right: tie clip)

5 Conclusions

This research contributes to developing cultural and creative products in the following ways. Firstly, we have used the AHP to objectively select design objectives, assisting designers and developers of cultural and creative products to clarify their direction. Secondly, analyzing their interrelationships, we have combined available graphic samples with Kansei imagery and preferences. The results of this study show that compared to silhouette graphics, line drawings that better depict the details of the Flying Fairies and the Mogao Caves received higher preference scores. Furthermore, the study on the relationship between Kansei and preference reveals that as the score for the "Miraculous - Ordinary" words decreases, indicating a stronger sense of mystique, the preference score increases. Among the five sets of samples, Sample 2 and Sample 5, which have richer details, effectively convey the mystical sensory imagery. Considering the distinctive features of Dunhuang regional culture, when designers engage in the design of Dunhuang cultural souvenirs, they should fully express the details to enhance user appeal. Finally, the research process proposed in this study is not limited to Dunhuang regional culture. However, it can also be applied to design cultural and creative products in other regions, helping designers transition from a "black box" to a "white box" thinking model and facilitating knowledge sharing in design. The focus of this study is on the establishment and conceptualization of theoretical frameworks.

However, in the practical application of cultural and creative product design, further analysis of various physical constitutive elements of the objective design objects is still needed. By thoroughly analyzing their physical quantities and combining them with relevant sensory and preference analysis methods, specific plans that can effectively guide design activities can be proposed.

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