

Application of Kansei engineering in the innovative design of traditional fashion elements

DOI: 10.35530/IT.075.03.202370

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ABSTRACT – REZUMAT

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Kansei engineering can quickly establish the relationship between human emotion and product composition, and it is expected to be an important method for design evaluation. This paper investigates the application of Yungang Grottoes Bodhisattva necklaces to modern attire, specifically the cheongsam, with a focus on the Kansei Engineering-based design approach. The study introduces sensory evaluation to analyse the suitability of various types of Yungang Grottoes Bodhisattva necklaces in cheongsam designs and the sensual style of high-fit cheongsam designs. Two experiments were conducted, with Experiment 1 assessing the suitability of Yungang Grottoes Bodhisattva necklaces on different traditional cheongsam, and Experiment 2 examining the overall style of cheongsam designs when combined with Yungang Grottoes Bodhisattva necklace designs. Fuzzy logic was employed in Experiment 1 to evaluate the suitability of each necklace element, while Experiment 2 incorporated sensory evaluation to determine the sensual style of high-fit cheongsam designs, assessed through subjective ratings by 50 industry experts and 50 evaluators (women aged 18 to 35). The investigation utilized standard procedures for subjective evaluation experiments, resulting in the determination of the suitability of three mainstream cheongsam designs with 24 Yungang Grottoes Bodhisattva necklaces, as well as the identification of high-fit cheongsam sensual styles. The paper concludes by providing recommendations for the design of Yungang Grottoes Bodhisattva necklaces on the cheongsam, utilizing the relative weight values of cheongsam designs as guidance for future applications. This research contributes to understanding the integration of cultural artefacts in contemporary fashion, offering insights into design considerations and potential enhancements of the cheongsam through the incorporation of Yungang Grottoes Bodhisattva necklaces.

Keywords: Yungang Grottoes, Bodhisattva necklace, cheongsam design, sensory evaluation

Aplicarea ingineriei Kansei în designul inovator al elementelor tradiționale de modă

Ingineria Kansei poate stabili rapid relația dintre emoția umană și compoziția produsului și este de așteptat să fie o metodă importantă pentru evaluarea designului. Această lucrare investighează aplicarea colierelor Bodhisattva din grottele Yungang la ținuta modernă, în special la rochia Cheongsam, cu accent pe abordarea de proiectare bazată pe ingineria Kansei. Studiul introduce evaluarea senzorială pentru a analiza adecvarea diferitelor tipuri de coliere Bodhisattva din grottele Yungang în modele de rochie Cheongsam și la stilul senzual al modelelor de rochie Cheongsam. Au fost efectuate două experimente, experimentul 1 analizând adecvarea colierelor Bodhisattva din grottele Yungang pe diferite tipuri de rochie Cheongsam tradiționale, iar Experimentul 2 analizând stilul general al modelelor de rochie Cheongsam, atunci când sunt combinate cu modelele de colier Bodhisattva din grottele Yungang. Logica de tip fuzzy a fost folosită în Experimentul 1 pentru a evalua adecvarea fiecărui element de colier, în timp ce Experimentul 2 a inclus evaluarea senzorială pentru a determina stilul senzual al modelelor de rochie Cheongsam, evaluate prin analize subiective de către 50 de experți din industrie și 50 de evaluatori (femei cu vârsta cuprinsă între 18 și 35 ani). Investigația a folosit proceduri standard pentru experimente de evaluare subiectivă, ceea ce a dus la determinarea adecvării a trei modele de rochie Cheongsam tradiționale, cu 24 de coliere Bodhisattva din grottele Yungang, precum și identificarea stilurilor senzuale de rochie Cheongsam. Lucrarea se încheie cu recomandări pentru proiectarea colierelor Bodhisattva din grottele Yungang pe modele de rochie Cheongsam, utilizând valorile scorurilor relative ale modelelor de rochie Cheongsam ca ghid pentru aplicații viitoare. Această cercetare contribuie la înțelegerea integrării artefactelor culturale în moda contemporană, oferind perspective asupra considerentelor de design și potențialelor îmbunătățiri ale rochiei Cheongsam prin integrarea colierelor Bodhisattva din grottele Yungang.

Cuvinte-cheie: Grottele Yungang, colier Bodhisattva, design de rochie Cheongsam, evaluare senzorială

INTRODUCTION

The research paper explores the application of Yungang Grottoes Bodhisattva necklaces to modern attire, particularly the cheongsam. The Yungang Grottoes, constructed during the Northern Wei

Dynasty, house numerous statues, including over 3,000 Bodhisattva statues [1]. The Bodhisattva necklace, crafted with various jewels, is an iconic decorative object used for body adornment. These statues represent a blend of Indian Buddhist art, indigenous Chinese art, and Xianbei art, reflecting their cultural

significance in China [2]. The rich variety of shapes and combinations of the Yungang Grottoes statues showcases exceptional carving techniques and traditional art styles, symbolizing prayers during tumultuous times. Therefore, incorporating the Bodhisattva necklace from the Yungang Grottoes into modern attire holds great importance for preserving traditional Chinese culture and art.

While traditional Chinese elements are highly suitable for traditional Chinese attire, their direct application to modern clothing can be challenging due to differences in dressing culture and habits [3]. However, the cheongsam, originating from the Republic of China, represents a blend of Chinese history and traditional culture. It has not only influenced the aesthetic style of the Republican era but also remains popular and wearable in modern times [4]. Thus, the cheongsam serves as a suitable sample for exploring the integration of traditional Yungang Grottoes Bodhisattva necklace elements.

The objective of this paper is to investigate the suitability of different types of Yungang Grottoes Bodhisattva necklaces in mainstream cheongsam designs. Experiment 1 employs sensory evaluation, [5] inspired by previous research on design elements in children's mackintoshes, to assess the compatibility of Yungang Grottoes Bodhisattva necklaces with cheongsam designs. Industry experts participate as subjects in this experiment. Experiment 2 selects the most suitable cheongsam designs based on the results of Experiment 1, utilizing expert interviews to identify appropriate sensual psychological words for the samples. Young women are chosen as evaluators to assess the sensual style of each cheongsam design. Through these experiments, the paper explores the application value of Yungang Grottoes Bodhisattva necklaces in modern clothing, specifically classic cheongsam designs.

The study is divided into four main parts: the description of the historical and aesthetic values of Yungang Grottoes Bodhisattva necklaces (2nd section), the implementation of a questionnaire-based experiment (3rd section), the discussion and analysis of the questionnaire findings (4th section), and the overall conclusions drawn from the study (5th section).

THE HISTORICAL AND AESTHETIC VALUES OF YUNGANG GROTTUES BODHISATTVA NECKLACES

The origins of Yungang Grottoes Bodhisattva necklaces can be traced back to the ancient South Asian subcontinent, where they were used by the nobility as body adornments. The term "Keyura" in Sanskrit refers to a jade ornament draped over the body, and it was worn by both male and female nobles in the Indian states [6]. As Buddhism originated in India, the necklace was frequently used to embellish statues of Buddha and Bodhisattvas. In ancient India, the wearing of necklaces held a hierarchical significance, and Bodhisattvas were privileged to wear them due to Prince Siddhartha Gautama, who later became the

founder of Buddhism and was revered as the Buddha [14]. During his time as a prince, Siddhartha Gautama adorned himself with necklaces, which consequently became prominent ornaments in the design of Buddha and Bodhisattva statues.

Bodhisattva statues in India were often depicted topless, and adorned with three or four intricately decorated necklaces to symbolize their prestige [15]. Before the Han dynasty in ancient China, the term "yingluo" was not commonly used and was perceived as a foreign concept. "Yingluo" refers to accessories made of precious stones and jade, with "ying" and "luo" carrying their respective connotations of precious stones. Ancient texts describe the necklaces on Buddhist statues, specifying that they were composed of jewels and jade such as pearls, which could emit five colours of light in the Buddhist realm. These necklaces were frequently employed as neck ornaments for Bodhisattva statues, serving not only as decorative elements but also conveying solemn and beautiful symbolism.

From an aesthetic standpoint, the shape and function of Yungang Grottoes Bodhisattva necklaces can be understood as an expression of its content and form, influenced by cultural factors and artisanal skills within different historical contexts. The shape of the Yungang Grottoes Bodhisattva necklace reflects the aesthetic pursuits and cultural ideologies of its time. Three main aesthetic features are observed in these necklaces. First, balance and symmetry are evident in the visual equilibrium between the stylized components and the overall necklace. Research indicates that the three primary types of Yungang Grottoes Bodhisattva necklaces – short, medium, and long – are symmetrical, contributing to the visual balance of the overall statue and accentuating its dignity and prestige. Second, design aesthetics encompass the regular arrangement of points and dots, lines and curves, and surfaces and textures, resulting in a richer aesthetic experience and a sense of rhythmic interchange. Finally, variety and unity are observed, indicating the variation in necklace styles while maintaining formal cohesion or the divergence of forms based on unified components. This approach allows for a greater diversity of necklace shapes while maintaining visual harmony and balance [7]. The versatile design and aesthetic features of Yungang Grottoes Bodhisattva necklaces have influenced subsequent ornament and attire designs, with their balanced rhythmic beauty frequently employed in later artistic creations [17]. These traditional cultural elements have been widely adopted, demonstrating the significant aesthetic value brought forth by Yungang Grottoes Bodhisattva necklaces' design elements and concepts to future generations [16].

Building upon these observations, this study conducts two experiments to investigate the practical application of Yungang Grottoes Bodhisattva necklaces in modern cheongsam designs.

EXPERIMENT 1: EVALUATING THE SUITABILITY OF YUNGANG GROTTOS BODHISATTVA NECKLACES APPLIED TO CLASSIC CHEONGSAM

Research methodology

Experiment 1 focused on assessing the suitability of Yungang Grottoes Bodhisattva necklaces when applied to classic cheongsam designs. The research employed a total of 24 representative Yungang Grottoes Bodhisattva necklaces and three classic cheongsams as research subjects. The aim was to investigate the overall compatibility of the 24 necklace types when paired with the three cheongsam designs. The research methodology encompassed three key phases: preparation, survey, and analysis. During the preparation phase, several tasks were undertaken, including literature summarization, questionnaire development, and the creation of stimulus pictures. The literature summarization involved reviewing relevant scholarly sources to gather pertinent information. Subsequently, a well-designed questionnaire was developed to collect data on participants' perceptions of the necklace-cheongsam combinations. Additionally, stimulus pictures were created to visually represent the necklace-cheongsam pairings.

In the survey phase, the questionnaires were distributed to the participants. The participants were asked to provide their evaluations and preferences regarding the compatibility of each necklace concerning the three different cheongsam designs. The questionnaire responses were collected for further analysis.

Finally, in the analysis phase, the survey results were analysed using triangular fuzzy numbers. This analytical approach enabled a comprehensive assessment of the participant's responses, considering their preferences and perceptions regarding the necklace-cheongsam pairings. The use of triangular fuzzy numbers facilitated a more nuanced interpretation of the data, considering the inherent subjectivity associated with aesthetic evaluations.

The specific research technique route followed in Experiment 1 is presented in figure 1, outlining the sequential steps undertaken during the research process.

Given the subjective nature of the evaluation in Experiment 1 and the need to capture relevant information for the design solution, the obtained results consist of semantic evaluations that cannot be directly quantified using conventional data analysis methods. To address this challenge, this research employs fuzzy logic as a means to quantify and process the subjective data, enabling the evaluation to be effectively analysed. By utilizing fuzzy logic, the data is defuzzified, transforming the fuzzy results into precise and scientifically grounded outcomes [8].

Fuzzy set tools, originally developed by Zadeh and Klaua [9], offer an alternative to classical set theory. In classical set theory, the membership of elements in

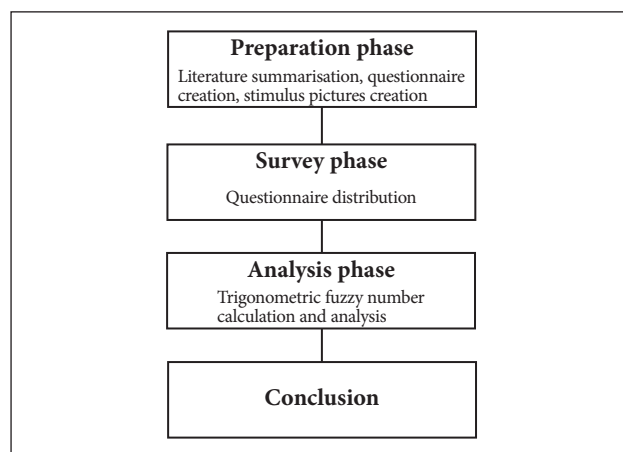


Fig. 1. Research technique route

a set is assessed in binary terms, where an element is either a member or not. However, fuzzy set theory allows for a gradual assessment of membership by employing membership functions that range within the real unit interval $[0, 1]$ [10]. Fuzzy sets provide a generalization of classical sets, as the membership functions of fuzzy sets encompass the indicator functions of classical sets when the latter only take values of 0 or 1 [11]. Given its ability to handle uncertain data, fuzzy set theory finds wide application in sensory/subjective evaluation, offering distinct advantages in dealing with linguistic and clustering problems [12, 13].

In this study, evaluators tended to use sensory words rather than numbers, so quantifying the suitability of clothing became a problem. The fuzzy logic method can solve this problem very well, as it can quantify the sensory fuzzy words into data for calculation. By leveraging the principles of fuzzy set theory, this research applies fuzzy logic to analyse the subjective data obtained in Experiment 1. This approach allows for a more comprehensive and robust evaluation, enabling the translation of subjective assessments into quantifiable and meaningful outcomes, thereby enhancing the scientific rigour of the study.

Sample identification

A significant portion of the Yungang Grotto Bodhisattva necklaces are worn on the upper body of the Bodhisattva and can be categorized based on their length: short (neck), medium (chest), and long (cross). Among these categories, the short necklaces are the most abundant within the Yungang Grottoes and exhibit an overall 'V' shape. Medium necklaces can be further classified into two primary types. The first type is characterized by a 'U' shape and consists of round beads of varying sizes that are intricately strung together. The second type, known as the 'W' shape or animal chest ornaments, features two symmetrical animal heads positioned on the chest, facing upwards towards each other. Lastly, the long necklaces represent the longest style among the Yungang Grotto Bodhisattva necklaces, extending down to the waist and abdomen in a crossed manner. The diverse array of shapes and styles observed in the Yungang

SHORT, MEDIUM AND LONG NECKLACE SHAPES	
The Yungang Grottoes Bodhisattva Necklace Categories	Necklace stylized picture
Short Necklaces	
Medium Necklaces	
Long Necklaces	

Grotto Bodhisattva necklaces led to the selection of 24 most representative types for investigation in Experiment 1, as depicted in table 1.

The 1930s and 1940s marked a significant period in the modern history of the cheongsam, characterized by its splendour. This era witnessed the influence of the historical phenomenon known as “Western Learning Spreading to the East”, which led to transformations in the design of the cheongsam. Notably, the length of the cheongsam was shortened from the extravagant sweeping-hem style to a more modest

length, reaching the mid-calf or knee. Concurrently, there was a tendency to eliminate or reduce the length of the sleeves and decrease the collar height, resulting in a simplification of the garment with fewer elaborate decorations. In Experiment 1, the selection of cheongsam designs drew upon the collection of cheongsams at the Jiangnan University Folk Costume Heritage Museum, as well as popular classic cheongsam styles from the twenty-first century. Three classic cheongsams were chosen for the research, each featuring a common high stand-up

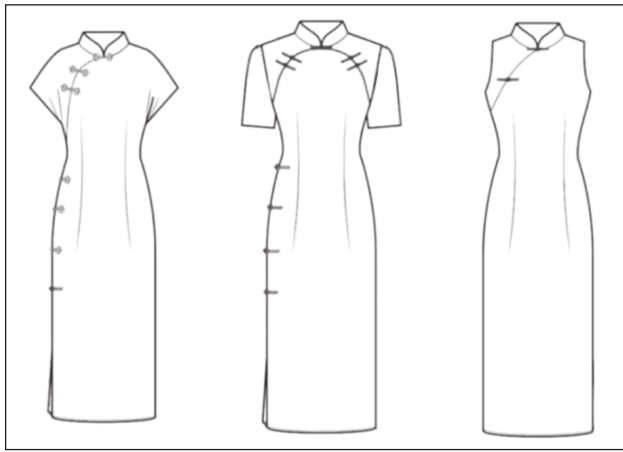


Fig. 2. Representative cheongsam design drawings

collar. Style A encompasses a large round front piece with raglan sleeves, while style B showcases a two-sided front piece with short sleeves. Lastly, style C exhibits an oblique front piece without sleeves. These selected cheongsam styles are illustrated in figure 2. Drawing upon a collection of 24 carefully chosen types of Yungang Grotto Bodhisattva necklaces and three representative classic cheongsams, the application of these necklaces to the basic cheongsam design was performed using Photoshop software. The resulting pairings were visually depicted and are presented in figures 3 to 5. Each pairing is assigned a unique identification number ranging from 01 to 24 for reference and analysis purposes.

Selection of survey respondents and determination of sample size

For Experiment 1, a carefully chosen group of experts within the apparel industry will serve as the survey respondents. The selection criteria for these respondents are as follows:

- (1) They possess a minimum of five years of experience in working or conducting research within the clothing industry.
- (2) They demonstrate a comprehensive understanding of traditional clothing, including consumer preferences and industry trends.
- (3) They possess prior research or practical experience in the domain of incorporating traditional culture into modern clothing design.

A total of 57 questionnaires were distributed online for Experiment 1. The survey sample comprised 13 apparel designers, 20 apparel industry researchers, one fashion buyer, and 23 other professionals actively engaged in the apparel industry.

Questionnaire design

The online research was divided into two parts, the first part investigated the basic information about the subject such as gender, age and occupation. The second part introduced fuzzy terminology, throughout the fuzzy concept the evaluator el ($l = 1, 2, \dots, m$, $m = 20$) will use the linguistic weight set Lk , $Lk = \{\text{far more matched, more matched, a little more matched, moderate, a little less matched, less matched, far less matched}\}$ ($k = 1, 2, 3, \dots, 6, 7$) to assess the relative suitability of the 24 Yungang Grottoes Bodhisattva necklaces to each cheongsam.

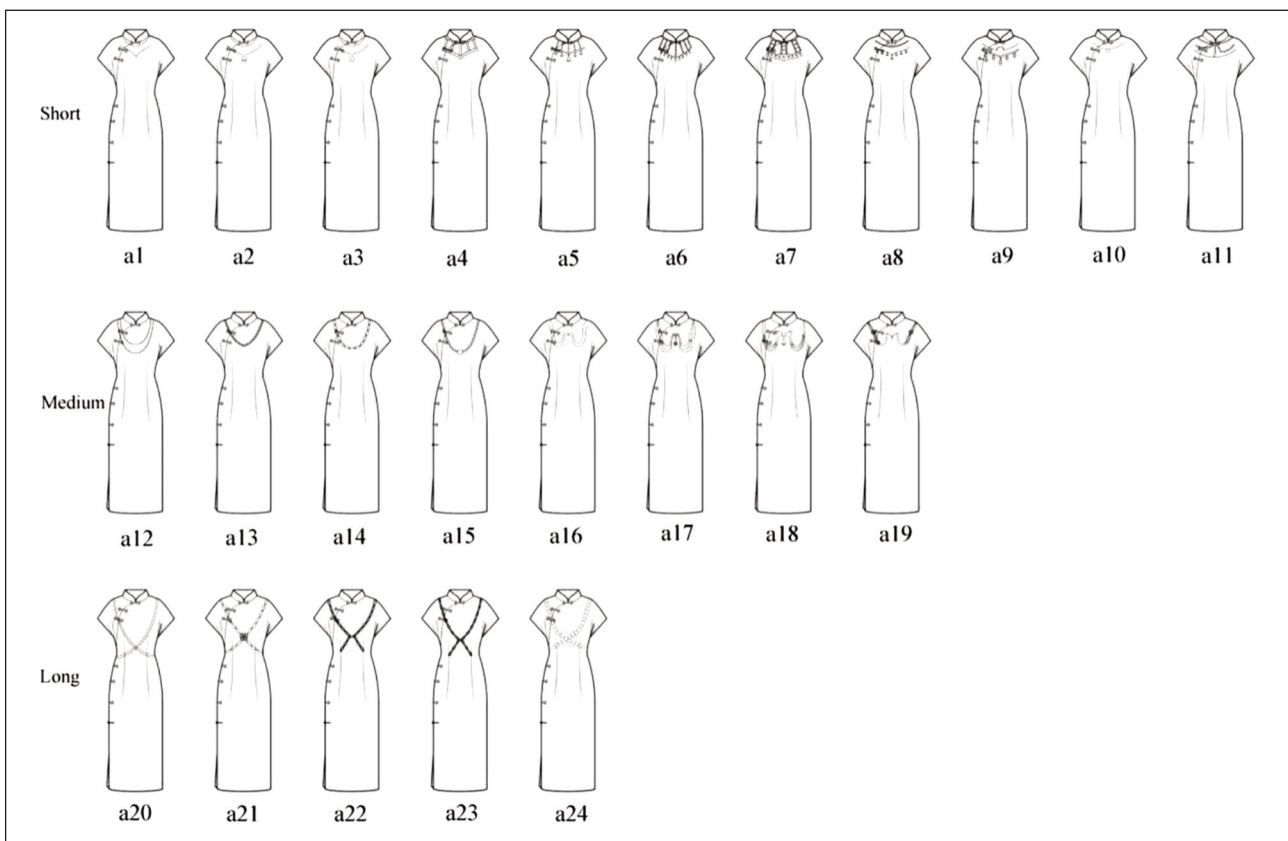


Fig. 3. Style A cheongsam with necklace designs

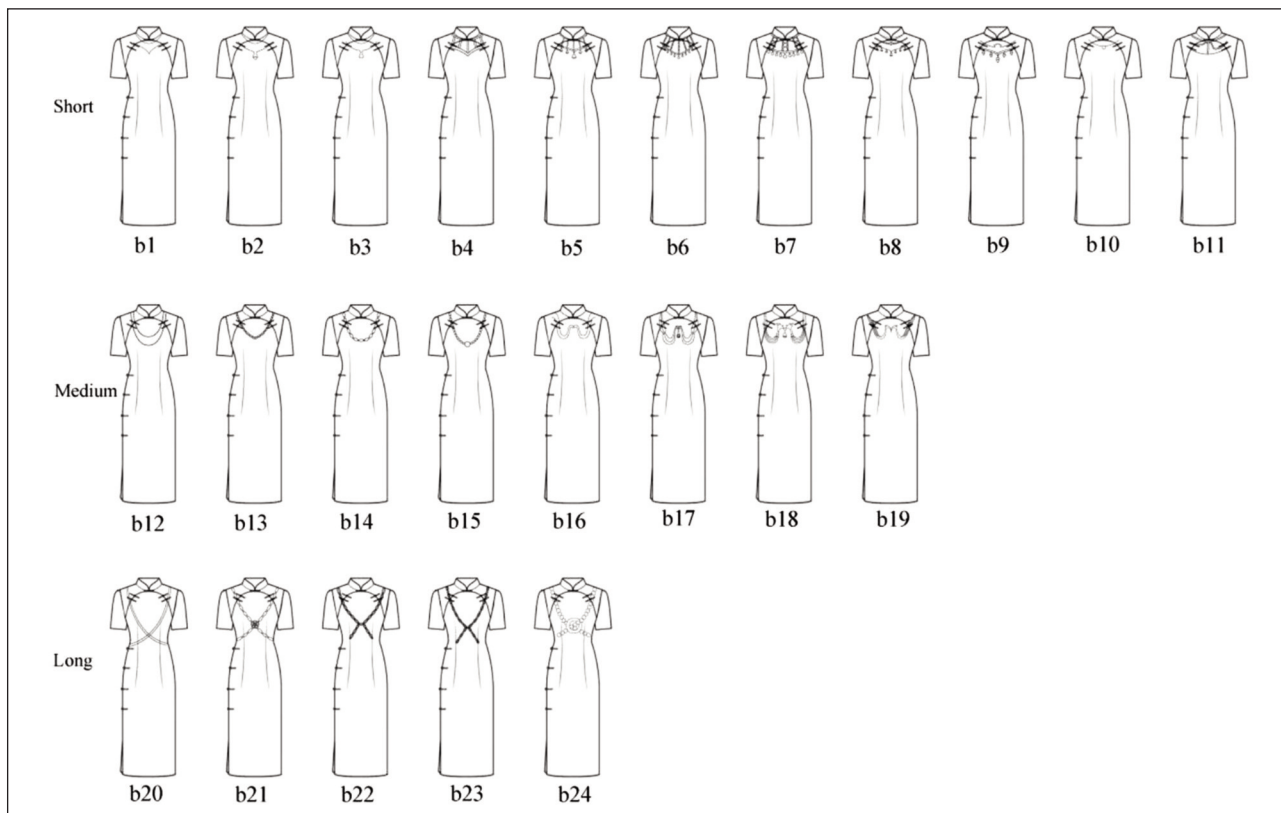


Fig. 4. Style B cheongsam with necklace designs

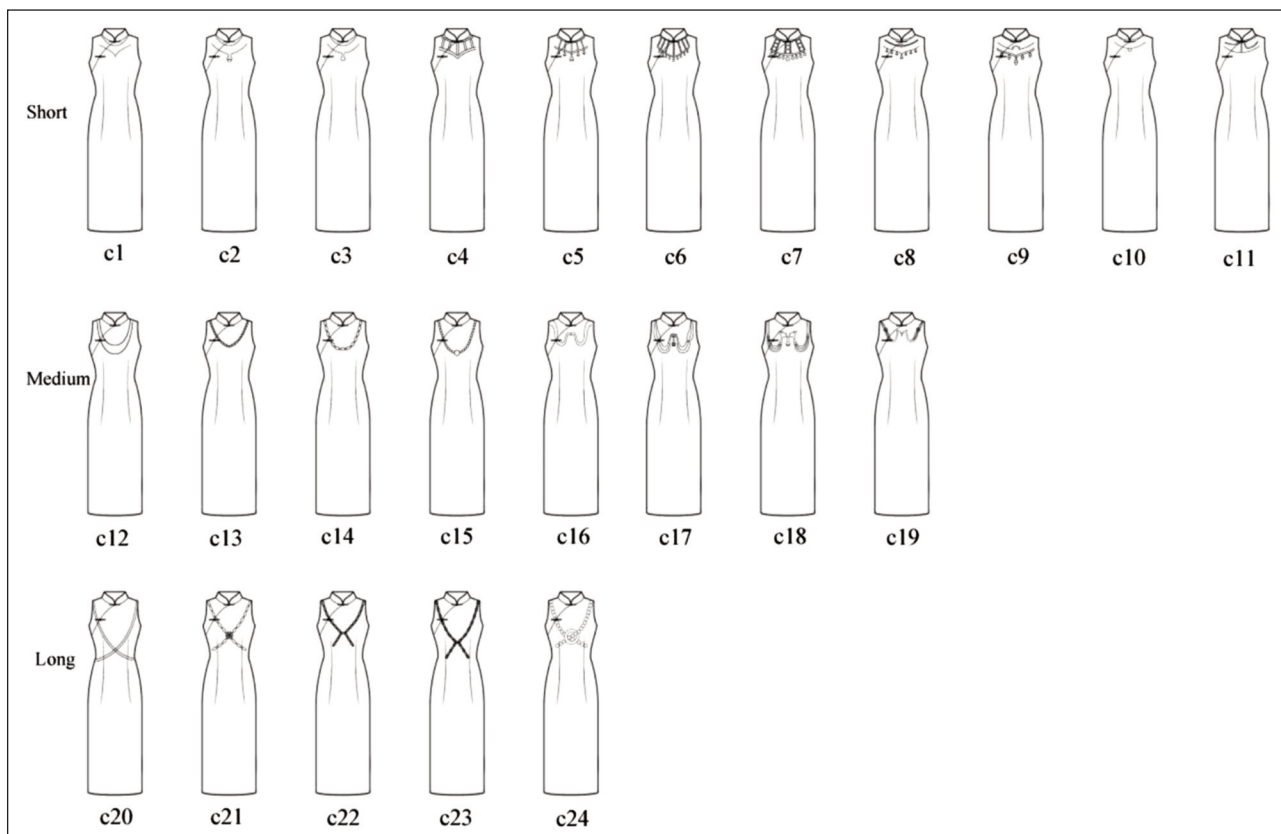


Fig. 5. Style C cheongsam with necklace designs

For example, evaluator e1 was asked to answer the following question: “The following is a drawing of each necklace with style A cheongsam, please eval-

uate the suitability of each necklace with this cheongsam based on your experience and aesthetic sense”. To answer this question, evaluator e1 could

choose an answer from L_k . The data collected by this process relies on the experience and knowledge of the evaluator, and the results of the experiment are subjective semantic data. To address this issue, we used the fuzzy set tool to quantify the results of the linguistic evaluation and then further processed these data.

Results discussion and analysis

Based on fuzzy set theory, linguistic terms of the linguistic rating scale L_k proposed can be quantified into Triangular Fuzzy Numbers (TFNs). A Triangular Fuzzy Number (TFN), M , can be denoted using tuples formalism as $M = (l/m, m/u)$ or $M = (l, m, u)$. Parameters l , m and u , respectively, denote the smallest possible value, the most promising value, and the largest possible value that describes a fuzzy event. Each TFN has linear representations on its left and right side such that its membership function can be defined as:

$$u_M(x) = \begin{cases} 0, & x \in [-\infty, 1] \\ \frac{x-1}{m-1}, & x \in [1, m] \\ \frac{x-m}{m-u}, & x \in [m, u] \\ 0, & x \in [u, +\infty] \end{cases} \quad (1)$$

If $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two TFNs, the operation laws between them can be defined as:

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$M_1 * M_2 = (l_1 * l_2, m_1 * m_2, u_1 * u_2) \quad (3)$$

$$t * M_1 = (t * l_1, t * m_1, t * u_1) \quad (4)$$

$$(l_1, m_1, u_1)^{-1} = (1/u_1, 1/m_1, 1/l_1) \quad (5)$$

Using TFNs, evaluation scores given by each of the evaluators can be quantified. Table 2 presents the

Table 2

LINGUISTIC TERMS OF THE LINGUISTIC RATING SCALE PROPOSED AND THEIR RELATED TFN	
Linguistic term	Related TFN
Far more matched	(0.84,1,1)
More matched	(0.67,0.84,1)
A little more matched	(0.5,0.67,0.84)
Moderate	(0.34,0.5,0.67)
A little less matched	(0.17,0.34,0.5)
Less matched	(0,0.17,0.34)
Far less matched	(0,0,0.17)

quantified TFNs of the linguistic rating scale proposed.

Based on the operation rules given by equations 3, 4 and 5, the evaluation scores given by each evaluator e_j can be aggregated as $\{a_{ijh} \mid i = 1, \dots, 7, j = 1, \dots, 7, h = 1, \dots, m\}$, where a_{ijh} represents the number of evaluators who choose one certain degree.

Therefore,

$$a_{ij} = \left(\frac{1}{m} \sum_j^1 a_{ijh} t_1, \frac{1}{m} \sum_j^1 a_{ijh} t_2, \frac{1}{m} \sum_j^1 a_{ijh} t_3 \right) \quad (6)$$

where t_1 , t_2 , and t_3 correspond to the values of the triangular fuzzy numbers, the values of which are taken from table 2. Table 3 gives the triangular fuzzy numbers for the suitability of the three Cheongsam with the short, medium and long necklace designs. Table 4 gives the triangular fuzzy numbers for the suitability of the three cheongsam designs with necklace numbers 1 to 24.

The evaluation matrix is processed using extent analysis. It is assumed that the evaluators' values processed by the extent analysis are:

$$M_{E_i}^1, M_{E_i}^2, M_{E_i}^3, \dots, M_{E_i}^m, i = 1, 2, \dots, n \quad (7)$$

where, $M_{E_i}^j (i = 1, 2, \dots, n)$ are all TFNs. The value of fuzzy synthetic extent concerning the i -th object is defined as:

$$S_i = \sum_{j=1}^m M_{E_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{E_i}^j \right]^{-1} \quad (8)$$

Let $A(a_{ij})_{n \times m}$ be a fuzzy analytical matrix, where $(a_{ij}) = (l_{ij}, m_{ij}, u_{ij})$ are defined by the calculated values:

$$l_{ij} = \frac{1}{u_{ij}}; m_{ij} = \frac{1}{m_{ij}}; u_{ij} = \frac{1}{l_{ij}}$$

If $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined-by:

$$V(M_2 \geq M_1) = \text{SUP}_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (9)$$

and can be expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_1}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_2 - u_1}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \quad (10)$$

Figure 3 illustrates equation 10, where 'd' is the ordinate of the highest intersection point. To compare M_1

Table 3

TRIANGULAR FUZZY NUMBERS FOR THE SUITABILITY OF THE THREE CHEONGSAM WITH SHORT, MEDIUM AND LONG NECKLACES			
Cheongsam	Style A	Style B	Style C
Short Necklace	(0.494,0.659,0.800)	(0.504,0.668,0.805)	(0.507,0.672,0.814)
Medium Necklace	(0.501,0.667,0.808)	(0.488,0.655,0.798)	(0.509,0.675,0.820)
Long Necklace	(0.422,0.588,0.739)	(0.430,0.593,0.746)	(0.457,0.624,0.776)

TRIANGULAR FUZZY NUMBERS FOR THE SUITABILITY OF THE THREE CHEONGSAM WITH THE RESPECTIVE NECKLACES			
Cheongsam number	Style A	Style B	Style C
1	(0.495,0.658,0.804)	(0.555,0.720,0.857)	(0.556,0.719,0.848)
2	(0.559,0.725,0.865)	(0.521,0.684,0.825)	(0.551,0.716,0.848)
3	(0.535,0.702,0.845)	(0.523,0.687,0.831)	(0.524,0.690,0.828)
4	(0.339,0.494,0.641)	(0.360,0.512,0.652)	(0.407,0.564,0.714)
5	(0.515,0.681,0.822)	(0.547,0.713,0.842)	(0.558,0.725,0.863)
6	(0.480,0.646,0.790)	(0.456,0.620,0.757)	(0.495,0.661,0.807)
7	(0.384,0.550,0.699)	(0.439,0.603,0.751)	(0.442,0.608,0.755)
8	(0.585,0.749,0.876)	(0.580,0.746,0.871)	(0.571,0.734,0.862)
9	(0.524,0.691,0.828)	(0.532,0.699,0.836)	(0.462,0.629,0.781)
10	(0.562,0.728,0.862)	(0.562,0.728,0.856)	(0.532,0.699,0.846)
11	(0.454,0.620,0.763)	(0.465,0.632,0.775)	(0.483,0.649,0.798)
12	(0.617,0.784,0.918)	(0.570,0.737,0.875)	(0.591,0.758,0.886)
13	(0.512,0.678,0.822)	(0.506,0.673,0.819)	(0.533,0.699,0.842)
14	(0.495,0.661,0.801)	(0.501,0.667,0.810)	(0.524,0.690,0.830)
15	(0.541,0.708,0.839)	(0.535,0.702,0.834)	(0.536,0.702,0.842)
16	(0.468,0.634,0.781)	(0.439,0.605,0.755)	(0.471,0.638,0.793)
17	(0.460,0.625,0.772)	(0.448,0.614,0.758)	(0.479,0.646,0.799)
18	(0.442,0.608,0.752)	(0.442,0.608,0.757)	(0.474,0.640,0.787)
19	(0.471,0.637,0.781)	(0.465,0.632,0.778)	(0.462,0.629,0.782)
20	(0.474,0.641,0.786)	(0.479,0.644,0.790)	(0.489,0.655,0.807)
21	(0.425,0.590,0.743)	(0.442,0.606,0.760)	(0.457,0.623,0.772)
22	(0.399,0.564,0.716)	(0.413,0.576,0.728)	(0.465,0.632,0.787)
23	(0.410,0.576,0.732)	(0.416,0.579,0.734)	(0.442,0.608,0.757)
24	(0.402,0.567,0.719)	(0.398,0.562,0.716)	(0.434,0.600,0.754)

and M_2 , we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$. The degree possibility for a convex fuzzy number to be greater than the k convex fuzzy M_i ($i = 1, 2, \dots, k$) numbers can be defined as:

$$V(M \geq M_1, M_2, \dots, M_k) = V[M \geq M_1 \text{ and } M \geq M_2 \text{ and } \dots M \geq M_k = \min V(M \geq M_i)] \quad i = 1, 2, \dots, k \quad (11)$$

Assuming that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, \dots, n$; $k \neq i$, then the weight vector will be given by

$$W' = [d'(A_1), d'(A_2), \dots, d'(A_n)]^T \quad (12)$$

where, A_i and $i = 1, 2, \dots$, and n denotes the i -th element and n the number of elements, respectively.

A fuzzy number is a convex, normalized fuzzy set $A \subseteq R$ whose membership function is at least segmentally continuous and has the functional value $\mu_{\tilde{A}}(x) = 1$ precisely on the element. Using the classical normalization operation, the normalised weight vectors are obtained as follows.

$$W = [d(A_1), d(A_2), \dots, d(A_n)]^T \quad (13)$$

where W is a non-fuzzy number.

The triangular fuzzy numbers presented in table 3 were initially categorized based on Style A, Style B, and Style C, and subsequently subjected to process-

ing using equation 8. By applying this equation, the initial weights indicating the suitability of short, medium, and long necklaces for each of the three cheongsam designs were computed. Subsequently, employing equations 9 to 13.

For example, in style A, the specific calculation steps of the suitable weight of medium, long and short necklaces are shown as follows. The numbers 1, 2, 3 represent short, medium, and long necklaces, respectively.

Using **equation 8**:

$$\begin{aligned} \tilde{S}_1 &= R_{R_1} \odot [R_{R_1} \oplus R_{R_2} \oplus R_{R_3}]^{-1} \\ &= (0.494, 0.659, 0.800) \odot \left(\frac{1}{1.417}, \frac{1}{1.913}, \frac{1}{2.347} \right) \\ &= (0.210, 0.344, 0.564) \end{aligned}$$

Similarly,

$$\tilde{S}_2 = (0.213, 0.349, 0.571), \quad \tilde{S}_3 = (0.180, 0.307, 0.522)$$

Thus, according to **equation 11**, numerical values of the evaluation criteria were obtained as:

$$d(R_1) = V(\tilde{S}_1 \geq \tilde{S}_2, \tilde{S}_3) = \min\{0.987, 1\} = 0.987$$

$$d(R_2) = V(\tilde{S}_2 \geq \tilde{S}_1, \tilde{S}_3) = \min\{1, 1\} = 1$$

$$d(R_3) = V(\tilde{S}_3 \geq \tilde{S}_1, \tilde{S}_2) = \min\{0.894, 0.881\} = 0.881$$

Then, according to **equation 12**, the ordering vector W'_R of C_1 , C_2 , and C_3 was obtained as $W'_R = (0.987,$

1, 0.881). Using classical normalization operations (equation 13), the normalized weight vector W_R can be defined as $W_R = (0.344, 0.349, 0.307)$.

The final suitability weights for short, medium, and long necklaces in each of the three cheongsam styles were determined, as outlined in table 5.

Table 5

SUITABILITY OF SHORT, MEDIUM AND LONG NECKLACES APPLIED TO THREE CHEONGSAM DESIGNS			
Cheongsam	Style A	Style B	Style C
Short Necklace	0.344	0.349	0.341
Medium Necklace	0.349	0.342	0.343
Long Necklace	0.307	0.310	0.316

Analysis of table 5 reveals that the medium necklace exhibits the highest degree of suitability for both Style A and Style C, whereas the short necklace demonstrates the highest suitability for Style B. Conversely, the long necklace exhibits the lowest level of suitability across all three styles, namely A, B, and C.

The triangular fuzzy numbers provided in table 4 were subsequently categorized based on Style A, Style B, and Style C. Subsequently, the initial suitability weights of the 24 necklace types in each of the three cheongsam designs were subjected to processing using equation 8. By employing equations 9 to 13, the final suitability weights for each necklace type in the three cheongsam designs were calculated, and the results are presented in table 6.

Table 6 illustrates the suitability rankings for a cheongsam with a large round front piece and raglan sleeves. Among the Yungang Grotto Bodhisattva necklaces, number 12 demonstrates the highest suitability, followed by numbers 8 and 10. Conversely, the lowest suitability is observed for necklaces No. 22, No. 7, and No. 4. Obviously, the basic style of Cheongsam A is classical and mature, while the 8th necklace is short with three loops, with small bells similar to flowers evenly distributed at the bottom, and the overall style is fresh and elegant. The 10th and 12th necklaces are two loops of necklaces, and the overall style is simple and elegant. Therefore, it can be seen that when matched with the classical and mature style cheongsam of Style A, the simple and elegant necklace is more suitable for the fresh and elegant style.

The suitability assessment for the cheongsam with a two-side front piece and short sleeves is denoted as style B. It is evident that necklace No. 8 exhibits the highest level of suitability, followed by No. 12 and No. 10. Conversely, the necklaces with the lowest suitability are No. 22, No. 24, and No. 4. Style B cheongsam style is elegant and modern, is a younger style. The whole double-circle design of the 12th necklace is classical and simple. When matching style B cheongsam, it is well balanced with its modern

Table 6

SUITABILITY OF EACH NECKLACE TO THE THREE CHEONGSAM DESIGNS			
Cheongsam number	Style A	Style B	Style C
1	0.044	0.055	0.052
2	0.060	0.049	0.051
3	0.055	0.049	0.046
4	0.006	0.014	0.023
5	0.049	0.054	0.053
6	0.041	0.036	0.041
7	0.019	0.033	0.031
8	0.065	0.061	0.055
9	0.051	0.051	0.036
10	0.061	0.057	0.048
11	0.035	0.038	0.039
12	0.074	0.059	0.060
13	0.049	0.047	0.048
14	0.045	0.045	0.046
15	0.055	0.052	0.049
16	0.039	0.034	0.037
17	0.037	0.035	0.039
18	0.032	0.034	0.037
19	0.039	0.039	0.036
20	0.040	0.041	0.040
21	0.029	0.034	0.034
22	0.023	0.028	0.036
23	0.026	0.029	0.031
24	0.024	0.026	0.030

sense, and at the same time adds a noble classical sense to it.

The evaluation of necklace suitability for the cheongsam with an oblique front piece and no sleeves is referred to as style C. It is observed that necklace No. 12 demonstrates the highest level of suitability, followed by No. 8 and No. 5. Conversely, the necklaces with the lowest suitability are No. 23, No. 24, and No. 4. Style C cheongsam style is modern simple and sexy. 12 necklace is elegant and light style with three circles, which is the most suitable for modern style cheongsam C. The next most suitable is a simple 8 necklace and an elegant and gentle 5 necklace. The second is the simple necklace No. 8 and the elegant and gentle necklace No. 5, which are more suitable for the modern cheongsam. It is worth noting that both necklaces #12 and #5 have a flower-shaped bell pendant at the bottom, which is a design element that can be well applied to cheongsam design.

Based on the findings, it is evident that the three main cheongsam designs exhibit stronger compatibility with the short Yungang Grotto Bodhisattva necklace variants, specifically No. 8 and No. 10, as well as the elegant and understated double-layered medium necklace, No. 12. No. 8 represents a C-shaped short

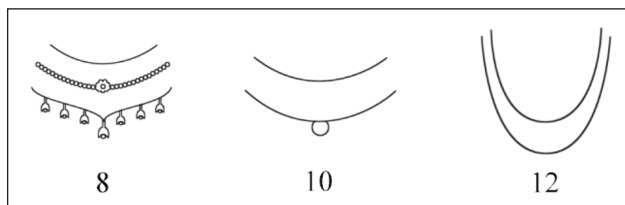


Fig. 6. Three best matches for the cheongsam

Yungang Grotto Bodhisattva necklace featuring a three-tiered structure characterized by a central floral scrolling motif and a pendant adorned with stones. On the other hand, No.10 represents a D-shaped short Yungang Grotto Bodhisattva necklace resembling a collar design, consisting of two semi-circular arcs positioned above and below a 'U'-shaped collar embellished with a semi-circular decoration. These Yungang Grotto Bodhisattva necklace designs are visually depicted in figure 6.

EXPERIMENT 2: ANALYSIS OF THE OVERALL STYLE OF YUNGANG GROTTOS BODHISATTVA NECKLACES WHEN APPLIED TO CLASSIC CHEONGSAM

Research methodology

Sensory evaluation is a technique that integrates sensibility and engineering to design products by primarily analysing human sensory perception and incorporating human preferences [11]. In Experiment 2, it was essential to explore the subjective perceptions of the participants to determine the sensory style of each cheongsam design. The utilization of sensory evaluation allows for the conversion of subjective perceptions into objective data, facilitating the improvement of product design and development. By converting subjective data from experts and consumers into concrete data and parameters, the subjective evaluations within sensory evaluation render the evaluation outcomes more scientifically robust and convincing [8].

Experiment 2 employs cheongsam designs that incorporate elements of Yungang Grottoes Bodhisattva necklaces as the subjects of sensory evaluation to investigate consumers' sensory psychology towards different Yungang Grottoes Bodhisattva necklaces in cheongsam designs. Building upon the results of Experiment 1, the design drawings demonstrating

high suitability will be selected as the focal points of the study. Consequently, activities such as adjective selection will be conducted, followed by the distribution of questionnaires and the analysis of mean values derived from the findings.

Sample identification

Based on the outcomes of Experiment 1, the cheongsam designs exhibiting the highest suitability were chosen for Experiment 2. These include style A, and style B paired with the No. 12 Yungang Grottoes Bodhisattva necklace, No. 8 and No. 10 short Yungang Grottoes Bodhisattva necklaces, and style C with the No. 12 Yungang Grottoes Bodhisattva necklace, No. 8, and No. 5 short Yungang Grottoes Bodhisattva necklaces. The designs are denoted by the numbers 1 to 9, as depicted in figure 7.

Sensory adjective identification

Fifty pairs of sensory adjectives were gathered to describe the cheongsam, with an initial selection of 26 adjective pairs based on relevant literature review and interviews conducted with cheongsam designers and consumers. Subsequent discussions were held with experts and professors specializing in ergonomics and traditional clothing research. Thirteen adjective pairs were selected based on their frequent usage in describing the overall aesthetics of the Yungang Grottoes Bodhisattva necklace when applied to cheongsam designs, while also exhibiting opposite meanings.

The selected 13 adjective pairs are as follows: classical - modern, casual - formal, simple - complicated, constricted - stretching, depressing - light, luxurious - plain, elegant - commonplace, fresh - flamboyant, mature - youthful, sexy - conservative, stable - lively, provocative - understated, like - dislike.

Survey participants and sample size determination

The survey participants consisted of young women aged 20 to 35, chosen due to their aesthetic capabilities, purchasing power, and enthusiasm for expressing their style and aesthetics through clothing. This demographic represents the primary consumer group for various clothing brands. For Experiment 2, a total of 52 questionnaires were distributed online via Questionnaire Star, out of which 20 responses were deemed valid.

Questionnaire design

The Semantic Difference (SD) method of sensory evaluation was employed for the questionnaire

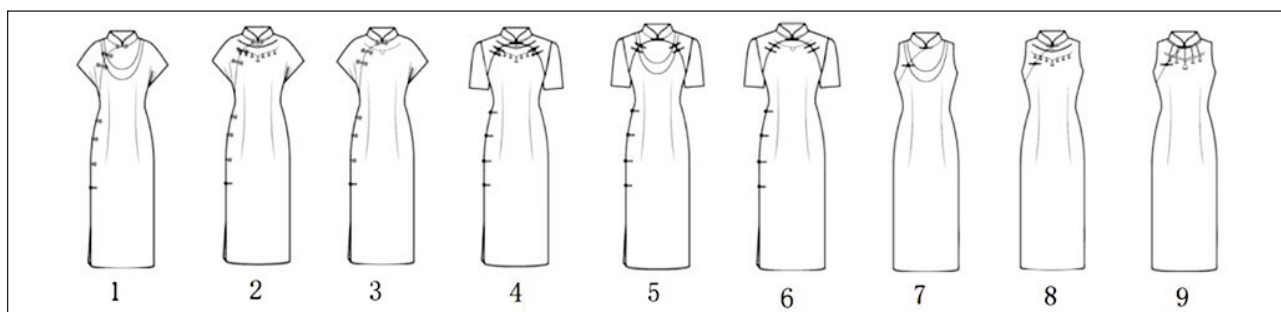


Fig. 7. The highest suitable cheongsam design drawings

design. The SD method is a widely used subjective evaluation technique that focuses on capturing the variability in individuals' understanding of a particular concept. It utilizes a 5-point Likert scale for scoring. For instance, the sensory adjective pair “classical-modern” is rated as follows: 1 indicates a significantly more classical perception, 2 represents a more classical perception, 3 denotes a neutral response, 4 signifies a more modern perception, and 5 indicates a significantly more modern perception.

Statistical analysis and results

Each cheongsam design received a total of 650 ratings (13 pairs of adjectives * 50 questionnaires) through the distribution of questionnaires. The scores for each adjective pair were initially calculated using the mean method, followed by the origin method. If the average score of an adjective pair is less than 3, the difference between 3 and the average score is taken, and the left adjective is associated with this value, representing a “classical” perception.

Conversely, if the average score is greater than 3, the difference between the average score and 3 is calculated, and the right adjective is associated with this value, indicating a “modern” perception. The resulting score represents the sensory psychological score of the stimulus image for that specific adjective pair. For example, a score of 0.98 for the “luxurious - plain” adjective pair assigned to cheongsam 01 indicates that the perception of plainness is particularly prominent in cheongsam 01, with a score of 0.98. The top three sensory adjectives were selected by ranking the extremes of the adjective scores for each stimulus image. The sensory psychological scores of the cheongsam designs are presented in table 7.

Table 7 displays the characteristics of each cheongsam design based on the sensory adjectives. Cheongsam 1, 3, and 6 are perceived as plain and understated, while Cheongsam 2 and 4 are perceived as complicated. Cheongsam 3, 5, and 6 are perceived as conservative and understated, Cheongsam 7 and 9 as light, and Cheongsam 8 as sexy, modern, and provocative.

The data obtained from the adjectives 'like-dislike' were analyzed to gain insights into user preferences regarding the incorporation of the Yungang Grottoes Bodhisattva necklaces into cheongsam designs. Table 8 presents the popularity of Cheongsam designs 1 to 9 among respondents. The most favoured cheongsam design among the participants was No. 8, a sleeveless cheongsam with a No. 8 short Yungang Grottoes Bodhisattva necklace and an oblique front piece. The top three sensory psychological words associated with this design were 'sexy', 'modern', and 'provocative'. The following popular words were “complicated”, “flamboyant”, and “mature” for the short-sleeved cheongsam with a No. 8 necklace and a two-side front piece. The third most popular designs were the short-sleeved cheongsam with a two-sided front piece and a No. 10 short necklace, and the sleeveless cheongsam with a No. 8 medium necklace. These findings indicate that young women

Table 7

SENSUAL PSYCHOLOGICAL ADJECTIVES AND SCORES FOR THE NINE CHEONGSAM DESIGNS		
Cheongsam number	Sensory psychology words	Score
1	Plain	0.98
	Understated	0.91
	Stable	0.77
2	Classical	0.47
	Formal	0.45
	Complicated	0.43
3	Plain	0.87
	Understated	0.68
	Conservative	0.62
4	Complicated	0.87
	Flamboyant	0.62
	Mature	0.62
5	Conservative	0.51
	Mature	0.43
	Understated	0.43
6	Understated	0.51
	Plain	0.47
	Conservative	0.45
7	Casual	0.98
	Simple	0.81
	Light	0.74
8	Sexy	0.6
	Modern	0.55
	Provocative	0.53
9	Light	0.47
	Modern	0.45
	Stretching	0.36

Table 8

POPULARITY OF NINE CHEONGSAM STYLES	
Cheongsam number	Popularity
1	2.43
2	2.98
3	2.72
4	3.21
5	2.94
6	3.09
7	3.09
8	3.26
9	2.91

prefer sleeveless cheongsams with short necklaces, followed by short-sleeved cheongsams with short necklaces and two-sided front pieces. The most popular Yungang Grottoes Bodhisattva necklace choice was the No. 8 short necklace.

Overall, it can be observed that among young women aged 20–35, complicated, sexy, modern, and flamboyant cheongsam designs are the most popular.

CONCLUSIONS

This research employed various methodologies such as the literature review, semantic difference method, and data analysis to examine the sensory designs of Yungang Grottoes Bodhisattva necklaces on cheongsam. Based on the findings, the following conclusions can be drawn:

- Significant variations were observed in the suitability of different necklace types for various cheongsam styles. Experiment 1, employing fuzzy terminology and industry experts as subjects, revealed that medium necklaces were most suitable for cheongsam designs with a large round front piece and raglan sleeves, as well as sleeveless cheongsam designs with an oblique front piece. On the other hand, short necklaces were most suitable for short-sleeved cheongsam designs with a two-sided front piece. Conversely, long necklaces were found to be the least suitable for all three cheongsam types.
- The three main types of Cheongsam exhibited the highest compatibility with short Yungang Grottoes Bodhisattva necklaces, specifically No. 8 and No. 10, as well as the simple and elegant double-layered medium necklace, No. 12.
- The choice of the Yungang Grottoes Bodhisattva necklace significantly influenced the overall sensuality of the cheongsam. Different Yungang Grottoes Bodhisattva necklace types and styles contributed to distinct visual effects, while variations in the cheongsam models also impacted the overall sense of style.
- Through mean value analysis of sensual psychology, the top three sensory word scores were compiled

for the nine stimulus charts. This approach facilitated a more precise description of the designs and enabled the identification of preferred cheongsam styles and types based on young women's preferred sensory psychology words.

- Among young women aged 20 to 35, cheongsam designs characterized by complexity, sexiness, modernity, and flamboyance were the most popular. Notably, the No. 8 short necklace emerged as the preferred choice among respondents.
- According to the three most popular cheongsam styles among young women, it can be found that young women prefer the modern cheongsam. In the collocation design of the future necklace and cheongsam, the design factors of the light classical style of three layers of necklace and the simple double layer of the necklace will be welcomed by young women. In particular, the design element with a bell pendant on the bottom will be loved by young women.
- In summary, this study sheds light on the sensory evaluation of Yungang Grottoes Bodhisattva necklaces when applied to cheongsam designs. The results underscore the importance of necklace selection in achieving desired aesthetic outcomes for cheongsam, with implications for design choices and preferences among young women.

ACKNOWLEDGEMENTS

This research was funded by the National Natural Science Foundation of China (Grant Number: 61906129), the China Association for Science and Technology Youth Support Talent Project (Grant Number: 2021-298), and the Hong Kong Polytechnic University GBA Startup Postdoc Programme 2022 (Grant Number: SP-22-13).

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