

Quantitative Analysis of Leather Closet Surface Material Based on Visual and Tactile Evaluation

Yidan Liu , Wei Wang,* Ziyao Tu, Nan Li, and Jingyu Sun

As people pay more attention to environmental issues, incorporating leather elements in solid wood furniture has become a new trend. This change reflects consumers' concern for sustainable materials and their quest for personalized home design. Due to the similarity between styling of leather custom closets in the market, its surface texture and color are the key factors influencing consumers' purchasing decisions. This study explored the visual-tactile perception of different leather materials by Chinese leather custom furniture consumers and establish an evaluation model. Based on Kansei engineering and market trend research, 12 representative leather samples and 7 perceptual phrases were selected through expert evaluation and KJ methods. Questionnaires were used to collect consumers' visual-tactile perception evaluations of leather samples. Analysis using SPSS software showed that surface roughness, softness, and comfort of the material were the key factors affecting the tactile perception, while the visual perception was closely related to the color characteristics and aesthetic of the material. Cluster analysis categorized these materials as suitable for 4 different styles of home environments. This paper provides a theoretical basis for selecting materials for leather customized furniture and guides future design.

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Keywords: Visual-tactile perception evaluation; Leather closet surface material; Kansei engineering; Cluster analysis; Factor analysis

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INTRODUCTION

In the past, people often chose solid wood furniture to decorate their living environment. Pure solid wood furniture is made of natural wood, and through material characteristics such as texture and color, it creates a warm and comfortable home atmosphere for consumers. However, the inherent characteristics of solid wood make it susceptible to changes in environmental temperature and humidity, and stability problems such as cracking and deformation often occur (Luimes *et al.* 2018). In contrast, an increasing number of consumers are opting for modern leather furniture as their preferred quality choice. This preference stems from its exceptional texture, remarkable durability, and its adaptability to diverse home styles, which collectively render it a more cost-effective option compared to wood furniture. Particularly, the contemporary leather industry has built a cross-industry circular economy model by recycling meat and dairy by-products into durable materials, demonstrating the unique environmental value of leather furniture (Omoloso *et al.* 2021).

With the continuous improvement in the quality of life of Chinese citizens and the gradual maturity of the customized domestic market, consumers are showing a preference

for customized furniture products that meet their aesthetic and emotional needs. This change is driving continuous growth in the customized closet furniture market (Zhou *et al.* 2023). Among the numerous customized furniture options, the leather closet is one of the most popular home decoration for consumers (Xu *et al.* 2022). This type of furniture uses leather as its surface material, often presenting a light luxury visual style. When choosing customized furniture, the customization features of the furniture and similar design styles between products will influence consumers' purchase intentions. Therefore, they tend to intuitively feel the key elements such as texture, size, and color matching of materials through meticulous observation and hands-on touch (Fujisaki *et al.* 2015). This way of perceiving material properties can provide consumers with an emotionally positive experience and quickly assist them in making purchasing decisions.

Consumers can feel unique emotional experiences from the surfaces of various furniture materials through the dual perception of visual and tactile senses (Guest and Spence 2003; McGlone *et al.* 2014). The texture and color characteristics of the materials are the main factors that influence the diversity of experiences (Sadoh and Nakato 1987). The surface characteristics of different materials give consumers different psychological feelings. For example, smooth surfaces often convey a comfortable and simple feeling, while rough textures may evoke warm and rustic emotions. Compared with touching the surface of coated materials, directly touching the natural and smooth texture of the material surface often brings more positive psychological feelings to consumers (Bhatta *et al.* 2017). The main dimensions for evaluating material tactile perception are composed of indicators such as surface roughness, hardness, and viscosity (Yoshioka *et al.* 2007). As demonstrated in the study by Etzi *et al.* (2014), there is a correlation between human satisfaction in response to tactile stimuli and surface smoothness, as perceived through the sense of touch. It was also found that the perception of tactile sensations undergoes alterations when the same material is engaged with different body parts.

The primary evaluation dimensions of material visual perception are comprised of color, tone, and brightness (Johnson and Ulrich 2018). In order to correctly figure out participants' perceptual preferences for material color, Yu *et al.* (2021) investigated participants' eye movement indicators when viewing different wood colors by combining eye-tracking technology and subjective rating methods. The results of the study showed that participants preferred low-tone, low-light wood colors, which were perceived as having more depth and elegance. These indicators affect not only the tactile experience of the consumer, but also their evaluation of the overall texture of the materials. Roberts *et al.* (2024) organized an experiment that invited 18 participants to compare their accuracy in humidity perception under two conditions: relying solely on vision and combining vision with touch. The experimental results indicate that when vision and touch work together, participants have a higher accuracy in perceiving humidity than when using only vision as a perception method. Therefore, the employment of sensory analysis methodologies becomes imperative to comprehend the consumer's apparent preference for customized closets that vary in their leather textures. This approach enables a more precise discernment of consumer requirements, ensuring that the customized furniture is more congruent with the aesthetic design of the residential environment.

Kansei engineering can assist designers in comprehending consumers' mental feedback when they encounter customized furniture products visually and tactilely (Nagamachi 1999). Nordvik *et al.* (2009) used the research method of Kansei engineering to explore the visual perceptual preference of Swedish end-consumers for wooden flooring in indoor scenarios, and they concluded that consumers' perceptual evaluations of products

are significantly subjective. Semantic differential analysis can effectively establish the association between consumers' perceived descriptions and the physical attributes of wood flooring (Zheng and Xu 2025). In addition, it helps designers to optimize their design solutions according to users' perceptual preferences for wood flooring attributes. Wang *et al.* (2018) focused on the study of the dual feedback mechanism of consumers' emotional value and functional attributes of products. To this end, they employed text mining techniques and perceptual engineering methods based on online product descriptions and consumer evaluations. They employed these methods to automatically extract effective information and summarize it into a prototype system they developed for quantitative analysis. Ding (2020) investigated the emotional needs of app interfaces based on Kansei engineering. This research has shown that visual elements such as layout, color, images, and navigation bars have a significant impact on the emotional appeal of consumers. Yin *et al.* (2021) applied perceptual engineering theory to consumer affective perceptions of plant-dyed cotton fabrics and found differences in user perceptions of plant-dyed *versus* industrially dyed cotton fabrics. Jin and Li (2023) took the visual-tactile experience of the elderly as an entry point and investigated the relationship between the physical properties of closet materials and the subjective emotional changes of the elderly. Tu and Wang (2024) quantified the differences in the perceptual images of different sofa fabrics by visual-tactile evaluation and Kansei engineering method and verified the effectiveness of this method in material design. Li and Wang (2024) employed a Kansei engineering approach to quantify children's visual and tactile perceptions of surface materials used in medical products. Their findings indicated that smooth, low-gloss surfaces can increase children's acceptance of such medical products. With the global manufacturing reform, footwear design is stepping into the era of intelligent manufacturing. Xu *et al.* (2023) used Matlab and neural networks to analyze the color and texture characteristics of leather to validate consumers' visual and tactile feedback. Hapsari *et al.* (2017) used the Kansei engineering method to design seats for Indonesian trains, with the aim of optimizing the passenger experience. This study proposes a multifunctional seat covered with synthetic leather as a design solution. Roh and Oh (2017) evaluated the subjective feel and consumer preference ratings of two types of artificial leathers, suede and polyurethane coated, through Kansei engineering. The study points out that the preferred feel depends on the type of leather and its product use.

In summary, these studies concentrate on sensory evaluation using vision or touch in isolation, while the research on the multi-sensory evaluation of vision and touch is limited. Kansei engineering can effectively transform users' subjective emotions into quantifiable design parameters, thus providing a scientific basis for product development. Additionally, research on Kansei engineering of leather materials mainly has focused on vehicle seats, footwear product design, and consumer usage preference evaluations. However, in the customized furniture field, research is rare. There has been a lack of a systematic evaluation framework of the user's visual and tactile perception of the leather materials in customized furniture, which makes it difficult for designers to accurately grasp the multidimensional perception of users' needs for leather materials.

Consequently, this study concentrates on the field of customized closet furniture, integrating the principles of Kansei engineering and subjective evaluation method to explore the influence mechanism of leather materials with different textures and colors on the emotional response of Chinese customized closet consumers. The study aimed to construct a complete set of quantitative assessment system of user perception to accurately refine user preference characteristics, and empirically test the theoretical model with the

help of design practice. In the questionnaire research, participants evaluated the visual and tactile perception of different leather surface materials. These leather materials had different textures and colors, and at the same time gave different style perception. Users were able to feel and evaluate the smoothness, softness, color brightness and other characteristics of these leather materials. Factor analysis can convert subjective perceptual evaluations into quantitative factor scores, which can identify which perceptual factors have the greatest influence on consumers' purchasing decisions. Cluster analysis helps to categorize leather materials with similar visual and tactile perceptual characteristics and analyze participants' preferences for each cluster. Together, these methods constitute a comprehensive quantitative evaluation framework for leather material perception and provide a scientific basis for leather material selection and design optimization of custom closet furniture.

EXPERIMENTAL

Test Subjects

The experimental subjects of this study were Chinese consumers and potential users of leather closet products. This study invited 42 subjects to participate in the experiment. In addition, designers, furniture design teachers, and student groups were invited to participate in the evaluation as experts. The participants covered different age groups, professional backgrounds and genders. Among them, the age distribution spanned between 18 and 60 years old. There were 26 males and 16 females. All of them had Chinese as their mother tongue. It should be emphasized that the sample of this study was representative and suitable for a comprehensive analysis. But the homogeneity of geographical and cultural backgrounds may limit generalizations of conclusions.

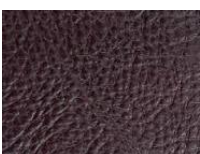
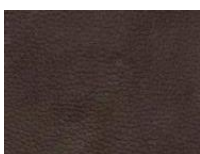
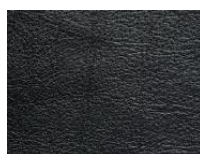
Test Samples

The research in this paper aimed to explore consumers' preference for surface materials when purchasing customized leather closets. Taking brand influence, product design style, and consumer recognition into account, leather closet products for furniture brands such as Poliform, Boloni, Toppinis, RARA and FINNNAVIAN were selected as research objects, and their surface materials were summarized and classified.

In order to minimize the impact of sample selection limitations on research results, this study adopted a combination of expert evaluation and KJ method for comprehensive evaluation. Expert evaluation method (Chen *et al.* 2022) brings together the opinions of experts in different fields, which helps to look at the problem from multiple perspectives. However, this method tends to be subjective, whereas the KJ method (Scupin 1997) is a qualitative data analysis tool. It provides an objective basis for subjective judgments by collecting and analyzing structured information. The combination of these two research methods helps to identify and correct errors or biases. Finally, 12 kinds of leather materials were selected, including natural and artificial leather. These materials are representative in terms of texture, color, and surface treatment, such that they can fully cover the main sensory characteristics of leather materials and provide sufficient experimental samples to support the subsequent multi-sensory evaluation study. Table 1 shows the diagram and sample numbers of these materials. M1, M2, M9, M10, M11, and M12 are natural leather; whereas M3, M4, M5, M6, M7, and M8 are artificial leather.

The size of the leather sample affects the participants' assessment results. Participants may have difficulty in perceiving the softness, roughness, or other characteristics of leather through a small contact area (Md Rezali and Griffin 2017). Therefore, all samples in this experiment were uniformly sized at 5×10 cm to ensure consistency of experimental conditions and to reduce the interference caused by the size difference.

Table 1. Leather Material Samples

Sample Number	M1	M2	M3	M4
Diagram				
Sample Name	Lychee Grain Leather	Crocodile Grain Leather	Ecological Leather	Nappa Leather
Sample Number	M5	M6	M7	M8
Diagram				
Sample Name	Plain weave Leather	Oil Waxed Leather	Snake Grain Leather	Vegetable-tanned Leather
Sample Number	M9	M10	M11	M12
Diagram				
Sample Name	Palm-patterned Leather	Top-grain Leather	Buffed Leather	Tumbled Leather

Visual and Tactile Subjective Evaluation Tests

A total of 60 sets of perceptual vocabulary related to leather closet materials were collected through multiple channels such as books, dictionaries, websites, and papers. The KJ method was used to classify these perceptual words according to vision and touch. After an initial screening, 10 people with relevant design experiences were invited to evaluate the 60 sets of words mentioned above in order to eliminate similar and repetitive words. Seven groups of representative image perceptions of semantic words were eventually selected: “rough-smooth”, “soft-hard”, “bright-dull”, “ugly-beautiful”, “retro-modern”, “stressed-relaxed”, “uncomfortable-comfortable”. Chinese was used as the research language throughout the whole process to ensure the smooth progress of the research work.

Based on the semantic difference method in Kansei engineering, the 5-point Likert scale was used to explore the surface material sample of leather closets. By providing subjects with leather material samples of closet surfaces of the same size and similar characteristics, they rated these 12 samples and 7 sets of perceptual semantic words using subjective visual and tactile evaluations with scores of -2, -1, 0, 1, and 2 (Emerson 2017). The lower score is closer to the description of the left perceptual semantic words, and the higher score is closer to the description of the right words. The content design of the questionnaire on visual and tactile perceptions of leather material is detailed in Table 2. To ensure the accuracy of the test results, the test environment is set to a quiet state, with the aim of eliminating external noise interference and avoiding other people's activities, thus preventing perceptual bias caused by participants' psychological fluctuations (Einhäuser *et al.* 2021).

Table 2. Questionnaire for Leather Material Visual-Tactile Perception Evaluations

Perceptual Vocabulary	-2	-1	0	1	2	Perceptual Vocabulary
Rough	○	○	○	○	○	Smooth
Hard	○	○	○	○	○	Soft
Dull	○	○	○	○	○	Bright
Ugly	○	○	○	○	○	Beautiful
Retro	○	○	○	○	○	Modern
Stressed	○	○	○	○	○	Relaxed
Uncomfortable	○	○	○	○	○	Comfortable

RESULTS AND DISCUSSION

Analysis of Visual and Tactile Subjective Evaluations

The evaluation questionnaire was distributed to Chinese consumers and potential users of leather closet products. A total of 42 validation questionnaires were finally collected for the 12 sample materials. Thirty-four of them were valid questionnaires and eight were invalid questionnaires, with a validity rate of 80.9%. The average perceptual evaluation score of 12 material samples was calculated, as shown in Table 3.

Table 3. Mean Scores of Visual-Tactile Perception Evaluations for Samples

Sample Number	Rough-Smooth	Hard-Soft	Dull-Bright	Ugly-Beautiful	Retro-Modern	Uncomfortable-Comfortable	Stressed-Relaxed
M1	-1.00	0.26	1.15	0.85	0.32	0.50	0.50
M2	-1.06	0.09	1.03	-0.06	0.85	-0.06	-0.03
M3	0.91	0.53	1.09	1.18	0.82	0.79	0.82
M4	1.09	0.29	0.06	0.59	0.85	0.71	0.74
M5	1.18	-1.32	0.56	0.56	0.94	0.47	0.50
M6	0.88	0.88	0.91	0.15	-0.65	0.91	0.97
M7	-1.18	-0.82	-0.53	-0.97	-0.09	-0.62	-0.82
M8	-0.65	-1.00	-0.56	0.12	-0.38	-0.47	-0.53
M9	-0.97	0.62	-0.35	-0.79	-0.29	-0.09	-0.56
M10	-0.56	1.06	-1.26	-0.59	-0.32	0.85	0.94
M11	-0.53	0.03	-1.53	-0.94	-0.15	0.41	0.35
M12	-0.29	1.12	-1.44	-0.12	-0.18	0.94	1.03

To ensure the accuracy and reliability of the data, Cronbach's alpha coefficient is used as a valid tool to assess the consistency of the scale data (Cronbach 1951). Data processing and analysis using SPSS 27.0 software showed that the Cronbach's alpha coefficient was 0.768. This value indicates that the results of visual-tactile subjective evaluation of selected samples were sufficient for comprehensive analysis, and the data collected from this questionnaire study had good reliability. This can provide a solid foundation for subsequent data analysis and research conclusions.

As shown in Fig. 1, the comfort grades of the subjective visual and tactile evaluation tests were in the following order: M12 (Tumbled Leather), M6 (Oil Waxed Leather), M10 (Top-grain Leather), M3 (Ecological Leather), M4 (Nappa Leather), M1 (Lychee Grain Leather), M5 (Plain weave Leather), M11 (Buffed Leather), M2 (Crocodile Grain Leather), M9 (Palm-patterned Leather), M8 (Vegetable-tanned Leather), and M7 (Snake Grain Leather). Among them, M12 tumbled leather had the highest comfort in the subjective visual and tactile tests, while M7 snake grain leather skin had the lowest comfort level.

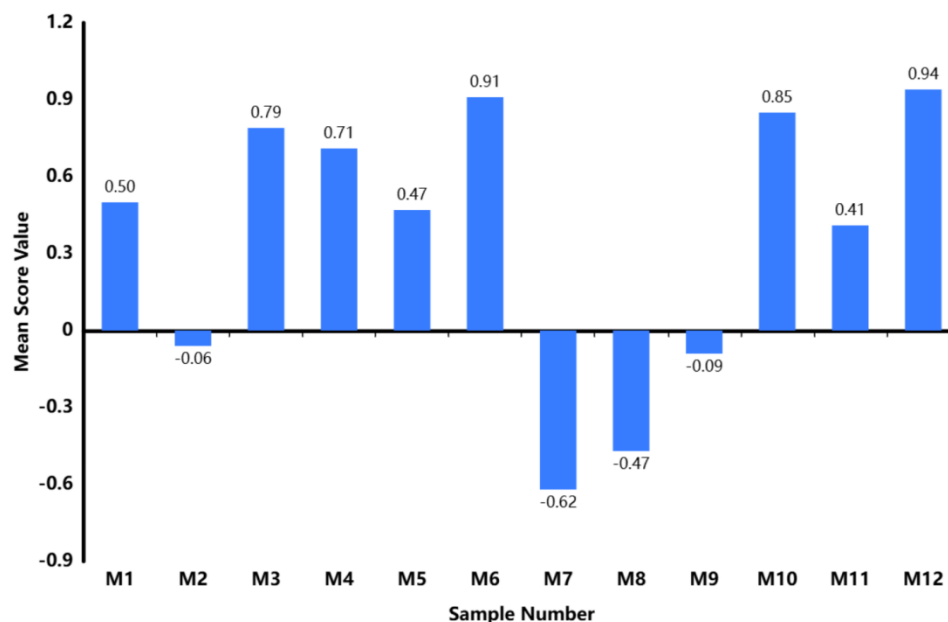


Fig. 1. Subjective evaluation of comfort

In addition to analyzing the users' perceptual ratings of the comfort levels of the leather samples, this study actively analyzed the ratings of six other groups of perceptual phrases. To report the analysis results more visually, three prominent perceptual phrases and vocabulary above the average were selected for each sample (Tu and Wang 2024). If the scores are equal, all these perceptual vocabularies with equal scores will be selected. The mean value of all positive values in Table 3 is 0.70 and the mean value of all negative values is -0.63. Values lower than 0.70 and values higher than -0.63 are filtered out. Values higher than 0.70 indicate a tendency to the right side of the perceptual vocabulary, while values lower than -0.63 indicate a tendency to the left side of the perceptual vocabulary, which relates the strong feelings of the researched people during the testing process. The tendency table of the perceptual vocabulary is shown in Table 4.

Table 4. Table of Perceptual Vocabulary Trends

Sample Number	Prominent Perceptual Phrases	Sensing Vocabulary Trends
M1	Dull-Bright, Rough-Smooth, Ugly-Beautiful	Bright (1.15), Rough (-1.00), Beautiful (0.85)
M2	Rough-Smooth, Dull-Bright, Retro-Modern,	Rough (-1.06), Bright (1.03), Modern (0.85)
M3	Ugly-Beautiful, Dull-Bright, Rough-Smooth	Beautiful (1.18), Bright (1.09), Smooth (0.91)
M4	Rough-Smooth, Retro-Modern, Stressed-Relaxed	Smooth (1.09), Modern (0.85), Relaxed (0.74)
M5	Hard-Soft, Rough-Smooth, Retro-Modern	Hard (-1.32), Smooth (1.18), Modern (0.94)
M6	Dull-Bright, Stressed-Relaxed, Uncomfortable-comfortable	Bright (0.91), Relaxed (0.91), Comfortable (0.97)
M7	Rough-Smooth, Ugly-Beautiful, Stressed-Relaxed, Hard-Smooth	Rough (-1.18), Ugly (-0.97), Stressed (-0.82), Hard (-0.82)
M8	Hard-Soft, Rough-Smooth	Hard (-1.00), Rough (-0.65)
M9	Rough-Smooth, Ugly-Beautiful	Rough (-0.97), Ugly (-0.79)
M10	Dull-Bright, Hard-Soft, Stressed-Relaxed	Dull (-1.26), Soft (1.06), Relaxed (0.94)
M11	Dull-Bright, Ugly-Beautiful	Dull (-1.53), Ugly (-0.94)
M12	Dull-Bright, Hard-Soft, Stressed-Relaxed	Dull (-1.44), Soft (1.12), Relaxed (1.03)

According to Table 4, the leather samples: M7 (Snake Grain Leather), M2 (Crocodile Grain Leather), M1 (Lychee Grain Leather), M9 (Palm-patterned Leather), and M8 (Vegetable-tanned Leather) all had a distinctive grain, so they were considered to be the roughest surface materials. M5 (Plain weave Leather), M4 (Nappa Leather), and M3 (Ecological Leather) were regarded as the smoothest surface materials. M5 (Plain weave Leather), M8 (Vegetable-tanned Leather), and M7 (Snake Grain Leather) were viewed as the hardest surface materials, while M12 (tumbled Leather) and M10 (Top-grain Leather) were considered as the most soft and relaxed surface materials. M1 (Lychee Grain Leather), M3 (Ecological Leather), M2 (Crocodile Grain Leather), and M6 (Oil Waxed Leather) were the brightest, and M11 (Buffed Leather), M10 (Top-grain Leather), and M12 (Tumbled Leather) were the dullest. M3 (Ecological Leather) and M1 (Lychee Grain Leather) were judged as the most beautiful. M5 (Plain weave Leather), M4 (Nappa Leather), and M2 (Crocodile Grain Leather) were the most modern samples.

As shown in Table 5, the correlation matrix points out the relationship between seven groups of perceptual phrases and the perception conveyed to participants by the leather material. In this case, a larger absolute value indicates a stronger correlation; a smaller absolute value indicates a weaker correlation (Pranjić and Deluka-Tibljajš 2022). According to the data, leather material showed a positive correlation in comfort-relaxation ($r = 0.982$), indicating that users were highly aligned in their comfort ratings and emotional relaxation. In terms of tactile-emotional association, “Rough-Smooth” was positively correlated with comfort ($r = 0.610$) and relaxation ($r = 0.615$), indicating that smooth surfaces are more likely to elicit a positive emotional response from consumers. “Hard-Soft” is also correlated with comfort ($r = 0.662$) and relaxation ($r = 0.589$), indicating that softness is a key user experience indicator. In terms of visual-aesthetic associations, “Dull-Bright” was strongly correlated with “Ugly-Beautiful” ($r = 0.720$), indicating that high-brightness materials are more likely to be perceived as aesthetically pleasing.

Table 5. Correlation Matrix

	Rough-Smooth	Hard-Soft	Dull-Bright	Ugly-Beautiful	Retro-Modern	Uncomfortable-comfortable	Stressed-Relaxed
Rough-Smooth	1.000	0.007	0.328	0.609	0.383	0.610	0.615
Hard-Soft	0.007	1.000	-0.116	-0.031	-0.291	0.662	0.589
Dull-Bright	0.328	-0.116	1.000	0.720	0.542	0.065	0.089
Ugly-Beautiful	0.609	-0.031	0.720	1.000	0.604	0.422	0.471
Retro-Modern	0.383	-0.291	0.542	0.604	1.000	0.100	0.147
Uncomfortable-comfortable	0.610	0.662	0.065	0.422	0.100	1.000	0.982
Stressed-Relaxed	0.615	0.589	0.089	0.471	0.147	0.982	1.000

Factor Analysis

In order to study the above variables more effectively and further understand, consumers' perceived preference for leather customized closets finish texture, factor analysis of the perceptual phrases was conducted using SPSS 27.0 software. Factor analysis is a method suitable for analyzing and processing common factors among complex variables (Sardarabadi and Van 2018). First, through the KMO and Bartlett's test to determine whether the data meet the conditions of factor analysis, if the KMO value is higher than 0.6 and the Bartlett's test corresponding to the p-value is lower than 0.05, it means that the data are suitable for factor analysis. The test results of the above data show that the KMO value was 0.611, the approximate chi square was 58.462, the degree of freedom was 21, and the significance level value was lower than 0.001. Therefore, the data exhibited a certain correlation and met the conditions of factor analysis.

In this paper, principal component analysis (PCA) was used to factor analyze the seven groups of perceptual words, and the results are shown in Table 5. Two public factors were obtained by extracting the public factors with factor eigenvalues higher than 1. The total variance contribution of the two public factors was 78.800%. From the third factor, the eigenvalue was less than 1, so the first 2 factors were extracted as common factors.

Table 6. Total Variance Explained

Compo-nent	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.827	4.035	48.035	3.362	48.035	48.035	2.813	40.185	40.185
2	2.154	30.765	78.800	2.154	30.765	78.800	2.703	38.615	78.800
3	0.700	9.996	88.797						
4	0.444	6.344	95.140						
5	0.211	3.018	98.158						
6	0.119	1.697	99.855						
7	0.010	0.145	100.000						

* Extraction Method: Principal Component Analysis (Gewers *et al.* 2022).

The Scree plot is shown in Fig. 2, the eigenvalue of the first 2 factors is greater than 1, and the fold line gradually flattens out after the second factor, so it is appropriate to extract the first 2 factors.

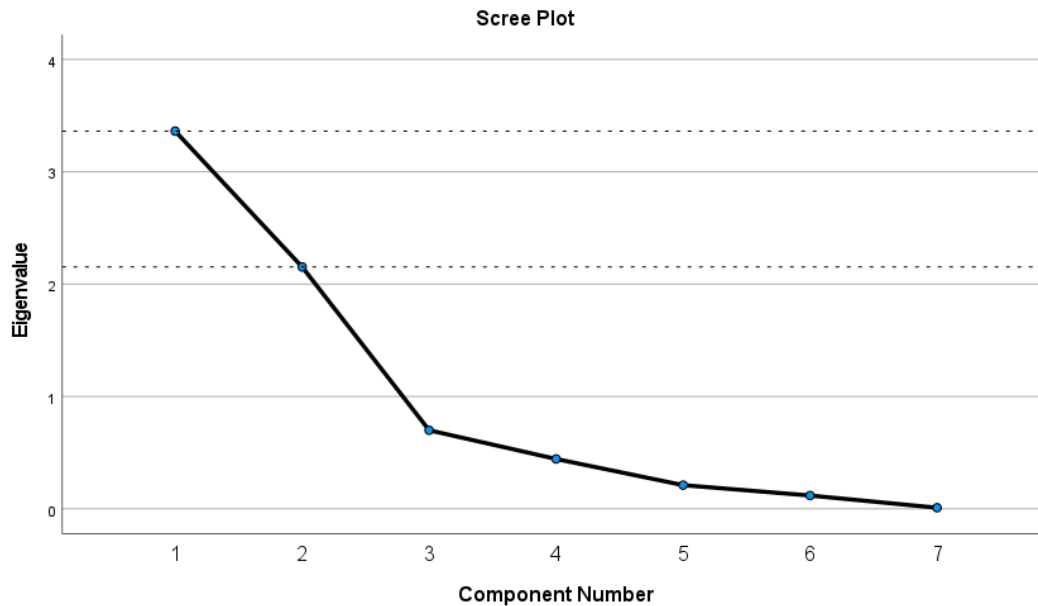


Fig. 2. Scree plot

The component matrix after the factor rotation is shown in Table 6. Two major components were extracted by principal component analysis. Factor 1 and Factor 2 represent different perceptual dimensions. Perceptual phrases with large absolute values for the Factor 1 loading component were: hard-soft, uncomfortable-comfortable, stressed-relaxed, and rough-smooth. All four perceptual phrases were related to the roughness, softness and comfort of the leather material. Therefore, Factor 1 was the key factor influencing tactile perception and can be named as the perceptual factor. Perceptual phrases with large absolute values for the Factor 2 loading component were: dull-bright, ugly-beautiful, and retro-modern.

Table 7. Rotated Component Matrix

Perceptual Vocabulary Group	Component	
	1	2
Rough-Smooth	0.514	0.624
Hard-Soft	0.786	-0.335
Dull-Bright	-0.055	0.815
Ugly-Beautiful	0.292	0.875
Retro-Modern	-0.081	0.827
Uncomfortable-comfortable	0.972	0.183
Stressed-Relaxed	0.944	0.237
*Extraction method: Principal component analysis; Rotation method: Varimax with Kaiser normalization (Cape 2024).		

All three perceptual phrases were related to aesthetic and color characteristics of leather materials. Therefore, Factor 2 was the key factor influencing visual perception and can be named as the visual factor. Through principal component analysis, it can be seen

that the rotated component matrix helped to clearly distinguish the different perceptual dimensions, and at the same time was able to help to better understand the relationship between different attributes, which provides an important theoretical basis for further research and application.

Cluster Analysis

Cluster analysis is an exploratory dimension-reduction analysis method that divides several sets of data into groups at different levels (Crowther *et al.* 2021). A systematic clustering method analyzed 12 leather samples to obtain a collection of sample types that satisfied consumer preferences. The results of the cluster analysis are detailed in Fig. 3.

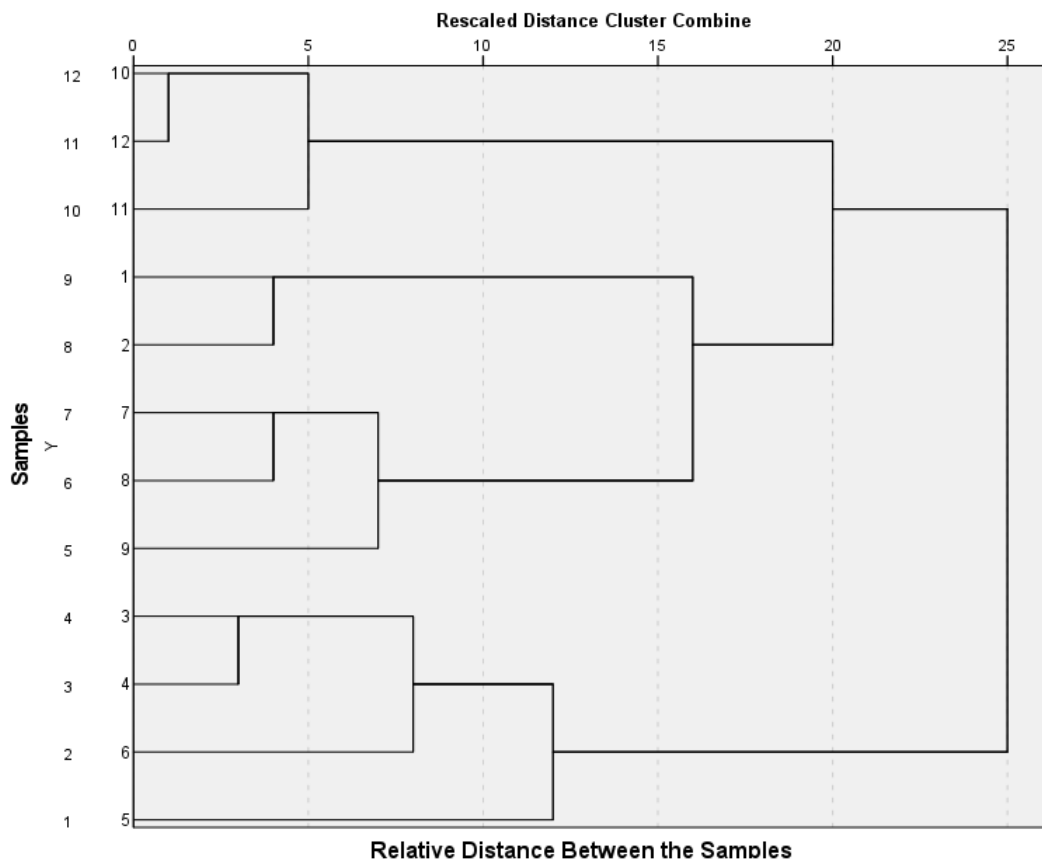


Fig. 3. Dendrogram using average linkage (between groups)

In Fig. 3, the leather material samples are represented by the vertical axis, while the relative distances between them are shown by the horizontal axis. A vertical line is plotted downwards from the horizontal position of the quantitative value 15. According to the four different intersections of this vertical line with the horizontal axis, the leather material samples were divided into four groups.

According to the results of the cluster analysis, it can be seen that the first cluster represent samples M10 (Top-grain Leather), M11 (Buffed Leather), and M12 (Tumbled Leather). Samples of this type are all in dark colors, with a soft texture that feels very comfortable and relaxing to the touch. They are suitable for low-key, advanced home environments. The second cluster includes M1 (Lychee Grain Leather), and M2 (Crocodile Grain Leather). This style is characterized by bright colors and a rough texture and is

suitable for simple and modern scenes in the home. The third cluster is comprised of M7 (Snake Grain Leather), M8 (Vegetable-tanned Leather), and M9 (Palm-patterned Leather). This type of leather material has a more pronounced surface texture and a distinctive color. It is rough and hard, suitable for making those furniture surface materials with vintage style and durability. The fourth cluster had samples from M3 (Ecological Leather), M4 (Nappa Leather), M6 (Oil Waxed Leather), and M5 (Plain weave Leather). This type of leather material has a delicate and smooth texture and is often chosen for warm, comfortable, and stylish furniture surfaces.

Design and Verification

Based on the above analysis, consumers in the leather custom closet product assess the surface material preference based on two major dimensions: one is the visual feedback, the second is the psychological feeling. As shown in Table 7, the results of the factor and cluster analyses indicate consumer perceptions of each sample type. The leather samples for each perceptual score dimension was sorted from left to right in ascending order of mean scores to infer the sample with the highest perceptual score among the participants.

Table 8. Perceived Evaluation Sorting of Leather Materials

Com- ponent	Perceptual Phrases	Perceived Evaluation Sorting											
Visual Factor	Dull-Bright	M 11	M 12	M 10	M8	M7	M9	M4	M5	M6	M2	M3	M1
	Ugly-Beautiful	M7	M 11	M9	M 10	M 12	M2	M8	M6	M5	M4	M1	M3
	Retro-Modern	M6	M8	M 10	M9	M 12	M 11	M7	M1	M3	M2	M4	M5
Perceptual Factor	Rough-Smooth	M7	M2	M1	M9	M8	M 10	M 11	M 12	M6	M3	M4	M5
	Hard-Soft	M5	M8	M7	M 11	M2	M1	M4	M3	M9	M6	M 10	M 12
	Uncomfortable- comfortable	M7	M8	M9	M2	M 11	M5	M1	M4	M3	M 10	M6	M 12
	Stressed- Relaxed	M7	M9	M8	M2	M 11	M1	M5	M4	M3	M 10	M6	M 12

According to the above results, participants had higher ratings for M12 (Tumbled Leather), M5 (Plain weave Leather), M3 (Ecological Leather), and M1 (Lychee Grain Leather). In terms of touch, participants will appreciate a smoother, softer touch. In the visual angle, the bright and soft materials will give people a modern fashion feeling. To verify the feasibility of the experimental results, design scheme addresses the relationship between design style and perceptual features. A representative sample was selected from each of the four cluster analysis categories. Finally, as shown in Table 8, M12 (Tumbled Leather), M5 (Plain Weave Leather), M9 (Palm-patterned Leather), and M1 (Lychee Grain Leather) were selected, and the design was generated in image form using KUJIALE software. A questionnaire was used to obtain the perceptions of the same participants on the design style of the leather customized closets.

Table 9. Schematic Diagram of the Design Scheme

Scheme Number	S1	S2	S3	S4
Diagram				

A total of 42 valid questionnaires were collected and four design options are shown in Fig. 4. From the comprehensive evaluation results shown in Table 8, it basically conforms to the relationship characteristics between the surface texture and the design style obtained in cluster analysis. Therefore, the research method performed was judged to be feasible.

Table 10. Design Scheme Evaluation

Design Scheme	Design Style	Frequency	Percent	Valid Percent	Cumulative Percent
S1	Low-key & Comfortable	6	14.30	14.30	14.30
	Simple & Modern	28	66.70	66.70	81.00
	Luxury & Advanced	8	19.00	19.00	100.00
S2	Low-key & Comfortable	26	61.90	61.90	61.90
	Vintage & Durability	1	2.40	2.40	64.30
	Simple & Modern	12	28.60	28.60	92.90
	Luxury & Advanced	3	7.10	7.10	100.00
S3	Vintage & Durability	25	59.50	59.50	59.50
	Simple & Modern	4	9.50	9.50	69.00
	Luxury & Advanced	13	31.00	31.00	100.00
S4	Low-key & Comfortable	6	14.30	14.30	14.30
	Vintage & Durability	12	28.60	28.60	42.90
	Simple & Modern	3	7.10	7.10	50.00
	Luxury & Advanced	21	50.00	50.00	100.00

CONCLUSIONS

1. Based on Kansei engineering, this study established a quantitative user perception assessment system for Chinese customized leather closet consumers' visual-tactile perception of different leather materials. Participants rated the visual and tactile perception of leather materials using a questionnaire, factor analysis converts these into scores, and cluster analysis was used to categorize materials according to perceptual characteristics and preferences. This provided a framework for evaluating leather perception in furniture design.
2. In subjective visual-tactile evaluation tests conducted on 12 leather samples, snake grain leather scored highest in terms of roughness. In evaluating the softness of materials, tumbled leather achieved the highest score, while plain weave leather ranked lowest, but its hardness was higher than that of the other samples used as controls. This

means that consumers prefer a soft leather texture to harder wood materials. Among the style ratings of the materials, oil waxed leather scored the highest in terms of vintage style, while plain weave leather scored the highest in terms of modern style. Ecological leather scored highest in terms of aesthetic value. In the material comfort assessment, tumbled leather received the highest rating for its natural texture and feel. Additionally, lychee grain leather received the highest rating for brightness in the color evaluation. In contrast, tumbled leather scored the lowest due to its matte finish.

3. Cluster analysis divided the leather samples into four groups, which allows designers to pinpoint similarities and differences between consumer perceptions of different leather samples and capture design trends. Top grain leather, buffed leather, and tumbled leather are suitable for upscale living environments. Lychee grain leather and crocodile grain leather are suitable for simple and modern scenes. Snake grain leather, vegetable-tanned leather, and palm-patterned leather can provide consumers with vintage and durable styles. In addition, consumers looking for warm and cozy style can choose from ecological leather, nappa leather, oil waxed leather, and plain weave leather. Factor analysis can be used to establish a relationship between the perceptual characteristics of leather materials and consumer preferences by extracting key factors through dimension reduction. Research results show that the roughness, softness, and comfort of leather materials are the key factors affecting tactile perception; the brightness, beauty and modern degree of leather materials are the key factors affecting visual perception.
4. Factor analysis and cluster analysis results collectively indicate the perception evaluation outcomes of different leather samples by Chinese consumer groups. Lychee grain leather, ecological leather, plain weave leather, and tumbled leather scored the highest in the comprehensive visual-tactile perception assessment by users. In terms of tactile sensation, consumers prefer a smooth, soft touch and a comfortable feel. Visually, consumers prefer bright color and a modern style. Improving the comfort, softness and smoothness of the leather material can improve the user's perceived experience. In the context of the rapid development of the customized closet industry, designers need to focus on the unity of tactile experience and visual aesthetics.

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REFERENCES CITED

- Bhatta, S. R., Tiippana, K., Vahtikari, K., Hughes, M., and Kyttä, M. (2017). "Sensory and emotional perception of wooden surfaces through fingertip touch," *Frontiers in Psychology* 8, article 367. DOI: 10.3389/fpsyg.2017.00367

- Cape, J. (2024). "On varimax asymptotics in network models and spectral methods for dimensionality reduction," *Biometrika* 111(2), 609-623. DOI: 10.1093/biomet/asad061
- Chen, Z., Zhong, P., Liu, M., Ma, Q., and Si, G. (2022). "An integrated expert weight determination method for design concept evaluation," *Scientific Reports* 12(1), article 6358. DOI: 10.1038/s41598-022-10333-6
- Cronbach, L. J. (1951). "Coefficient alpha and the internal structure of tests," *Psychometrika* 16(3), 297-334. DOI: 10.1007/BF02310555
- Crowther, D., Kim, S., Lee, J., Lim, J., and Loewen, S. (2021). "Methodological synthesis of cluster analysis in second language research," *Language Learning* 71(1), 99-130. DOI: 10.1111/lang.12428
- Ding, Y. (2020). "Application research of quantitative deductive Kansei Engineering in app interface optimization design," *IOP Conference Series: Materials Science and Engineering* 733(1), article 012003. DOI: 10.1088/1757-899X/733/1/012003
- Einhäuser, W., Sandrock, A., and Schütz, A. C. (2021). "Perceptual difficulty persistently increases dominance in binocular rivalry—Even without a task," *Perception* 50(4), 343-366. DOI: 10.1177/0301006621999929
- Emerson, R. W. (2017). "Likert scales," *Journal of Visual Impairment and Blindness* 111(5), 488-488. DOI: 10.1177/0145482X1711100511
- Etzi, R., Spence, C., and Gallace, A. (2014). "Textures that we like to touch: An experimental study of aesthetic preferences for tactile stimuli," *Consciousness and Cognition* 29, 178-188. DOI: 10.1016/j.concog.2014.08.011
- Fujisaki, W., Tokita, M., and Kariya, K. (2015). "Perception of the material properties of wood based on vision, audition, and touch," *Vision Research* 109, 185-200. DOI: 10.1016/j.visres.2014.11.020
- Gewers, F. L., Ferreira, G. R., Arruda, H. F. D., Silva, F. N., Comin, C. H., Amancio, D. R., and Costa, L. D. F. (2022). "Principal component analysis: a natural approach to data exploration," *ACM Computing Surveys* 54(4), 1-34. DOI: 10.1145/3447755
- Guest, S., and Spence, C. (2003). "What role does multisensory integration play in the visuotactile perception of texture?," *International Journal of Psychophysiology* 50(1-2), 63-80. DOI: 10.1016/S0167-8760(03)00125-9
- Hapsari, S. N., Sjafrizal, T., and Anugraha, R. A. (2017). "Designing train passenger seat by kansei engineering in Indonesia," *MATEC Web of Conferences* 135, article 17. DOI: 10.1051/mateconf/201713500017
- Jin, D., and Li, T. (2023). "Research on decorative materials properties used in the production of cabinets based on visual/tactile experience," *Coatings* 13(1), article 178. DOI: 10.3390/coatings13010178
- Johnson, O., and Ulrich, P. (2018). "The relationship between color cycles in home furnishings and apparel, 1969–2009," *Fashion and Textiles* 5(1), article 12. DOI: 10.1186/s40691-017-0124-y
- Li, N., and Wang, W. (2024). "Research of surface materials for children's household medical products based on visual and tactile experience," *Applied Sciences* 14(19), article 8910. DOI: 10.3390/app14198910
- Luimes, R. A., Suiker, A. S. J., Jorissen, A. J. M., Van Duin, P. H. J. C., and Schellen, H. L. (2018). "Hygro-mechanical response of oak wood cabinet door panels under relative humidity fluctuations," *Heritage Science* 6(1), article 72. DOI: 10.1186/s40494-018-0233-y

- McGlone, F., Wessberg, J., and Olausson, H. (2014). "Discriminative and affective touch: Sensing and feeling," *Neuron* 82(4), 737-755. DOI: 10.1016/j.neuron.2014.05.001
- Nagamachi, M. (1999). "Kansei Engineering: the implication and applications to product development," *IEEE International Conference on Systems*. IEEE, 1999. DOI: 10.1109/ICSMC.1999.816563
- Nordvik, E., Schütte, S., and Broman, N. O. (2009). "People's perceptions of the visual appearance of wood flooring: A Kansei Engineering approach," *Forest Products Journal* 59(11–12), 67-74. DOI: 10.13073/0015-7473-59.11.67
- Omoloso, O., Mortimer, K., Wise, W. R., and Jraisat, L. (2021). "Sustainability research in the leather industry: A critical review of progress and opportunities for future research," *Journal of Cleaner Production* 285, article 125441. DOI: 10.1016/j.jclepro.2020.125441
- Pranjić, I., and Deluka-Tibljajš, A. (2022). "Pavement texture–friction relationship establishment via image analysis methods," *Materials* 15(3), article 846. DOI: 10.3390/ma15030846
- Roberts, R. D., Li, M., and Allen, H. A. (2024). "Visual effects on tactile texture perception," *Scientific Reports* 14(1), article 632. DOI: 10.1038/s41598-023-50596-1
- Roh, E. K., and Oh, K. W. (2017). "The subjective hand and preferences evaluation of artificial leather by use," *Fashion & Textile Research Journal* 19(1), 79-89. DOI: 10.5805/SFTI.2017.19.1.79
- Sadoh, T., and Nakato, K. (1987). "Surface properties of wood in physical and sensory aspects," *Wood Science and Technology* 21(2), 111-120. DOI: 10.1007/BF00376191
- Sardarabadi, A. M., and Van Der Veen, A.-J. (2018). "Complex factor analysis and extensions," *IEEE Transactions on Signal Processing* 66(4), 954-967. DOI: 10.1109/TSP.2017.2780047
- Scupin, R. (1997). "The KJ method: A technique for analyzing data derived from Japanese ethnology," *Human Organization* 56(2), 233-237. DOI: 10.17730/humo.56.2.x335923511444655
- Tu, Z., and Wang, W. (2024). "Perceptual imagery of soft sofa fabrics based on visual-tactile evaluation," *BioResources* 19(4), 8427-8442. DOI: 10.15376/biores.19.4.8427-8442
- Wang, W. M., Li, Z., Tian, Z. G., Wang, J. W., and Cheng, M. N. (2018). "Extracting and summarizing affective features and responses from online product descriptions and reviews: A Kansei text mining approach," *Engineering Applications of Artificial Intelligence* 73, 149-162. DOI: 10.1016/j.engappai.2018.05.005
- Xu, B., Wang, Y., Guo, D., Gao, Y., Liu, W., Wu, W., Sun, L., Yu, X., Zhao, J., and Xiong, J. (2022). "Determination of the key parameters of VOCs emitted from multi-layer leather furniture using a region traversal approach," *Science of the Total Environment* 819, article 153126. DOI: 10.1016/j.scitotenv.2022.153126
- Xu, D.-D., Wu, C.-F., and Wang, C.-S. (2023). "A study on perception of visual–tactile and color–texture features of footwear leather for symmetric shoes," *Symmetry* 15(7), article 1462. DOI: 10.3390/sym15071462
- Yin, W., Lyu, J., and Xu, B. (2021). "Difference evaluation between plant dyed and industrial dyed cotton fabrics based on perceptual factors," *Journal of Physics: Conference Series* 1790(1), article 012012. DOI: 10.1088/1742-6596/1790/1/012012
- Yoshioka, T., Bensmaïa, S. J., Craig, J. C., and Hsiao, S. S. (2007). "Texture perception through direct and indirect touch: An analysis of perceptual space for tactile textures

in two modes of exploration,” *Somatosensory and Motor Research* 24(1–2), 53-70.
DOI: 10.1080/08990220701318163

Yu, N., Wang, J., Hong, L., Tao, B., and Zhang, C. (2021). “Evaluation of the color aesthetics of fine wood based on perceptual cognition,” *BioResources* 16(2), 4126–4148. DOI: 10.15376/biores.16.2.4126-4148

Zheng, L., and Xu, L. (2025). “Comparing AI and human emotional responses to color: A semantic differential and word-color association approach,” *Color Research and Application* col.22978. DOI: 10.1002/col.22978

Zhou, C., Gu, W., Luo, X., and Kaner, J. (2023). “Building a 4E interview-grounded theory model: A case study of demand factors for customized furniture,” *Plos One* 18(4), article e0282956. DOI: 10.1371/journal.pone.0282956

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