Exploring the Relationship between Visual Evaluation and User Preference in Wooden Cork Flooring: An Application of the Semantic Differential Method

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To enhance consumers' preference for the appearance of cork flooring, this work employed the semantic differential method to explore the relationship between consumers' visual perceptions and their preferences. First, a collection of cork flooring product images was assembled, and a lexicon of perceptual vocabulary describing the visual characteristics of cork flooring was developed. Subsequently, a survey based on the semantic differential method and preference questionnaires was completed. A regression model was established to analyze the relationship between the scores of perceptual vocabulary and consumer preferences. The results indicated that the perceptual terms "light" and "warm" had a significant positive impact on consumer preferences. Furthermore, the study explored the relationship between the granularity, grain arrangement, and color of cork flooring samples and the perceptual vocabulary, revealing distribution patterns of the samples in terms of "light" and "warm" characteristics. The findings suggest that increasing the saturation and brightness of cork flooring surface colors, reducing granularity, and enhancing the rhythmic arrangement of patterns can improve consumers' preference for the appearance of cork flooring.

DOI: 10.15376/biores.20.4.9051-9062

Keywords: Semantic differential method; Cork flooring; Visual evaluation; Regression analysis; Cluster analysis

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INTRODUCTION

Cork is derived from the outer bark of *Quercus variabilis* or *Quercus suber*. It is a natural, renewable, and sustainable resource (Pérez *et al.* 2020; Li *et al.* 2023). Cork is widely used in various fields due to its excellent properties such as sound insulation, thermal insulation, highly elastic nature, heat retention, anti-slip, wear resistance, and shock absorption (Gonzalez *et al.* 2000; Chang *et al.* 2019; Cunha *et al.* 2020). Cork flooring is primarily applied in residential and commercial settings. In residential applications, it is favored by consumers for its elastic texture, sound insulation, durability, and weather resistance (Hao and Lei 2012; Sun and Xia 2012). Additionally, the rustic and natural surface patterns of cork flooring exhibit a sense of layering and continuity, which can alleviate the monotony of flat surfaces and create a simple, warm, and natural atmosphere in home environments (Sang and Li 2022). Furthermore, the eco-friendly properties of cork flooring align with sustainability requirements of modern commercial buildings, Lino *et al.* (2019), making it widely used in hotels, conference rooms, libraries, kindergartens, and other spaces (Fan *et al.* 2020). As a versatile and multifunctional natural material, cork demonstrates significant application potential and value. With advancements in technology and evolving market demands, the prospects for cork applications are expected to expand even further.

The relationship between visual evaluation and user preference for cork flooring has been minimally researched and lacks systematic and scientific theoretical support. European scholars have conducted earlier research on cork flooring, primarily focusing on material properties, processing techniques, and sustainability. For example, Pintos *et al.* (2024) explored the sustainability characteristics of cork. They also investigated the design and application of large-format additive manufacturing of cork composites in sustainable products. In regard to visual evaluation, Broman (2001) investigated people's preferences for wood knots and explored the relationship between the aesthetic features of wood knots and visual preferences. Nordvik *et al.* (2009) used the Kansei engineering method to study the relationship between visual characteristics of wood flooring and people's reactions to indoor wood products, analyzing statistical links between attributes and semantics to quantify user preferences. Imanishi and Nakamura (2011) examined the impact of visual image features on the visual impressions of wood flooring patterns by objectively describing the characteristics of given patterns. In China, the cork flooring industry has focused on optimizing production processes and improving product performance, Qiu *et al.* (2011) and has gradually moved towards refined processing, high added value, and increased automation (Lu *et al.* 2011). However, research on the appearance of cork flooring and consumer preferences remains limited. Only a few studies have used the semantic differential method to explore the influence of color and pattern on user preferences. These studies primarily focused on traditional wood flooring, with limited in-depth research on cork flooring. In summary, although existing research provides a theoretical foundation for visual evaluation and user preference of cork flooring, further studies are needed to drive innovation in cork flooring design.

Cork board constitutes a composite material formed by cork granules bonded with polymeric adhesives under hot-pressing (typically >100° C). The visual appearance of cork boards is determined by morphological parameters of the cork granules, including colour, particle size distribution, and geometric configuration. Industrial production techniques — such as chromogenic treatment (Chang *et al.* 2009), assembly of heterogeneous granule patterns, and precision milling processes—enable changes in the appearance of the cork board. These methods are routinely employed by manufacturers to engineer cork flooring products that cater to diversified consumer aesthetic preferences. However, compared with solid wood or parquet flooring, cork flooring still exhibits limitations such as monotonous patterns, dull colors, and a lack of variety (Lu *et al.* 2021). Manufacturers often overlook consumer aesthetic preferences during production, resulting in cork flooring designs that fail to meet the aesthetic demands of modern home environments (Wang and Lye 2019). In a market where cork flooring products are highly homogeneous (Miao and Miao 2023), innovative designs that align with consumer aesthetic preferences are crucial for enhancing product competitiveness (Li *et al.* 2021).

It is hypothesized that the visual characteristics of cork flooring, when assessed using the semantic differential method, will demonstrate a significant relationship with user preferences that will predict users' emotional responses to different design elements. By quantifying users' perceptions of visual features such as color and texture, the study seeks to identify the driving factors behind users' emotional responses to different visual characteristics. Results of this work is hope to provide valuable insights for the development, production, and design of cork flooring and surface decoration materials, including color, texture, and surface effects, and ultimately improve consumers' visual experience with cork flooring.

EXPERIMENTAL

The semantic differential method is a widely used technique in psychological and social science research (Yu and Yuan 2012). It is designed to measure psychological perceptions through the use of adjective pairs and verbal scales (Zhang *et al.* 2021; Wang *et al*. 2023). It has been extensively applied across various disciplines (Zhu *et al.* 2024). The method involves presenting participants with a series of adjective pairs (often antonyms) and asking them to select the terms that best describe their perception. These adjective pairs reflect individuals' emotional tendencies or cognitive evaluations of the assessed object. In this work, the semantic differential method was used to explore the relationship between consumers' visual perceptions and preferences for cork flooring. The specific methodology is as follows.

Sample Collection and Selection

In this work, 16 sample images of cork flooring products were collected to investigate factors influencing consumer preferences. Samples were taken from multiple brands to comprehensively cover types of surface decoration available on the market. As shown in Fig. 1, Samples 1-4 featured warm-toned (yellowish-brown and brown) cork granules with random arrangements and gradually increasing granule sizes.

Fig. 1. Cork flooring samples

Samples 5-8 exhibited fixed but irregular patterns, such as gray curves in Sample 5 and squares of varying sizes in Sample 6. The surface patterns of Samples 9-12 consist of vertical stripes, which are arranged in an orderly manner. Samples 13-16 have minimal granule texture and significant color contrasts between warm and cool tones. The 16 samples varied in color, granule size, and arrangement, to provide a basis for comparative analysis.

Development of the Perceptual Vocabulary Lexicon

Development of a perceptual vocabulary lexicon is fundamental to the semantic differential method for analyzing consumer visual preferences. This method involves describing the visual attributes and characteristics of image samples to select appropriate and accurate perceptual descriptors (Chen and Guan 2021). In this study, five participants were involved in the collection of perceptual vocabulary based on their intuitive visual impressions of 16 image samples. A total of 35 valid perceptual terms were collected initially, and these were then expanded to 68 terms with additional sources such as online resources, books, and expert evaluations (Miao and Guan 2013). These 68 terms were further consolidated and categorized by using the KJ method (Zhao et al. 2024), resulting in nine terms that accurately and comprehensively describe the image samples: natural, messy, luxurious, retro, simple, heavy, artificial, warm, and delicate (Zhou *et al.* 2021; Niu and Chen 2023; Wei and Wu 2024). Antonyms were assigned to these nine terms. This process yielded seven pairs of antonymous terms: natural–artificial, messy–ordered, luxurious–simple, retro–modern, heavy–light, warm–cold, and delicate–coarse. These pairs constitute the perceptual vocabulary lexicon for the SD method. It is worth noting that "warm–cold" is a visually induced emotional experience that does not involve real tactile sensations.

Visual Evaluation and Preference Survey

The survey employed the semantic differential method, using the nine pairs of perceptual terms as the evaluation criteria. A 7-point semantic differential scale (−3 to 3) (Zhou *et al.* 2020; Liu and Guan 2024) was created for each term. Participants were asked to rate their perceptions of each sample image based on the scale, with the results reflecting their cognitive evaluations. Additionally, participants rated their subjective preferences for each sample on a scale (−3 to 3). The survey included 16 sample images and was completed by 30 participants (15 males and 15 female). An example of the questionnaire for Sample 1 is shown in Table 1.

Table 1. Semantic Differential Scale for Samples

Sample 1									
	Scale								
	natural	−3	−2	−1	0	1	2	3	artificial
	messy	−3	−2	−1	0	1	2	3	ordered
	luxurious	−3	−2	−1	0	1	2	3	simple
	retro	−3	−2	−1	0	1	2	3	modern
	heavy	−3	−2	−1	0	1	2	3	light
	warm	−3	−2	−1	0	1	2	3	cold
	delicate	−3	−2	−1	0	1	2	3	coarse
Preference for Samples	dislike	−3	−2	−1	0	1	2	3	like

RESULTS AND DISCUSSION

Survey Results and Analysis

The 30 completed survey forms were collected, and the results are presented in Table 2. Values in Table 2 represent the average scores for each perceptual term across the image samples S1-S16.

Taking "natural–artificial" as an example, a mean score less than 0 corresponds to the left-side perceptual term, indicating a preference for "natural," while a mean score greater than 0 corresponds to the right-side term, indicating a preference for "artificial." In subsequent analyses exploring the relationship between perceptual terms and preferences, the numbered perceptual terms will be used to represent the surface visual characteristics of cork flooring, as shown in Table 3.

Table 2. Mean Scores of Perceptual Term Evaluations for Samples

	natural–artificial	messy–ordered	luxurious–simple	retro–modern	heavy–light	warm–cold	delicate–coarse	Preference Level
S1	−0.10	−1.37	0.83	−1.60	−1.73	−1.10	1.33	−0.90
S2	−0.27	0.27	0.73	−0.73	−0.07	−0.97	−0.67	0.27
S3	−1.00	−0.93	0.20	−0.40	−0.80	−1.03	0.60	−0.37
S4	−0.50	0.10	0.83	−1.10	−0.40	−0.90	0.23	−0.27
S5	1.20	0.67	0.67	0.90	1.10	0.53	−0.97	0.47
S6	1.40	0.87	0.37	−0.80	−1.33	1.10	0.47	−1.20
S7	0.10	−0.13	0.90	−0.10	0.17	−0.23	−0.13	−0.10
S8	−0.23	−0.73	−0.23	−1.00	0.03	−0.07	−0.07	−0.13
S9	−0.60	1.40	0.50	0.50	0.87	−0.33	−0.40	0.43
S10	0.47	1.40	0.93	−0.23	−0.10	−0.13	0.43	0.23
S11	−0.43	0.73	0.87	0.37	0.53	−0.53	0.37	0.43
S12	0.90	1.53	0.57	−0.37	−0.43	−0.60	0.13	0.50
S13	−0.17	0.77	0.27	1.13	1.13	−0.20	−0.77	1.23
S14	−0.60	0.33	−0.57	0.27	1.70	−0.90	−1.17	1.50
S15	0.17	0.00	0.67	0.33	0.97	0.17	−0.27	0.77
S16	0.43	0.13	0.90	0.37	1.27	0.47	−0.30	0.77
Mean Value	0.05	0.31	0.53	−0.15	0.18	−0.30	−0.07	0.23

Table 3. Semantic Bias of Perceptual Terms for Visual Evaluation

Number	Perceptual Term Pairs	Mean Value	Preferred Perceptual Terms
1	natural–artificial	0.05	F1 (Artificial)
2	messy–ordered	0.31	F2 (Ordered)
3	luxurious–simple	0.53	F3 (Simple)
4	retro–modern	−0.15	F4 (Retro)
5	heavy–light	0.18	F5 (Light)
6	warm–cold	−0.03	F6 (Warm)
7	delicate–coarse	−0.07	F7 (Delicate)

As shown in Table 3, the perceptual terms derived from the semantic differential method to describe the visual characteristics of cork flooring were F1 (Artificial), F2 (Ordered), F3 (Simple), F4 (Retro), F5 (Light), F6 (Warm), and F7 (Delicate). This indicates that consumers perceive the visual characteristics of cork flooring in multiple dimensions, (Ming *et al.* 2024) which reflects the diversity and complexity of cork flooring design.

Linear Regression Analysis

Before conducting linear regression analysis, a factor analysis was performed on the perceptual terms. Factor analysis was employed to examine whether there were common factors underlying the seven perceptual terms. The Kaiser–Meyer–Olkin (KMO) value was 0.522, below the threshold of 0.6, indicating few common factors among the perceptual terms and suggesting that factor analysis was not suitable. The weak correlations also confirmed that the KJ method provided a reasonable classification of the terms. To explore the factors influencing consumer preferences, a correlation analysis was first conducted between the seven perceptual terms and preference scores. After confirming significant correlations, a regression analysis was performed with the seven perceptual term scores as independent variables, and preference score as the dependent variable to identify the underlying factors affecting preferences (Qian and Ding 2021). Additionally, participants' preference scores for cork flooring samples are denoted as FD.

Table 4. Correlation Analysis between Perceptual Terms and Preference

	F1	F2	F3	F4	F5	F6	F7	FD
F1	1							
F2	0.408	1						
F3	0.281	0.141	1					
F4	−0.073	−0.499*	0.052	1				
F5	−0.117	0.333	−0.227	−0.842**	1			
F6	−0.753**	−0.333	−0.096	0.343	−0.194	1		
F7	0.008	0.348	−0.375	−0.682**	0.850**	−0.182	1	
FD	−0.177	0.381	−0.256	−0.768**	0.905**	0.062	0.776**	1

* indicates significance at the 0.05 level (two-tailed); ** indicates significance at the 0.01 level (two-tailed).

As shown in Table 4, among the seven perceptual terms in this experiment, three showed significant positive correlations with preference: F4 (Retro), F5 (Light), and F7 (Delicate). To further investigate the relationship between the seven perceptual terms and preference, a regression analysis was conducted with participants' preference scores for cork flooring surface patterns as the dependent variable and the seven perceptual term scores as independent variables. The results of the analysis are presented in Table 5.

Table 5. Multiple Regression of Preference on Perceptual Terms

	β	*t*	*p*	R^2
F1 (Artificial)	0.39	2.20	0.059	0.94
F2 (Ordered)	0.08	0.82	0.435	
F3 (Simple)	−0.24	−1.40	0.201	
F4 (Retro)	−0.12	−0.73	0.489	
F5 (Light)	0.76	4.22	0.003**	
F6 (Warm)	0.64	3.74	0.006**	
F7 (Delicate)	−0.21	−0.99	0.354	
Dependent variable = Preference. * indicates p < 0.05; ** indicates p < 0.01.				

The Durbin–Watson value for the residual sequence correlation of the regression model was 1.996. This was close to the standard value of 2, indicating that the residual sequence was largely uncorrelated. The histogram of standardized residuals and the normal probability plot of the regression model are shown in Fig. 2. The dependent variable followed a normal distribution, and the residuals met the assumptions of normality, independence, and homoscedasticity, satisfying the requirements for multiple linear regression analysis.

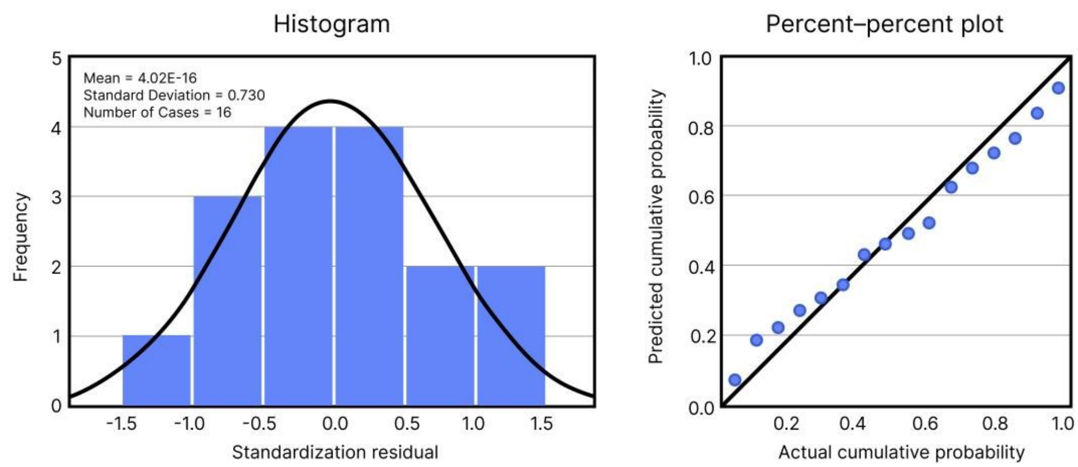

Fig. 2. Histogram and normal P–P plot of regression standardized residuals

The multiple linear regression model equation was as follows:

$$FD = 0.014 + 0.390 \times F1 + 0.077 \times F2 - 0.237 \times F3 - 0.123 \times F4 + 0.763 \times F5 + 0.642 \times F6 - 0.205 \times F7$$

Among these, F5 (Light) and F6 (Warm) had significant positive effects on participants' preference scores. The higher the perceived lightness and warmth in the surface patterns of cork flooring, the higher the participants' preference for the flooring. Therefore, the cork flooring industry can better satisfy consumer preferences by modifying surface patterns to create lighter and warmer visual effects.

Cluster Analysis

To clarify the relationship between cork flooring patterns and perceptual terms, a cluster analysis was conducted based on the scores of F5 (Light) and F6 (Warm), and a scatter plot was generated (Fig. 3). The samples were divided into four groups: Group 1 includes Samples 1, 2, 3, 4, and 12; Group 2 includes Samples 5, 7, 8, 9, 10, 11, 13, 15, and 16; Group 3 includes Sample 6; and Group 4 includes Sample 14 (Gao and Wei 2020; Cui and Guan 2023). In the ANOVA analysis, the p values for F5 and F6 were both less than 0.001, confirming the validity of the clustering results. As shown in Fig. 3, Group 1 is represented by the red circle, Group 2 by the blue circle, Group 3 by the green circle, and Group 4 by the yellow circle. The preference scores for each group are presented in Table 6.

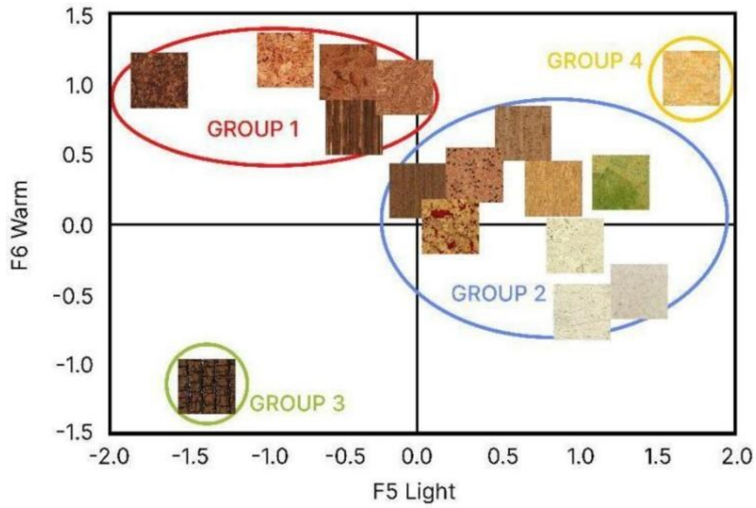

Fig. 3. Distribution plot of sample scores

Table 6. Preference Scores of Samples

Group	Samples	Preference Scores of Samples	Group Mean Score
1	1	−0.90	−0.15
	2	0.27	
	3	−0.37	
	4	−0.27	
	12	0.50	
2	5	0.47	0.46
	7	−0.10	
	8	−0.13	
	9	0.43	
	10	0.23	
	11	0.43	
	13	1.23	
	15	0.77	
	16	0.77	
3	6	−1.2	−1.2
4	14	1.5	1.5

The four groups exhibited distinct characteristics. Group 1, located in the second quadrant, was characterized by warmth but lacked lightness. The samples in this group were predominantly brown or dark brown, which contributed to their warm appearance. Sample 1, with the darkest color and smallest granularity, scored the lowest on the F5 axis. Group 2, distributed across the first and fourth quadrants, conveyed a sense of lightness. Samples 5, 15, and 16 had low color saturation and cool tones, resulting in lower scores on the F6 axis. Samples 7, 8, 9, 10, 11, and 13 featured varied colors and patterns with warm tones, which gave them a light and warm appearance. Group 3, located in the lower-left corner of the third quadrant, scored low on both F5 and F6. This sample, with its smooth, dark brown, alligator-skin-like texture, evokes a sense of coldness and heaviness. Such chromatic and textural attributes may lead consumers to associate darker patterns with higher material density, thereby inferring reduced elasticity. Group 4, diagonally opposite Group 3, featured high saturation and brightness in yellow tones with green accents, creating a dynamic and rhythmic pattern, resulting in high scores on both F5 and F6. The preference scores in Table 4 show that Group 4 had the highest average score (1.50), followed by Group 2 (0.46), Group 1 (−0.15), and Group 3 (−1.20). Single colors and patterns often fail to create a complete emotional perception, Jin *et al.* (2024), and users tend to prefer cork flooring that appears light and warm, aligning with modern minimalist styles and the need for spatial openness, as well as the comfort and sense of belonging emphasized in emotional design. This study confirmed that higher scores for “warm” and “light” characteristics in cork flooring surface designs correspond to higher user preferences, consistent with the regression analysis results.

The analysis revealed that neutral warm colors such as brown and tan increase warmth scores but decrease lightness scores. Low color saturation in cork flooring increases lightness scores. Strong granule texture reduces lightness scores. Increasing the rhythmic arrangement of patterns enhances lightness scores. Therefore, using warm colors, increasing the saturation and brightness of cork flooring surfaces, reducing granule texture, and enhancing pattern rhythm can improve warmth and lightness scores, thereby aligning with consumer preferences.

RESEARCH LIMITATIONS AND FUTURE WORK

The main limitations of the present study can be summarized as follows. First, the exclusive focus on visual characteristics (*e.g.*, color saturation, granular patterns) overlooks critical tactile properties (*e.g.*, elasticity, thermal insulation) and physical performance attributes inherent to cork flooring. Second, the perceptual vocabulary, though systematically derived, may not exhaustively capture semantic diversity across demographic and cultural contexts. To address these, future research should: (1) Implement cross-modal assessment frameworks coupling subjective visual preference metrics with instrumented tactile quantification (*e.g.*, compressive resilience index, surface tactile perception); (2) Expand descriptor databases through large-scale semantic mining of consumer feedback using Natural Language Processing techniques; (3) Establish cross-modal correlation models between physical properties (*e.g.*, elastic modulus, hardness, thermal insulation) and holistic consumer satisfaction. Such initiatives will bridge the gap between aesthetic perception and functional performance in sustainable flooring design.

CONCLUSIONS

1. From an initial pool of 35 perceptual terms, seven pairs of terms were identified as suitable for describing cork flooring: natural–artificial, messy–ordered, luxurious–simple, retro–modern, heavy–light, warm–cold, and delicate–coarse.
2. The semantic differential method was used to determine participants’ emotional tendencies toward cork flooring. A linear regression analysis of perceptual term scores and preference scores yielded an R^2 value of 0.94, indicating a well-fitted model. The

analysis identified two perceptual terms with significant positive effects on preference: F5 (Light) (β = 0.76, p = 0.003**) and F6 (Warm) (β = 0.64, p = 0.006**). To enhance consumer preference for cork flooring, designers should focus on increasing warmth and lightness in surface designs.

3. Cluster analysis was used to explore the relationship between granule size, arrangement, and color of cork flooring samples and perceptual terms. The present findings demonstrated that enhancing the saturation and brightness of surface colors, minimizing granular textural features, and optimizing the rhythmic arrangement of patterns can improve the perceived warmth and lightness of cork flooring, thereby aligning with consumer preference tendencies.

ACKNOWLEDGMENTS

This research was funded by the International Cooperation Joint Laboratory for Production, Education, Research and Application of Ecological Health Care on Home Furnishing.

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Article submitted: May 8, 2025; Peer review completed: August 8, 2025; Revised version received: August 12, 2025; Accepted: August 13, 2025; Published: August 26, 2025.
DOI: 10.15376/biores.20.4.9051-9062