

Evaluating Perceptual Quality of Office Chair Surface Materials Through Visual-Tactile Synesthesia Assessment

Xi Liu , and Wei Wang *

In the context of increasing demands for health, comfort, and aesthetic quality in office environments, this study investigated how surface materials of office chairs influence users' emotional responses through visual–tactile perception. Ten typical office chair surface material samples were sourced from manufacturers and evaluated in a controlled laboratory setting. Participants provided feedback *via* a semantic differential questionnaire, designed using the Kawakita Jiro (KJ) method and expert screening. Visual-tactile evaluation data were analyzed using SPSS software, employing factor analysis to explore perceptual groupings and latent emotional dimensions. Results showed four material clusters aligned with different user needs, including support, comfort, skin-friendliness, and breathability. Factor analysis extracted four core dimensions: physical comfort, thermal-affective feedback, quality–breathability trade-off, and material essence. To further support material selection, a method was established using the Analytic Hierarchy Process (AHP) to clarify the weight of each perceptual factor. This study integrated Kansei engineering with visual-tactile synesthesia theory to construct a multidimensional evaluation framework, providing implications for the design of office chairs with greater attention to emotional and health-related factors.

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INTRODUCTION

In the contemporary workplace, where sedentary behavior has become a prevalent health concern, office chairs transcend their traditional role as mere functional furniture to become a critical interface between human physiology, emotional experience, and productivity (Diesbourg *et al.* 2025). Most of the existing office chair products have single functions, mainly focusing on the basic sitting and standing functions, often neglecting the visual and tactile emotional experience of users during the usage process. As the part that directly contacts the human body, the design of the material of the office chair in terms of color, texture, and pattern will significantly affect the user's perceptual cognition, and this perceptual cognition also largely influences the purchasing decision of consumers (Li *et al.* 2022).

The sensory experience of office chair materials fundamentally arises from the interaction between visual and tactile systems (Liu *et al.* 2025). Visual perception creates

an immediate impression through surface color, gloss, and texture, while tactile perception provides feedback related to softness, roughness, elasticity, and temperature (Vlaovic *et al.* 2025). These two channels together shape users' emotional and cognitive evaluation of materials (Spence and Gallace 2011). Theoretical foundations for this interaction can be traced back to Gibson's ecological perception theory, which emphasizes active perception through visual exploration and tactile engagement as a means of understanding the environment (Reed 1988). Similarly, Merleau-Ponty's phenomenology argues that vision and touch together constitute a complete and embodied experience of the material world (Merleau-Ponty *et al.* 2013). These theories provide the conceptual basis for treating vision and touch not as isolated modalities, but as interdependent systems that co-construct meaning in material interaction.

Despite these developments, most research on office chairs still emphasizes mechanical and ergonomic performance, such as pressure distribution, structural support, and fatigue reduction (Lu *et al.* 2023). In the context of health and rehabilitation, Tavares *et al.* (2023) proposed a standardized instrumentation method for office chairs designed to monitor physiological parameters, aiming to prevent posture-related disorders and improve work efficiency. Channak *et al.* (2024) explored seat cushions to evaluate designing of two types of dynamic cushions to assess their effects on posture shifts, trunk muscle activation, and spinal discomfort. Regarding material studies, Zhang *et al.* (2022) applied an ISSA-LSSVM-based model to predict the comfort level of office chair surface materials, assisting users in selecting suitable seat materials. While these functional studies are valuable, they collectively overlook a critical aspect: the integral role of perceptual and emotional responses elicited by visual-tactile material interaction. Consequently, a significant gap exists in understanding how the multisensory experience of chair surfaces shapes user perception, satisfaction, and long-term product acceptance beyond mere physical comfort.

In contrast, other design fields have embraced multisensory evaluation to enhance user engagement. For instance, Guest *et al.* (2011) established a multidimensional perceptual model including roughness, softness, slipperiness, and warmth. Their findings suggest that visual stimuli can rapidly convey material expectations, but tactile input plays a dominant role in emotional appraisal. In the domain of industrial design, Philips adopted a soft plastic that visually resembled metal in a razor, which led to decreased user satisfaction due to a mismatch between vision and touch (Ludden *et al.* 2012). Toyota, in its car interior UX process, implements "texture–texture mapping" to ensure that visually smooth surfaces convey a corresponding similar tactile smoothness, thus avoiding sensory incongruity (Okamoto *et al.* 2013). In furniture design, research shows that a warm-looking wood that feels cold or synthetic may result in significantly lower preference scores (Albiñana and Vila 2012). More recently, Tu and Wang (2024) applied visual-tactile evaluation methods in fabric design, confirming the effectiveness of Kansei engineering in identifying emotional differences across materials. Inspired by these successful cross-domain applications, this study similarly employs a Kansei engineering approach, integrating visual-tactile evaluation to bridge the identified gap in office chair material design.

These cross-disciplinary examples demonstrate the design value of visual-tactile congruence: when visual impressions align with tactile feedback, users experience greater satisfaction, trust, and emotional attachment (Spence and Gallace 2011). However, these methods and findings have not been sufficiently applied to the design of office chairs, where material choice directly impacts long-term comfort, aesthetic appeal, and even brand differentiation. Thus, there is a clear research opportunity to bring established theories and

techniques from multisensory design and Kansei engineering into the context of office chair material design.

In the field of office furniture, material perception plays a central role, especially for products that require prolonged body contact and visual exposure. Surface materials, as a core surface element of office chairs, not only affect ergonomic function but also strongly influence emotional experience and product image. Understanding how users respond emotionally and cognitively to different surface materials can help designers select materials that better meet aesthetic and sensory expectations. Despite the recognized importance of user experience in design, few studies have quantitatively explored how visual and tactile cues interact in shaping the emotional evaluation of office chair surface materials.

Given this significant gap and the demonstrated value of multisensory approaches in other domains, this study focuses on office furniture and investigates users' emotional responses to different surface materials of office chairs from both visual and tactile perspectives. A questionnaire survey was conducted among long-term office chair users, who evaluated a diverse selection of actual material samples varying in texture, composition, and surface finish. This hands-on interaction enabled participants to assess attributes such as softness, texture, comfort, and breathability in an immersive and comparable way. To analyze the collected data, the study first employs factor analysis to extract key Kansei dimensions underlying users' emotional impressions. These dimensions offer insight into how material properties translate into perceptual and emotional experiences. Building on this, the AHP method is applied to quantify the relative importance of each perceptual dimension, enabling the construction of a structured evaluation model for material selection. Together, these methods provide a comprehensive framework for understanding and prioritizing user perceptions of office chair surface materials. The findings aim to guide designers in aligning material characteristics with user preferences, supporting both improved ergonomic comfort and emotionally engaging product experiences. By bridging sensory perception with design strategy, this study contributes to more user-centered, Kansei-driven office furniture design.

This study develops a specialized evaluation framework for office chairs that delivers dual novel contributions: it identifies and quantifies previously overlooked emotional dimensions, such as thermal-affective feedback, which are critical to long-term user satisfaction, and establishes a prioritized model of design criteria offering actionable, evidence-based guidance for ergonomic material selection.

EXPERIMENTAL

Test Subjects

This study recruited 45 participants through purposive sampling, including long-term sedentary office workers, furniture design professionals, and students, as well as experts with backgrounds in materials or ergonomics. Sedentary office workers were defined as individuals engaged in seated desk work for over six hours a day, five days a week, for at least one consecutive year. The expert group included furniture designers, design researchers, and ergonomics specialists. Participants ranged in age from 18 to 55, with a gender distribution of 23 males and 22 females. All participants were native Mandarin speakers, aligning with the cultural context of the study. While the sample included a diversity of age, profession, and gender, most participants were urban residents

from Eastern China, which may limit the generalizability of the findings due to regional and cultural concentration.

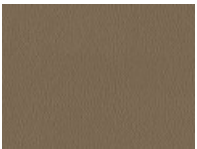
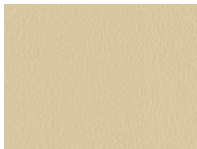
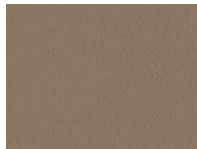
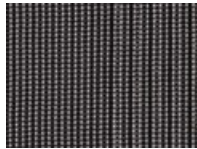
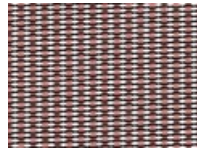
Test Samples

This study utilized an online research methodology to examine office chair listings across major domestic and international e-commerce platforms. According to the results of expert evaluation, eight professional office furniture brands with high domestic recognition, stable consumer bases, and positive market reception were selected: Novah Furniture, Lamex Office Furniture, Sunon Furniture Group, Aurora Group, Loctek Ergonomic Technology, Steelcase, Herman Miller, and Wilk Hahn. Using official sales data from brand websites, the five best-selling office chair models from each brand were chosen, resulting in a total sample of 40 chairs. For the subsequent perceptual evaluation phase, physical material samples representing the primary contact surfaces of these selected chairs were sourced from our research group's manufacturing partners. These physical material samples, not images of chairs or fully assembled products, served as the stimuli for sensory evaluation in the experiment.

The research specifically focused on primary contact surface materials, defined as those covering the largest area of direct user body contact, with auxiliary materials excluded. Although some models featured different materials on the seat and backrest, these were evaluated as a unified material system based on overall sensory experience.

By integrating the Kawakita Jiro (KJ) method with expert evaluation, 10 typical and representative office chair surface materials were identified: Genuine Leather, Synthetic Leather, Premium Synthetic Leather, Textured Leather, Eco-friendly Leather, Coarse Woven Fabric, Smooth Polyester Fabric, Mesh Fabric, Composite, and Specialty Textured Surface.

Table 1. Research Samples of Office Chair Surface Materials

M1	M2	M3	M4	M5
Genuine Leather	Synthetic Leather	Premium Synthetic Leather	Textured Leather	Eco-friendly Leather
				
M6	M7	M8	M9	M10
Coarse Woven Fabric	Smooth Polyester Fabric	Mesh Fabric	Composite	Specialty Textured Surface
				

Questionnaire Design and Survey

Through literature review and experimental investigation, this study compiled 140 pairs of sensory descriptors for office chair surface materials. Utilizing the KJ method, 10 representative pairs of perceptual descriptors were ultimately identified:

‘Hard-Soft’, ‘Tense-Relaxing’, ‘Slack-Supportive’, ‘Artificial-Natural’, ‘insecure-Secure’, ‘Oppressive-Pleasant’, ‘Cold-Warm’, ‘Stuffy-Breathable’, ‘Rough-Smooth’, and ‘Cheap-Premium’. These descriptor pairs were analyzed using the Semantic Differential (SD) method and incorporated into a questionnaire employing a five-point Likert scale (Palacios-Ibáñez *et al.* 2024). 45 pre-selected participants evaluated standardized material samples measuring 20 by 20 centimeters with identical properties. The evaluation was conducted individually in isolated testing booths to prevent inter-participant influence. Participants were instructed to first visually inspect each sample and then perform tactile evaluation, providing a single integrated rating for each descriptor pair based on this combined sensory experience. To ensure experimental rigor, multiple control conditions were implemented, including randomization of sample presentation order for each participant, maintenance of constant laboratory lighting and temperature levels, and cleaning of all samples with 75 percent alcohol between evaluations.

Under controlled environmental conditions, subjects rated all 10 material samples across the 10 perceptual descriptor pairs through subjective visual-tactile assessment. When the score is lower, it is closer to the description of the left perceptual semantics, and the higher the score, the closer it is to the description of the right word. The content design of the Material Visual and Tactile Perception Questionnaire is detailed in Table 2.

Table 2. Questionnaire for Perception Evaluations

Perceptual Vocabulary	-2	-1	0	1	2	Perceptual Vocabulary
Hard	○	○	○	○	○	Soft
Tense	○	○	○	○	○	Relaxing
Slack	○	○	○	○	○	Supportive
Artificial	○	○	○	○	○	Natural
Secure	○	○	○	○	○	Insecure
Oppressive	○	○	○	○	○	Pleasant
Stuffy	○	○	○	○	○	Breathable
Cold	○	○	○	○	○	Warm
Rough	○	○	○	○	○	Smooth
Cheap	○	○	○	○	○	Premium

RESULTS

Subjective Evaluation Data Processing

A total of 45 valid questionnaires were collected in this study. After rigorous screening based on predetermined criteria, including completeness of responses, internal consistency checks, and elimination of outliers, three questionnaires were identified as invalid. Specific exclusion criteria consisted of questionnaires with over 20% missing data, responses showing obvious patterned answering or contradictory ratings, and questionnaires with uniform scoring across all descriptors indicating non-differentiated responses. This process retained 42 valid responses with an effective rate of 93%.

To account for potential fluctuations in individual subjective evaluations, mean values were calculated to minimize the impact of individual variations. As presented in Table 3, the study established average ratings for 10 office chair surface materials across 10 perceptual descriptor pairs. These values were obtained through standardized data processing procedures.

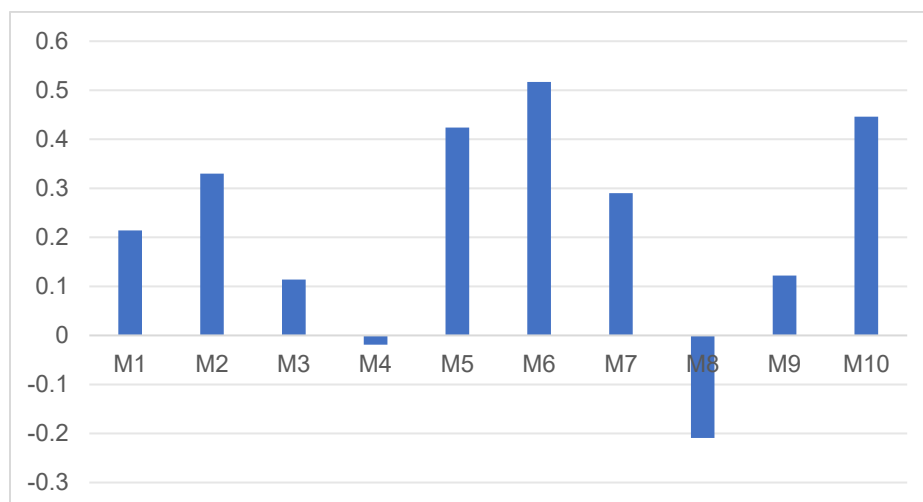
Table 3. The Average Score of Visual Tactile Evaluation of Office Chair Surface Materials

Sample Number	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Hard-Soft	0.41	0.77	0.43	0.05	1.00	1.08	-0.21	0.20	0.03	1.08
Tense-Relaxing	-0.09	0.67	0.36	0.12	0.46	1.08	0.48	-0.50	-0.19	0.93
Slack-Supportive	0.45	1.09	1.01	0.30	-0.27	-0.45	-0.12	1.09	1.17	-0.32
Stuffy-Breathable	-0.90	0.12	-0.26	-0.19	0.36	1.08	0.74	0.74	0.62	-0.19
Artificial-Natural	1.01	-0.80	-0.71	-0.52	-0.57	0.60	0.10	-0.57	-0.59	-0.57
Secure-Insecure	0.39	0.48	-0.09	0.08	0.48	0.58	0.34	-0.64	-0.09	0.89
Oppressive-Pleasant	0.05	0.58	-0.07	0.48	0.58	0.81	0.77	-0.50	0.15	0.72
Cold-Warm	0.34	0.50	0.22	0.48	0.55	0.36	0.79	-0.16	0.81	0.60
Rough-Smooth	-0.33	-0.04	-0.28	-1.14	0.74	0.43	-0.02	-1.54	-0.69	0.46
Cheap-Premium	0.81	-0.07	0.53	0.15	0.91	-0.40	0.03	-0.21	0.00	0.86

Subjective Comfort and Mean Analysis

To ensure data reliability and internal consistency, reliability analysis was performed using IBM SPSS Statistics 27.0 software (IBM Corp., Armonk, NY, USA). The results showed a Cronbach's α coefficient of 0.821 (> 0.8), indicating high reliability and confirming the stability of the measurements for subsequent analysis (Gao *et al.* 2024).

As demonstrated by the mean distribution in Fig. 1, visual-tactile synesthetic evaluation revealed distinct comfort gradients across office chair surface materials. The descending comfort ranking was sequenced as: M10 (Specialty Textile Surface), M6 (Coarse Woven Fabric), M5 (Eco-friendly Leather), M7 (Smooth Polyester Fabric), M2 (Synthetic Leather), M1 (Genuine Leather), M9 (Composite Material), and M3 (Premium Synthetic Leather). Notably, M4 (Textured Leather) and M8 (Specialty Textured Surface) registered significantly lower comfort scores, indicating potential ergonomic limitations in these material types.

**Fig. 1.** Subjective comfort evaluation

To highlight the most representative perceptual characteristics, this study selected two perceptual phrases per sample demonstrating ratings significantly above the mean value (Crowther *et al.* 2021). In instances where multiple descriptors received identical scores, all were included in the analysis. Table 3 presents the analytical outcomes revealing a mean score of 0.56 for positive descriptors and -0.40 for negative descriptors. Consequently, definitive screening criteria were established: positive descriptors scoring at or above 0.56 were retained as significantly endorsed attributes, while negative descriptors scoring at or below -0.40 were retained as significantly rejected attributes.

This thresholding approach carries explicit statistical significance. High-scoring terms such as soft and breathable reflect strong positive perceptions, whereas low-scoring terms such as rough and cold indicate pronounced negative perceptions (Crowther *et al.* 2021). Table 4 details the final screened descriptors and their directional distribution. The right-skewed high-scoring terms correspond to participants' most salient preferences during testing, contrasting with left-skewed low-scoring terms representing primary aversions. These outcomes provide critical insights for understanding multidimensional material perception.

Table 4. Table of Perceptual Vocabulary Trends

Sample Number	Prominent Perceptual Phrases	Sensing Vocabulary Trends
M1	Artificial-Natural, Stuffy-Breathable	Natural (1.01), Stuffy (-0.90)
M2	Slack-Supportive, Artificial-Natural	Supportive (1.09), Artificial (-0.80)
M3	Slack-Supportive, Artificial-Natural	Supportive (1.01), Artificial (-0.71)
M4	Rough-Smooth, Artificial-Natural	Rough (-1.14), Artificial (-0.52)
M5	Cheap-Premium, Oppressive-Pleasant	Premium (0.91), Pleasant (0.58)
M6	Hard-Soft, Tense-Relaxing	Soft (1.08), Relaxing (1.08)
M7	Cold-Warm, Oppressive-Pleasant	Warm (0.79), Pleasant (0.77)
M8	Rough-Smooth, Stuffy-Breathable	Rough (-1.54), Breathable (0.74)
M9	Slack-Supportive, Cold-Warm	Supportive (1.17), Warm (0.81)
M10	Hard-Soft, Tense-Relaxing	Soft (1.08), Relaxing (0.93)

Analysis of perceptual vocabulary trends revealed significant sensory divergence among the ten materials. M1 (Genuine Leather) exhibited the strongest natural attributes, contrasting with the pronounced artificial feel of M2 (Synthetic Leather), M3 (Premium Synthetic Leather), and M4 (Textured Leather). Tactile evaluation identified M6 (Coarse Woven Fabric) and M10 (Specialty Textured Surface) as the softest materials, while M9 (Composite Material) and M3 demonstrated superior supportiveness. Surface characterization showed M4 and M8 (Mesh Fabric) with the highest roughness. For comfort perception, M6 and M5 performed optimally, with M6 and M10 being the most relaxing. M7 and M9 generated comparable warmth, and premium perception was led by M5.

Correlation Analysis

Validity analysis was conducted to verify the structural appropriateness and factorability of the perceptual vocabulary data before dimensionality reduction. The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity were employed to

quantitatively assess sampling adequacy and variable intercorrelations, which are critical prerequisites for ensuring the reliability of subsequent factor analysis (Bhatta *et al.* 2017). Statistical analysis yielded a KMO value of 0.622 (> 0.5), which exceeds the threshold of 0.5 and thus indicates adequate sampling sufficiency for factor analysis, though it should be acknowledged that this value is relatively moderate. Bartlett's test of sphericity showed significant results ($\chi^2 = 90.34$, $df = 36$, $P < 0.001$), rejecting the null hypothesis that variables are uncorrelated in the population. Although the fourth factor explains a relatively modest 12% of the variance, it was retained based on the scree plot inflection point, its eigenvalue exceeding 1.0, and its theoretical relevance to the study's perceptual framework. These results collectively confirm the validity of the perceptual construct and justify proceeding with factor extraction.

Based on the validity analysis, a further correlation matrix analysis was carried out to examine the relationship between these 10 pairs of perceptual intention vocabulary and the perceptual psychological state reflected by them. By comparing pairs of perceived intention words, it can be seen that when the absolute value was larger, the correlation was stronger (Lipovac and Burnard 2023).

Table 5. Correlation Matrix

	H-S	T-R	S-S	S-B	A-N	S-I	O-P	C-W	R-S	C-P
H-S	1.00	0.68	-0.45	-0.04	0.02	0.64	0.38	0.00	0.71	0.30
T-R	0.68	1.00	-0.66	0.13	0.08	0.83	0.84	0.45	0.83	0.06
S-S	-0.45	-0.66	1.00	-0.14	-0.41	-0.72	-0.74	-0.35	-0.68	-0.26
S-B	-0.04	0.13	-0.14	1.00	-0.10	-0.19	0.18	-0.06	0.04	-0.71
A-N	0.02	0.08	-0.41	-0.10	1.00	0.28	0.14	0.04	0.18	-0.01
S-I	0.64	0.83	-0.72	-0.19	0.28	1.00	0.85	0.63	0.86	0.39
O-P	0.38	0.84	-0.74	0.18	0.14	0.85	1.00	0.74	0.73	0.03
C-W	0.00	0.45	-0.35	-0.06	0.04	0.63	0.74	1.00	0.54	0.22
R-S	0.71	0.83	-0.68	0.04	0.18	0.86	0.73	0.54	1.00	0.41
C-P	0.30	0.06	-0.26	-0.71	-0.01	0.39	0.03	0.22	0.41	1.00

Note: H-S: Hard-Soft, T-R: Tense-Relaxing, S-S: Slack-Supportive, Stuffy-Breathable, A-N: Artificial-Natural, S-I: Secure-Insecure, O-P: Oppressive-Pleasant, C-W: Cold-Warm, R-S: Rough-Smooth, C-P: Cheap-Premium

According to the data, it was found that there were three typical association patterns in the 10 groups of perceptual vocabulary in Table 5. The psychological comfort cluster showed a strong positive correlation synergistic effect: relaxation and pleasure ($r = 0.84$) and security ($r = 0.83$) were mutually enhanced, and security and smoothness were highly correlated ($r = 0.86$). The functional contradiction group revealed the negative relationship between support and pleasure ($r = -0.74$) and security ($r = -0.72$). This pattern suggests a potential trade-off between ergonomic support requirements and positive emotional experiences in material design. The isolated dimension showed a significant negative correlation between air permeability and high-grade perception ($r = -0.71$), but a weak correlation with other dimensions ($|r| < 0.2$). This indicates that breathability operated independently within the main influence system of perceptual factors, representing a unique consideration that does not align with the other identified clusters. Furthermore the analysis revealed a transmission pathway from tactile to psychological perception: soft touch indirectly enhances the sense of security ($r = 0.64$) through its positive relationship with smoothness ($r = 0.71$), forming a distinctive 'tactile-emotion' transformation mechanism.

Factor Analysis

As shown in Table 6, there were four factors with eigenvalues greater than 1. Among these, Factor 1 accounted for 49.59% of the variance contribution percentage, Factor 2 contributed 18.29%, Factor 3 had a cumulative contribution of 11.88%, and Factor 4 showed a cumulative contribution of 11.18%. This demonstrated that these four common factors collectively explain the majority of the information.

Table 6. Explanation of Total Variance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	T	V%	C%	T	V%	C%	T	V%	C%
1	4.959	49.588	49.588	4.959	49.588	49.588	4.125	41.245	41.245
2	1.829	18.285	67.873	1.829	18.285	67.873	1.866	18.656	59.901
3	1.188	11.878	79.751	1.188	11.878	79.751	1.841	18.406	78.307
4	1.118	11.177	90.928	1.118	11.177	90.928	1.262	12.621	90.928
5	0.439	4.395	95.322						
6	0.302	3.024	98.346						
7	0.124	1.238	99.584						
8	0.024	0.245	99.829						
9	0.017	0.171	100.000						

To visualize inter-factor relationships more intuitively, the scree plot in Fig. 2 distinctly demonstrated a pronounced change in slope starting from the fourth factor. The first four eigenvalues exceeded 1.0 and were markedly higher than subsequent points, with the fifth eigenvalue positioned at the elbow point. Beyond this, the eigenvalue trajectory flattened progressively, ultimately confirming the extraction of four principal components.

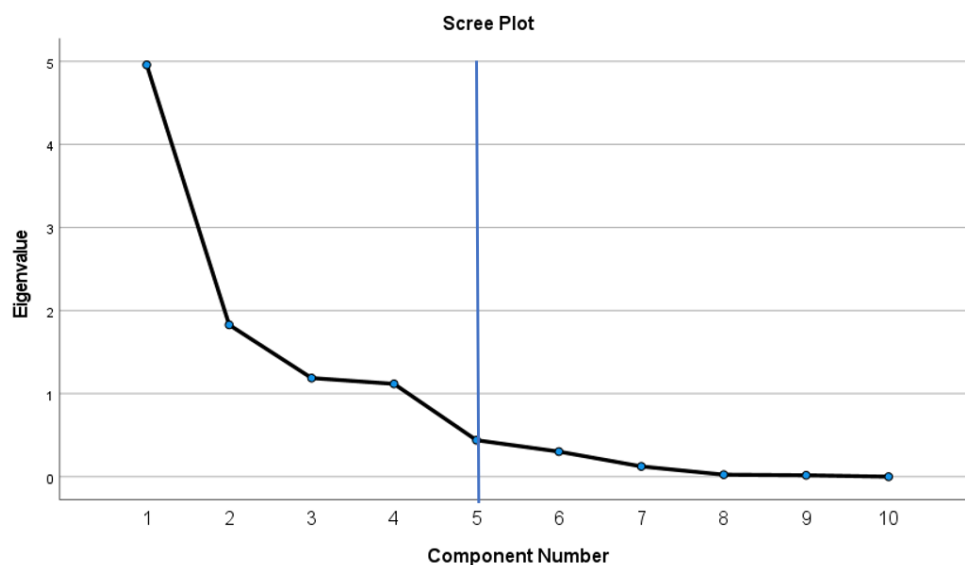


Fig. 2. Scree plot

The primary purpose of employing a rotated component matrix is to enhance the interpretability of the factor solution. It achieves this by rotating the factor axes to approximate a simple structure, wherein each variable loads predominantly onto a single factor, and each factor is defined by a cluster of high-loading variables with coherent semantic meanings (Lin *et al.* 2024). Perceptual vocabulary pairs are sorted by descending order of factor loading magnitude. Positive values indicate positive associations, while negative values denote inverse relationships. The absolute value of a factor loading is proportional to its correlation strength with the factor—larger absolute values signify stronger correlations. The rotated component matrix is presented in Table 7.

Table 7. Rotated Component Matrix

	Component			
	1	2	3	4
Hard-Soft	0.905	-0.308	0.135	-0.092
Tense-Relaxing	0.904	0.255	-0.119	0.023
Slack-Supportive	-0.692	-0.279	0.018	-0.471
Stuffy-Breathable	0.105	0.057	-0.928	-0.066
Artificial-Natural	0.073	-0.030	0.036	0.976
Secure-Insecure	0.811	0.424	0.253	0.217
Oppressive-Pleasant	0.693	0.654	-0.152	0.139
Cold-Warm	0.164	0.962	0.044	-0.039
Rough-Smooth	0.878	0.292	0.146	0.082
Cheap-Premium	0.237	0.073	0.913	-0.031

As shown in Table 7, ‘Hard-Soft’ and ‘Tense-Relaxing’ had the highest loadings in Principal Factor 1, while ‘Cold-Warm’ and ‘Oppressive-Pleasant’ were most prominent in Principal Factor 2. Principal Factor 3 was characterized by ‘Cheap-Premium’ and ‘Stuffy-Breathable’, whereas ‘Artificial-Natural’ together with ‘Slack-Supportive’ stood out in Principal Factor 4. Based on the analysis of visual–tactile synesthesia of office chair surface materials, four core perceptual dimensions were identified. The first was related to physical comfort, dominated by hardness and relaxation levels, which define users’ initial tactile impressions. The second involves thermal and emotional perception, where feelings of warmth and pleasantness influence long-term emotional feedback. The third dimension reflected the perceived quality and breathability of materials, highlighting a common design tension between premium feel and ventilation. The fourth, accounting for 12.62% of variance, captured the essential nature of the material, reflecting its naturalness and structural support.

AHP-Based Decision Model for Health-Oriented Material Selection

Hierarchical framework construction

To enhance the accuracy of experimental results, this study employed the AHP method and incorporated findings from prior factor analysis into the construction of its evaluation index model. The hierarchical structure of the model adhered to the standard

AHP framework, comprising three levels: the Target Layer, Criteria Layer, and Sub-Criteria Layer (Liu *et al.* 2023).

The Target Layer focused on the design optimization of office chair surface materials. The Criteria Layer was established based directly on research findings concerning image perception of office chair surface materials and their design characteristics: Through analysis of the rotated factor loading matrix, six pairs of perceptual descriptors strongly correlated with principal components were identified. Combined with cluster analysis results of perceptual vocabulary, four core evaluation dimensions were ultimately distilled—Physical Comfort, Thermo-Affective Feedback, Quality-Breathability Trade-off, and Material Essence—which constituted the Criteria Layer of the model. The Sub-Criteria Layer represented specific material solutions under investigation. The complete hierarchical structure model ultimately developed is presented in Fig. 3.

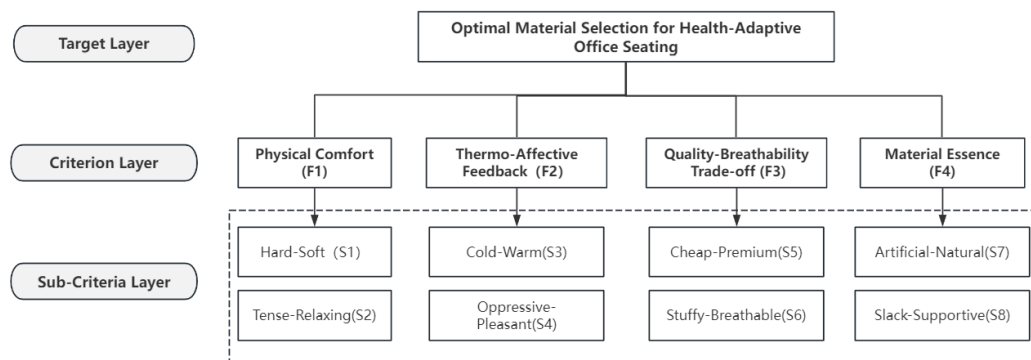


Fig. 3. Hierarchical structure model for office chair surface material evaluation

Construct judgment matrix

A notable characteristic of the AHP method is its evaluation of parameters through pairwise comparisons to assess their relative importance (Demircan and Yetilmezsoy 2023). The computational procedure necessitates constructing a pairwise comparison matrix A , where each element b_{ij} represents the relative importance of parameter i relative to parameter j . Conversely, the relative importance of parameter j relative to parameter i is defined as the reciprocal value, expressed as $1/b_{ij}$. The pairwise comparison matrix A is constructed as formalized in Eq. 1.

$$A = (b_{ij})_{m \times n} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \quad (1)$$

Judgment matrix and weight calculation

Due to the influence of subjective factors, different decision-makers exhibit variations in judging the importance of design elements. Additionally, numerous design parameters are heterogeneous in nature, making direct comparisons challenging. Accordingly, this study employed the AHP method and organized a 25-member group comprising design faculty, graduate students, and furniture industry professionals. Participants conducted paired comparisons of adjacent parameters within the same

hierarchy level using a 1-to-9 scale to enhance evaluation accuracy (Yu *et al.* 2024). Through constructing judgment matrices and subsequent calculations, the weights of each indicator were ultimately determined, with results presented in Tables 8-12.

Table 8. Weight of the Criterion Hierarchy

Index	F1	F2	F3	F4	Weighted Value
F1	1	5	4	7	0.552
F2	1/5	1	1/3	3	0.122
F3	1/4	3	1	5	0.231
F4	1/7	1/3	1/5	1	0.095

Table 9. The Judgment Matrix and Weight of the Product Appearance F1

F1	S1	S2	Weighted Value
S1	1	3	0.75
S2	1/3	1	0.25

Table 10. The Judgment Matrix and Weight of the Product Appearance F2

F2	S3	S4	Weighted Value
S3	1	2	0.667
S4	1/2	1	0.333

Table 11. The Judgment Matrix and Weight of the Product Appearance F3

F3	S5	S6	Weighted Value
S5	1	1/4	0.20
S6	4	1	0.80

Table 12. The Judgment Matrix and Weight of the Product Appearance F4

F4	S7	S8	Weighted Value
S7	1	1/3	0.25
S8	3	1	0.75

The AHP was calculated as follows:

Step 1: The judgment matrix was constructed according to the evaluation indexes in Eq. 1 and Table 1.

Step 2: The judgment matrix was normalized according to Eq. 2, and b_{ij} was the demand indicator in row i and column j .

$$\bar{b}_{ij} = \frac{b_{ij}}{\sum_{k=1}^n b_{ki}}, i, j = 1, 2, \dots, n \quad (2)$$

Step 3: The average value of each row of parameters in the judgment matrix was calculated according to Eq. 3.

$$W_i = \sum_{j=1}^n \frac{\bar{b}_{ij}}{n}, i = 1, 2, \dots, n. \quad (3)$$

Step 4: The maximum eigenvalue ($\lambda_{\max}$) of the judgment matrix was calculated according to Eq. 4.

$$\lambda_{\max} = \sum_{i=1}^4 \frac{(AW)_i}{(nW)_i} \quad (4)$$

Consistency test and comprehensive weight ranking

Following weight determination across all hierarchical levels *via* the AHP method, stringent consistency verification was conducted. The criterion layer yielded a consistency ratio of 0.0837, which falls below the 0.1 acceptability threshold. Meanwhile, all sub-criterion layers registered CR values of zero. These results satisfy consistency requirements, confirming both the logical coherence of expert judgment matrices and the reliability of weight allocations.

Table 13. Weight Value of Comprehensive Judgment Matrix of Factors

Target layer	Primary Index	Weight	Secondary Index	Weight	Relative Weight	Rank
Optimal Material Selection for Health-Adaptive Office Chair	Physical Comfort (F1)	0.552	Hard-Soft (S1)	0.750	0.414	1
		0.122	Tense-Relaxing (S2)	0.250	0.138	3
	Thermo-Affective Feedback (F2)	0.231	Cold-Warm (S3)	0.677	0.083	4
		0.095	Oppressive-Pleasant (S4)	0.333	0.041	7
	Quality-Breathability Trade-off (F3)	0.552	Cheap-Premium (S5)	0.200	0.046	6
		0.122	Stuffy-Breathable (S6)	0.800	0.185	2
	Material Essence (F4)	0.231	Artificial-Natural (S7)	0.25	0.024	8
		0.095	Slack-Supportive (S8)	0.75	0.071	5

Building on this foundation, evaluation matrices were subsequently established to calculate weights for second-tier evaluation indicators under each sub-criterion across three evaluation standards. These comprehensive weights were derived through hierarchical synthesis, specifically by multiplying second-level sub-criterion weights with corresponding first-level weights followed by global prioritization, as systematically tabulated in Table 13. Analysis revealed that at the normative level, S1 demonstrated the highest weighting, trailed by S6 and S2 respectively. Among specific evaluation metrics, the perceptual descriptor pairs exhibiting greatest influence were “Hard-Soft”, “Stuffy-Breathable”, and “Tense-Relaxing”. Importantly, user needs analysis corroborated that these indicators capture core user requirements with heightened precision.

CONCLUSION

This study moved beyond traditional ergonomic approaches by developing a Kansei engineering framework that decodes the visual-tactile perception of office chair materials and their link to user emotion.

1. This study identified clear perceptual differences among office chair surface materials along visual–tactile dimensions. These differences influence users’ emotional responses and material preferences. Users seeking relaxation and emotional comfort tend to prefer soft textures and warm tones—such as textured weaves and coarse

fabrics—which evoke calm and security. In contrast, users who value structural support and control show a stronger preference for synthetic leathers and technical surfaces. These materials deliver a heightened sense of tension and visual firmness, reinforcing a perception of supportiveness.

2. Factor analysis extracted two primary dimensions: the Physical Comfort Factor and the Emotional Response Factor. This highlights a dual demand in material selection: users expect both functional support and emotional resonance. Designers should consider how softness, surface tension, and thermal properties influence comfort. At the same time, materials should convey emotional qualities such as naturalness, premium feel, or approachability to build stronger user connections.
3. Analytical hierarchy process (AHP) analysis further clarified the weight of each perceptual indicator. ‘Hard–Soft’ and ‘Stuffy–Breathable’ emerged as the most influential dimensions, indicating that physical comfort and thermal regulation are top concerns in office seating. ‘Tense–Relaxing’ and ‘Artificial–Natural’ also played key roles in shaping user trust and brand attachment over time.

In summary, this study established a validated, multi-method framework that translates subjective user perceptions into quantifiable design parameters for office chair material selection. It equips designers with an actionable decision-making tool, enabling them to strategically balance tactile comfort with emotional appeal to create products that excel in both ergonomic performance and user-centered emotional engagement.

This study has limitations regarding the participant sample’s geographic concentration and the integrated sensory evaluation protocol. Future research should incorporate culturally diverse cohorts and controlled isolation experiments to better understand individual sensory contributions and enhance the model's generalizability.

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