Emotional Design and Evaluation of Children's Furniture Based on AHP-TOPSIS

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Children's physical and mental health development is highly related to furniture and integrating the emotional design concept into children's furniture design helps cultivate children's personalities and promote healthy growth. The model framework of children's furniture emotional design was constructed from the instinctive level, behavioral level, and reflective level. The comprehensive weight of the design factors was calculated using the Analytic Hierarchy Process (AHP), and three schemes were designed according to the priority of the design factors. The evaluation matrix was constructed by combining the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the distances of each scheme from the positive and negative ideal solutions were calculated, and the optimal scheme was selected according to the relative proximity ranking of the three schemes. The experimental results verified the importance of the reflective level in the three levels of the emotional design theory and emphasized the key role of emotional design in children's furniture. Therefore, the evaluation system based on AHP and TOPSIS is feasible, which can effectively reduce the influence of subjective factors, make the design decision more scientific, and provide a new reference approach for furniture design.

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INTRODUCTION

The special characteristics of children's developmental stages has necessitated higher design requirements for children's furniture, including the emotional elements between furniture and children, color preferences (Jiang *et al*. 2020; Ding *et al*. 2021), furniture system life cycle (Bianco *et al*. 2021; Li *et al*. 2023), and so on. Different from the furniture design concepts of sustainable design and modular design (Bumgardner and Nicholls 2020; Phuah *et al*. 2022; Wang 2022), emotional design can comprehensively consider the emotional relationship between furniture and people, enhance the distance between furniture and people, and generate emotional resonance. Sun (2021) elaborated on the principles of emotional design of wooden furniture through the dimensions of material, color, and experience. Their work emphasizes that emotions should be incorporated into wooden furniture to meet the psychological needs of users, noting the direction of emotional design for furniture. Wang and Zhang (2022) studied six art forms of chairs, such as traditional, modern, and fashionable, explored the emotional changes brought by different styles to consumers, and pointed out the design principle that furniture should be compatible with users' emotions. Research has shown that emotional design can also help

to enhance the user experience for a particular group of people (Bevilacqua *et al*. 2021; Chen 2022).

Among the many factors that affect consumers' purchases of products, the emotional appeal of products has become a key factor in influencing consumers' purchase behavior (Liu *et al*. 2023a). Emotional design is centered on the emotional demands of the human heart, making users feel the emotional value of the product in physiological and psychological aspects. This approach can be adapted to the characteristics of children in the growth stage, especially for children's furniture design. Children's furniture design should establish children's correct perception of their surroundings, make interaction between children and furniture, and cultivate children's good behavioral habits (Tong 2012). Salvador (2015) took the high chair as the research object, analyzed children's behavior towards certain furniture, and pointed out the key role of ergonomics in maintaining the emotional sustainability of children and furniture. According to the physiological and psychological development characteristics of preschool children, Zhao *et al*. (2020) summarized the principles of emotional design of children's furniture, such as guidance, fun, safety, art, *etc*., and designed bedroom furniture that meets the physiological and psychological needs of preschool children, guiding them to generate positive emotions in their interaction with the furniture and helping them grow. Wang *et al*. (2022) analyzed the commonalities between montage theory and children's growth furniture, integrated the characteristics of montage narrative and ideology into the design of the furniture, and designed a coat rack that can record children's growth through parallelism, metaphor, contrast, color, and other tactics, which provides a new design idea for the emotional development of children's furniture. Wang *et al*. (2023) took bamboo children's hangers as the design object and proposed the essential function and emotional function dual-track design method, which solves the problems of children's emotional needs and physical and psychological care. The reasonable introduction of emotional concepts in children's furniture design is in line with children's cognitive development and plays a key role in guiding growth. Although there have been fewer studies on the emotional design of children's furniture, the concept has been widely recognized by designers and manufacturers, and it also pointed out the direction for the subsequent design.

Many factors affect consumers' decisions to buy children's furniture, including function, appearance, material, price, *etc*. These factors form a complex decision-making problem. AHP can simplify complex problems and solve practical problems by combining qualitative and quantitative methods. On this basis, the combination of TOPSIS and AHP can further improve the evaluation in the design process (Gangurde and Akarte 2013). The significant advantages of AHP are the automatic calculation of variables and sensitivity analysis, particularly in decision-making (Mallick *et al*. 2018). However, the subjective factors of the evaluator will affect the accuracy of the judgment to some extent and cannot provide specific plans for the design. The TOPSIS method applies to multiple evaluation objects, which can accurately reflect the gap between the programs and effectively reduce the impact of subjective factors. Singh *et al*. (2020) proposed an optimal method for mobile phone selection based on the KANO-AHP-TOPSIS method to help designers and mobile phone manufacturers design and select a suitable feature for a customer-oriented mobile phone. Xie *et al*. (2023) combined AHP and comprehensive gray correlation analysis (GCA) to evaluate the green design of kindergarten furniture, and the results verified the feasibility of the green design evaluation method and provided a reference approach for kindergarten furniture designers. Liu *et al*. (2023b) proposed an AHP-FAHP method-based hierarchical model of user needs for dining room chairs, which verified the symmetry and

validity between user needs and evaluation results. Zhao and Xu (2023) proposed an evaluation model consisting of the Kano model, hierarchical analysis, and gray relationship analysis, which verified the feasibility of the modular children's wooden storage cabinet scheme. Among the many studies on combining AHP and TOPSIS, most have focused on engineering and risk assessment (Demircan and Yetilmezsoy 2023; Boonsothonsatit *et al*. 2024). However, there have been few studies related to the furniture industry, especially the systematic design and evaluation of furniture.

Based on the theory of emotional design, this study explored children's deep-seated behaviors at the instinctive, behavioral, and reflective levels, constructed a hierarchical model of user needs, and designed three emotional children's furniture design schemes according to the ranking of the comprehensive weights. The relative proximity of the design scheme was sorted through the scientific evaluation system, and the design scheme with the highest customer satisfaction was selected. In contrast, this study focused more on children's emotional needs, maintained positive interaction between children and furniture, and helped children grow up healthily. The design evaluation system proposed in this study can effectively reduce the influence of subjective factors and make reasonable decisions on design solutions, which is of reference value to furniture designers and manufacturers and provides a new research approach for furniture design.

EXPERIMENTAL

The Research Approach of Emotional Theory

Emotional design is based on the appearance, color, material, texture, experience, and other elements of the product and satisfies the emotional needs of users through specific expression techniques and symbolic semantics, so that users can feel the emotional value in the interaction with the product. Contrasting with the functional attributes emphasized by modernism, emotional design focuses on human beings and emotional development, which can better meet the requirements of the times. Donald A. Norman, an American cognitive psychologist, systematically elaborated the three levels of emotional design in Emotional Design (2005): instinctive, behavioral, and reflective, as shown in Fig. 1.

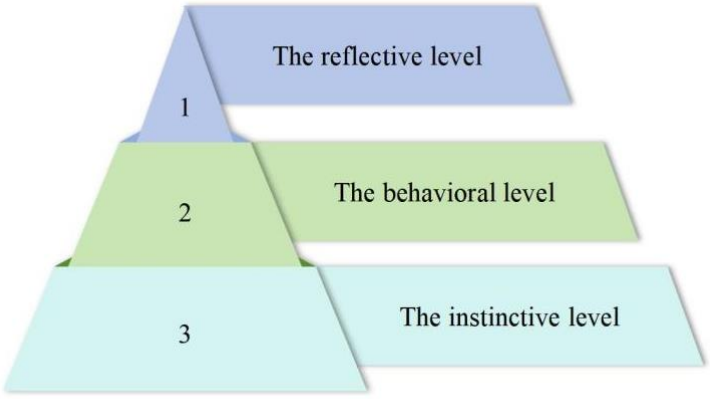

Fig. 1. Three levels of emotional design theory

1. The instinctive level refers to the intuitive feeling brought by the product's shape, material, color, and other characteristics. This kind of feeling can cause sensory stimulation, which causes consumers to instinctively make quick reactions and judgments. Different appearances give people different feelings, which requires designers to constantly explore the emotional connection between the product and the user and make changes in the shape.

2. The behavioral level refers to the functional value of the product. The product function is an important parameter in the consumer evaluation index, and the function affects the user's emotions and experience, especially in the process of human interaction with the product. As a result, emotional design must consider how to avoid functional defects.

3. The reflective level refers to a deeper level of emotion and thinking that arises from a combination of the instinctive and behavioral levels. The reflective level focuses on the process of thinking about the product, which involves the subject's knowledge, consciousness, life experience, and other aspects. The reflective level conveys information through the product, makes consumers think about the information, and triggers deeper psychological feelings such as joy, excitement, and worry.

Early children's physical and psychological development is slow, and lack of independence, behavior habits, and personality development are easily affected by external factors. According to Norman's emotional design theory, furniture is designed from the three levels of instinct, behavior, and reflection so that furniture can play a positive educational role in the growth process of children, and they can get spiritual pleasure and emotional satisfaction in the process of interacting with furniture. Based on the theory of emotional design, this study constructed a hierarchy model of user needs and designed a children's furniture scheme to meet the emotional needs. The design and evaluation process are shown in Fig. 2.

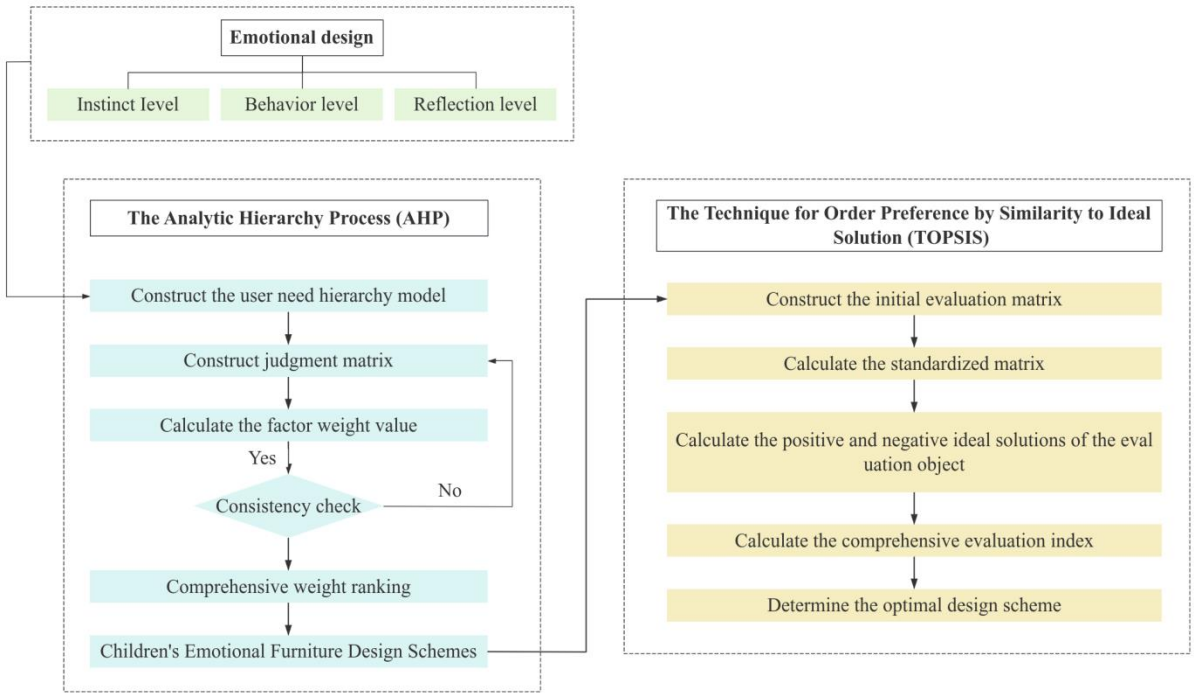

Fig. 2. Flowchart of emotional design and evaluation of children's furniture based on AHP-TOPSIS

Construct the User Need Hierarchy Model

User needs have an important reference value for the design and development of products in the early stages, and an in-depth understanding of the various needs of target users is the premise of design. To have more accurate experimental results, two children's furniture designers, five parents, and five design experts were invited to participate in the preliminary study. Field interviews were conducted with children and parents, and the results indicated that most of the children felt helpless at times, could not communicate effectively with their parents when they were depressed, and longed for their parents' attention. In contrast, most parents indicated that they seldom paid attention to their children's emotional changes, expressed concern about their children's psychological conditions, and hoped that they could observe and actively alleviate their children's negative emotions promptly. Secondly, questionnaires were distributed to children and parents, respectively. The three levels of emotional design were taken as the evaluation criteria, experts were invited to conduct multiple rounds of statistics according to the Delphi method, and the results of 13 user needs with the most concentrated opinions were obtained.

According to the AHP method (a multilevel analytical decision-making approach proposed by Prof. T. L. Saaty in the 1970s), the three levels of emotional design are combined with the evaluation index model of AHP, and the hierarchical structure of the model is from left to right: the target hierarchy, the criterion hierarchy, and the object hierarchy (Liu *et al*. 2024). The three hierarchies correspond to different design factors:

(1) Target hierarchy: The children's furniture emotional design optimal scheme A.

(2) Criterion hierarchy: According to Donald Norman's theory of emotional design, the instinctive, behavioral, and reflective levels correspond to product appearance, product function, and emotional experience, respectively.

(3) Object hierarchy: According to the results of the questionnaire and experts after multiple rounds of statistics, product modeling, color matching, and material texture are included in the product appearance hierarchy. The product function hierarchy specifically included interest, comfort, safety, intelligence, usability, and durability. Interactivity, emotional companionship, guidance, and entertainment are divided into the emotional experience hierarchy. The user needs hierarchy model is shown in Fig. 3.

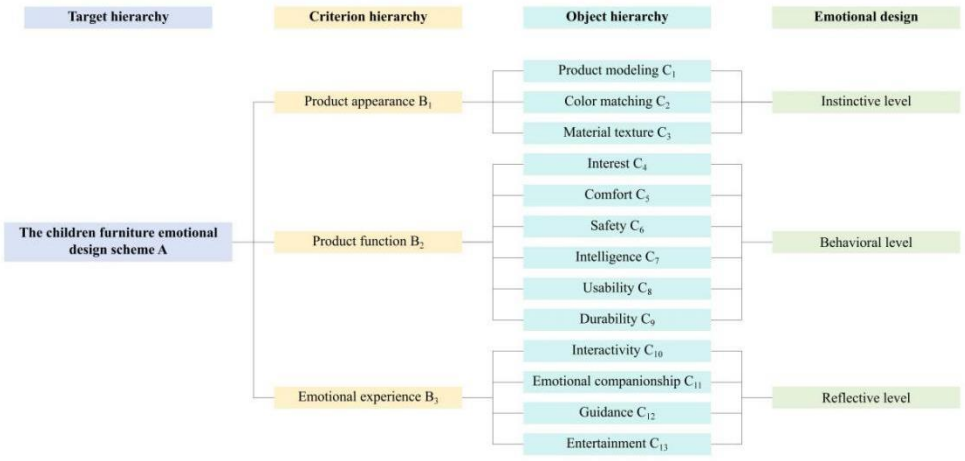

Fig. 3. Analytic hierarchy process model of children's furniture emotional design

Construct Judgment Matrix

A distinguishing feature of the AHP method is that the parameters were compared two by two to assess the relative importance between the parameters (Kurek *et al*. 2022). When the AHP was used for calculation, the pairwise comparison matrix A needed to be constructed first, where b_{ij} represents the relative importance degree of the parameter relative to the j parameter. Conversely, the relative importance degree of the j parameter relative to the i parameter was represented by $1/b_{ij}$. The pairwise comparison matrix A was constructed by Eq. 1.

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

Among many parameters, it was difficult to compare the parameters directly due to the different properties. Therefore, comparing two neighboring parameters in the same hierarchy using the 1 to 9 point scale can improve the accuracy (Harker and Vargas 1988; Saaty and Vargas 2012). The 1 to 9 point scale has been widely used in the application of the AHP method (Solangi *et al*. 2021; Ahadi *et al.* 2023; Yu et al. 2023). The numerical definition of the 1 to 9 point scale is shown in Table 1.

Table 1. 1 to 9 Point Scale for Comparison Values

Evaluation Scale	Explanation
1	Both parameters are of the same degree of importance
3	Comparing the two parameters, parameter i is slightly more important than parameter j
5	Comparing the two parameters, parameter i is strongly more important than parameter j
7	Comparing the two parameters, parameter i is very strongly more important than parameter j
9	Comparing the two parameters, parameter i is extremely more important than parameter j
2,4,6,8	The median value of the two adjacent degrees of importance
* Reciprocal values if inverse comparisons, i.e., 1/3, 1/5, 1/7, 1/9	

Calculate the Factor Weight Value

Due to the influence of subjective factors, different decision-makers have different judgments on the importance of design factors. A program evaluation expert team composed of 15 experts (including three children's furniture designers, five parents, two product project managers, and five design professors) was organized to evaluate the emotional design of children's furniture according to the evaluation index system in Fig. 3. The 1 to 9 point scale was used to make pairwise comparisons between the primary and secondary indicators of the emotional design of children's furniture, and a judgment matrix was constructed, as shown in Tables 2 to 5. 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 is normalized according to Eq. 2, and b_{ij} is the demand indicator in row i and column j.

$$\overline{b_{ij}} = \frac{b_{ij}}{\sum_{k=1}^{n} b_{ki}}, i, j = 1,2,\ldots,n, \quad (2)$$

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

$$W_i = \sum_{j=1}^{n} \frac{\overline{b_{ij}}}{n}, i = 1,2,\ldots,n. \quad (3)$$

Step 4: The maximum eigenvalue (λ_{max}) of the judgment matrix is calculated according to Eq. 4.

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

Table 2. Weight of the Criterion Hierarchy

A	B_1	B_2	B_3	Weights (W_A)
B_1	1	1/3	1/4	0.123
B_2	3	1	1/2	0.320
B_3	4	2	1	0.557

Table 3. The Judgment Matrix and Weight of the Product Appearance B_1

B_1	C_1	C_2	C_3	Weights (W_{B1})
C_1	1	1/2	1/3	0.159
C_2	2	1	1/3	0.252
C_3	3	3	1	0.589

Table 4. The Judgment Matrix and Weight of the Product Function B2

B_2	C_4	C_5	C_6	C_7	C_8	C_9	Weights (W_{B2})
C_4	1	1/3	1/5	1/2	1/3	1/5	0.048
C_5	3	1	1/3	5	3	3	0.239
C_6	5	3	1	5	3	3	0.367
C_7	2	1/5	1/5	1	1/3	1/5	0.056
C_8	3	1/3	1/3	3	1	1/2	0.114
C_9	5	1/3	1/3	5	2	1	0.176

Table 5. The Judgment Matrix and Weight of the Emotional Experience B_3

B_3	C_{10}	C_{11}	C_{12}	C_{13}	Weights (W_{B3})
C_{10}	1	1/3	1/2	3	0.172
C_{11}	3	1	3	5	0.512
C_{12}	2	1/3	1	3	0.238
C_{13}	1/3	1/5	1/3	1	0.078

Consistency Check

To maintain consistency and rationality in the evaluation process, it is crucial to conduct a consistency test on the calculation results of each judgment matrix (Saaty 1980). A CR (consistency ratio) value below 0.1 is considered accurate, while an unacceptable CR indicates the need for experts to readjust parameters until the CR value falls within the

acceptable range (Lee and Chan 2008). The calculation steps for the consistency test are as follows:

Step 1: Calculate the consistency index (CI) according to Eq. 5. λ_{max} is the maximum eigenvalue in the matrix, and n is the order of the judgment matrix.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

Step 2: The CR was calculated by Eq. 6. When CR is less than 0.1, the calculation result of the judgment matrix satisfies the consistency test.

$$CR = \frac{\lambda_{max} - n}{(n-1) \cdot RI} \quad (6)$$

The CR value was calculated according to the calculation results from Tables 2 to 5 and Eqs. 5 and 6. The results showed that the CR values of target hierarchy A and the three criterion hierarchies (B_1, B_2, and B_3) were all less than 0.1, which satisfied the consistency test. The consistency test results are shown in Table 6.

Table 6. Consistency Test Results

	A	B_1	B_2	B_3
λ_{max}	3.018	3.054	6.472	4.105
CI	0.009	0.027	0.094	0.035
RI	0.520	0.520	1.260	0.890
CR	0.018	0.052	0.075	0.039

Comprehensive Weight Ranking

To analyze the relative importance of the 13 evaluation factors more intuitively, the comprehensive weights of each secondary indicator were calculated and ranked according to the weight values in Tables 2 through 5. The results are shown in Table 7.

Table 7. Weight Value of Comprehensive Judgment Matrix of Design Factors

Criterion Hierarchy	Weights	Object Hierarchy	Weights	Comprehen-sive Weights	Comprehen-sive Ranking
Product appearance B_1	0.123	Product modeling C_1	0.159	0.020	11
		Color matching C_2	0.252	0.031	10
		Material texture C_3	0.589	0.072	6
Product function B_2	0.320	Interest C_4	0.048	0.015	13
		Comfort C_5	0.239	0.077	5
		Safety C_6	0.367	0.118	3
		Intelligence C_7	0.056	0.018	12
		Usability C_8	0.114	0.036	9
		Durability C_9	0.176	0.056	7
Emotional experience B_3	0.557	Interactivity C_{10}	0.172	0.096	4
		Emotional companionship C_{11}	0.512	0.285	1
		Guidance C_{12}	0.238	0.133	2
		Entertainment C_{13}	0.078	0.043	8

RESULTS AND DISCUSSION

In the criterion hierarchy (A), the factors that affected the emotional design of children's furniture were ordered as follows: emotional experience > product function > product appearance, which verified the importance of the reflective level in the three levels of emotional design theory. Emotional experience was the most important factor affecting consumers' purchasing behavior. Therefore, children's furniture design should pay more attention to the diversified emotional needs of children based on satisfying the appearance and function of the furniture.

In the hierarchy of emotional experience (B_3), emotional companionship had the highest weight value and was also the first design factor in the comprehensive weight ranking. The details should be considered in the development of children's furniture, so that children can feel the warmth of the furniture. Guidance was ranked second in the comprehensive evaluation system. The guidance refers to the positive behavioral habits generated by children through furniture, which requires that furniture design should be centered on children's psychological habits to strengthen their ability to self-reflect.

In the hierarchy of product function (B_2), the importance of each design factor was ranked as follows: safety > comfort > durability > usability > intelligence > interest. Safety was the prerequisite for realizing the value of the product, and children's furniture with a stable structure, no edges and corners, and free of contamination should be designed according to children's physiological development characteristics. Comfort requires that the size and material of the furniture conform to the physiological laws of children so that they feel comfortable in contact with the furniture. Durability refers to the systematic life cycle of furniture. Furniture is not luxury jewelry, and consumers value the service life of furniture to meet their psychological expectations.

In the emotional design of children's furniture, the appearance of the product has less influence on consumer purchasing behavior. Material texture has the highest weight value in the product appearance hierarchy (B_1). The texture of different materials brings different psychological feelings, the material will affect the consumer's purchasing behavior. Secondly, children are more sensitive to color. Different colors will bring different emotional experiences to children, and the different psychological feelings brought by the combination of different colors should be considered in the choice of colors.

Design Practice

According to the ranking of comprehensive weights, the top 6 priority design factors (emotional companionship, guidance, safety, interactivity, comfort, and material texture) were selected as the focus of the emotional design of children's furniture, and three schemes were designed, as shown in Fig. 4. Wood has a positive effect on the healthy growth of children, considering the service life of children's furniture and consumer preferences (Wan *et al*. 2015; Wei and Madina 2022; Muhammad *et al*. 2022). Three design schemes used all wooden materials. Design scheme 1 is inspired by the seesaw, which combines the seesaw with a bench to provide children with furniture that integrates the functions of lying, sitting, and entertainment. Children are encouraged to interact with furniture and communicate emotionally with parents and peers through the seesaw to promote children's psychological development. Scheme 2 is a children's coat rack, which contains different modular components that are combined through different ways of splicing. The goal is to exercise the children's practical and self-thinking abilities so that the furniture can witness their growth and accompany them through every stage. Scheme

3 is a children's locker with a car shape. The concrete appearance design helps children establish a correct understanding of their surroundings and cultivate observation skills. Some features were added to the design to exercise children's hands-on skills.

The AHP method has the advantages of being systematic and objective, and can make a comprehensive judgment on complex problems. However, due to the influence of qualitative analysis and subjective factors, the experimental results may be biased. Technique for Order Preference by Similarity to Ideal Solution was combined to make up for these deficiencies. The TOPSIS method avoided the subjectivity of data through quantitative analysis and was able to make a scientific decision between the evaluation object and the idealized goal (Fu *et al*. 2022; Shirali *et al*. 2023).

Fig. 4. Children's furniture emotional design schemes

Construct the Initial Evaluation Matrix

To ensure the accuracy and effectiveness of the evaluation results, two parents, three furniture design professors, and five children's furniture designers were invited to score the 13 design factors of the three design schemes by using the 1 to 10 scoring method, respectively. The 1 to 10 scale is defined as follows: 1 to 3 represents very poor, 3 to 5 means unqualified, 5 to 6 means good, 6 to 8 means excellent, and 8 to 10 indicates very excellent. The arithmetic mean of the evaluation score was taken as the initial score result. The initial evaluation matrix was constructed by Eq. 7, as shown in Table 8.

$$X = (X_{ij})_{mn} \quad (7)$$

Table 8. Initial Evaluation Matrix

Target Hierarchy	Criterion Hierarchy	Object Hierarchy	Scheme 1	Scheme 2	Scheme 3
The children furniture emotional design optimal scheme A	Product appearance B_1	Product modeling C_1	6.6	7.0	6.8
		Color matching C_2	7.2	7.7	6.6
		Material texture C_3	7.2	6.7	7.0
	Product function B_2	Interest C_4	7.1	7.3	7.5
		Comfort C_5	7.2	6.4	7.0
		Safety C_6	6.9	6.4	7.7
		Intelligence C_7	7.0	7.7	7.4
		Usability C_8	7.8	7.5	7.3
		Durability C_9	7.5	7.4	7.7
	Emotional experience B_3	Interactivity C_{10}	8.4	6.7	7.4
		Emotional companionship C_{11}	8.3	7.0	7.4
		Guidance C_{12}	7.4	7.3	6.9
		Entertainment C_{13}	7.9	6.9	7.7

Calculate the Standardized Matrix

The initial evaluation results of the three design schemes in Table 9 were standardized to obtain the standardized matrix $Y = (Y_{ij})_{mn}$. The weighted standardized matrix $Z = (Z_{ij})_{mn}$ is calculated by Eqs. 8 and 9. The weighted standardized evaluation matrix is shown in Table 9.

$$Y_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} (i = 1,2...m,\ j = 1,2...n) \quad (8)$$

$$Z_{ij} = W_j Y_{ij} (\mathrm{i} = 1,2...\mathrm{m},\ \mathrm{j} = 1,2...\mathrm{n}) \quad (9)$$

Table 9. Weighted Standardized Evaluation of Three Design Schemes

Target Hierarchy	Criterion Hierarchy	Object Hierarchy	Scheme 1	Scheme 2	Scheme 3
The children furniture emotional design optimal scheme A	Product appearance B_1	Product modeling C_1	0.0074	0.0079	0.0076
		Color matching C_2	0.0179	0.0192	0.0165
		Material texture C_3	0.0429	0.0400	0.0417
	Product function B_2	Interest C_4	0.0084	0.0087	0.0089
		Comfort C_5	0.0466	0.0414	0.0453
		Safety C_6	0.0670	0.0621	0.0747
		Intelligence C_7	0.0099	0.0109	0.0104
		Usability C_8	0.0215	0.0207	0.0201
		Durability C_9	0.0322	0.0318	0.0330
	Emotional experience B_3	Interactivity C_{10}	0.0618	0.0493	0.0545
		Emotional companionship C_{11}	0.1800	0.1518	0.1605
		Guidance C_{12}	0.0789	0.0778	0.0736
		Entertainment C_{13}	0.0261	0.0228	0.0254

Calculate the Positive and Negative Ideal Solutions of the Evaluation Object

The positive and negative ideal solutions of the evaluation object were obtained by Eqs. 10 and 11. The positive ideal solution of the evaluation object was Z^+ = (0.0079, 0.0192, 0.0429, 0.0089, 0.0466, 0.0747, 0.0109, 0.0215, 0.0330, 0.0618, 0.1800, 0.0789, and 0.0261), and the negative ideal solution of the evaluation object was Z^- = (0.0074, 0.0165, 0.0400, 0.0084, 0.0414, 0.0621, 0.0099, 0.0201, 0.0318, 0.0493, 0.1518, 0.0736, and 0.0228).

$$Z^+ = (Z_1^+, Z_2^+, ...Z_n^+) \quad (10)$$

$$Z^- = (Z_1^-, Z_2^-, ...Z_n^-) \quad (11)$$

Calculate the Comprehensive Evaluation Index

The distances between the three design schemes and the positive ideal solution (Z^+) and the negative ideal solution (Z^-) were calculated by Eqs. 12 and 13. D^+ and D^- were the distances between the evaluation object and the positive and negative ideal solutions, respectively.

$$D_i^+ = \sqrt{\sum_{i=1}^{n} (Z^+ - Z_{ij})^2} \quad (12)$$

$$D_i^- = \sqrt{\sum_{i=1}^{n} (Z^- - Z_{ij})^2} \quad (13)$$

The relative proximity (C) of the three design schemes and the positive ideal solution Z^+ were calculated by Eq. 14.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}, \quad (i = 1,2,..., m) \quad (14)$$

Relative proximity is an important index to measure the nearness between the design scheme and the ideal solution. The relative proximity represents the degree of superiority of the design scheme. The greater the relative proximity, the better the design scheme can meet the expected needs. According to the value of the relative proximity, the three design schemes were ranked as follows: design scheme 1 > design scheme 3 > design scheme 2. Design scheme 1 was chosen as the final optimal design scheme, as shown in Table 10.

Table 10. Evaluation Results of Each Design Scheme

Scheme	Positive ideal solution distance (D^+)	Negative ideal solution distance (D^-)	Relative proximity (C)	Ranking
Scheme 1	0.008	0.032	0.800	1
Scheme 2	0.034	0.005	0.128	3
Scheme 3	0.022	0.017	0.436	2

CONCLUSIONS

1. This study proposed an evaluation system for the emotional design of children's furniture based on AHP and TOPSIS. The user needs a hierarchy model of children's furniture emotional design was constructed based on the three-level theory of emotional design. The Analytic Hierarchy Process was used to calculate the comprehensive weights of the 13 design factors in the object hierarchy, and three schemes were designed according to the priority of the design factors. The TOPSIS method was used to calculate the distance between the three design schemes and the positive and negative ideal solutions, and the optimal scheme was selected according to the ranking of the relative proximity. This evaluation system can reduce the influence of subjective factors, making the design scheme more scientific and effective, which provides reference value for furniture designers and manufacturers.
2. According to the user needs hierarchy analysis model constructed by AHP, in the criterion hierarchy, the weight values of product appearance, product function, and emotional experience were 0.123, 0.320, and 0.557, respectively. The results showed the importance of emotional experience in the emotional design of children's furniture and verified the significance of reflection level in the three-level theory of emotional design.
3. According to the calculation results of AHP, among the factors that affected the emotional design of children's furniture, the comprehensive weight values of emotional companionship, guidance, and safety were the highest, with 0.285, 0.133, and 0.118,

respectively, followed by interactivity, comfort, and material texture, with comprehensive weight values of 0.096, 0.077, and 0.072, respectively. In comparison, the comprehensive weight values of product modeling, intelligence, and interest had lower comprehensive weight values of 0.020, 0.018, and 0.015, respectively.

4. Three design schemes were evaluated by TOPSIS. The distances from scheme 1 to the positive and negative ideal solutions were 0.008 and 0.032, the distances from scheme 2 to the positive and negative ideal solutions were 0.034 and 0.005, and the distances from scheme 3 to the positive and negative ideal solutions were 0.022 and 0.017, respectively. The relative proximity of the three design schemes was 0.800, 0.128, and 0.436, respectively. Therefore, scheme 1 with the highest relative proximity was chosen as the optimal design scheme. This study verified the feasibility of AHP and TOPSIS in the emotional design of children's furniture and provided a new research approach for furniture design.

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