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Design Evaluation of Parent-child Interactive Game Furniture Based on AHP-TOPSIS Method

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AHP-TOPSIS 방법에 기초한 부모-자식 인터랙티브 게임 가구의 설계 평가

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Abstract Through the research on the design evaluation index of parent-child interactive game furniture, it is convenient for designers to quantitatively analyze the design advantages and disadvantages of related products, which is of positive help to control and improve the design quality. Combined with AHP and TOPSIS, this study proposes the evaluation model of three design criteria and 26 design indexes. After expert scoring, calculation, and consistency test of each index, the weight value of each design index is obtained, and the index is classified according to the importance of each index. Finally, eight essential indicators, eleven secondary indicators, and seven general indicators are classified. A case study was conducted with TOPSIS, and the design samples of three parent-child climbing game furniture were analyzed. Finally, the three samples' relative proximity was 0.505, 0281, and 0.640, respectively. The research shows that the AHP-TOPSIS method can scientifically and effectively sort and screen the advantages and disadvantages of design schemes and provide a reference for the research and development of related products.

Key Words : Parent-child interactive game, Furniture design evaluation, Evaluation Index, AHP, TOPSIS

요 약 부모-자식 인터랙티브 게임 가구에 기초한 설계지표의 연구는 설계사들이 관련 상품의 설계의 장단점을 정량적으로 분석할 수 있게 하여 설계의 질을 관리하고 향상하는데 긍정적인 도움이 된다. 본 연구에서는 AHP와 TOPSIS를 결합하여 3가지 설계기준과 26가지 설계지수의 평가모델을 제안하였다. 각 지표에 대한 전문가들의 채점, 계산 및 일관성 테스트를 거쳐 각 설계지표의 가중치를 얻어낸 다음 각 지표의 중요정도에 따라 지표분류를 진행하였다. 분류결과 설계지표들을 8개의 중요지표와 11개의 보조지표, 7개의 일반지표로 분류하였다. 사례 연구에서는 TOPIS를 이용하였다. 세 종의 부모-자식 등반 게임 가구의 디자인 표본을 분석해 본 결과 세 표본의 상대 근접도는 최종적으로 각각 0.505, 0281 및 0.640 이였다. 연구를 통하여 AHP-TOPSIS 방법이 설계방안의 장단점을 과학적으로 효과적으로 분류 및 선별하고 관련 제품의 연구 및 개발에 참고를 제공할 수 있는 아주 유용한 방법이라는 것이 밝혀졌다.

주제어 : 부모-자녀 인터랙티브 게임, 가구설계평, 설계평가지표 , AHP, TOPSIS

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1. Introduction

With the continuous improvement of people's material and spiritual living standards, Chinese society has paid more attention to early childhood education and the cultivation of parent-child relationships. Frost believes that 2-6 years old is an essential stage of children's growth. During this period, all aspects of children's physical functions developed rapidly and continued to take shape and stabilize [1]. Parents can establish and cultivate children's physiological and psychological functions through rich parent-child interactive games, which play an essential auxiliary role in children's physical and mental health development [2]. On the other hand, the continuous attention of Chinese society to the physical and mental development of preschool children and the massive demand for parent-child products urge relevant industries to take scientific child development theory as the basis for R & D, especially in the field of furniture[3]. Nowadays, Chinese furniture design and academic circles have paid more and more attention to parent-child interactive furniture. However, the related design evaluation research is still in the exploratory stage. Design evaluation plays a crucial role in improving the quality of product design and quality control [4].

The analytic hierarchy process (AHP) is an efficient evaluation method. It is comprehensive decision-making and evaluation method including qualitative and quantitative analysis proposed by T.L. Saaty, a famous American operational research scientist and professor of Pittsburgh University in the mid-1970s [5]. This method decomposes the complex problem into several related elements and divides it into different levels according to different attributes, including target level, criterion level, index level, etc. By establishing a progressive hierarchical structure, combined with appropriate measurement scales, each element's relative importance is compared to calculate the weight and construct the judgment matrix. This study calculates the relative importance ranking of the elements of a layer corresponding to the previous layer's elements and obtains the optimal decision [6]. TOPSIS is a method proposed by C.L. Hwang and K. Yoon in 1981 to rank according to the proximity between limited evaluation objects and idealized objectives. It is to evaluate the relative advantages and disadvantages of existing objects. TOPSIS method only requires each utility function to be monotonically increasing (or decreasing). It is a commonly used and effective method for multi-objective decision analysis [7].

This study uses the AHP-TOPSIS method, combined with relevant literature research and expert interviews, to make a qualitative and quantitative judgment and analysis on the furniture design elements of parent-child interactive games. This study calculates and determines each element's same-level weight and global weight and classifies each element according to its weight. TOPSIS is used to calculate the proximity between different furniture design schemes and the optimal scheme and evaluate the advantages and disadvantages of different designs of the same type of product. Parent-child interactive game furniture products are an essential part of parent-child interactive furniture. The design and development of related products directly and positively impact developing suitable parent-child game activities and improving parent-child game interactive experience and emotional experience. It can indirectly promote the establishment of a healthy parent-child relationship, and harmonious family atmosphere, and the sustainable development of children. Because furniture design quality directly impacts the utility of functions and user experience, it is of great significance and necessity to study the furniture design evaluation of parent-child interactive games. This study combined AHP and TOPSIS to evaluate the design of parent-child interactive game furniture to provide a reference for product R & D and conceptual design in related fields.

2. Research status

At present, the evaluation method based on AHP-TOPSIS is applied to evaluation research in many fields. The most recent research mainly includes: Bathrinath et al. identify and examine the possible risks of accidents and critical alternatives in the textile industry. Through the AHP-TOPSIS method, the textile industry in the southern state of Tamil Nadu, India, was studied to identify the most influential risks and preventive measures. It is found that ventilation, lighting, dust, noise, and human subjective factors lead to accidents [8]. Based on the AHP-TOPSIS method, Ali et al. focused on the security evaluation of healthy Internet of things (IoHT) equipment and proposed an evaluation framework of security attributes (ISA) of healthy Internet of things system. Wang et al. applied the improved AHP-TOPSIS method to the comprehensive risk assessment of oil and gas pipelines. A pipeline risk evaluation index system is constructed based on five indexes affecting the safety of oil and gas pipelines. To make TOPSIS more suitable for pipeline risk assessment, the normalization equation for calculating positive and negative ideal solutions and benefit/cost indicators is improved. The improved AHP-TOPSIS oil and gas pipeline risk evaluation model can evaluate the risk factors scientifically and comprehensively[10]. Li et al. evaluated the sustainable packaging design scheme by using the AHP-TOPSIS method. The evaluation model involves eight evaluation indexes, including packaging design, packaging materials, and packaging cost as the criteria. The sustainable packaging schemes of three kinds of tea were analyzed and evaluated [11]. Sharma et al. studied and analyzed the views of 100 young users on sustainable brands through the AHP-TOPSIS method. The results show that brand social responsibility, green products, and environmental protection contribute to brand performance [12]. Chen studied the design and evaluation method of tourist souvenirs in Xiamen, China, using the AHP-TOPSIS method. The evaluation model with three criteria attributes and ten evaluation indexes of economic, cultural, and process attributes is established. The evaluation results show that regionality, market demand, folklore, history and culture, and innovation affect souvenir design [13]. Lukić et al. used the AHP-TOPSIS method to empirically analyze food retailers' financial performance and efficiency in Serbia. It is found that among all optimization criteria, the cost of sales is the most important. The establishment of self-owned brands, multi-channel sales, organic food sales, and other models positively impact the efficiency of food retailers [14].

The review of relevant literature found that the AHP-TOPSIS method has been widely used in evaluation research in different fields and provides effective help for the best and ideal decision-making choice. However, we find that there is still a lack of evaluation research on the furniture design of parent-child interactive games by using the AHP-TOPSIS method. The literature survey found that in the existing furniture design evaluation research based on AHP, there is a general lack of empirical analysis on the optimal design scheme of actual samples. Therefore, from the perspective of parent-child interactive game furniture design, this study studies the indicators affecting product design and evaluates the design advantages and disadvantages of three parent-child interactive game furniture.

3. Research process

Firstly, expert interviews and literature research determine the design index level of parent-child interactive game furniture. The judgment matrix is constructed through the pairwise comparison of each index, and the consistency is tested. This study identifies the weight value of each indicator and ranks the weight of the indicators. This research also determines the classification rules of the indicators and classifies the indicators. Based on the index classification, the design advantages and disadvantages of three parent-child interactive game furniture are evaluated and sorted by the TOPSIS method, and the optimal scheme is determined.

4. Methodology

4.1 Determination of design evaluation index

Based on the relevant evaluation indexes of General Safety Technical Specification for Children's Furniture SN_T 2144-2008 and General Technical Requirements for Children's Furniture GB 28007-2011 in China, combined with the relevant literature research and expert discussion results, the evaluation indexes are determined. Taking child protection design, furniture hardware design, and parent-child game interactive design as the standard level indicators, the index level indicators covered include: no fragile materials, fire and flame retardancy, no protrusions, no sharp corners, safety stop devices, reinforcement of small parts, sleek edge design, the limit of harmful substances, the load-bearing capacity of furniture, game safety and child protection, product color and pattern matching, structural strength and stability, functional visibility, use of lightweight materials, affinity styling design, product cost control, use comfort, reasonable size, quality performance, storage function, ease of use and ease of operation, children's ability training and learning, children's behavior guidance, game fun and challenge, game rhythm and adaptability, parent-child interaction of the game [15-19].

4.2 Index connotation

4.2.1 Safety attributes of furniture

Child protection is the fundamental attribute, and the child protection attribute is the guarantee of availability. Child protection based on parent-child game interaction can be understood from two aspects: the security of furniture hardware configuration and the security of the user use process. The safety of furniture hardware means that the characteristics, composition, appearance, and other elements of all physical components of furniture will not bring hidden dangers and threats to users' personal safety and health and can be used safely by users, especially children. The safety guarantee of the user's use process refers to the whole process from the user's use of the product to the end of use is safe and stable. The user's use behavior, state, and the design and implementation process of the game itself are safe. The product can provide a sufficient safety guarantee for the user in the whole use process. For example, when children play climbing games, furniture will provide certain protective functions to prevent children from sliding or other potential safety hazards [17].

4.2.2 User's sensory experience

Norman mentioned in the book Emotional Design: Why We Love (or Hate) Everyday Things that the human emotional system is divided into three levels: instinct, behavior, and reflection [20]. Users' sensory experience is based on the experience of the instinct layer, that is, through the direct sensory image and subjective feeling brought to users by the design of five senses, to improve users' favor. For example, children's favorite cartoon modeling or the use of color can be used to improve the affinity of the product, or the visual quality of the product appearance can be improved through the matching of materials with different textures; smooth edge processing can give users a safe and reliable experience from vision and touch.

4.2.3 Cost control

Implementing cost control in the project design stage is the most effective way of cost control [21]. During the design period, the purchase, transportation, processing, and process cost of product raw materials shall be fully considered, and the cost shall be reduced as much as possible under the condition of meeting the expected objectives.

4.2.4 Furniture function use and game experience

In terms of product use, furniture design based on parent-child game interaction should meet the needs of users' essential use and game interaction, and furniture products should be easy to use. It requires designers to fully consider the influence relationship between products and users in the design stage [22]. The size and shape of furniture shall meet the relevant ergonomics requirements and consider the comfortable feeling of adults and children. In terms of function options, function integration can be considered to improve the utilization rate of furniture. Regarding parent-child interactive games, we should pay attention to the game design itself, determine the game objectives, and consider the functional integration between the game and furniture. In terms of game experience, we should fully consider the experience needs of parents and school-age children.

4.3 Index hierarchy model

Based on the determined design evaluation indexes, a hierarchical model of parent-child game interactive furniture design evaluation indexes is established. As shown in the following Fig. 1.

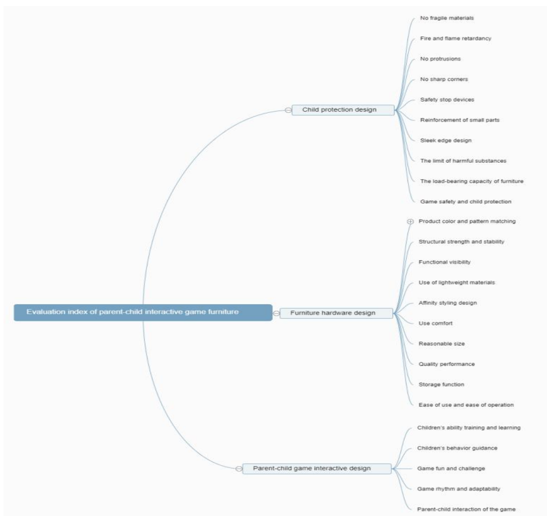


Fig. 1. Hierarchical model of design evaluation index

4.4 Analysis steps of analytic hierarchy process and TOPSIS

This study uses the expert survey method to determine the relative importance of each index and the overall goal. A total of 12 experts with relevant research backgrounds were invited to fill in the questionnaire (Table 1). The questionnaire uses nine scales to measure the importance of each index (Table 2).

Table 1. Professional background and working time of each expert

Expert serial number	Professional background	Working hours (Years)
1	Parent-child education, children's education	9
2	Parent-child education, children's education	12
3	Industrial design, design education	15
4	Industrial design, furniture design, home product design, design education	12
5	Children's toy design	10
6	Industrial design, interactive design	7
7	Industrial design	9
8	Furniture design, soft decoration design	18
9	Visual design, industrial design	16
10	Children furniture engineer	11
11	Industrial design, Furniture engineer	7
12	Industrial design, Furniture engineer	5

Table 2. Nine-level scale

Scale	Definition (Comparing index i and index j)
1	Index i is as important as index j
3	Index i is slightly more important than index j
5	Index i is more important than index j
7	Index i is really more important than index j
9	Index i is absolutely more important than index j
2 4 6 8	The Intermediate value of the adjacent judgment
Reciprocal	uij=1/uji Represents the judgment uij of the comparison between index i and index j, then the comparison judgment between j and i is uij=1/uji

4.4.1 Analytical steps of analytic hierarchy process

The target layer is represented by a, and the judgment matrices P1 and P2 are established by the weighted arithmetic average method. Where P1 refers to the relative importance judgment matrix of the criterion layer Bi and P2 refers to the relative importance judgment matrix of the index layer Cij. The P1 matrix and P2 matrix are normalized respectively to obtain the weight value of each index, and the consistency test is carried out. The steps of determining the weight by analytic hierarchy process (AHP) are as follows:

(1) Construct a judgment matrix. ui,uj (i,j = 1, 2, ⋯, n) represent factors. uij represents the relative importance value of u_i to u_j. And the judgment matrix P is composed of u_{ij}.

$$P = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{nn} \end{bmatrix} \quad (1.1)$$

The judgment matrix P must have the following properties:

$$u_{ij} > 0, \quad u_{ij} = \frac{1}{u_{ji}}, \quad u_{ii} = 1 \quad (1.2)$$

(2) The elements of matrix P are normalized by column:

$$\bar{w}_{ij} = \frac{u_{ij}}{\sum_{i=1}^{n} u_{ij}} \quad (2.1)$$

Add and sum the normalized matrix by row:

$$\bar{w}_i = \sum_{j=1}^{n} \bar{w}_{ij} \quad (2.2)$$

The resulting rows and vectors are normalized:

$$w_i = \frac{\bar{w}_i}{\sum_{i=1}^{n} \bar{w}_i} \quad (2.3)$$

Calculate the largest characteristic root:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(Pw)_i}{nw_i} \quad (2.4)$$

(3) Consistency inspection. The rationality of weight distribution is determined by checking the consistency of the judgment matrix. Test formula is as follows:

$$CI = \frac{\lambda max - n}{n - 1} \quad (3.1)$$

$$CR = \frac{CI}{RI} \quad (3.2)$$

CI is the consistency index of the judgment matrix, and CR is the random consistency ratio of the judgment matrix.

N is the order of the judgment matrix. RI is the average random consistency index of the judgment matrix. Refer to (Table 3) for the RI value of the judgment matrix of orders 1-9.

Table 3. Average random consistency index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

When the CR of the judgment matrix P is less than 0.1 or $\lambda max = n$, CI=0, it is considered that P has a satisfactory consistency; otherwise, the elements in P need to be adjusted to make it have a satisfactory consistency.

4.4.2 Analysis steps of TOPSIS method

An evaluation matrix is formed by m evaluation objects, and n evaluation indicators, and ideal solutions and negative ideal solutions are determined by normalizing the matrix. Calculate the distance from each evaluation object to the ideal solution and the negative ideal solution, and compare the closeness of the evaluation object to the ideal solution so as to obtain the order of the advantages and disadvantages of each evaluation object.

Through the vector norm method, the normative decision matrix Z is obtained:

$$Z = \begin{bmatrix} Y_{11} & Y_{12} & \bullet\bullet\bullet & Y_{1n} \\ Y_{21} & Y_{22} & \bullet\bullet\bullet & Y_{2n} \\ \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet \\ \bullet & \bullet & \bullet & \bullet \\ Y_{m1} & Y_{m2} & \bullet\bullet\bullet & Y_{mn} \end{bmatrix} \quad (4.1)$$

$$Z_{ij} = \frac{Y_{ij}}{\sqrt{\sum_{i=1}^{m} Y_{ij}^2}} \quad (4.2)$$

Form a weighted norm matrix X:

$$X_{ij} = W_j \bullet Z_{ij} \quad (4.3)$$

Determine the positive and negative ideal solution:

$$X_j^+ = \{X_1^+ \;\; X_2^+ \;\; \bullet\bullet\bullet \;\; X_n^+\} = \{(maxX_{ij} | j \in I), \; (minX_{ij} | j \in I)\}$$
$$X_j^- = \{X_1^- \;\; X_2^- \;\; \bullet\bullet\bullet \;\; X_n^-\} = \{(minX_{ij} | j \in I), \; (maxX_{ij} | j \in I)\} \quad (4.4)$$

Where j is the cost attribute, and I is the benefit attribute.

Calculate the distance between each evaluation object and the positive and negative ideal solution:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (X_{ij} - X_j^+)^2}$$
$$d_i^- = \sqrt{\sum_{j=1}^{n} (X_{ij} - X_j^-)^2} \quad (4.5)$$

Calculate the closeness of each evaluation object to the ideal solution:

$$C_i^* = \frac{d_i^-}{d_i^- + d_i^+}$$
$$(i = 1, 2, \bullet\bullet\bullet, \; m) \quad (4.6)$$

According to Ci*, rank the evaluation objects in descending order.

4.5 The weight ranking of each evaluation index

The AHP analysis method is used to obtain the weight value of each index, and the average direct method is used to solve the group decision. See Table 4 for the weight ranking of the criteria level and Table 5 for the numerical ranking of the index level weights. The child protection design has the highest index weight value in the criteria level, which is 0.5594. The second is furniture hardware design, with a weight of 0.2372, and the final design for parent-child game interaction, with a weight of 0.2034. In the actual design of these three aspects, designers and R&D personnel should give full consideration, especially in the design of child protection should be given more attention.

Table 4. The ranking of the evaluation index weights at the criterion level

Criterion-level evaluation index	Weights	Sort
B1 Child protection design	0.5594	1
B2 Furniture hardware design	0.2372	2
B3 Parent-child game interactive design	0.2034	3
CR=0		

Table 5. The ranking of index layer weights

Criterion layer	Sibling weight	Global weight	Index Layer	Sort
B1 Child protection design	0.1111	0.0622	C11 Game security	3
	0.0904	0.0505	C12 No fragile materials	7
	0.1372	0.0668	C13 Fire retardant	2
	0.0638	0.0357	C14 No protrusions	10
	0.1205	0.0574	C15 No sharp corner design	5
	0.0353	0.0196	C16 Safety stop device	22
	0.0355	0.0199	C17 Small parts reinforcement treatment	21
	0.1206	0.0574	C18 Sleek edge design	5
	0.1765	0.0889	C19 Hazardous substance limit	1
	0.1091	0.0612	C110 Furniture load-bearing capacity	4
B2 Furniture hardware design	0.0357	0.0183	C21 Product color and pattern matching	23
	0.1399	0.0334	C22 Structure strength and stability	12
	0.1288	0.0305	C23 Function visibility	15
	0.0312	0.0249	C24 Use of lightweight materials	19
	0.0768	0.0182	C25 Modeling design with an affinity	24
	0.1303	0.0330	C26 Product cost control	13
	0.1489	0.0353	C27 Use comfort	11
	0.1011	0.0242	C28 Reasonable size	20
	0.0382	0.0291	C29 Quality performance	16
	0.0532	0.0126	C210 Storage function	25
	0.1159	0.0275	C211 Ease of use and operation	17
B3 interactive design of the parent-child game	0.2084	0.0424	C31 Children's ability training and learning	8
	0.1186	0.0384	C32 Child behavior guidance	9
	0.1756	0.0257	C33 Game fun	18
	0.1582	0.0322	C34 Game rhythm and adaptability	14
	0.3392	0.0547	C35 Parent-child interaction of games	6
CR=0.009				

In the indicator layer, the global weight value of the hazardous substance limit indicator is 0.0989, and the other indicators are ranked according to the weight value: fire retardancy, game safety, furniture load-bearing capacity, smooth edge design, no sharp corner design; the parent-child interaction of the game, no fragile materials, children's ability training, and learning, children's behavior guidance, no protrusions, use comfort, structural strength and stability, product cost control, game rhythm and adaptability, visual functions Performance, quality performance, ease of use and ease of operation, game fun, use of lightweight materials, reasonable size, reinforcement of small parts, safety stop devices, product color and pattern matching, affinity modeling design, storage function. The three indicators of hazardous substance limit, the comfort of use, and parent-child interaction of the game have the same weight values of 0.1765, 0.1489, and 0.3392, which are the highest in their respective standard levels, and require additional attention in actual product development. Followed by fire and flame retardancy, structural strength and stability, children's ability training and learning; the weight values are 0.1372, 0.1399, 0.2084. These should also be considered in the design.

4.6 Classification of indicators

According to the global weight ranking of the indicators, the evaluation indicators are divided into three categories according to the weight value range (Fig. 2). Indexes with a weight value ranging from 0.05-0.1 are divided into essential indexes, indexes with a weight value of 0.025-0.05 are divided into secondary indexes, and indexes with a weight value of less than 0.025 are divided into general indexes. Among them, there are eight essential indicators, namely game safety, no fragile materials, fire and flame retardancy, no sharp corner design, sleek edge design, hazardous substance limit, furniture load-bearing capacity, parent-child interaction of the game, and the weighted sum is 49.91 %. There are a total of eleven secondary indicators, namely, no protrusions, structural strength and stability, functional visibility, product cost control, use comfort, quality performance, ease of use and ease of operation, and children's ability to develop and learn, children's behavior guidance, game fun, game rhythm and adaptability, and the total weight is 36.32%. There are a total of seven general indicators, namely safety stop device, small parts reinforcement treatment, product color and pattern matching, light material use, affinity modeling design, reasonable size, and storage function. The total weight is 13.77%.

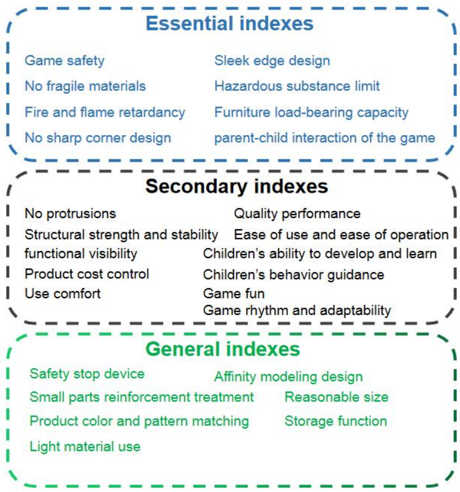


Fig. 2. Classification of indicators

4.7 TOPSIS case analysis

The established parent-child interactive game furniture evaluation system analyzes three furniture conceptual design samples (A1, A2, A3) based on parent-child climbing games (Table 6). All three samples come from the China Luxun Academy of Fine Art furniture design studio. A total of five reviewers were invited, two of whom were children's furniture designers, one furniture product engineer, and two children's parents. After introducing the specific details of the conceptual design and design instructions to the reviewers, the samples are scored. The scoring standard is 1-10 points, and the final assignment is the average value (Table 7).

Table 6. Three furniture samples based on parent-child climbing games

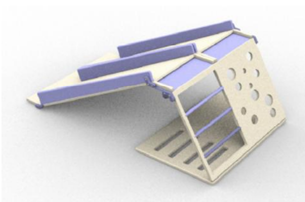
Sample	Sample description
 A1	Design Features: 1. Foldable and storable 2. Equipped with a safety stop device
 A2	Design Features: 1. Modular combination 2. Combination design of climbing frame and table
 A3	Design Features: 1. Combination design of children's bed and climbing game 2. A variety of entertainment methods

Table 7. Scoring of three samples

n m	A1	A2	A3
Game safety	4.6	2.6	7
No fragile materials	4.6	7.4	7.8
Fire and flame retardancy	3	2.2	4.8
No sharp corners design	2.8	2	5.6
Sleek edge design	4	2	7
Limits of hazardous substances	6	4.8	4.6
Furniture load capacity	3	7.4	6.2
Parent-child interaction of the game	6.4	4.4	7.8
No protrusions	3.6	5.8	5.2
Structural strength and stability	3.8	6.8	7.8
Functional visibility	6.6	7.4	8
Product cost control	5.2	3.8	5.2
Use comfort	4	3.4	6.6
Performance of sense of quality	6	6.4	8
Ease of use and operation	3.8	3.6	6.6
Children's ability training and learning	3.8	2	6.2
Child behavior guidance	7	4	7.2
Game interest	6.6	4.2	8.4
Game rhythm and adaptability	4.6	2.2	6.8
Safety stop	7.4	1.6	2.2
Reinforcement of small parts	4	5.2	5.2
Product color and pattern matching	6.8	4.8	7.4
Use of lightweight materials	6.4	4	4.2
Modeling design with an affinity	6.8	5.2	8
Reasonable size	4.6	5.2	6.6
Storage function	6.6	4	1.8

According to formula (4.2), the scoring data are normalized. The normalized results are shown in Table 8.

Table 8. Standardized results

n m	A1	A2	A3
Game safety	0.183	0.109	0.212
No fragile materials	0.183	0.311	0.237
Fire and flame retardancy	0.119	0.092	0.146
No sharp corners design	0.111	0.084	0.170
Sleek edge design	0.159	0.084	0.212
Limits of hazardous substances	0.238	0.202	0.140
Furniture load capacity	0.119	0.311	0.188
Parent-child interaction of the game	0.254	0.185	0.237
No protrusions	0.143	0.244	0.158
Structural strength and stability	0.151	0.286	0.237
Functional visibility	0.262	0.311	0.243
Product cost control	0.207	0.160	0.158
Use comfort	0.159	0.143	0.200
Performance of sense of quality	0.238	0.269	0.243
Ease of use and operation	0.151	0.151	0.200
Children's ability training and learning	0.151	0.084	0.188
Child behavior guidance	0.278	0.170	0.219
Game interest	0.262	0.176	0.255
Game rhythm and adaptability	0.183	0.092	0.206
Safety stop	0.294	0.067	0.067
Reinforcement of small parts	0.159	0.218	0.158
Product color and pattern matching	0.270	0.202	0.225
Use of lightweight materials	0.254	0.168	0.128
Modeling design with an affinity	0.270	0.218	0.243
Reasonable size	0.183	0.218	0.200
Storage function	0.262	0.168	0.055

After weighting the standardized data according to formula (4.3), each evaluation object's positive and negative ideal solutions are obtained according to formula (4.4). (Table 9)

Table 9. Positive and negative ideal solutions for each evaluation index

Index category	Index	Positive ideal solution	Negative ideal solution
Essential indexes	Game safety	0.798	0.296
	No fragile materials	0.667	0.393
	Fire and flame retardancy	0.790	0.362
	No sharp corners design	0.852	0.304
	Sleek edge design	0.843	0.241
	Limits of hazardous substances	0.670	0.514
	Furniture load capacity	0.732	0.297
	Parent-child interaction of the game	0.709	0.400
Secondary indexes	No protrusions	0.676	0.420
	Structural strength and stability	0.708	0.345
	Functional visibility	0.628	0.518
	Product cost control	0.628	0.459
	Use comfort	0.783	0.403
	Performance of sense of quality	0.674	0.505
	Ease of use and operation	0.783	0.427
	Children's ability training and learning	0.822	0.265
	Child behavior guidance	0.666	0.370
	Game interest	0.732	0.366
	Game rhythm and adaptability	0.800	0.259
General indexes	Safety stop	0.939	0.203
	Reinforcement of small parts	0.621	0.478
	Product color and pattern matching	0.664	0.431
	Use of lightweight materials	0.741	0.463
	Modeling design with an affinity	0.683	0.444
	Reasonable size	0.689	0.480
	Storage function	0.833	0.227

According to formulas (4.5) and (4.6), the distance and closeness of each sampling plan to the positive and negative ideal solutions are obtained (Table 10).

Table 10. The distance and closeness of each sampling plan to the positive and negative ideal solutions

Sample	D+	D-	Relative proximity	Sorting results
A1	1.212	1.236	0.505	2
A2	1.795	0.703	0.281	3
A3	0.954	1.697	0.640	1

From the results of the AHP-TOPSIS analysis method, among the three selected parent-child climbing game furniture samples, the relative closeness of the A3 sample is 0.640, which has the highest closeness. Followed by the A1 scheme, the relative proximity is 0.505. The last is the A2 plan, with a relative closeness of 0.281. The results show that the comprehensive design index of the A3 sample is the most suitable design plan among the three samples compared with the other two plans.

5. Discussion and conclusion

This research provides a feasible quantitative evaluation method for designing and selecting parent-child interactive game furniture. First, through literature research and expert interviews, combing and summarizing the indicators that affect the design of parent-child interactive game furniture so as to construct a parent-child interactive game furniture design evaluation system. Through the AHP method and scoring by experts, the importance of each index is calculated. The TOPSIS method is used to evaluate the design of three conceptual design samples, and a scientific evaluation result is obtained.

Because AHP has a certain degree of subjectivity, TOPSIS ignores the index weight. Therefore, the combination of AHP and TOPSIS methods can complement the advantages of the two methods, make a more scientific and comprehensive judgment [11], and provide a reference for the design evaluation of parent-child interactive game furniture. This study uses the TOPSIS method to rank the pros and cons of interactive game furniture design samples, which can positively affect the development and design of related products. This paper proves the feasibility of the design evaluation system and parent-child interactive game furniture evaluation method by analyzing and researching three design cases.

Combined with the existing conclusions of this study, the following suggestions are provided for the design and development of parent-child interactive game furniture:

The first suggestion is to include seven critical indicators in the child protection design guidelines. The order of importance of these seven critical indicators is: limit of hazardous substances〉fire and flame retardancy〉play safety and child protection〉furniture load-bearing capacity〉none Sharp corner design = smooth edge design〉 no fragile materials. Explain that the research and development of children's furniture products should be based on the use of non-toxic and high-temperature resistant materials. At the same time, pay attention to the formaldehyde content of furniture, and try to use low-formaldehyde or non-toxic materials, adhesives, and coatings. In the furniture design, additional attention should be paid to the protection of the furniture for children to ensure that there will be no safety hazards during the game due to the unreasonable design of the furniture. The protection method should be selected based on the actual game form, function, and user behavior. The reinforcement treatment of safety stop devices and small parts is a general indicator, indicating that in this type of furniture design, the use of fixed parts can be reduced, and the use of fixed parts and movable devices will also increase safety to a certain extent—the hidden dangers.

The second suggestion is that the comfort of use in the furniture hardware design criteria is the most important indicator, indicating that people still regard comfort as an essential criterion for evaluating furniture design quality. It requires designers to combine game action behaviors in the furniture design process to comprehensively consider the plan to improve the comfort of the furniture, which can start with material selection, ergonomics, and game methods. In addition, we must also pay attention to the cost control of the product in the research and development cycle and the visibility of product functions, and integrate the concept of Affordance into the form design of furniture products.

The third suggestion is that in the design criteria of parent-child game interaction, we should pay attention to the parent-child interaction of the game itself. In other words, while meeting children's interest in games, we should also pay extra attention to parents' participation in games and their interest in games. This requires designers to fully understand the interactive needs of users and interactive design games targeted before game design. At the same time, we should also pay attention to the guiding effect of games on children and provide a guiding function by matching game behavior and auxiliary game function of furniture. The function of guidance should be targeted to guide children's specific ability improvement. The interactive design of games should be comprehensively considered in combination with users' game experience and children's ability training.

Parent-child interactive furniture plays an essential and active role in enhancing the parent-child relationship and child training. This research takes furniture design based on parent-child interactive games as an example, proposes three design criteria and an evaluation system of 26 design evaluation indicators. The weights are normalized by AHP analytic method, and finally, eight important indicators and eleven items are obtained. Minor indicators and seven general indicators. The TOPSIS method is used to analyze and rank the pros and cons of the three design cases, and finally, the A3 scheme is the optimal design scheme. In the furniture design of parent-child interactive games, we should focus on selecting furniture materials, game interactive design and game safety, game guidance, and furniture comfort. In the index evaluation system constructed by the AHP method, the relationship between each index is independent. However, there will also be interdependence and interaction between indicators and indicators. The relationship between these indicators cannot be ignored entirely in the actual design and evaluation process[21]. Therefore, in the following research, the interaction and feedback relationship between parent-child interactive game furniture design indicators can be studied and analyzed in conjunction with ANP.

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