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Community Infant and Toddler Public Space Design Based on Sensory Experience

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SUMMARY: *The declining birth rate side by side reflects the people's demand for high-quality childcare. Guided by that demand, the effective design of community infant and toddler public spaces is particularly important. In this paper, we collect text data of social networking site comments related to the sensory experience of community infant and toddler public spaces from the target audience to construct a research dataset. Utilizing the preprocessed standard data, LDA topic model is established and combined with semantic relatedness calculation to determine the optimal number of topics. After that, through the random forest algorithm using CART decision tree as a class learner, the text data were categorized to mine the highest value design features, and these design features were used as the basis for enhancing the experience of public space for infants and toddlers in the community.The number of themes outputted from the LDA model was four. On this basis, the random forest algorithm mines the 10 best design features including visual. Based on the 10 features, we completed the design and remodeling of a number of public spaces for infants and toddlers in District Y. The final evaluation of the public spaces by the target population on all dimensions reached an average score of 4 or more. The design of public spaces for infants and toddlers based on sensory experience is effective.*

KEYWORDS: *sensory experience; community public space; infants and toddlers; LDA theme; random forest; CART decision tree*

1 Introduction

Children are the hope of society and the inheritors of human civilization, and the cultivation of children is related to the development of the future world, therefore, the cultivation of sound, intelligent and creative children will be an important goal of the whole society [1]. However, nowadays, children are facing the difficult environment of “lack of childhood innocence”, and they are forced to adapt to the adult's vision to understand the rapidly advancing social environment, which will inevitably have a considerable impact on children's physiology and psychology. In recent years, public facilities and activity spaces to serve children have appeared rapidly, but with the increase in the number of children, the design of high-quality activity spaces has limitations, and it is difficult for children to get pleasure and satisfaction from them [2, 3]. Infant public space as an important place for infants and parents daily behavioral activities, so that infants and young children most directly feel the external environment and urban culture of the space, in such a place to build a diversified art form can contribute to the high-quality environment and promote the cultural atmosphere, high-quality and diversified art form can help to promote the active participation of children in the construction of the public

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space, and to promote the cause of early childhood development [4-7]. On the one hand, it establishes the concept of behavior with infants and young children, and on the other hand, infant and young children's development influences the social environment, thus shaping spatial values and urban culture [8]. It is this mutual shaping relationship in which people, public space, art and culture, and social environment are integrated into a benign interaction and creative multifaceted synthesis [9].

The development of the times is rapidly changing, and as China steps into the comprehensive construction of a moderately prosperous society and realizes the first hundred years of struggle, it begins to turn to the second hundred years of struggle [10]. The community is the basic unit of the city, which is an important cornerstone for promoting the high-quality development of society and the modernization of national governance [11]. Community reflects two basic attributes, namely sociality and territoriality. Sociality refers to the organizational, emotional and functional ties that exist and are formed in people's common life [12]. Territoriality refers to the fact that the community has certain boundaries and is an open space surrounded by entities such as buildings or structures, and the community space has a wide range of components, including community streets, public green spaces, recreational facilities, etc. [13, 14]. Therefore, community public space also possesses both locality and sociality.

Sensory experience is based on the multiple senses of the human body, which can provide a comprehensive and three-dimensional multi-sensory experience, promote the relationship between human-environment-nature, and satisfy people's material needs and spiritual needs [15]. Through sensory design, the designer inputs information into the user's senses by utilizing natural elements to express his/her intention, and the user then expresses his/her inner feelings through the senses to form the information output [16, 17]. The comprehensive nature of the senses in the design is no longer like a single design in the past, in the past, the design of the visual as the dominant, although it has a certain role in guiding, but there are certain shortcomings, so that the human body stays in the two-dimensional perception. On the contrary, the use of multi-dimensional design forms, comprehensive mobilization of human vision, smell, taste, hearing, touch, the establishment of a relationship between the design and people, so that a variety of senses intertwined and fused to produce multiple experiences so that the design of the formation of three-dimensional three-dimensional interactive form [18, 19]. Therefore, in the context of children's activity space features generally patterned, the study on the visual art form of sensory public space for infants and toddlers is of great significance in guiding the culture and development of public space for infants and toddlers.

In the context of high urbanization and population aging, academics began to pay attention to the construction of children's public space at an early stage. Literature [20] reviewed and found that relevant articles about children's public space mainly focus on three aspects: methodology, spatial experience and spatial elements, which can help to build a system for evaluating the usefulness of public space, determine the motivation of children's participation in public space activities, and then optimize the public space in a targeted way. Literature [21] absorbed the academic experience of children's public space design, investigated the outdoor activities of children in China, and put forward community public space design strategies that are more suitable for children's activities in China, aiming to improve the theoretical system of children's public space design. Literature [22] studied children's play behaviors in public space, children's activities in different spatial environments have both commonalities and differences, and the study pointed out the design elements in public space that are not conducive to child-friendly and ecologically sensitive design, and provided a framework for optimizing public space that meets the needs of children's activities. Literature [23] started from the perspective of friendly development of children's public space, utilized spatial grammar and convolutional

neural network to excavate the key elements of children's participation in public space activities, and then collected suggestions for the rectification of public space through interviews and surveys, and based on which explored the renewal strategy of children's public space. Literature [24] analyzed how to design practical children's public space from the perspective of children's living habits, and the results of the study showed that children want to be happy in public space, and optimizing spatial comfort and interactivity can improve children's adaptability in public space.

With the continuous development of the concept of child-friendly city, the design optimization of residential public space as an important field for children's daily activities not only needs to pay attention to the reasonableness of the physical space, but also needs to deeply understand children's behavioral characteristics and sensory experience in the space [25, 26]. Literature [27] pointed out that people experience community public space through their senses, so based on immersive virtual reality technology for public space sensory experience planning, and integration of light projection methods and Unity callback mechanism to enhance the visibility of the user's field of view, the study provides reference decision-making for improving children's public space. Literature [28] analyzes the problems of children's activity public space in Ningbo, China through a case study, which provides a new direction for the re-planning and design of children's activity public space, i.e., to adopt intelligent technology to design intelligent public space based on sensory experience to satisfy more children's activity needs.

In addition, literature [29] investigated the multi-sensory needs of children in hospital public spaces, processed the collected data with natural language processing and thematic clustering and measured satisfaction, and found that visual, auditory, and tactile elements have a greater impact on children's satisfaction, while olfactory elements can enhance children's comfort in public spaces. Literature [30] explored a socio-technical systems approach for the creation of sensory-based public spaces, which incorporated key sensory experience design principles and was effective in two sensory design cases in public spaces, which were expected to enhance children's sensory experience. Literature [31] points out that children with mobility and deafblindness face many problems in public spaces, and in order to increase the participation of these children in public spaces, optimization measures that explore visual communication as a direction of improvement and incorporate multi-sensory experiences are proposed to increase the inclusiveness of public spaces for children with disabilities.

In this paper, various types of text data collected on evaluation and experience of public space for community infants and toddlers are followed to complete data preprocessing to improve the text specification and the scientificity of the subsequent research by following the steps of screening, feature word extraction and correction, and data saturation test. The preprocessed data are used to train the LDA topic model, which calculates the semantic relevance of high-frequency words through the Topic Consistency Index (TC), sets the most appropriate number of topics, and reduces the probability of redundancy in classification. Randomly selected samples are used to train CART decision tree, a class learner for random forests, to optimize the classification accuracy, to find the optimal number of features as well as the specific features of the community infant public space design, and to improve the acceptance of the target population for the design.

2 Technical support for the optimization of sensory experiences in community public spaces for infants and young children

2.1 Data Acquisition and Preprocessing

2.1.1 Text data acquisition

With the popularity and development of mobile devices and social networking sites, each resident using the community's public spaces for infants and toddlers can readily share his or her feelings about their use, containing a great deal of information about their experience of the space and its senses. These data form a natural dynamic text database. Through data analysis, the perceptual characteristics of spatial imagery can be generalized.

The commonly used basic data for spatial imagery and attribute analysis generally come from a variety of sources, including descriptive texts and photographs related to the generation of rundowns, evaluations, experiences, and recommendations for community infant and toddler public spaces based on sensory experiences. Based on this, natural spatial text clusters are formed around different community infant and toddler public spaces. These textual data were selected for an imagery study using community infant/toddler public spaces as the study area.

2.1.2 Textual data screening

Acquired data is screened for valid data.

1) Redundant data elimination

Due to crawling data content characteristics, etc., data duplication, excess, etc., often occurs, making the reliability reduced. A large number of data redundancy reduction mechanisms are used to eliminate duplicate copies of data, and appropriate data preprocessing methods can also be selected based on dataset characteristics, problems to be solved, performance requirements, and other factors.

2) Noisy data elimination

Noisy data includes data that does not fall within the scope of the study, data published by marketing accounts, and data from which spatial imagery cannot be extracted. According to the determined scope of the study, the spatial text data that matches it is filtered out; for the elimination of the content published by public accounts, only the original content published by individual users is retained; and the data that cannot extract spatial imagery is deleted.

2.1.3 Feature word extraction and correction

Words are the basic unit of analyzed data, and conversion from text to feature words requires invalid character removal, word separation processing, deactivation processing, and feature word correction.

Invalid text data are cleared or replaced with the help of regular expressions and other processing, including punctuation marks. Sentence structure is canceled for note paragraphs, and continuous text is split into words or Chinese characters with boundary markers to complete word splitting. Considering that the text after word separation contains data redundancy and irrelevant data, upload a dictionary of deactivated words in the word separation program to screen the word separation data. After the above steps, a text document composed of feature words, i.e., a collection of feature words, will be obtained. Considering the existence of network terms and so on in this collection, regular expressions are utilized to replace this kind of text to complete the feature word correction.

2.1.4 Data saturation test

Appropriate samples are key to ensuring the validity of a study; too much or too little sample size is flawed. Develop appropriate saturation tests to determine whether the data are saturated and decide on the amount of data to be collected.

2.2 Text Topic Extraction

The processed text data were used as input for building the LDA topic model, and the Gensim library in Python was called to perform topic clustering analysis of the text to identify the focus of the public's attention on the sensory experience of the public spaces for community infants and children, and to summarize and refine the dimensions of the CES perception of the public spaces for community infants and children in District Y. The LDA topic model was developed by using the Gensim library in Python to conduct the topic clustering analysis of the text. Before training the LDA topic model, hyper-parameters must be set, including the distribution parameter α of document-topic, the distribution parameter β of topic-word, and the number of topics K.

The Gibbs sampling method is adopted to automatically learn the optimal α and β parameters through multiple iterations of sampling until the model reaches a converged state. Choosing the appropriate number of topics has a significant impact on the results of the model, so it is crucial to determine a reasonable number of topics before performing LDA modeling.

In this paper, we select the proper number of topics by using the Topic Consistency Index (TC), which evaluates the topic quality by calculating the semantic relatedness between words with high scores in a topic. The frequency of occurrence of a word v in a document is denoted by $D(v)$, while $D(v,v')$ denotes the frequency of simultaneous occurrence of two words v and v' in the same document, based on which the formula for calculating Topic Consistency is defined (1):

$$C(t;V^t)=\sum_{m=2}^{N}\sum_{l=1}^{m}\log\frac{D(v_m^t,v_l^t)+1}{D(v_l^t)} \tag{1}$$

where: $V^t=(v_1^t,v_2^t,\cdots,v_N^t)$ refers to the set of N words with the highest probability of being in topic t. The higher the quality of the topic, the closer $D(v_m^t,v_l^t)$ is to $D(v_l^t)$ and the closer the value of $C(t;V^t)$ is to 0.0.

2.3 Random Forest Based Text Classification

Random forest is improved on the basis of the bagging algorithm, which reduces the variance of the model by randomly selecting m subsamples from the original dataset using a random sampling method with put-back, and training m class learners with these m subsamples. And there are two improvements of Random Forest, first: when training each class learner, instead of selecting the optimal features from all the features to slice the nodes, it randomly selects k features, and selects the optimal features from these k features to slice the nodes, which reduces the variance of the model even further; second: the class learner used by Random Forest is the CART decision tree.

The specific steps of the algorithm are as follows:

1) Let the number of samples in the original training set be given as N and the number of feature attributes be given as M, and Bootstrap sampling technique is used to randomly select N samples from the original training set to form a training subset.

2) Randomly select m features from M feature attributes as candidate features $(m \le M)$, and select the optimal attributes for splitting at each node of the decision tree in accordance with some rules (Gini index, information gain rate, etc.) until all the training samples at that node belong to the same class, with complete splitting and no pruning in the process.

3) Repeat the above two steps k times to construct k a decision tree to generate a random forest.

4) Use the random forest for decision making, let x represent the test sample, h_i represent the single decision tree, Y represent the output variable, i.e., the classification label, I is the indicative function, H is the random forest model, and the decision formula is:

$$H(x) = \arg\max_{Y} \sum_{i=1}^{k} I\left(h_i(x) = Y\right) \tag{2}$$

Summarize the classification results of each decision tree for the sample, and the class with the most votes is the final classification result.

3 Public space design practices based on textual data analysis

3.1 Text high-frequency word statistics and theme extraction

3.1.1 High Frequency Words and Percentage of Comment Data

The high-frequency words and their proportion in the preprocessed text data were counted to analyze the content of spatial imagery and sensory experience that the target group of community infant and toddler public space is most concerned about. Table 1 shows the statistical results of high-frequency words (the first 30) in the text data of community infant and toddler public space comments based on sensory experience. The top three words with the highest frequency of occurrence in the text data are "infants and toddlers" (8,636 times), "companionship" (6,851 times), and "play" (5,781 times). It can be seen that the target group using the community infant and toddler public space is most concerned about whether the space can well fulfill its function of accompanying children. Ranked 4-10 are “environment, space, vision, touch, hearing, smell, taste, quiet”, to realize the function of accompanying children, it also puts forward high requirements for the sensory experience of the space.

Figure 1 shows the frequency ratio of high-frequency words in each category of community infant and toddler public space review text data based on sensory experience. The high-frequency words with a frequency of 200 or more (3,500 words in total) were categorized and counted, and eight categories were obtained, including “five senses of space, spatial environment, spatial layout, spatial resources, spatial services, spatial features, spatial activities, and others”. The category of “five senses of space” accounted for the highest proportion, at 42.07%, followed by “spatial environment” at 15.25%.

Table 1: High-frequency word statistics results of comment text data (Top 30)

Serial Number	High-frequency words	Frequency	Serial Number	High-frequency words	Frequency
1	Infants and toddlers	8636	16	Feeling	2387
2	Company	6851	17	Reservation	2370
3	Playing	5781	18	Self-service	2263
4	Environment	4895	19	Atmosphere	2257
5	Space	4449	20	Culture	2252
6	Vision	3678	21	Region	2250
7	Tactile sense	3665	22	service	2226
8	Auditory sense	3637	23	Activity	2196
9	Smell	3481	24	Decoration	2157
10	Taste	3227	25	Open up	2145
11	Silence	2856	26	Free	2134
12	Registration	2651	27	Weekend	2123
13	Location	2643	28	Design	2110
14	Suitable	2627	29	Nearby	2074
15	Convenience	2513	30	Comfortable	2036

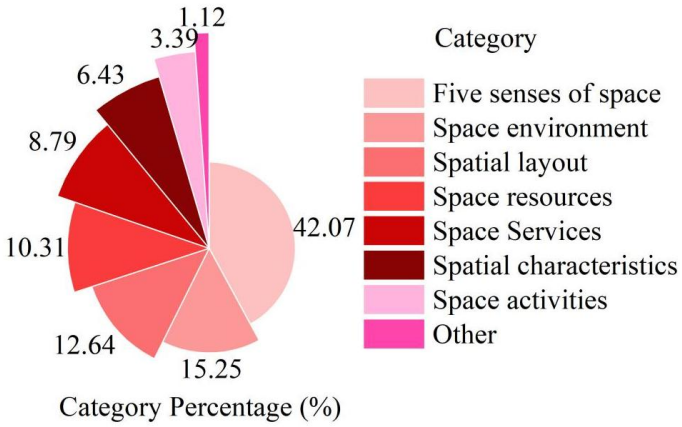

Figure 1: Frequency ratios of high-frequency words in each category

3.1.2 Text Topic Count Extraction and Analysis

The text data after counting the high-frequency words is used as the input of the LDA model to further determine the number of themes of the LDA model, in order to achieve the purpose of reducing the redundancy of theme repetition and improving the theme accuracy. Figure 2 shows the distribution of themes output from the LDA model.The number of themes output from the LDA model is 4, including: spatial environment and five senses experience, spatial layout and features, spatial resources and activities, spatial services and others. On the basis of the original categories, similar and repetitive categories are merged into one category to improve the accuracy of theme extraction.

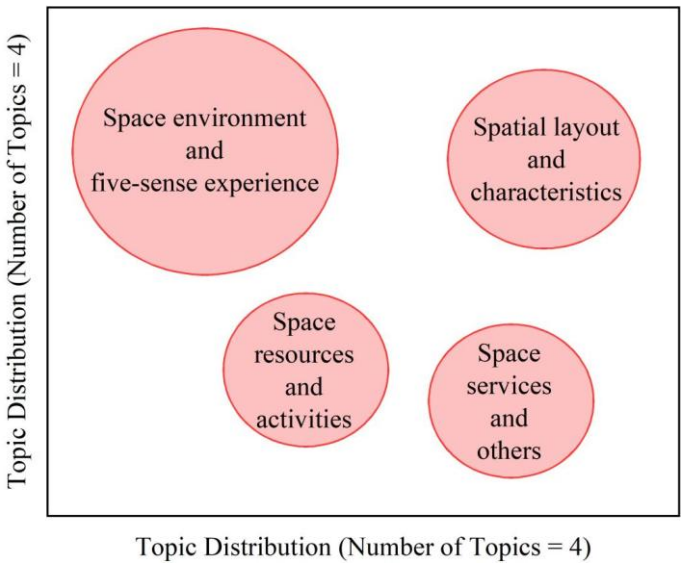

Figure 2: The topic distribution output by the LDA model

3.2 Random Forest-based feature selection for public space design

3.2.1 Model error and parameter optimization

The training effect of random forest directly affects the text classification effect and the selection of design features, so this section examines the model classifier effect and optimizes the CART decision tree parameters by random sampling. Draw the random forest coordinates in Fig. 3 and the structure of model error-decision tree relationship in Fig. 4. According to the random forest coordinates graph can be found that the classification effect of the 4 types of samples is more concentrated, which intuitively reflects the model's classification effect is good. Observe the model error and decision tree relationship graph, check whether the current number of trees (600) is the optimal parameter, it can be seen that the error in the number of trees 500 tends to stabilize (0.1205-0.1416), and the error of 500 trees and 600 trees did not see a significant change, and therefore retain the default number of trees set in the model (tree=600).

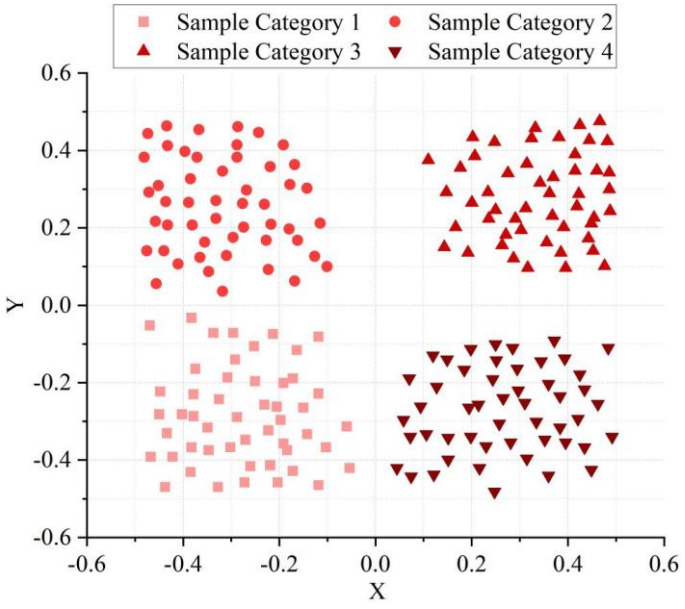

Figure 3: Random Forest Coordinates

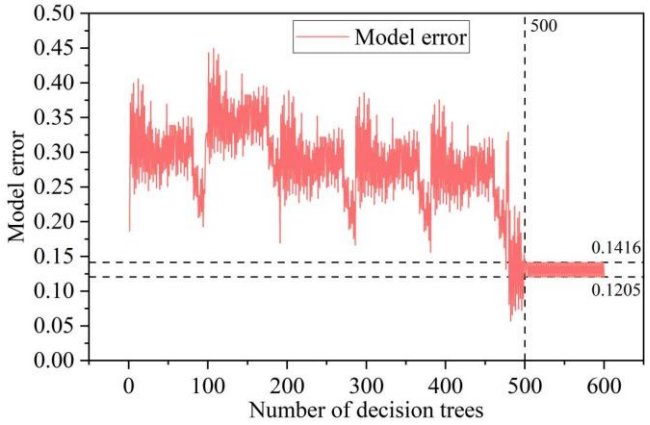

Figure 4: Model Error and Decision Tree Relationship

3.2.2 Contribution calculation and determination of optimal number of features

After determining the effect of the classifier obtained from learning, the random forest model is utilized for the design feature selection of public space for community infants and toddlers. First, the contribution degree of the design features to the value of the public space is output, and the distribution of the feature contribution degree is plotted in Figure 5. Analyzing the feature contribution scatter plot, it can be found that under the two contribution parameters of MDA and MDG, there are some differences in the contribution of the 25 design features to the value of public space for community infants and toddlers for the dependent variable, and some features have large differences in the contribution between them. Comparing the magnitude of the contribution of each design feature, it was found that the total contribution of the top 10 features was the largest under both the MDA and MDG parameters. Therefore the optimal number of design features for the model is set to 10.

Further analyze what exactly are the top 10 features in the random forest model under autonomous estimation sampling in Figure 6. The 10 design features that the target population of community infant and toddler public space pays the most attention to are: sight, hearing, touch, smell, taste, wall, line, point, color, and light. It can be seen that the target population is more concerned about the sensory experience that the public space can bring than the spatial services and spatial resources, which determines whether infants and toddlers can have a sense of security and belonging in the space, as well as whether they can play happily.

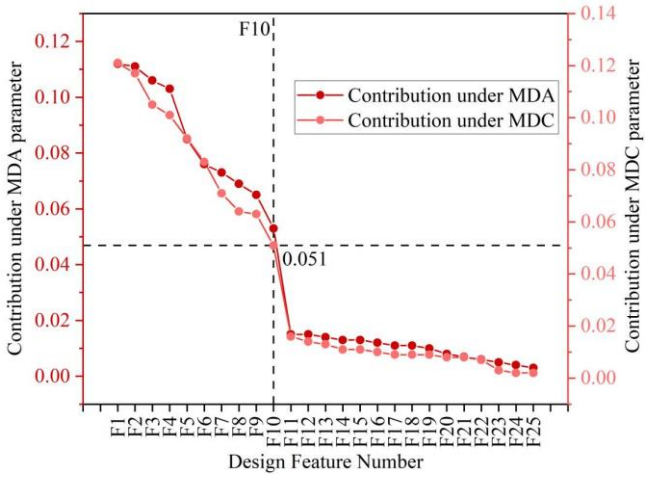

Figure 5: The contribution of design features to public spaces

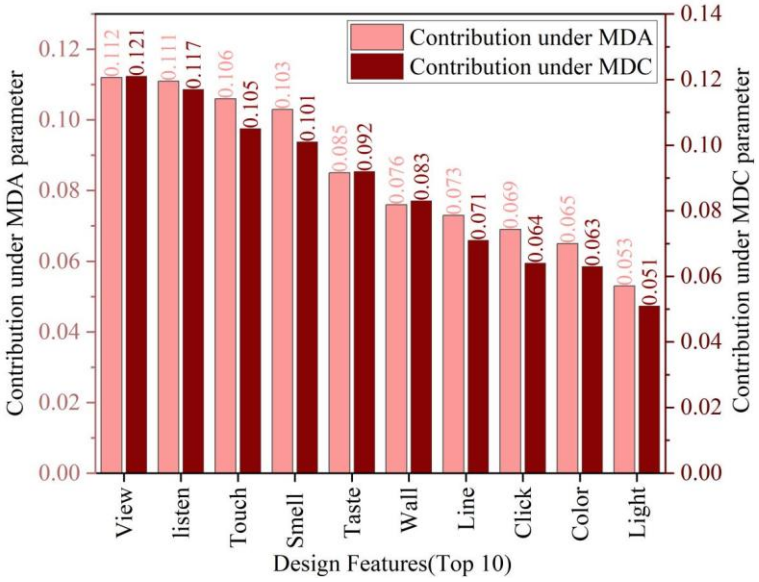

Figure 6: The top 10 features in the random forest model

4 Design and scoring of public spaces for infants and toddlers based on sensory experience

4.1 Public space design based on sensory experience

Design optimization of several community infant and toddler public spaces in the Y based on the 10 most critical design features analyzed by the Random Forest Model. The most influential part of sensory experience is visual experience, and color is also the most important part of visual experience. When planning and designing various color education environments in community public spaces for infants and toddlers, it is necessary to deeply understand the physiological mentality of infants and toddlers to cultivate various colors, and to consciously grasp their visual appreciation and image understanding of various colors, so as to reasonably carry out holistic color decoration and image construction in community public spaces for infants and toddlers. For example, in the guidance system of community public space for infants and toddlers, high purity and bright colors, minimalist lines and geometric shapes can be used more often as the guide of the space.

Environmental comfort also has an impact on infants and toddlers, who are dependent on the activity environment and whose level of physical and mental development and tastes are modified by the environment. Restoring nature and enhancing sensory experience are also the basic principles of community public space design for infants and toddlers, aiming to create a pleasant, comfortable, healthy, energetic, stimulating thinking and imagination environment and space for infants and toddlers. For the design and creation of public space for infants and toddlers in the community, in addition to meeting the requirements of safety, hygiene, health and other requirements of smell and taste, the walls, seats, free activity areas, etc., should also return to the colors and light of nature as the basis of design, restore the sounds that exist in nature, as well as the plants and animals that can be touched.

4.2 Overall rating for public space design

After completing the design and remodeling of a number of community spaces for infants and toddlers in District Y, 150 infants and toddlers and their parents were invited to experience these

community spaces for infants and toddlers in the district. After completing the experience, the parents of the infants and toddlers, as well as the infants and toddlers who were able to make their own evaluations, were asked to evaluate the public spaces they experienced through a questionnaire. The design of the community infant/toddler public spaces was evaluated in 10 dimensions, with 2 questions for each dimension, and each question was rated on a scale of 1-5. Table 2 shows the results of the evaluation scores of community infant and toddler public spaces based on sensory experience. The overall score of community public space for infants and toddlers based on sensory experience is 4.440±0.191, and the highest score in each dimension is “good visual experience” (4.489±0.159), and the second highest score is “space with sufficient light” (4.421±0.135). Overall, the mean scores of the 10 dimensions were all above 4.00, indicating that the target population is more satisfied with the design of community public spaces for infants and toddlers based on sensory experience.

Table 2: Evaluation score of public spaces for infants and toddlers in community

Evaluation dimension	Mean±Std.	Variance	Standard error	Mean value 95% CI(LL)	Mean value 95% CI(UL)	Coefficient of variation (CV)(%)
Overall evaluation	4.440±0.191	0.816	0.094	4.118	4.073	27.460
Excellent visual experience	4.489±0.159	0.829	0.094	4.194	4.143	26.015
Excellent auditory experience	4.164±0.230	0.855	0.072	4.076	4.049	28.272
Excellent tactile experience	4.361±0.187	0.902	0.098	4.109	4.017	27.502
Excellent olfactory experience	4.315±0.163	0.811	0.107	3.837	3.885	31.345
Excellent taste experience	4.420±0.127	0.832	0.096	4.245	4.179	25.268
Variety of colors of wall	4.375±0.318	0.722	0.088	4.367	4.226	23.832
Variety of geometric lines	4.275±0.194	0.913	0.101	4.046	4.013	28.293
Well-lit of space	4.421±0.135	0.738	0.103	3.781	3.811	33.513
Variety of plants and animals	4.286±0.182	0.652	0.086	4.427	4.343	23.087
Clearly visible directional signs	4.289±0.211	0.905	0.095	4.101	4.062	27.475

5 Conclusion

This paper integrates the LDA topic model and random forest algorithm to provide design features and other references for the design of public spaces for infants and children in the community.The text data is classified best when the number of LDA topics is 4. Random forest calculates the 10 features with the highest contribution of design value as: sight, hearing, touch, smell, taste, wall, line, point, color, and light. Based on the data analysis results of the community infant and toddler public space design, the overall score is around 4.440 ± 0.191, and the user's visual and other sensory experience satisfaction is very high. Enhancing the

sensory experience of community infant and toddler public spaces is good news for both infants and toddlers involved in community activities and their parents. This not only enhances the quality of infant and toddler growth and promotes family harmony, but also provides a boost to people's well-being.

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