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A STUDY ON DESIGN ELEMENTS OF INTERACTIVE FACILITIES IN PUBLIC SPACES BASED ON CHILDREN’S PLAY BEHAVIOR

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ABSTRACT
This paper examines the activity behavior patterns of children in both older residential communities and modern urban communities, comparing the activity patterns and needs of children during their cognitive development. By exploring the connections between children’s activities and spatial elements, the study extracts key environmental design elements based on children’s observed behaviors. Additionally, during the pandemic, children’s activities became more frequent but also more constrained within community spaces. Through a review of existing literature and analysis of firsthand data from surveyed environments, this research identifies commonalities and differences in children’s activities across various spatial settings, outlining the essential design elements for creating child-friendly spaces. It also highlights the elements that detract from child-friendly and ecologically sensitive designs. This research endeavors to contribute to the conceptualization and design strategies regarding the creation of child-friendly spaces. It plays a catalytic role in facilitating the renewal and transformation of aged urban public spaces that fall short in catering to children’s growth and development requirements. Moreover, it functions as a critical framework for designing child-friendly environments that effectively support children’s development and well-being.

Keywords: Space Design, Child-friendly, Public Space, Facility Design

1 INTRODUCTION

With the advancement of urban modernization and the improvement of people’s living standards, there have been significant changes in the activity patterns of children in cities, along with notable differences in the activity preferences and characteristics of children at different age levels. This has created new demands for spatial design. While children aged 3 to 5 engage in mainly simple and equipment-assisted activities with more sitting and standing games, those aged 6 to 8 are more active and restless, and children aged 9 to 12, being in a crucial cognitive growth phase, have a higher demand for puzzle games. Through qualitative research, the focus is on children aged 6 to 12 in this study as they are in a key growth and cognitive period [1]. Compared with the previous generation (around 1970s), the activity patterns and game varieties of modern children have gradually become monotonous. For example, scribbling with chalk, playing hide-and-seek, playing marbles, playing street baseball, stepping on seesaws, doodling on the ground, disassembling old baby carriages, climbing railings, etc. They can better feel sand, stones, sunlight and rain, but nowadays outdoor spaces leave them with nothing to do [2].

Outdoor spaces are an essential component of children’s environments, profoundly influencing their development. A well-designed outdoor environment enhances children’s sensory perception and provides valuable experiential opportunities [3]. These spaces mainly promote their physical and mental development in the following aspects: (1) Improve motor skills and tactile perception; (2) Promote children’s understanding and cognition of the world; (3) Promote their ability to interact with others; (4) Develop moral qualities and personality characteristics [4].

Some poor designs in space also restrain children’s activities, such as undulating roads, overly hard pavement, and uninteresting facilities. A study shows that improper application of plants in space has caused rhinitis in children. There are even cases showing that excessive screen time and sedentary behavior of children have also led to symptoms such as childhood obesity [5]. If outdoor spaces are not attractive enough for children’s activities, then it will inevitably increase sedentary time and time spent

on video games. On a deeper level, to a certain extent, it contributes to problems such as childhood obesity, social barriers, and mental health problems. Therefore, children's activity spaces need to be adapted to children's cognitive growth.

Although theories of human-environment interaction in public space design provide significant reference value for spatial planning [6], children's spaces often lack sufficient attention and detailed considerations. While emphasizing the significance of functional configurations and visual appeal in promoting children's physical and mental development, some scholars contend that children often adopt passive roles in spatial interactions [7].

A study integrates literature on urban green spaces, child-friendly cities and environments, and children's infrastructure, proposing the concept of Child Green Infrastructure (CGI). It emphasizes the need for more equitable, inclusive, and participatory approaches [8]. In addition, a study on kindergarten space design indicates that three critical dimensions are essential for children's spatial design: human-to-human interaction, human-to-object interaction, and human-to-environment interaction [9]. Furthermore, cognitive psychology provides essential guidance in understanding children's needs [10], enabling the design of environments that align with their psychological traits and behavioral patterns. For instance, preschool spaces should prioritize exploration and interaction, while adolescent spaces should address social and privacy needs [11]. Additionally, the integration of design thinking principles further refines the approach to designing children's spaces [12]. These insights offer a valuable foundation for constructing frameworks tailored to child-friendly public spaces.

However, participatory design strategies and framework is especially crucial. Further research on children's public spaces should focus on children's autonomous, play-oriented behaviors that frequently occur in these environments. Children's activities in spaces represent dynamic human-environment interactions, requiring designers to move beyond merely addressing physical functions to consider carefully crafted and rationalized user experiences. Drawing from the five elements of interaction design—users, actions, tools, goals, and contexts—designers should integrate children's developmental research to better understand their spatial perceptions and preferences [13].

This study investigates children's behavioral patterns and provides insights for creating optimal activity spaces. It aims to assist designers in comprehending children's motivations and preferences in play, thereby exploring novel approaches to child-friendly space design. For children, enhanced environments promote outdoor activities and fulfill cognitive and developmental needs through active spaces. For designers, developing spatial strategies from the perspective of children's activities helps update urban public spaces, fostering human-centered, child-friendly environments.

The objective of this research is to compare children's behavioral patterns across different community environments, specifically between spaces with high activity levels and those in aging communities with limited child-friendly features. It examines the types, frequencies, and preferences of children's activities in these environments, exploring how spatial elements influence children's interactions, play, and socialization. This paper aims to establish a catalog of spatial elements favored by modern urban children, describe spatial features that attract them, and explore fundamental principles for designing child-friendly environments. Emphasizing the long-term applicability and effectiveness of these principles, the study offers valuable insights for urban renewal and the design of children's facilities.

2 METHODS

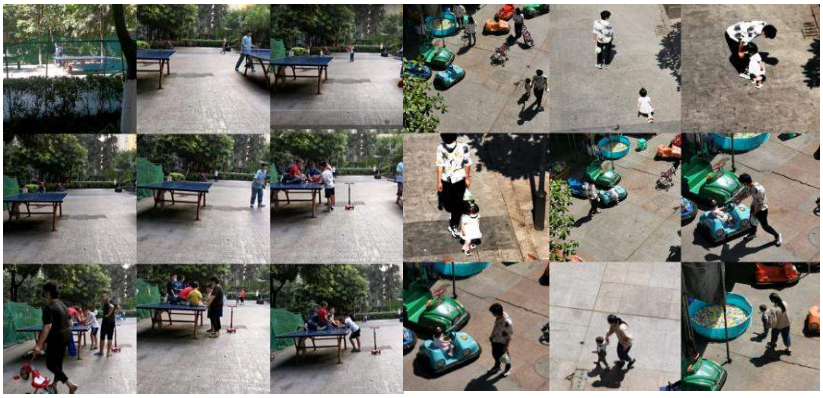
This research aims to derive insights from the comparison of time and space. Through qualitative and quantitative analysis, two typical public spaces lacking child-friendly design, one old and one new, are selected and investigated. The activity spaces in a modern community in Chongqing (lacking facilities but with more children's activities) and an old-fashioned community in Chongqing (with imperfect facilities and relatively less play space) were compared and studied. The study uses a combination of research methods, including time-lapse photography (Figure 1), fixed-point observation, marking characteristics, and activity classification, based on public space research theory [14]. At the same time, the sample spaces mainly have the following standards: (1) Located within the research area; (2) Located at the intersection of major traffic routes such as residential areas; (3) Public areas. Subsequently, the morphological indices of these spaces are then measured, and children's activity patterns are recorded.

The specific process of the research method is as follows: First, the study selects eight objective indicators in four aspects related to space: site area, green coverage rate, number of seats, pergola coverage rate [15], color diversity within sight, and surrounding greening rate [16] (Table 1). These indicators are convenient to measure and have a great correlation with children's activities. After

investigation and measurement, the data of each sample space is summarized and analyzed. Methods such as interviews, preliminary investigations, on-site surveys, questionnaires, literature analysis, and data analysis are used to discover site problems and propose design visions and strategies.

Table 1: Percentage of objective indicators of the spatial form of a sample A and Sample B

Sample	Space Composition		Facility Configuration		Landscape Characteristics	
	Site area	Green coverage rate	Seat area	Pergola coverage rate	Hard pavement	Waterscape area
Sample A: modern community space	1	32.4%	0.57%	4.7%	60.2%	2.2%
Sample B: an old-fashioned community	1	11.7%	0.15%	1%	58.9%	area 1.7%



(A) (B)

Figure 1. Time-lapse photography. (A) Community Space Ping Pong Table. (B) Community Commercial Street Playground Facilities.

Within a continuous period of one month, the study combined with the spatiotemporal relationship of the site, has continuously observed children's daily behaviors in the selected sample spaces, and record continuously for no less than 7 hours. To accurately document children's daily lives, this study adopts an approach that allows for a clear observation of their activities and cognition while seamlessly integrating with spatial dynamics. During the recording process, both the observers and the recording equipment are positioned to minimize interference with the children's activities and avoid drawing their attention. Time-lapse records are taken to make a study on activity frequencies at different times of the day. Classify the surveyed children (Table 2) and record the frequency of each activity type.

Table 2: Coding and interpretation of children's behaviors

Type	Coding	Interpretation
Interpretation	Buying things	Selecting goods, making payments, and getting change at neighboring supermarkets or small stores.
Leisure activities	Playing with pets	Petting, amusing, feeding, and playing with pets.
	Eating or drinking	Literal meaning
	Conversing	Two-way communication.
Chasing games	Chasing games	Chasing and playing around. Generally, the person who loses a game chases other player.
	Throwing sandbags	(Stones, cloth toys, hats, etc. can all serve as sandbags). Confirm the target through throwing sandbags and conduct forward and backward chasing and catching.
	Machine gun games	Using toy versions of toy guns, some with plastic bullets and some with laser guns.
Tabletop toys	Playing cards	Spreading out cards on a table or on the ground in groups of three to five and playing according to the rules of game cards and collecting.
	Assembling toys	Spreading out model parts on a table and several children assemble them together.
	Playing house	(mostly for girls) Simulated business games and simulated talking and imitating forms with dolls.
	Playing table tennis	Literal meaning
Cycling	Cycling activities	Slapping game, In the form of guessing fists or black and white matching among two or more children, the loser accepts the punishment of being slapped on the hand.
	Riding a skateboard	(Children's skateboards are of different types, mostly two-wheeled skateboards with handrails, and there are also single-wheeled and styles without handrails).
	Riding a bicycle	Literal meaning
Sport	Dancing	Literal meaning
	Hopscotch	Drawing grids on the ground with chalk and playing games.

	Long jump	Literal meaning
	Skipping rope	Literal meaning
	Flying a kite	Literal meaning
Reading		Literal meaning
Playing with mobile phones		Literal meaning
Passing by		Passing through the space without stopping (just passing through here to go to another place without other activities).

3 RESULTS

3.1 Probability of occurrence of different behaviors

Through observation and questionnaires, in the two sample spaces, most children are aged 6-12, while the proportions of those aged 3-6 and 12-16 are only 17% and 28% respectively (Figure 2). Thus, middle and low-aged children are determined as the main research objects. Among them, the activity frequency of children is mainly activities such as playing cards, riding toy cars, playing with toys, and gathering to play video games. The activity time of children is mostly around 1 to 2 hours. From a spatiotemporal relationship, their playtime is mostly after dinner, concentrated and regular, and activities increase on weekends and on sunny days. Subsequently, children's activity data is sorted out according to time-lapse photography and photos.

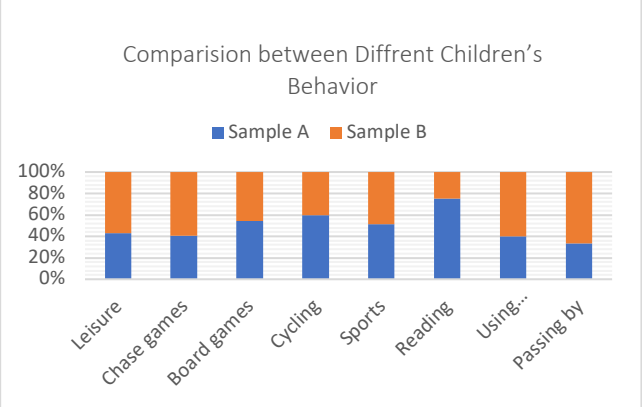


Figure 2. Frequency of Occurrence of Children's Behaviors. The frequency of sample A is calculated as sample A / (sample A + sample B), and the frequency of sample B is calculated as sample B / (sample A + sample B).

According to *Life Between Buildings* [17], longer outdoor stays are typically observed in vibrant residential areas and urban spaces. Based on behavioral surveys, this study analyzes the types of behaviors exhibited by children in these spaces and the frequency of their occurrence. Using "conversing" as an example, the study combines spatial form index data to explore the impact of spatial configuration on the frequency of children's activities.

Among them, the main activities with high frequency are the following categories: chess and card games, cycling, and sports activities. These activities are strongly correlated. Although behaviors such as chasing or onlooking occur less frequently, when they do, they tend to last longer and draw in additional children. The results show that when designing child-friendly spaces, priority should be given to meeting the activity needs with high probability of occurrence. In this study, the occurrence frequencies of "skateboarding," "dancing to music," "chasing," "passing by," and "playing musical instruments and singing" in the two sample spaces are higher than other behaviors and are worthy of consideration.

3.2 Impact of spatial form on children's behavior

Based on the analysis results, this study deeply explored the "chasing game". Through sample comparison, it was found that in the two spatial form indicators, the width of the adjacent street and the number of seats significantly affect the frequency of the "chasing game" among children in the public space. The activity space used by children has an uneven spatiotemporal distribution. In public space A with a large area, conversations are more likely to occur. The wider the adjacent street, the stronger the sense of openness. It can be inferred that the sense of openness of the public space may affect the frequency of children's chasing games.

There are more seats and spaces for people to rest in sample A than in sample B. In terms of activities, reading and tabletop games are also significantly more than in sample B. Thus, it shows that the number of seats and tables has an impact on the frequency of children's conversations and reading. More plans for sitting down to relax and chat increase the possibility of communication. Tables provide a platform for children to place game toys. Therefore, a reduction in the number of tables and chairs will have a negative effect on the frequency of conversations.

Children have diverse activity methods and complex behavior patterns [18]. Children's amusement facilities are difficult to meet children's activity needs. In the space, entertainment facilities are the carriers of children's outdoor entertainment. Children are interested in some "wild" corners, such as long ladders, flower bed corners, slopes, etc., but use traditional and stereotyped amusement facilities less frequently. It can be concluded that landscape planning needs to be coordinated with children's facilities.

In the landscape, especially the improper configuration of plants, such as sparse plants and shrubs, there are potential safety hazards for children's activities. In terms of the combination of landscape and space, the planting of flowers and the like will attract children more. The shade of big trees also makes children more active. Small-scale landscape spaces are more charming. The proportion of green space area is relatively high, but children's activities rarely involve it, which is obvious in both residential areas. The reason is that on the one hand, because the green space is a restricted activity type, reasons such as uneven ground make it difficult for dynamic activities favored by children such as bicycles and scooters to pass through this space [19].

3.3 Children are more active in communities with better facilities and landscapes

There is a certain sense of disorder and safety threat in the activities, and it is more obvious in sample A. In the comparison of old and new communities, children's activities are more frequent in communities where the elderly are active. This finding is in line with the positive and negative effect processes: the occurrence of activities is due to the occurrence of activities [17]. Children's activities are intervened by parents to different degrees and are related to the activities of the elderly. In the negative effect process, on the contrary, a bad environment reduces children's activities and increases children's dependence on virtual games, and may also exacerbate children's emotional disorders and autistic tendencies.

3.4 Consideration of safe distance in facility design

Under the suspension of classes due to the epidemic, it did not lead to a large fluctuation in the activity volume of children in the residential area. Insufficient and poor activity venues in the residential area are the main constraining factors. The residential area environment guides the choice of children's activity types. Under the epidemic, a safe distance is consciously maintained in activities [20], and overly crowded or aggregated activities are dispersed. The view that "activity venues should be kept at a distance" under the epidemic is a common consideration factor in our space design.

4 SOLUTIONS

4.1 The perspective of behavioral observation in space

In general, the children's behaviors and environmental cognition, as shaped by the epidemic, reflect patterns that have universal applicability. There are fewer children's activities in old communities with poor environments, which are closely related to environmental factors such as children's amusement facilities, landscape configuration, space safety, and space negative effects. By studying children's activity patterns - the activities with the largest proportion are card games and cycling, improving unfavorable and friendly designed public spaces-narrow areas and excessive hard pavement. For beneficial spaces, analyze the proportion of elements - high greening rate and low-lying landscapes can more conform to children's game patterns, summarize spatial elements, and are also applicable to the design of children's activity spaces during the epidemic closure period and after the lifting of the closure.

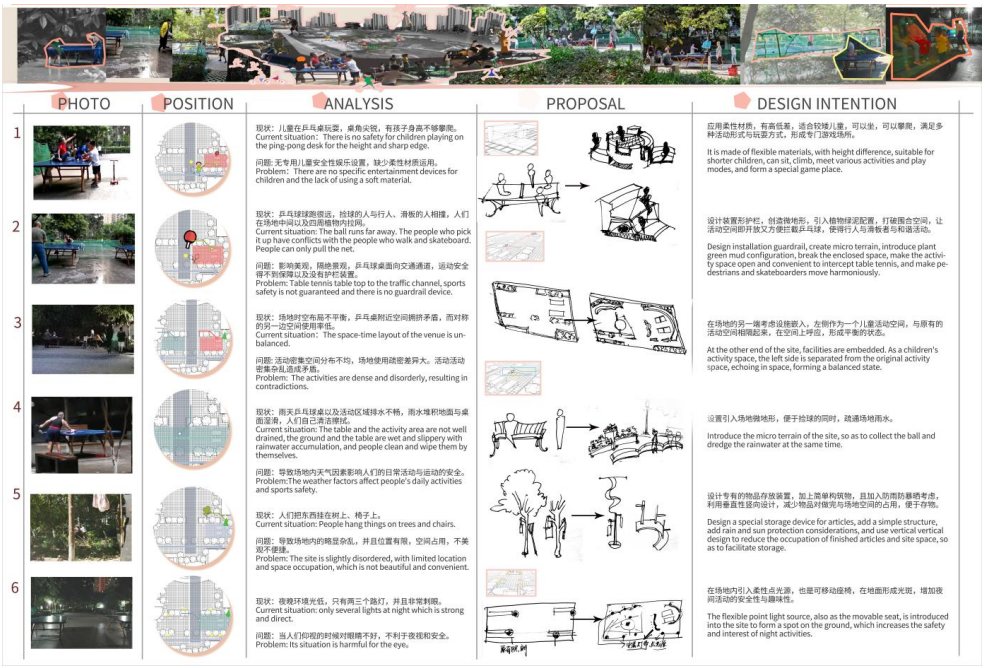


Figure 3. Children's space improvement design proposal

The proposal for the improvement of child-friendly spaces summarized in this study is put forward based on the observational perspective of children's behaviors (Figure 3). Through analyzing the positions of their behaviors in the space as well as the current situation and existing problems of the space, a new design proposal based on behavioral observation is presented. This framework encompasses the design inspirations (intentions). It evolves from "Photo position and nice Proposal" to "design intentions".

The Double Diamond Model consists of four stages (Figure 4), namely "Discover", "Define", "Develop", and "Deliver". During the "Discover" stage, in the research on children's spatial behaviors, in addition to conventional methods, social observation and interview-based research on spaces with high children's activity levels are added. From the perspective of planar space, the relationship between behaviors and spatial elements is analyzed to construct an observational mechanism, which is a refinement and expansion of the traditional "Discover" stage. In the "Define" stage, core problems, requirements, and goals are clarified based on the preliminary information to determine the design direction. In the "Develop" stage, various design schemes are conceived by utilizing relevant materials according to the determined direction to improve the design. In the "Deliver" stage, the design schemes are evaluated and screened, the optimal one is selected and further refined to ensure the feasibility and practicality of the design implementation.

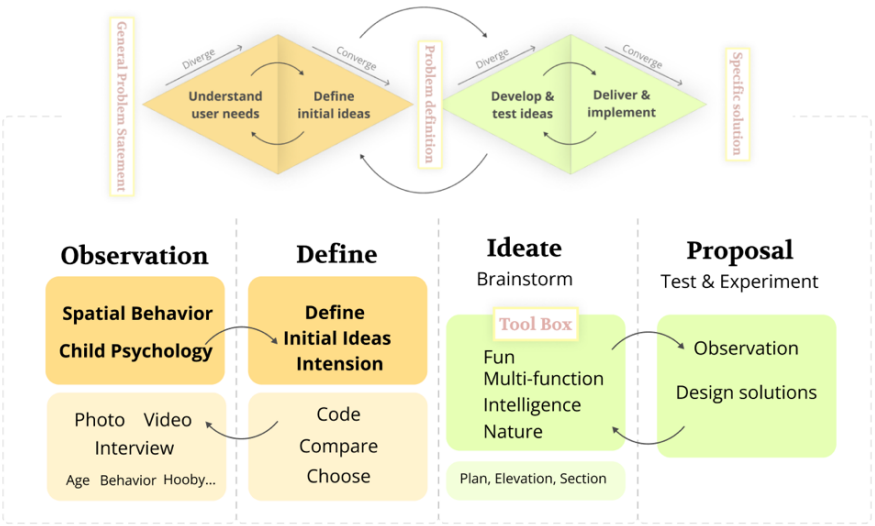


Figure 4. Double Diamond Design Process for Designing Child-friendly Spaces

Through the close integration with elements such as children's behavioral observation, the design process becomes more scientific and targeted, serving the goal of improving child-friendly spaces. Meanwhile, Photo observation is combined with user interviews and other aspects, and the "position" part is associated with user journey maps and the like. The new strategy disassembles and analyzes from multiple dimensions, enriches and improves the flattened design schemes, and its preliminary work corresponds to the sketching and other links in the design thinking process.

4.2 Design with More Functional Elements through the "Toolbox"

Based on the conclusions of research and observation, this study has put forward a toolbox strategy centered around children's activity elements, which expands from four dimensions, namely Fun, Intelligence, Multi-function, and Nature, aiming to enrich the application of design elements in the design of children's spaces.

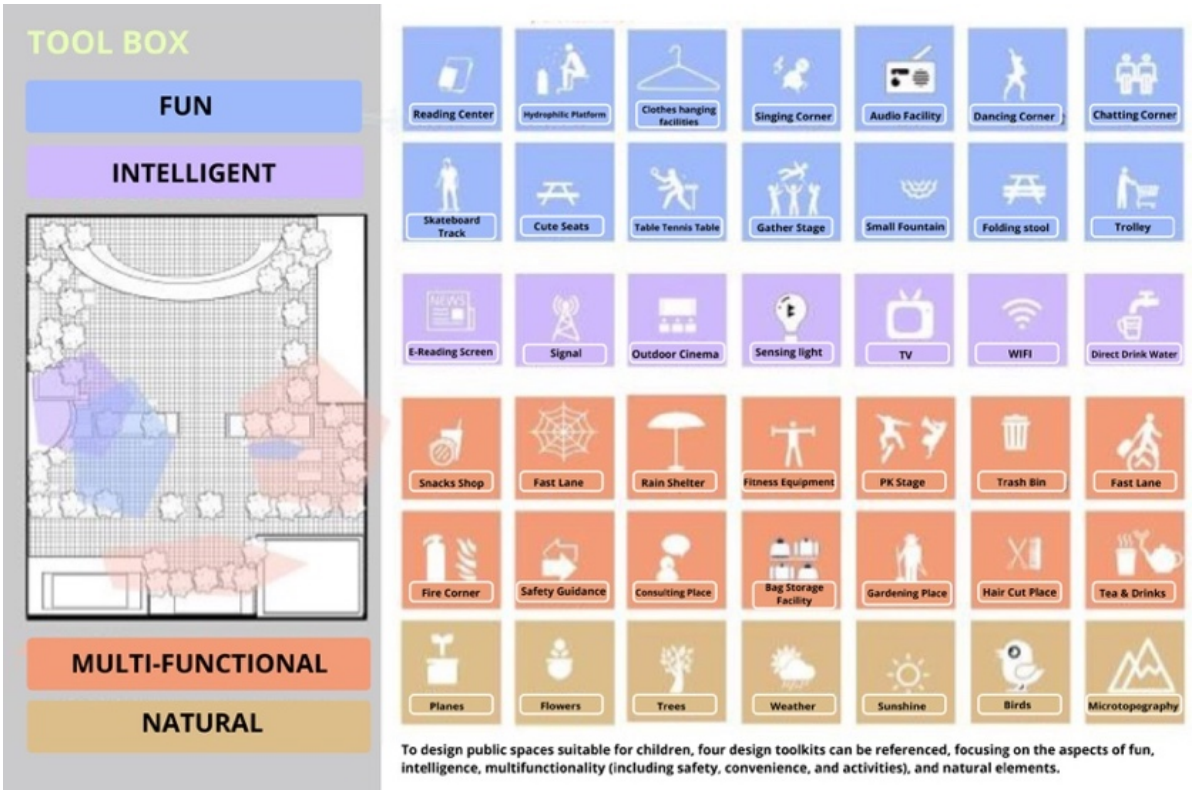


Figure 5. Newly added toolbox of children's activity elements

Based on the conclusions of research and observation, this study proposes a strategy of a toolbox for children's activity elements, which expands from four dimensions, namely "fun", "intelligence", "multi-function", and "nature" (Figure 5), increasing the application of different elements of design content in the design of children's spaces. In terms of interesting settings, the toolbox includes elements such as reading corners, waterfront platforms, singing corners, music flash mob stages, skateboarding areas, table tennis areas, folding stools, and various exclusive devices for children, aiming to stimulate children's interests and enhance the attractiveness of the spaces. From the perspective of intelligence, the toolbox incorporates technical devices like electronic reading areas, wireless network coverage, outdoor film screening systems, and intelligent lighting devices, with the expectation of providing children with a more convenient and modern user experience. In the realm of multifunctionality, the toolbox presents numerous innovative designs that address children's needs. For example, there are small pavilions with both rain shelter and resting functions, fitness facility parks equipped with guardrails, intelligent trash cans, fire hydrants, emergency passages, chatting areas, and storage racks, etc. These add diverse usage scenarios to children's activity spaces and achieve functional integration.

4.3 Specific Solutions

4.3.1 Improve Children's Amusement Facilities

To cultivate child-friendly public spaces, the diversification of children's amusement facilities should be prioritized alongside the integration of spatial installation art. Innovative installations and landscape arrangements can enrich these spaces, while the design process must be informed by a scientific understanding of children's cognitive and developmental stages. By tailoring spatial design to their age-specific needs, public spaces can support children's educational and sensory development.

A systematic analysis of children's sensory experiences is essential for effectively organizing artistic resources, with attention to the application of color [21]. Rather than relying on adult-oriented rational planning, designs should stimulate children's color perception, utilizing artistic installations and thoughtful material choices to encourage active participation. Flexible materials and low-saturation, soft color palettes can foster outdoor installations that blend functionality with imaginative, childlike qualities, enhancing both engagement and educational value. Designers should integrate more functional elements into the space to broaden the variety and possibilities of children's activities, thereby providing a richer range of experiences and interactive opportunities.

4.3.2 Enhance the Integration of the Elderly and Children in the Space.

Enhancing the design of environmental spaces that cater to both the elderly and children is crucial. In children's activity areas, it is important to consider their group travel patterns and family-accompaniment modes by creating opportunities for positive interactive engagement. Designing play areas for children should be complemented with adjacent activity spaces for parents, promoting shared experiences. Efficient utilization of the site is necessary, ensuring an even distribution of activities across time and space. For instance, alongside children's play zones, integrating flower bed seating and accessible water features for the elderly can provide comfortable resting areas. Such two-way interaction design not only enhances the positive impact of the space but also fosters vibrancy, encouraging greater participation and enriching the overall spatial experience.

4.3.3 Differentiate Space Design according to Children of Different Age Groups.

As indicated by literature research and observation results above, there are significant differences in the activity patterns of children of different ages, and their growth and cognitive needs also vary. Therefore, while children are playing, it is necessary to introduce phased and different forms of recreational activities. When it comes to space design, designers can create areas for popular science enlightenment, leisure and relaxation, sports activities, natural experiences, etc., which respectively correspond to various needs of children such as leisure, entertainment, sports, and cognition. Through such an approach, it may be possible to bring order to children's activities, enabling them to play without disturbing each other and allowing children of all ages to enjoy themselves harmoniously together.

4.3.4 Make Children's Spaces Ecological and Immersive

Make full use of natural elements to stimulate exploration interests and create an ecological and immersive environment for children's spaces. Plant low shrubs in the site, design landscape gardens, and rationally match color relationships according to the landscape changes in four seasons to create an immersive landscape environment and create "wildness" and "liveliness" in residential areas for children to explore and play in. For example, as pointed out in the case [22], forest kindergartens designed through planting gardens connect children and nature. As Jane Jacobs said that children's outdoor activities accumulate [23]. They have a greater sense of liveliness and freedom in their requirements for space.

5 CONCLUSION

In the design of children's environments, it is essential to adopt a holistic approach. As William Whyte aptly noted, elements such as sunlight, fresh air, accessible refreshments, and seating arrangements are fundamental to creating engaging spaces [24]. Public spaces, by nature, are intended for universal participation, necessitating a comprehensive consideration of all elements and stakeholders within the targeted area.

Combined with the characteristics and needs of children's activities exposed under the epidemic situation, by introducing child-friendly environmental factors, design safe and comfortable activity

methods to improve the living environment. Designers need to construct more humanized and attractive child-friendly spaces for them [25]. The research results of this experiment on the relationship between spatial form and children's behavior can be used as learning data on the relationship between children's activity behavior and space under the epidemic situation and applicable under the normalized epidemic situation, providing design references. Moreover, the experimental findings on the impact of spatial configurations on children's behavior provide critical insights for informing decision-making logic in the design process. Designers should leverage these results as a foundation for systematically observing and analyzing children's behavioral patterns within various environments, while accommodating their evolving cognitive and developmental trajectories. Such an approach can lead to the refinement and optimization of existing child-friendly public space design frameworks.

In conclusion, by synthesizing research on children's psychological development, cognitive behavioral patterns, and interaction design theories, a more systematic and comprehensive design methodology can be established. This integrated framework offers robust theoretical underpinnings and practical strategies for advancing the design of future child-friendly public spaces.

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