Analysis of the Relationship between Landscape and Children’s Behaviour in Chinese Residential Quarters

Rui Zeng\(^1\) and Zao Li*\(^2\)

\(^1\)Ph.D. Candidate, Hefei University of Technology, China  
\(^2\)Professor, Hefei University of Technology, China

Abstract
The aim of this study is to investigate how children behave in the landscape of three Chinese residential quarters. Based on information collected through investigation using Principal Component Analysis and Cluster Analysis, the residential landscapes are classified into ten types, each of which can be generally described according to four spatial factors—exposure, proximity to water, accessibility, and relative building facade. The results show that: 1) playing is the most typical behaviour of children; 2) space with some degree of exposure has a more obvious effect on the distribution of children’s behaviour, and most children prefer to play along the waterside; 3) children without independent action ability tend to play in a semi-open space with a safe and stable environment, while those with independent action ability choose their play space more freely; 4) integrated open space that can be easily accessed, has a waterfront landscape and is near a building facade, may significantly stimulate children’s behaviour.

Keywords: children’s behaviour; residential landscape; principal component; cluster; visualization

1. Introduction
Most children learn about the surrounding world by physically interacting with it. For them, life is movement and sensory stimulation (Piaget, 1952). Apart from preschool or school, residential outdoor space, especially landscape, is possibly the most common outdoor built environment experienced by children (Sonenstein, \textit{et al.} 2002). Many previous studies have provided evidence that such environments potentially offer substantial physical and psychological benefits. Activity and communication in residential landscapes develops children’s abilities and shapes their worldviews.

Recently, with the development of the Chinese economy and the rapid acceleration of urbanisation, more and more urban residential quarters have been built. However, as they are driven by external and economic constraints (budget, licensing and space limitations), rather than educational or children’s health requirements (not to mention their psychological requirements), some residential environments nowadays concentrate more on the aesthetics of place, without fully considering residents’ physical requirements, especially those of children. The direct result is that children lack a suitable place to play and engage in free activities. Accordingly, the utilisation rate of some public spaces is decreasing, with many landscape facilities remaining unused.

This is the main reason for conducting this study. It seeks to reveal children’s behavioural characteristics and psychological demands in urban residential landscape, and to find out the impact of landscape on children’s behaviour, so as to incorporate improvements in the quality and usability of residential landscapes in future design and practice.

Based on observation and visualization records, this study attempts to make clear the relationship between the landscape and children’s behaviour. More specifically, it aims to explain the distribution of behaviours in the classified space, and to distinguish the behaviours of two kinds of children— young children with no or little independent action ability and older children with independent action ability— using both qualitative and quantitative methods.

2. Previous Studies
2.1 Theoretical Research
Children learn about the environment and themselves by picking up environmental cues and by performing physical activities such as climbing, catching, jumping, rocking, rolling, running, sliding, walking and so on. However, the environment must be designed to afford these activities (Cosco, 2013).
Since environmental psychologist Heft (1998) published a taxonomy of children's environmental affordances, presenting a preliminary conceptual and operational framework, the concept of affordance has been regarded as key to explaining the relationship between the built environment and children's behaviour (Gibson and Pick, 2000). According to the theory of affordance, the individual and the environment can be considered as an interactive system. The environment helps children learn about both the functional properties of the environment (layout, objects, and events) and themselves by using themselves in relation to their physical abilities (Gibson and Pick, 2000).

Other significant research includes Chatterjee's 2006 examination of the relationship between children and space. Chatterjee summarised four types of children's favourite place: interesting place, creative place, study place, and sheltered place. In 2010 Märit revealed— through interviews and questionnaire surveys— that particular play equipment can attract children, but that the frequency of their visits is not only related to the equipment but is also associated with its placement, the whole environment, and place-specific qualities.

2.2 Method Exploration

Behavioural observation is the most common method used to investigate children's behaviour in associated environments. Japanese researchers Young-sam Yun et al. (2003) researched the relationship between ways of using space, the specific characteristics of place for staying, and environmental factors. Through observing children's behaviour, the authors studied patterns in the place for staying and other spaces using various parameters, including time and users, and additional environmental factors such as different ground surfaces that may enhance the flexibility and variety of play.

Based on behavioural observation, behaviour mapping is a visual observation method that uses points to represent behaviours. It records the location of subjects and measures their activity levels simultaneously. It is an innovative method for assessing built environment components and attributes associated with physical activity levels (Cosco, et al. 2010). The method is based on the concepts of affordance, as mentioned previously, and behaviour settings, which are ecological units where the physical environment and the behaviour are indissolubly connected (Heft, 1998). Behaviour settings can be defined by material lines on the ground subdividing physical components of the landscape, like the edge of a pathway or the boundary of a playhouse.

Through application of behaviour mapping, Kinoshita (2007) used pencil-and-paper methods to gather data and hand graphics to spatially represent results at the level of residential neighbourhoods, parks, playgrounds and schoolyards, so that the behavioural dynamics of the built environment could be made clear.

2.3 Related Research in China

In China, research on children's behaviour and psychology in activity spaces started relatively later, and most scholars paid more attention to the theoretical study of activity space planning methods. Meanwhile, motivated by current common problems of children's activity spaces in urban residential quarters, some researchers have studied the physiological, psychological and behavioural characteristics of children at different ages via questionnaires and behavioural observation, and pointed out the main requirements that should be noted in designing children's recreation spaces (Qin, 2010).

Unlike previous studies, this research analyses children's behaviour in classified residential landscapes, and explores the relationship between the two.

The method applied in this study combines behaviour observation and mapping. The variety of children's behaviours can be visualised clearly by using different symbols on maps instead of single points. As a result, with statistics and visualization records, we can gain a better understanding of children's behaviour in residential landscapes.

3. Materials and Methods

3.1 Outline of Investigation

The authors chose to investigate the central landscape of three typical residential quarters, named SJ, AJ and XY, all located in Anhui Province, in the valley of the Yangtze River in eastern China. Constructed in the 2000s, 1990s and 1980s, respectively, SJ, AJ and XY represent the typical residential quarters of each era in terms of scale and planning concepts.

There are similar population sizes and children's populations in each residential quarter (Table 1.). Observations were conducted for 12 hours (from 7:00 to 19:00) on National Day holidays in October, or during weekends in September. Times were chosen with fine weather that was suitable for children to engage in outdoor activities: cloudy to clear with a temperature of 15-25°C.

| Residential Quarter | SJ | AJ | XY |
|---------------------|----|----|----|
| Total Population | 16510 | 15680 | 15610 |
| Population of Children | 2320 | 2203 | 2193 |
| Total Observation Hours | 12h (7:00-19:00) | 12h (7:00-19:00) | 12h (7:00-19:00) |
| Observation Day | One of National Day holidays in October | One of National Day holidays in October | Sunday in September |

3.2 Division of Landscape

According to the concept of behaviour settings discussed previously, the landscape observed in each residential quarter can be divided into several sections (Fig.1. and Table 2.). The division is based on the
material interfaces of physical components, such as the outline of the central round square, the edge of a paved area with stone tables and seats, or the zigzag boundary of a bridge, etc. Because of the inseparable connection between behaviour and physical environment, the occurrence of various activities usually matches with the space enclosed by various material interfaces in the landscape (Heft, 2001). For example, it is more likely to find behaviour of playing in a paved area, and viewing or playing with water tends to occur along watersides, while resting and playing tend to occur on grass.

Accordingly, the residential quarter of SJ is divided into 12 sections, while AJ is subdivided into 16 sections and XY into 12 sections (Table 2.). There are a total of 40 sections across all landscapes, with 1-3 observers assigned to each section (according to the size and popularity of the section).

Children’s behaviours were observed and recorded on paper maps using symbols that coded basic information such as children’s attributes and behaviour. Because this method codes the behaviour rather than the child, only behaviours that lasted for more than three seconds were recorded, and behaviours were recorded in a new round of observations every half hour. This avoided coding more than once, or not coding fast-moving children, or coding stationary children too frequently.

3.3 Definition of Childhood and Types of Children

The definition of *childhood* is controversial. In most psychologists’ opinions, it can be narrowly defined as the age range of 0-12 years or, more broadly, as 0-18 years. According to the United Nations *Convention on the Rights of the Child*, published in 1989, children are those individuals under the age of 18 years, unless national legislation says otherwise.

Observation and previous investigation have clearly established that children do not perform the same way at different ages. This study classifies children into two groups on the basis of their behaviour and psychological traits: those who have the ability to act on their own, and those who need to be taken care of by their parents. Children with independent action capability are mainly those above Grade 1 or 2 (about 9-18 years old), and have developed their own behavioural habits with the ability of judging and thinking for themselves. Alternatively, children without (or with little) independent action capability are almost all those before Grade 1 or 2 (about 0-8 years old), whose behaviours are more unstable and random. Usually they cannot adjust their actions by themselves, and have to be looked after carefully. In this study, which age group a child is assigned to is generally inferred through observation and judgement, and their properties and behavioural features were recorded for further analysis (Table 3.).

![Fig.1. Section Division of Landscape](image)

**Table 2. Description of Each Section**

| Section   | Description of Features | Area (m²) |
|-----------|-------------------------|-----------|
| SJ        | Central Round Square    | 201       |
| SJ-1A     | Circular Steps around Square | 127      |
| SJ-1B     | Fan-shaped Platform      | 243       |
| SJ-1C     | Circular Open Square    | 408       |
| AJ        | Walkable Lawn           | 186       |
| AJ-1A     | Space with table tennis tables | 163    |
| AJ-1B     | Fan-shaped Square near Main Road | 175     |
| AJ-1C     | Gym Facilities          | 117       |
| AJ-2A     | Space with Shade near Entrance | 159  |
| AJ-2B     | Circular Terraced Space | 132       |
| AJ-2C     | Arcade Space near Shade | 225       |
| AJ-3A     | Gym Facilities near Entrance | 190    |
| AJ-3B     | Space with Shade near Main Road | 185    |
| AJ-3C     | Space with Gym Facilities | 172     |
| AJ-3D     | Space with Shade near Main Road | 154    |
| AJ-3E     | Walkable Lawn near Entrance | 154     |
| AJ-4A     | Walkable Lawn near Main Road | 125    |
| AJ-4B     | Space with Shade near Main Road | 971   |
| AJ-5A     | Space with Shade near Entrance | 302    |
| AJ-5B     | Gym Facilities near Entrance | 546    |
| AJ-6A     | Stone Tables and Seats near Main Road | 172   |
| AJ-6B     | Walkable Lawn near Main Road | 117    |
| SJ        | Central Round Square    | 49        |
| SJ-1A     | Circular Steps around Square | 227      |
| SJ-1B     | Fan-shaped Platform      | 128       |
| SJ-1C     | Circular Open Square    | 243       |
| SJ-2A     | Circular Terraced Space | 408       |
| SJ-2B     | Space with Shade near Entrance | 227    |
| SJ-2C     | Gym Facilities near Entrance | 224    |
| SJ-3A     | Space with Shade near Main Road | 235    |
| SJ-3B     | Space with Shade near Main Road | 185    |
| SJ-4A     | Space with Shade near Main Road | 154    |
| SJ-4B     | Walkable Lawn near Main Road | 154     |
| SJ-5A     | Walkable Lawn near Entrance | 971     |
| SJ-5B     | Space with Shade near Main Road | 302    |
| SJ-6A     | Gym Facilities near Entrance | 546     |
| SJ-6B     | Stone Tables and Seats near Main Road | 172   |
| SJ-6C     | Walkable Lawn near Main Road | 117    |
| XY        | Open Square near Main Road | 1256    |
| XY-1A     | Central Steps around Square | 227      |
| XY-1B     | Fan-shaped Platform      | 128       |
| XY-1C     | Circular Open Square    | 243       |
| XY-2A     | Circular Terraced Space | 408       |
| XY-2B     | Space with Shade near Entrance | 227    |
| XY-2C     | Circular Open Square    | 408       |
| XY-3A     | Gym Facilities near Entrance | 117    |
| XY-3B     | Space with Shade near Main Road | 185    |
| XY-3C     | Space with Shade near Main Road | 154    |
| XY-4A     | Space with Shade near Main Road | 125    |
| XY-4B     | Gym Facilities near Entrance | 190     |
| XY-4C     | Space with Shade near Main Road | 154    |
| XY-5A     | Gym Facilities near Entrance | 117     |
| XY-5B     | Space with Shade near Main Road | 154    |
| XY-6A     | Gym Facilities near Entrance | 117     |
| XY-6B     | Space with Shade near Main Road | 154    |
| XY-6C     | Gym Facilities near Entrance | 117     |

Fig.1. Section Division of Landscape
4. Analysis of Relationship between Landscape and Children’s Behaviour

4.1 Statistics of Children’s Behaviour

Based on investigation, children’s behaviour can be divided into four categories, namely:

- **1. Resting**
- **2. Viewing**
- **3. Playing**
- **4. Others (composed of Eating, Dancing, Watching Performances, and Reading Books)**

Table 4 shows that **Playing** occurred most frequently (recorded 1293 times), and was considered to be the dominant behaviour in the landscape. The subdivision of **Playing** shows that the frequency of **Playing without Water** (recorded 1072 times) was clearly higher than that of any other behaviour.

The sections with the highest frequency of behaviours in each residential area were described as follows: a **Waterside Open Space (XY-6A):** recorded 2091 times), a **Space with Gym Facilities (AJ-3C):** recorded 153 times) and a similar space near **Entrance** (SJ-1C: recorded 130 times, Table 4.)

Comparing the areas of each section (Fig.2.), it can be seen that the area of **Open Lawn near Main Road (SJ-2C):** is the largest (1987 m²) of all the sections (average area = 333 m²), while the occurrence frequency in it is not very high (51 times, the overall average is 43). **Open Square near Main Road (SJ-6, 1256 m², 28 times)** and **Walkable Lawn near Entrance** (AJ-3G, 971 m², 17 times) are similar, with relatively large areas but low occurrence frequency. In contrast, there are clearly a relatively high number of occurrences in sections with smaller areas, such as the **Space with Table Tennis Tables (AJ-3A, 163 m², 129 times), Space with Gym Facilities (AJ-3C, 190 m², 153 times and XY-6B, 117 m², 91 times)** and a similar space near **Entrance** (SJ-1C, 172 m², 130 times). Thus, as the landscape sections are commonly defined by material lines of physical components, there is no inevitable relationship between behaviour and the size of a landscape section.

Furthermore, sections with relatively small areas but high occurrence frequency are mostly spaces with gym facilities (SJ-1C, AJ-3A, AJ-3C and XY-6B, Fig.2.), suggesting that gym facilities attract children to some extent.

4.2 Behaviour Analysis According to Landscape Classification

The authors further analysed behaviour by using Principal Component Analysis and Cluster Analysis in order to study the distribution of children’s behaviour in the various categories of landscapes.

1) Classification of Landscapes

Data related to the features of space—such as proximity to water, degree of exposure, accessibility, relative facade of buildings (<20 m), amount of grassed
or paved ground, and facilities— were collected and tabulated. In each section, "1" denotes that the feature exists and "0" that it does not (Table 5).

The data in Table 5. were processed using Principal Component Analysis. The results show that the cumulative contribution rate is over 60%, and is statistically significant, as shown in columns 1-4 of Table 6.

It can be seen that the significant negative eigenvalues of the first axis indicate the features Open and Degree of Paving (>0.5), while the significant positive eigenvalues indicate the features Degree of Grass (>0.5) and Degree of Plants (>0.5). Generally, as the proportion of paved area increases, so does the area for activity; the space will be more open with a higher degree of exposure. On the other hand, a higher proportion of plants and grass results in a space being more enclosed. Therefore, the first column stands for Degree of Exposure of space (Expo. for short in Table 7).

The significant positive eigenvalues of the second axis indicate the features Close to Water, Landscape Facilities above Water and Capable of Touching Water with Hand, all of which are obviously connected with the proximity to water. Thus, the second column stands for Proximity to Water of space (Prox. for short in Table 7).

The significant positive eigenvalues of the third axis indicate the features Walking Distance to Nearest Main Road (>15 m) and Walking Distance to Nearest Entrance of Residential Quarter (>200 m). It is known that, due to the privacy and safety requirements of residential landscapes, some distance is usually kept from the entrance and main road of the residential quarter. This helps to create a stable and comfortable environment which is not easy to reach from outside. In other words, the distance to entrance and to main road stand for the accessibility of landscape to some extent. Accordingly, the third column represents the Accessibility of space (Acc. for short in Table 7).

The significant negative eigenvalue of the fourth axis indicates the feature Close to Main Facade, while the significant positive eigenvalue indicates the feature Close to Lateral Facade. Therefore, the fourth column represents Relative Facade of Buildings (Faca. for short in Table 7).

To some extent, these four factors—degree of exposure, proximity to water, accessibility and relative

Table 5. Elements of Landscape

| Section | Category | Exposure | Degree of Paving ( > 0.5 ) | Degree of Grass ( > 0.5 ) | Degree of Plants ( > 0.5 ) | Relative Facade of Buildings (Faca.) | Proximity to Water (Prox.) | Accessibility (Acc.) | Degree of Open (Open) |
|---------|----------|----------|-----------------------------|---------------------------|-----------------------------|----------------------------------|--------------------------|---------------------|-----------------------|
| SI      | 1A       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 1B       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 1C       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 1D       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 1E       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 1F       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
| AJ      | 2A       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 2B       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 2C       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 2D       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 2E       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 2F       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
| XY      | 3A       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 3B       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 3C       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 3D       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |
|         | 3E       | 1        | 1                            | 1                         | 1                           | 1                                | 1                        | 1                   | 1                     |
|         | 3F       | 0        | 0                            | 0                         | 0                           | 0                                | 0                        | 0                   | 0                     |

Table 6. Scores of Categories

| Category | Axis 1 | Axis 2 | Axis 3 | Axis 4 |
|----------|--------|--------|--------|--------|
| (1)      | .21    | .90    | .02    | .03    |
| (2)      | .35    | .75    | .10    | .13    |
| (3)      | .51    | .28    | .28    | .33    |
| (4)      | .57    | .28    | .35    | .41    |
| (5)      | .48    | .06    | .15    | .22    |
| (6)      | .28    | .18    | .69    | .15    |
| (7)      | -.15   | .24    | .40    | .32    |
| (8)      | .15    | -.01   | .77    | .15    |
| (9)      | -.68   | .10    | .23    | .26    |
| (10)     | .06    | .32    | .45    | .72    |
| (11)     | .14    | -.14   | .51    | .70    |
| (12)     | .70    | .21    | .14    | .03    |
| (13)     | .72    | .31    | .21    | .06    |
| (14)     | .73    | .23    | .02    | .21    |
| (15)     | .21    | .78    | .09    | .03    |
| (16)     | -.09   | .13    | .46    | .54    |
| (17)     | .15    | -.37   | .10    | .30    |
| CumCon   | 21.4   | 15.9   | 12.9   | 10.8   |

*1. Area of Grass (m²)/Area of Section (m²) > 0.5
*2. Area of Plants (m²)/Area of Section (m²) > 0.5
*3. Area of Paving (m²)/Area of Section (m²) > 0.5

Fig. 3. Cluster of Sections
building facade—may explain the qualities and characteristics of all the landscapes in this study.

Then, the 40 sections were classified into ten types based on scores for the four factors, as shown in the dendrogram (Fig. 3).

2) **Distribution of Behaviour based on Types of Landscapes**

Diagrams of each type of landscape are given in Table 7, to illustrate their spatial features. A typical section for each type was chosen to reveal the distribution of children's behaviour in the various spatial categories according to observations recorded on maps, so that the influence of space on children's behaviour can be clarified.

a) Open spaces have mostly high accessibility, such as Types 1 and 2. For open spaces that can be easily reached, the distribution of children's behaviour was related to the proximity to water. Behaviours of *Playing* tended to scatter along the waterside in spaces close to water (Type 1), while in spaces far away from water or without water, *Playing* and *Taking exercise* were observed in uneven distribution (Type 2).

b) Semi-open spaces with close proximity to water may generally have lower accessibility, such as Types 3, 4 and 6, in which children's waterside behaviours are commonly influenced by the relative facade of surrounding buildings. In the types of spaces next to the main facade of buildings (Types 4 and 6), it is clear that *Playing* tended to occur along the waterside, while in spaces that are only close to the lateral facade (Type 3), waterside behaviours scattered more sparsely.

c) Semi-open spaces with high accessibility are generally distant from water, such as Types 5, 7, 8 and 9, in which the distribution of children's behaviours were affected by the relative facade of buildings. In types of spaces that are near the main facade of buildings (Types 5, 8 and 9), *Playing* and *Taking Exercise* were observed in clusters or evenly distributed, while activity distributions were relatively uneven next to the lateral facade of buildings (Type 7).

d) Spaces with some degree of exposure, including open or semi-open spaces (Types 1-9), may have a relatively obvious distribution of behaviours. In contrast, sheltered spaces (Type 10) with far proximity to water...
to water and high accessibility, which are near the lateral facade of buildings, do not play positive roles concerning children's behaviour.

e) According to the Principal Component Analysis, the landscape element of Gym Facilities does not have significant eigenvalue, indicating that from the perspective of spatial inherent features, the explanatory power of gym facilities over space is not as strong as those of the four spatial factors. However, in particular spaces with gym facilities such as AJ-3A (of Type 2) and AJ-3C (of Type 9), it can be seen that there are a large number of Taking Exercise arrayed in clusters around the instruments due to their layouts (Table 7.). Overall, combined with the results of statistical analysis in Section 4.1 (Statistics of Children's Behaviour), it can be inferred that children's behaviours are more likely to be influenced by the comprehensive effect of inherent spatial factors and gym facilities.

3) Distribution of Two Groups of Children’s Behaviour based on Types of Landscape

Fig.4. shows differences in the distributions of two groups of children's behaviour according to landscape type. As the dominant children's behaviour is Playing, the distribution of this behaviour will be compared between the two groups and analysed on the basis of landscape characteristic (Table 7.).

Children without independent action ability tended to play in Types 5 and 6, demonstrating that under the influence of carers, this group of children may prefer semi-open and surrounded spaces that are not close to the lateral facade of buildings, while they do not strongly demand proximity to water and high accessibility.

Meanwhile, children who require less supervision were more inclined to play in Types 2, 4, 7, 8, 9 and 10, indicating that the degree of exposure, proximity to water, accessibility or relation to any facade of buildings makes almost no difference to the playing activity of this group of children.

Consequently, children with independent action ability have more freedom to decide where and how to play, with a wider scope of activities and lower requirements of the environment, while children who need to be taken care of usually tend to play in safer, more stable environments with a more limited scope of activity, which is determined by carers to some extent.

5. Conclusions

The following conclusions are drawn:

1) The dominant behaviour in the landscapes is Playing. It has the highest occurrence frequency, for children to play in all the sections. Therefore, it is clear that providing spaces for playing encourages children to stay in a landscape.

2) Based on Principal Component Analysis and Cluster Analysis, the residential landscape was classified into ten types described by four spatial factors. In brief, the main results can be summarised as follows:

a) Four spatial factors

The four factors that may describe landscape characteristics are the degree of exposure, proximity to water, accessibility, and the relative building facade. These factors should be taken into consideration when investigating the determinants of behaviour and activity in urban landscapes.

b) Relationship between landscape and behaviour

Spaces with some degree of exposure, including open or semi-open spaces (Types 1-9), have an obvious positive effect on occurrence of children's Playing and other activities, while sheltered spaces with a lower degree of exposure (Type 10) discourage them.

In open spaces with high accessibility, children prefer to play near watersides (Type 1). While far away from water, behaviours of Playing and Taking exercise occur with an uneven distribution (Type 2).

In semi-open spaces near the main facade of buildings, Playing tends to occur along watersides (Types 4 and 6), but when far away from water, behaviours distribute evenly or in clusters (Types 5, 8 and 9). Near the lateral facade of buildings, the distributions are sparser or uneven (Types 3 and 7).

c) Differences in the two groups of children’s behaviour

Children without independent action ability tend to play in semi-open spaces with safe and stable environments. Present findings support the idea that adults are more likely to take children outdoors in attractive, green surroundings, which are also considered healthy (Soderstrom, et al. 2004). By contrast, children with independent action ability have a wider range of activity options, and usually do not care about the features of a space as much.

![Fig.4. Distribution of Two Groups of Children's Behaviour](image-url)
3) Diversity in landscape attributes, such as vegetation and topography, has been demonstrated to be the major influence on making outdoor play areas attractive to children. Integrated open spaces that can be easily accessed, have a waterfront landscape, are near a building facade, and are equipped with gym facilities, may optimally stimulate movement, support extended exploration, and facilitate social interaction for both types of children.

4) This study indicates that behaviour mapping is a viable method for obtaining useful data and information on the impact of the landscape on children's behaviour.

In this paper, the relationship between classified landscape and children's behaviour are explained systematically, providing a theoretical basis for creating an attractive and child-friendly landscape. However, as children have natural creativity and may be affected by the weather, seasons, gender, and socio-economic conditions, future studies should attempt to classify their various behaviours in more detail, and explore the specific roles of other variables.

Finally, the design and construction of attractive landscapes should not only be based solely on the findings of this study. For basic security requirements, barrier-free designs for children, especially those with less independent action ability, must be considered. For visual aspects, privacy and aesthetics should also be thought over. For auditory requirements, traffic noise from main roads should be blocked out with appropriate design techniques, etc. In summary, children's behavioural and psychological requirements should be taken into account in an objective, scientific and comprehensive way when planning urban landscapes and environments.

Acknowledgements

The authors would like to express their sincere gratitude for the support received from the National Natural Science Foundation (51208162) of China.

Note

1 Data on the total populations of the three residential quarters were obtained through interviews of community neighbourhood committees. The populations of children were calculated according to a proportion coefficient based on census data from the Hefei Municipal Bureau (Hefei Municipal Bureau of Statistics: http://tjj.hefei.gov.cn/8688/8689/13d7j/201701/20170105_2149545.html)

References

1) Chatterjee, S. (2006) Children's friendship with place: An exploration of environmental friendliness of children's environments in cities. Doctoral Thesis. http://www.lib.ncsu.edu/resolver/1840.16/5206

2) Cosco, N. (2013) Developing evidence-based design: Environmental interventions for healthy development of young children in the outdoors. Open Space. People Space. Published by: Katerina Georgescu, pp.125-135.

3) Cosco, N., Moore, R. and Islam, M. (2010) Behaviour mapping: A method for linking preschool physical activity and outdoor design. Medicine & Science in Sports & Exercise. pp.513-519.

4) Gibson, E. and Pick, A. (2000) An ecological approach to perceptual learning and development. New York: Oxford University Press.

5) Heft, H. (1998) Towards a functional ecology of behaviour and development: The legacy of Joachim F. Wohlwill. In: Gorlitz D, Harlffo HJ, Mey G, Valsiner J, editors. Children, cities, and psychological theories: Developing relationships. Berlin (Germany): Walter De Gruyter, pp.85-110.

6) Heft, H. (2001) Ecological psychology in context. Mahwah, NJ: Lawrence Erlbaum.

7) Kinoshita, I. (2007) Children's participation in Japan: An overview of municipal strategies and citizen movements. CYE [Internet]. [cited 2008 Oct 15]. Available from: http://www.colorado.edu/journals/cye/17_1/17_1_16_MunicipalStrategies.pdf.

8) Li, Z. Munemoto, J. and Yoshida, T. (2011) Analysis of behaviours along the waterside in a Chinese residential quarter. Journal of Asian Architecture and Building Engineering, 10, pp.85-92.

9) Li, Z. Zeng, R. and Ye, M. (2012) Investigation of the relationship between place characteristics and child behaviour in residential landscape spaces: A case study on the Century Sunshine Garden Residential Quarter in Hefei. Frontiers of Architecture Research, 1(1), pp.186-195.

10) Márít Jansson (2010) Attractive playgrounds: Some factors affecting user interest and visiting patterns. Landscape Research, 35(1), pp.63-81.

11) Piaget, J. (1952) The origins of intelligence in children. London: Routledge & Kegan Paul.

12) Qin, L. (2010) Planning and design research on children's activity spaces in residential districts. Housing Science, (10), pp.27-30.

13) Soderstrom, M., Martensson, F., Grahn, P., Blenmanow, M. (2004) The outdoor environment of day care centers. Its importance to play and development. Ugeskr Laeger, (166), pp.3089-3092.

14) Sonenstein, F., Gates, G., Schmidt, S., Bolshun, N. (2002) Primary child care arrangements of employed parents: Findings from the 1999 national survey of America's families. Washington (DC): The Urban Institute, pp.3-4.

15) Yun, Y., Saiou, N., Aizawa, H., and Goto, T. (2003) A study on the characteristics of children's place to stay and environmental factors on the outdoor space in public elementary school sites. Journal of Architecture, Planning and Environmental Engineering, Transaction of AJJ. (564), pp.149-156.