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Effect of Space Configurational Attributes on Social Interactions in Urban Parks

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Abstract: Urban parks are one of the most common spaces for social interactions in modern cities. The design of park spaces, especially space configuration, has significant influences on people's social behaviors in parks. In this study, the associations between space configurational attributes and social interactions were investigated using space syntax theory. An observation analysis of social behaviors was carried out in two urban parks in Beijing, China. Nine space configurational attributes, including depth to the gate, depth to the main road, connectivity, normalized angular integration (NAIN), and normalized angular choice (NACH) with three radii, were calculated using a segment model. The variance analysis and regression analysis reveal the strong joint effect of space type, space scale factors, and space configurational attributes on social interaction behaviors in parks. The personal interaction group contained 23% of the total observed people involved in social interactions. Pathway length, zone area, and NACH-10K (NACH with a radius of 10,000 m) are positively associated with the number of people involved in personal interactions. For the social interaction group (77% of the total observed people), the space scale and depth to main city road were found to have a positive and negative influence on social interaction intensity.

Keywords: space syntax; personal interaction; social interaction; behavior mapping

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1. Introduction

With urbanization and population aging, living alone and the corresponding social isolation has become an important problem in China and all over the world [1–3]. Urban parks, an essential component of the urban open spaces, were suggested to have the potential to improve physical activity and social interaction [4–6]. However, green resources are limited and unevenly distributed, especially in compact cities [6]. Therefore, how to improve the usage of urban parks has drawn attention from city administrators and designers. Numerous studies have been carried out to investigate the associations between park characteristics and the behavior of people in urban parks, which can inform park planning and design.

Up until now, it has been well established that multiple factors could facilitate people's activities in urban parks, including park characteristics [7–10], environment quality [11,12], social-economic factors [13–18], and individual characteristics [19–21]. Proximity was suggested by previous studies as one of the key factors for park use [20,22,23]. People are more likely to engage in park use when there is a park nearby [20]. Moreover, park use was found to increase with the increase of park size [10] and the improvement of physical qualities of the park [7,8,24]. At the micro level, well-maintained infrastructure, facilities, and amenities have been found to support people's physical activities in urban parks [22].

Recently, increasing evidence has indicated that space configuration could also promote activities in urban parks [9,23–25]. Since space configuration attributes provide a structure to locate other design elements, such as squares, street furniture, and pavilions, it is an essential design decision that needs to be made at the beginning stages. Therefore, quantitative analysis of space configurational attributes could provide valuable guidance for landscape architects to enhance park use. At the city level, distance together with spatial factors calculated from road segments were found to be useful in improving the accessibility of the park [6,21,24,26]. At the neighborhood level, sidewalks and intersections were found to have positive associations with park use [24,25]. At the park level, pathway configuration attributes, integration for instance, were suggested to encourage senior walking behavior in urban parks [23]. To quantitatively analyze the spatial characteristics of urban parks, space syntax has been widely used [26,27]. In space syntax, complex urban spaces are modeled as axial lines, which allows mathematical analysis of the configurational attributes of urban spaces [9,28].

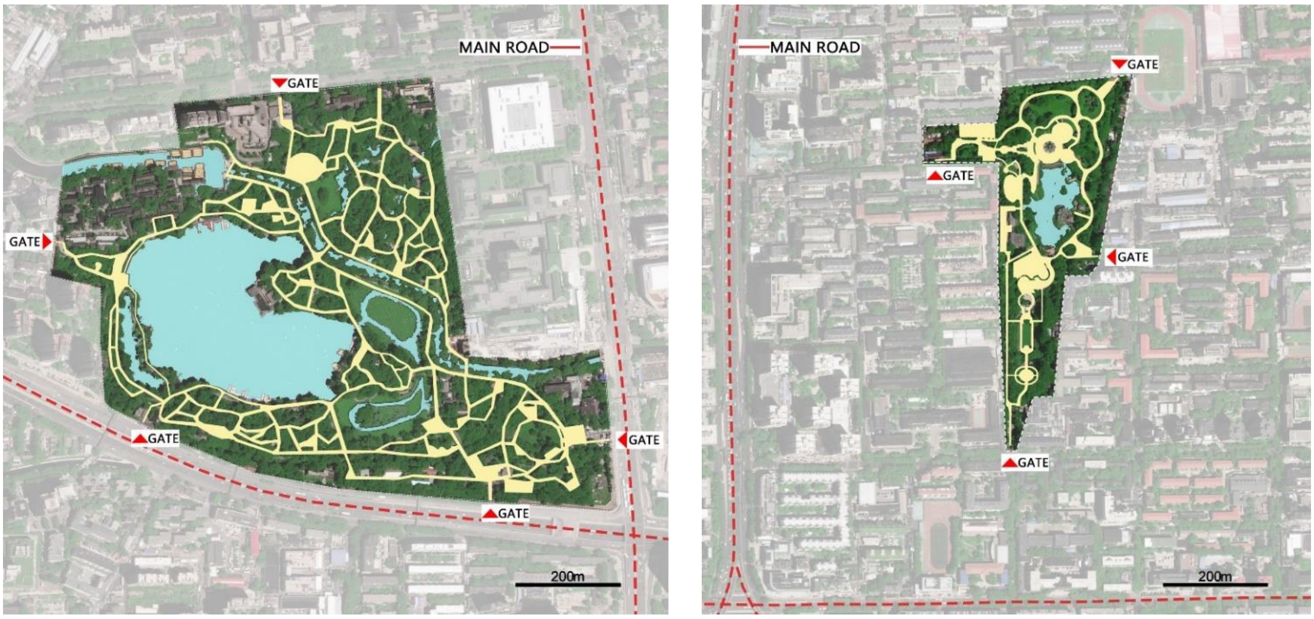
However, the existing literature mainly focuses on the overall use of and physical activity in parks. The association between spatial configurational attributes and social interactions remains in question. In the context of the urban environment, some exploratory studies have revealed the significant impact of space configurational features on social interactions within urban spaces [29–31]. Soares et al. investigated the potential associations between spatial configuration and the possibility of socialization on school campuses [30]. Focusing on in-between spaces, Can and Health revealed that street connectivity is important for long-duration activities and social interactions [29]. As suggested by Zerouati and Bellal, social activities depend on the degree of permeability, and they noted that social interaction activities increased in the least connected areas [31]. However, few studies have examined the relationships between space configurational attributes and social interaction behaviors in the context of urban parks.

To address the aforementioned gaps, this study aims to investigate the effect of space configurational attributes on social interaction activities in urban parks using space syntax theory. A segment model at the city level is established by merging a detailed park pathway model into a large city road model. The method of measurement for human social interaction and space syntax analysis is presented in Section 2. The distribution of social interactions and space configurational attributes are then analyzed in Sections 3.1 and 3.2. Variance analysis and regression analysis are applied in Section 3.3 in order to reveal the influential factors of social interaction activities in urban parks.

2. Methodology

2.1. Study Sites

This field research was carried out in two city parks (Zizhuyuan Park and Rendinghu Park) in Beijing, China. Beijing is the capital of China and has a population of 20 million people. The two selected parks are both neighborhood parks located in the city center, surrounded by residential communities. Therefore, the function, physical environment, and social-economic conditions are very similar. Meanwhile, as shown in Figure 1, the area, pathway network in the parks, and road network in the nearby urban area are quite different for two parks, which could produce the diversity of the space configuration attributes needed for the study. Rendinghu Park is relatively small (0.103 km^2) with a relatively simple pathway network inside the park. The park is located in the center of a residential community and is connected to the internal narrow roads network of the community. On the contrary, Zizhuyuan Park is a larger park (0.504 km^2) located close to the city main roads. Meanwhile, the internal pathway network is more complex, with more winding paths and intersections.



(**a**) Zizhuyuan Park (**b**) Rendinghu Park

Figure 1. Zizhuyuan Park (**a**) and Rendinghu Park (**b**) in Beijing, China.

2.2. Measurements of Social Interactions in the Park: Observation

The observation method has been widely used for measuring people's behavior in urban public spaces [32]. Among numerous practices, the behavior mapping technique based on field observation has been suggested, as it is cost-effective and time-effective [33]. Before field observation, a clear definition or classification of human behaviors is needed. The physical distance based classification method has been widely used, as suggested by Hall [34]. In this method, the distance between two people was used to categorize social relationships into four groups, including intimate distance (0 to 45 cm), personal distance (46 cm to 1.3 m), social distance (1.31 to 3.75 m), and public distance (>3.75 m). For activities that comprised more than two people, the average distance within a group was suggested by Cao and Kang for social interaction classification in urban open spaces [35]. Three social relationship types were identified, including: (1) intimate (intimate pair), (2) personal (intimate group), and social (social group). The physical distance- based classification method is applicable for analyzing static social relationships. However, the physical distances between people were constantly changing for some social interactions, in activities such as playing and dancing, for instance. The measurements of physical distance and classifications through videotape could be rather difficult and inaccurate, especially if the physical distances were quite small.

Instead of measuring the physical distances, the recognition of interaction types was carried out by examining the personal behaviors collected during the observations in this study. The social interactions observed in the parks were classified into two categories: (1) personal groups and (2) social groups. Personal interaction behaviors, including kissing, touching, and hugging were used as signs of personal groups, and included relationships such as lovers, friends, and families. The social groups were identified as a group of people without personal interaction behaviors. Most of the social groups involved cultural and physical activities, for instance, dancing and singing. The number of people involved in the social interactions during the observation was counted as the measure of interaction activity intensity.

To avoid the impact of the weather conditions on social activity, the field survey was conducted on continuously sunny days in November 2020. Meanwhile, to represent the most common weather conditions of the whole year, the temperature during the survey was approximately equal to the average temperature of the whole year in Beijing.

The observation of social interactions in urban parks was carried out in November 2020. Previous studies have indicated that the type and duration time of activities depended on the space type [35,36]. Therefore, in this study, the accessible spaces in the parks were first classified into two categories: pathways and activity zones linked by pathways (plaza or playground). A pathway between two intersections or an activity zone linked by pathway was considered as one analysis unit in further observation and spatial characteristic analysis. For each observation unit, a five-minute videotape was recorded for further behavior analysis during one of the observation processes. The same observation process was carried out four times a day in each park (7 AM, 10 AM, 3 PM, and 5 PM). Each park was measured for two days, and measurement included a weekday and a weekend.

2.3. Space Configurational Attributes: Space Syntax Analysis

Space syntax is a theory introduced by Hillier and Hanson that quantifies and studies the relationship between human behavior and the built environment [37]. In space syntax, an "axial map" or a "segment map" is established based on a real urban map to represent the urban network configuration. Actual urban spaces are modeled as nodes linked by a road network for the quantitative measurements of space configurational attributes. In this study, the curved pathway network in parks was modeled by a series of continuous segments. A series of space syntax parameters were proposed for space relationship quantization, including depth, connectivity, control, integration, and choice [23,26,28,38–40]. Four types of parameters included in the segment analysis were analyzed in this study, including:

(1) Depth. Depth is the basic measure of space syntax, which measures the spatial distance between the starting space and the terminal space [41]. Angular depth is suggested for evaluating the shortest journeys through the spatial network by considering the cost of the connection angle [42]. In this study, metric step depth (MSD) is used, which follows the shortest angular path from the whole system to the selected space. Depth to gate (DtoG) and depth to city main road (DtoR) are calculated to represent the spatial distance from the staring space to the entrance of the parks and the city road network;

(2) Connectivity. Connectivity represents how many spaces are directly connected to the staring space. The angular connectivity offers a better description of space relationships by considering the weight of each connected space according to the turn angle (0 for 0 degree, 0.5 for 45 degrees, and 1 for 90 degrees). In this study, the calculation of connectivity for each space follows the rules of angular connectivity;

(3) Integration. Integration is the most widely used index in space syntax and represents how easily a space can be reached from other spaces [42]. A higher integration value indicates that the space is more accessible within the given spatial network on average. To enable the comparison between systems of different sizes, normalized angular integration (NAIN) was suggested by Hiller and Yang, which was used in this study as the measure of the integration for each space [43];

(4) Global integration calculates the integration of the starting space to the whole system [23,28]. However, when focusing on people's behavior or movement patterns, the local integration is commonly used by applying a calculation radius [39,44]. In this study, two radii, 200 and 1000 m, were first selected according to the range of the park scales to represent walking accessibility. In addition, a larger radius of 10,000 m was also selected to analyze the spatial accessibility of the whole city traffic network through multiple methods of transportation;

(5) Choice. Choice is a measure of space usability that considers the potential for each segment element to be selected as the shortest path [45]. A higher choice value indicates that the calculated space is more likely to select by the through-movement in the network. Same as the integration, the normalized angular choice (NACH) with three calculation radii (200, 1000, and 10,000 m) was applied to represent local usability in this study.

In total, nine configurational attributes were calculated by DepthMap X in this study. In the space syntax segment model, the spatial configurational attributes were calculated for each segment. The attributes of each pathway between two intersections were then analyzed by calculating the average value of the corresponding segments. For the activity zones, the attributes of each space were calculated as the average value of the segments directly linked to the zone.

As suggested by the existing research, human behaviors are affected by various factors. Therefore, several micro-level design characteristics were also considered in this analysis, including space type, space scale, and lateral visibility [23,46]. The type and size of the activity space have been widely argued to be influential on social activities in parks [10,47,48]. In this study, the type and the scale of the space were measured as a categorical variable (pathways and activity zones) and a continuous variable (length of pathways and area for activity zones), respectively. To include the effect of green elements, vegetation density has been widely used for park environment evaluation [46,49]. However, as suggested by Kaplan, the perceived openness rather than the physical attributes were more useful in describing how people perceive the environment in parks [50]. Openness was defined as the amount of space perceivable to the viewer [50]. Based on the analysis of the density and type of vegetation in parks, lateral visibility was suggested for the evaluation of space openness [23]. In this study, lateral visibility was measured in three categories according to lateral sightline interruption: (1) open (no interruption on either side of the pathway; interruption along the boundary of the activity zone less than 30%); (2) moderate open (interruption on one side of the pathway; interruption along the boundary of the activity zone between 30% to 70%); and (3) closed (interruption on both sides of the pathway; interruption along the boundary of the activity zone more than 70%).

3. Results

3.1. Social Interactions Observed in Urban Parks

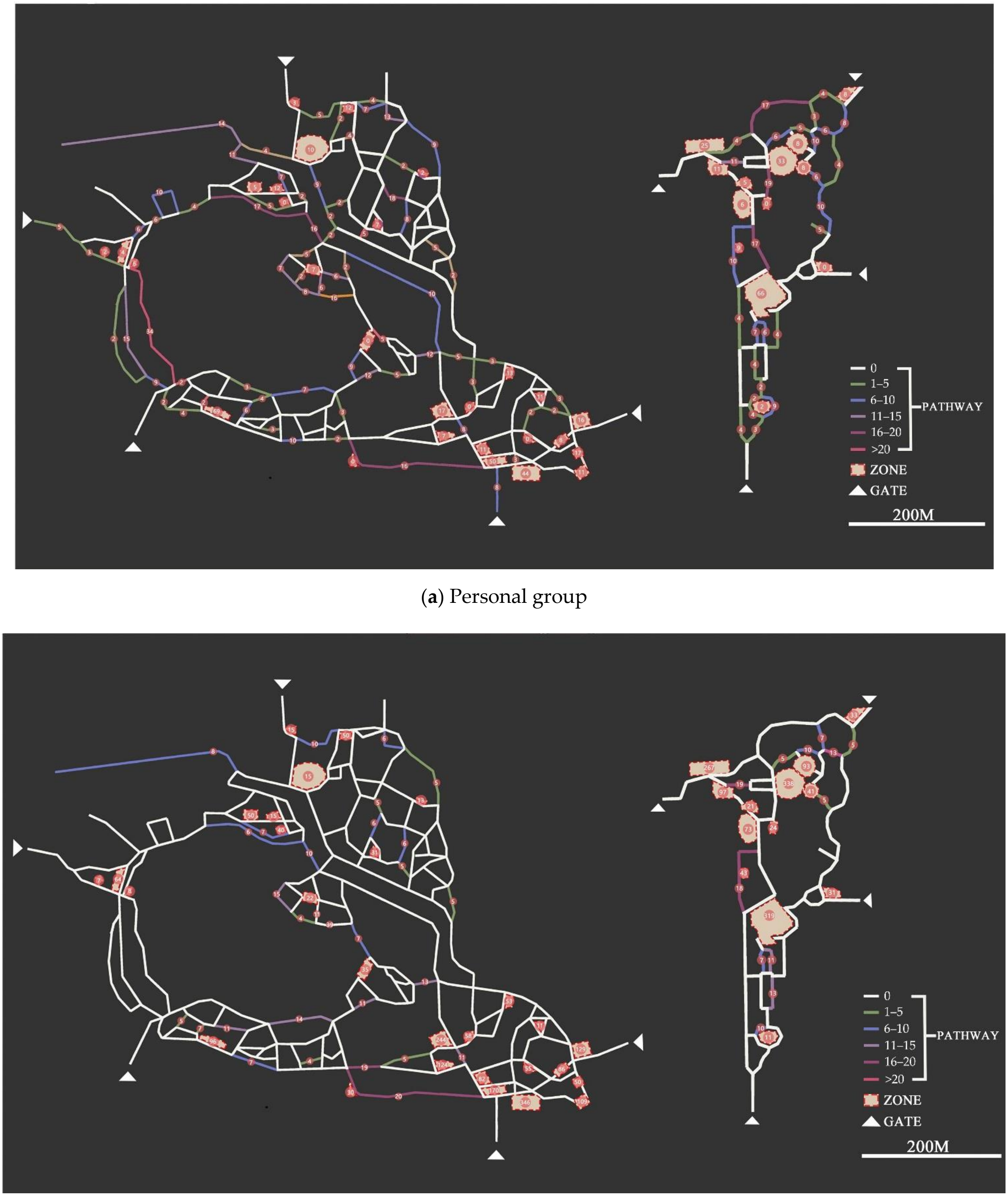
During the observation, A total of 4983 people involved in 735 social interaction activities were observed, as shown in Table 1. A larger number of involved people (3824, 77%) indicates that social groups are more active than personal groups in urban parks. The number of intimate groups is larger (446, 61%), but the number of people in those groups is relatively small (1159, 23%). The average number of people in the social groups (17.2) is much higher than that in the personal groups (2.6).

Table 1. Number of social interaction activities and people observed in two parks.

	Activity Type	Space Type		
		Pathway	Zone	Total
Number of People	Personal Group	643 (13%)	516 (10%)	1159 (23%)
	Social Group	425 (9%)	3399 (68%)	3824 (77%)
	Total	1068 (21%)	3915 (79%)	4983 (100%)
Number of Activity	Personal Group	267 (36%)	179 (24%)	446 (61%)
	Social Group	60 (8%)	229 (31%)	289 (39%)
	Total	327 (44%)	408 (56%)	735 (100%)

Meanwhile, the intensity of the social interactions depends on the space type. The number of social activities is approximately equal in two spaces: 327 (44%) on pathways and 408 (56%) in activity zones. However, the number of people involved in social activities shows great differences: 1068 (21%) on pathways and 3915 (68%) in activity zones. The reason is that the activity types in different spaces are different. Social group interactions were more frequently observed in activity zones, which had a larger number of people involved (17.2 per group). Meanwhile, the main social activities on the pathways were in personal groups, which commonly contained only 2–3 people (2.6 per group).

Some qualitative tendencies can be deduced from the inhomogeneous distribution for social activity in Figure 2. Personal groups were observed on almost all of the pathways with varying numbers of involved people. Pathways around the central lake and near the entrance were found to have relatively larger numbers of people involved in personal interactions. Social groups were more commonly observed in activity zones, especially when the activity zones were connected by multiple pathways. Meanwhile, space scales, including the length of pathways and the area of the activity zones, show significant influences on the number of people involved in social interactions. More social interactions were found on long pathways and large activity zones. However, it can also be seen that social interaction intensities in two adjacent spaces could be very different, even they shared very similar locations and scales.



(**a**) Personal group

(**b**) Social group

Figure 2. Spatial distribution of social interaction activities observed in parks.

3.2. Spatial Configuration Characteristics in the Parks

The distribution of nine configurational attributes is shown in Figure 3, including depth to city main road (DtoR), depth to gate (DtoG), connectivity, NACH, and NAIN with three different calculation radii. Some tendencies are similar in both parks. DtoG and DtoR are higher in the central area than those in the marginal area because they are correlated to the distance from space to the gate and main city road, respectively. Connectivity is smaller in areas with straight and sparse paths, the lakeside, for instance, because fewer paths are linked to each other. NACH and NAIN, which represent usability and accessibility respectively, are significantly affected by the calculation radius (R). With a small radius (R = 200 m), the calculated values indicate local walking behavior (<5 min), which leads to higher values in the high-density pathway network area. With the increase of the radius (R = 1000 m, approximately 15–20 min walk), a long pathway that connects two areas, a pathway around the lake and a pathway directly linked to gate, for instance, produced higher NACH and higher NAIN. With a very large radius (R = 10,000), NACH and NAIN are mainly determined by the city road network. High NACH and NAIN could be found for pathways near the entrance gate, where they are more accessible through the city road network.

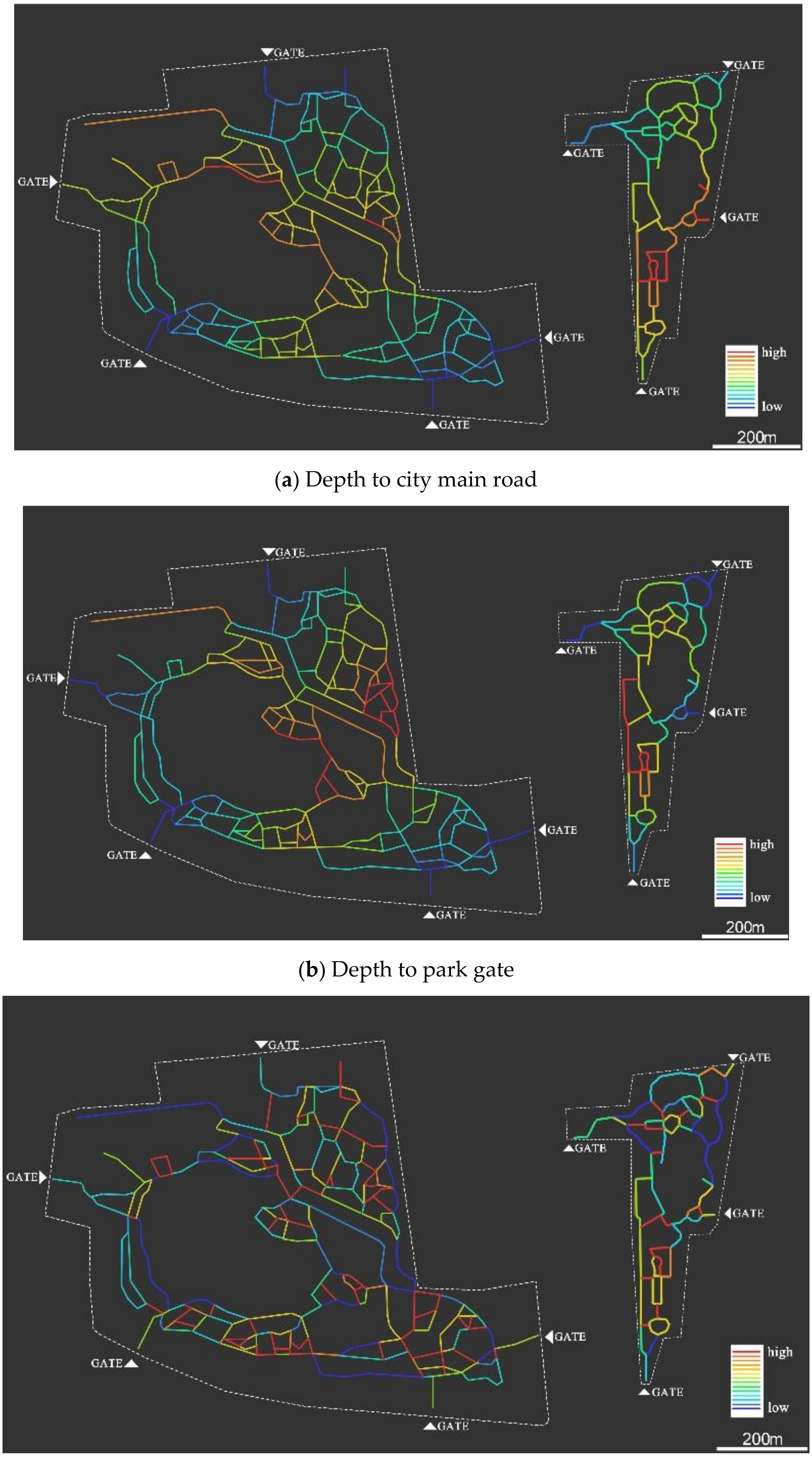
The differences in the area and location between the two parks lead to significant differences ($p < 0.01$ in two-sample *t*-test) of all spatial attributes, as shown in Figure 4. A larger DtoR and a smaller DtoG are found in Zizhuyuan Park compared to Rendinghu Park because Zizhuyuan Park is larger and closer to the city main road. Connectivity, NACH, and NAIN with small radii are mainly determined by the pathway density inside the parks. Therefore, a higher average value can be found in Zizhuyuan Park because of its denser and more complex pathway network. For a large calculation radius, connection with the main road is very influential for NAIN. Being directly connected to city main road (Zizhuyuan Park) leads to higher NAIN. With a very large calculation radius (R = 100,000), the NACH and NAIN differences between the two parks are relatively small because of the similarity of surrounding urban context.

As shown in Figure 3, all nine space configurational attributes were not independent from each other. Therefore, a correlation analysis was performed to investigate the relationship between these attributes. The results (Table 2) shows that the DtoR and three NAIN indices are highly correlated (Person coefficient > 0.5, Sig. < 0.01). Meanwhile, NACH and NAIN are all significantly correlated with each other (Sig. < 0.01), where higher correlations can be found with the same calculation radius (Person coefficient > 0.57, Sig. < 0.01). DtoG and connectivity represent the spatial locations in the park and their relationships with the local pathway network, respectively. Therefore, they are relatively independent from the other attributes, though small correlations with NACH and NAIN (<0.25) could be found.

Table 2. Result of correlation analysis between space configurational attributes.

	DtoR	DtoG	Connectivity	NACH-200	NACH-1K	NACH-10K	NAIN-200	NAIN-1K	NAIN-10K
DtoR	1								
DtoG	0.16 *	1							
Connectivity	−0.13	0.10	1						
NACH-200	−0.20 **	−0.03	−0.20 **	1					
NACH-1K	−0.19 **	−0.09	−0.23 **	**0.63 ** **	1				
NACH-10K	−0.24 **	−0.13	−0.24 **	**0.54 ** **	**0.86 ** **	1			
NAIN-200	−0.61 **	0.21 **	0.00	**0.59 ** **	0.45 **	0.43 **	1		
NAIN-1K	−0.69 **	0.06	0.03	0.41 **	**0.57 ** **	**0.52 ** **	**0.81 ** **	1	
NAIN-10K	−0.65 **	−0.21 **	0.00	0.28 **	**0.52 ** **	**0.57 ** **	**0.60 ** **	**0.83 ** **	1

Note: * and ** represents significant correlation at 0.05 and 0.01 level, respectively. Correlation coefficients >0.5 are bolded.



(**a**) Depth to city main road

(**b**) Depth to park gate

(**c**) Angular connectivity

Figure 3. *Cont.*

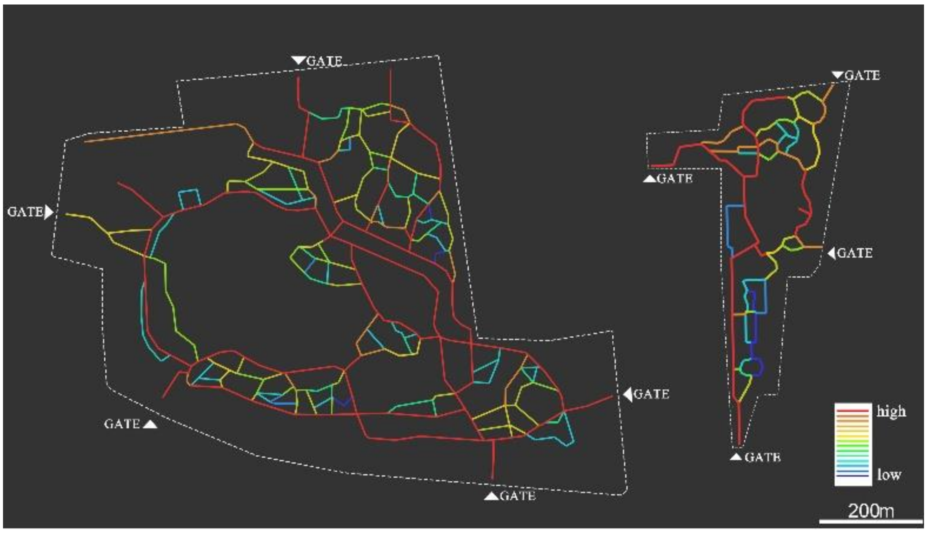
(**d**) NAIN-200

(**e**) NAIN-1K

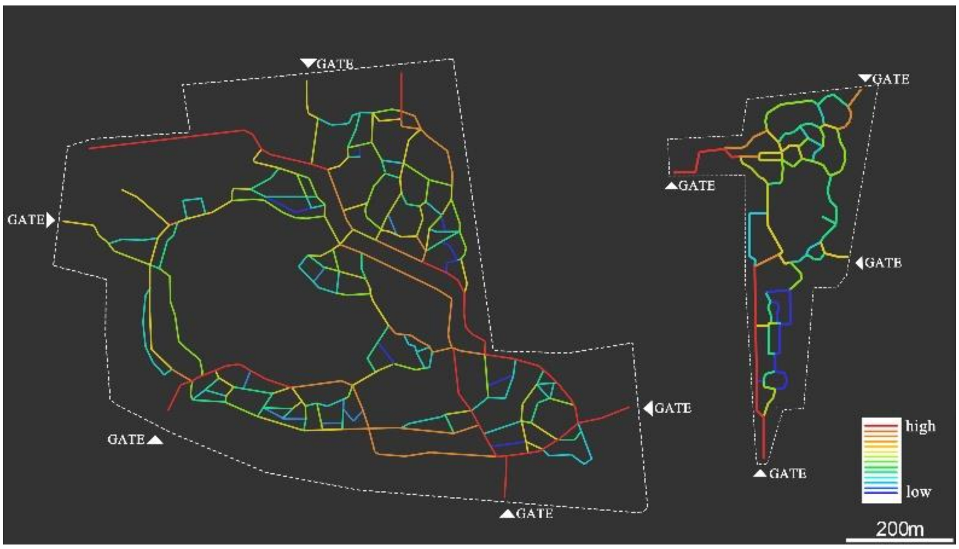
(**f**) NAIN-10K

Figure 3. *Cont.*

(**g**) NACH-200



(**h**) NACH-1K



(**i**) NACH-10K

Figure 3. Distribution of space configurational attributes of in two parks.

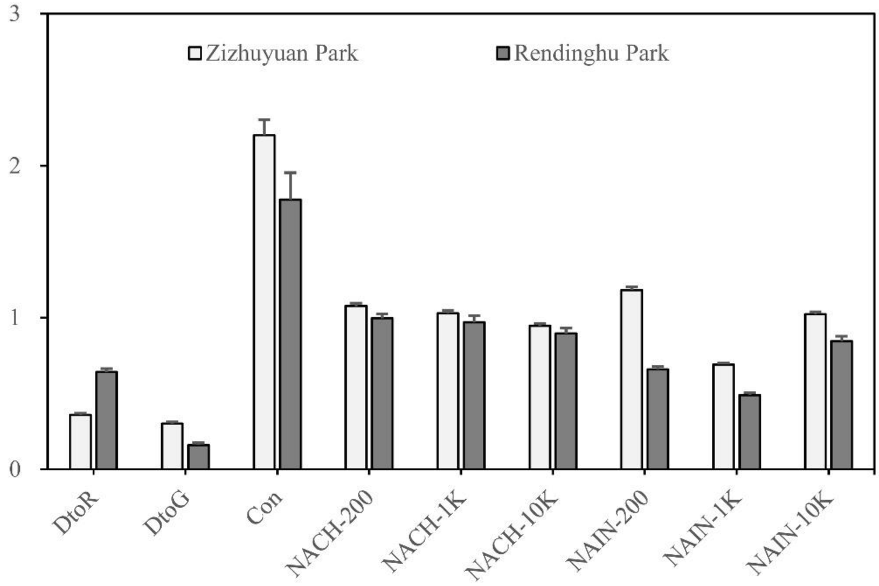


Figure 4. Comparison of space configurational attributes between two parks.

3.3. Relationship between Space Characteristics and Social Interaction

A multivariate analysis of variance (MANOVA) was applied to detect the associations between the social interaction activity and space type (pathway or activity zone), activity type (personal or social), time (weekday or weekend), and lateral visibility (open, moderate open or closed). The results (Table 3) indicate that space type and activity type have significant influences on the number of people involved in social interaction activities (Sig. = 0.000). The average number of observed people in activity zones (22.76) is much larger than that on pathways (1.19). Meanwhile, the average size a the social group (7.13) is much larger than that of a personal group (2.16). The partial eta square indicates the effect size of each factor. As shown in Table 3 and Figure 5, the effect of the space type (η_p^2 = 0.226) is much more significant than that of the activity type (η_p^2 = 0.028). Different from walking behavior, 78% of social interactions occur in social groups, which are commonly fixed in the same space rather than being randomly selected by visual information. Meanwhile, these two parks are neighborhood parks, and the visitors are mainly local residents. Therefore, the time factor and lateral visibility are not statistically significant (Sig. > 0.05).

Table 3. MANOVA analysis of the number of observed people involved in social interaction activities.

Source	SS	df	MS	F	Sig.	η_p^2
Time	9.896	1	9.896	0.046	0.830	0.000
Space Type	67,216.550	1	67,216.550	311.516	0.000 **	0.226
Activity Type	6625.210	1	6625.210	30.705	0.000 **	0.028
Lateral Visibility	1009.242	2	504.621	2.345	0.096	0.004

Note: SS = Type III sum of squares; df = degrees of freedom; MS = mean square; F = F ratio; Sig. significance; η_p^2 = partial eta square (effect size). ** indicates significance at 0.01 level.

In the second stage, regression analysis was used to reveal the relationship between space characteristics and social interaction activities with the space type and activity type as control variables. Because of the significant correlation between space configurational attributes, the stepwise algorithm was applied to minimize the collinearity. A significant joint effect of the space scale factors (length or area) and configurational attributes (depth, NACH, or NAIN) on social interaction activity can be found, as shown in Table 4. A small VIF for all predictors (<1.5) indicates that there is no significant collinearity. All four regression models based on space characteristics are significant (Sig. < 0.001) in explaining the social interaction behaviors in urban parks.

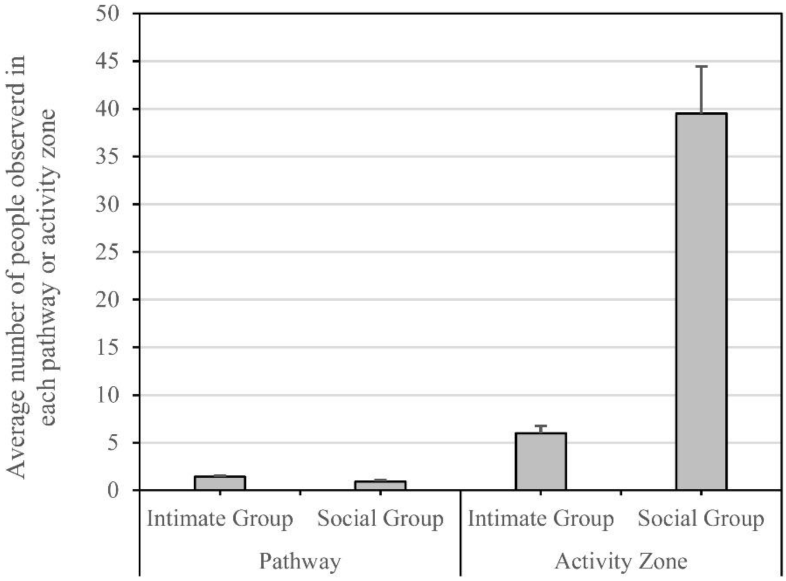


Figure 5. Effect of space type and activity type on social interaction activity in parks.

Table 4. Stepwise regression of the number of observed people with space characteristics.

Controlled Variables (Number and Percentage of Observed People)		Predictor Variables	Coef. (B)	SE	Sig.	VIF	Overall Model
Pathway	Personal Group (643, 13%)	Length	0.027	0.003	0.000	1.026	R^2_{adj} = 0.147; Sig. = 0.000
		NAIN-1K	−4.983	1.151	0.000	1.385	
		NACH-10K	2.758	0.865	0.002	1.370	
	Social Group (425, 9%)	DtoR	0.003	0.000	0.003	1.014	R^2_{adj} = 0.028; Sig. = 0.000
		Length	0.011	0.004	0.006	1.014	
Activity Zone	Personal Group (516, 10%)	Area	0.37	0.042	0.000	1.108	R^2_{adj} = 0.492; Sig. = 0.000
		NAIN-1K	120.333	22.275	0.000	1.108	
	Social Group (3915, 68%)	Area	0.056	0.008	0.000	1.170	R^2_{adj} = 0.351; Sig. = 0.000
		DtoR	−0.016	0.004	0.000	1.170	

For 78% of the observed interactions (interaction occurring in the activity zone), a strong influence of the space characteristics is revealed with the high proportion of explained variances (35.1–49.2%). For the other 13% of the observed interactions (personal groups on pathways), 14.7% of the variance is explained by the combination of spatial scale and configurational attributes. For the other rare interactions (social groups on pathway, 9% of the total observed people), the interaction location contains high level of randomness and strong uncertainty, which led to a small proportion of variance that can be explained by space characteristics (2.8%).

It can be seen that the key configurational attributes for different activity groups are different. For the personal groups, NAIN-1K, which indicates walking accessibility, was found to have a significant influence on social interaction activities. Moreover, for the personal groups on pathways, NACH-10K, which indicates the usability in the urban context, was found to have a positive effect on the number of observed people. For social groups, DtoR, which represents the depth of space to the city main road network, is positively and negatively associated with interaction intensity on the pathways and in the activity zones, respectively.

In all four models, space scale factors (pathway length and zone area) were found to be positively associated with the number of observed people involved in social interaction activities (B = 0.011~0.37, Sig. < 0.001). With the increase of pathway length and zone area, the capacity to accommodate people increases, which leads to a larger number of observed people.

4. Discussions and Conclusions

By examining two parks in Beijing, China, this study investigated the association between spaces configurational attributes calculated using space syntax theory and social interaction activity. Space scale and space configurational attributes (depth to gate, NACH, and NAIN) were found to have a joint effect on social activity intensity. The results show that more social interactions can be found in prominent activity zones with a larger area, higher walking accessibility (NAIN-1K), and that are closer to the city main road network (depth to the main road). On the contrary, long pathways with low walking accessibility (NAIN-1K), large usability (NACH-10K) in the urban context, and that are far from city road network (depth to city main road) tend to improve social interactions on the pathways of urban parks.

The results in this study indicate that people's behaviors in parks are affected by park design. Depth and integration have been identified as the influential attributes, which agree with the results in the literature [26,33,35]. Higher integration value and lower depth lead to higher accessibility and lower cost of use. Therefore, more integrated spaces are likely to be preferred by the frequent users, including the social groups in this study, walking seniors in parks [23], and residents in the neighborhood [29]. Because of privacy demands, more close interactions are more likely to happen in the less integrated spaces to avoid possible interruptions [31]. The value of these two parameters is determined by both the location information (including the spatial location in the park and the park's location in the city road network) and the park pathway configuration.

The findings from this study can be useful for guiding the planning and design of urban parks to improve social interaction activities under different conditions. First, the results in this study offer some advice on the design of open spaces and pathway networks in parks, squares, for instance. Location and pathway configuration determined the accessibility of each open space. To improve social interactions in general, open spaces should be located near the main city road and connected with highly accessible pathways. More accessible walking pathways are produced by setting longer pathways that connect different areas. Further detailed optimization of pathway networks can be conducted by utilizing space syntax software. To improve the social interactions of personal groups, 'hidden' pathways with less accessibility are favorable. Therefore, a pathway configuration with a certain mixture of different degrees of accessibility could meet the diverse needs of social interactions. On the other side, the findings of this study can be used to optimize the spatial distribution of support facilities, such as benches. Pathways and zones preferred by social interactions can be recognized by analyzing spatial attributes in the design stage. More support facilities should then be placed to meet the demands of social interactions. The same principle can be also used in activity zones to improve cultural and physical activity.

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