STUDY ON THE DIFFERENCES OF DAY AND NIGHT BEHAVIOR IN URBAN WATERFRONT PUBLIC SPACE BASED ON MULTI-AGENT BEHAVIOR SIMULATION

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Abstract. In the 'twenty-four hour city' era, how to optimize public spaces based on night behavior demands to promote full-time use has become a significant issue of urban design. Taking Shanghai North Bund as an example, the study collects data through site survey and questionnaire including environment elements, users' attribute and behaviors. Next, the study sets up the simulation environment and translate the interaction of space and behavior into model language. Then, by setting up agent particles, running and fitting, the study obtains an ideal model. Finally, through sub-simulation and analysis, the study quantitatively explores the interaction mechanism between the physical environment and behavior from three levels of different spaces, different groups of people and different light conditions. The study finds that the differences of day and night behavior are produced under the combined effect of changes in attractiveness of environmental elements and changes in users' demands and preferences. Compared with adults, the behaviors of elderly people and children show more obvious differences between day and night, and are more susceptible to space lighting, ground conditions and operating hours of facilities. Furthermore, the same kind of environment element will further affect users' behavior in the night under different light conditions.

Keywords. Self-Organization Behavior; Behavior Differences; Day and Night; Multi-Agent Behavior Simulation; Waterfront Public Space.

1. Introduction

With the prosperity of night economy, our city has gradually transformed into a 'twenty-four hour city' (Tim, 1997). As the main space for citizens' activities, public space is undergoing significant changes in the proportion of day and night activities carried. Facing an increasing number of nighttime users, the traditional

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urban public space design guided by daytime behavior can no longer meet the demands. It is imperative to promote the full-time use of urban public space.

In order to promote the full-time use of urban public space, it is necessary to study the differences of users‘ day and night behavior. The study first summarizes the current status of research on urban public space and night behavior, as well as research on multi-agent behavior simulation. Then, the study selects Shanghai North Bund to conduct field surveys, and uses multi-agent behavior simulation technology to establish an ideal model, so as to study the differences of users' day and night behavior and the causes. Based on the analysis, the study diagnoses the space combining the actual situation to provides a foundation for creating a public space that meets the demands of day and night behavior (Figure 1).

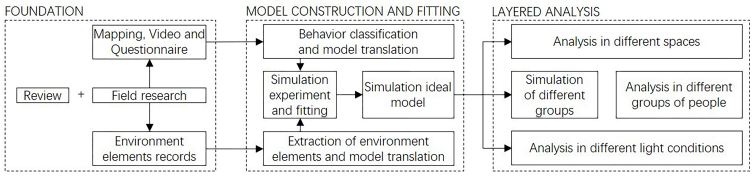

Figure 1. Research framework.

2. Literature review

2.1. RESEARCH ON URBAN PUBLIC SPACE AND NIGHT BEHAVIOR

Scenario-based researches have become a trend. Compared to discussing issues in ideal spaces or large-scale urban spaces, it is more conducive to analyze in depth based on a specific space. In recent years, community streets, streets and squares in commercial districts, and public spaces in urban villages have become important scenarios. Scholars have discussed the safety, walkability and spatial vitality of these urban public spaces at night through methods such as correlation analysis and regression analysis (Lee, 2013; Zhang, 2017). In contrast, research on the waterfront public space and the recreational behavior inside at night is relatively scarce.

The discrepancies of the impact of physical environment elements in day and night are gradually revealed. The diurnal changes in the impact of environmental elements are an important reason for the difference of day and night behavior. Thanks to the development of information technology, scholars have used big data to analyze the diurnal changes in the impact of environmental elements on spatial vitality or individual behavior from the urban morphology level (Wu, 2018; Zhang, 2020). These studies have found some macroscopic environmental elements that have significant diurnal changes in the impact, such as land use, intensity, street network, landscape greening, etc., but have not yet involved microscopic environmental elements.

Researches gradually go deep into the discussion of the particularity of night behavior and its mechanism. Lun analyzed the differences of users' demands and behavior characteristics in day and night from three aspects: demographic

structure, perception and behavior. It was found that the psychological feelings, perceptions and behavior characteristics of users in the night are significantly different from those in the day (Lun, 2017). But the research lacked the discussion on the spatial dimension.

2.2. DEVELOPMENT AND APPLICATION OF MULTI-AGENT BEHAVIOR SIMULATION TECHNOLOGY

Multi-agent behavior simulation treats pedestrians as individuals with rational behaviors, which can help researchers analyze the relationship between individual behaviors and the relationship between individual behaviors and environment from a micro dynamic perspective. For example, cellular automata model, social force model, etc. can better realize the simulation of individual path choice, conflict avoidance and other behaviors. On this basis, some simulation software platforms also provide the possibility of secondary development, which helps scholars to optimize the model to meet their research needs (Chen, 2015; Jia, 2017).

In terms of application, the application of multi-agent behavior simulation technology has gradually expanded from the simulation of evacuation behavior in small-scale traffic and building nodes to the simulation of leisure and recreation behavior in large-scale outdoor space research. In recent years, scholars have simulated and predicted behaviors such as leisure walking, recreational viewing, and commercial consumption through statistics and summary of pedestrian travel patterns in different outdoor spaces (Wang, 2017; Kevin, 2019; Sun 2019). In the simulation process, some scholars try to optimize and improve the model to obtain a more suitable ideal model, and use MATLAB to verify the optimized model.

3. Methodology

3.1. SUBJECTS

3.1.1. Site status and environment elements

The study takes Shanghai North Bund as the example which is the key node of the 45-kilometer public space connection project on both sides of the Huangpu River. Compared with some urban public spaces such as squares, parks, and streets, waterfront public space is more complicated because of its special elements such as different height base planes and shorelines. How to extract and sort out complex environment elements will directly affect the effectiveness and accuracy of subsequent simulations. Combining site survey, questionnaire and the overview of researches on waterfront public space elements (Geraldine, 2013; Nihal, Tayfun, Reyhan, 2011), this study sorts out the environment elements of the site into three levels: base planes, facilities and buildings, totaling 18 categories (Figure 2).

3.1.2. Crowd composition and behavior types

The site surveys are conducted on workdays and weekends with clear weather and suitable temperatures in October 2020. At this time, the COVID-19 pandemic in China has been brought under control and citizens' travel has returned to normal. The survey time during the day is 14:00-16:00, at night is 20:00-22:00. In order to

obtain user attributes and behavior data, the study adopts multiple methods such as mapping, video recordings, and questionnaires to make up for the incompleteness and limitations of a single method. Mapping marks the user's attributes and behavior in the site plan. The video recordings record gender, group, travel route, distribution status, etc. The questionnaires obtain age, purpose, route, attraction preference, etc. Composition of crowd and behavior are shown in the figure (Figure 3).

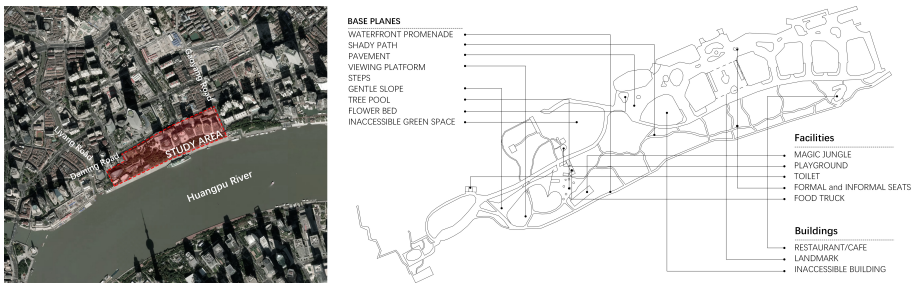

Figure 2. Site location and environment elements.

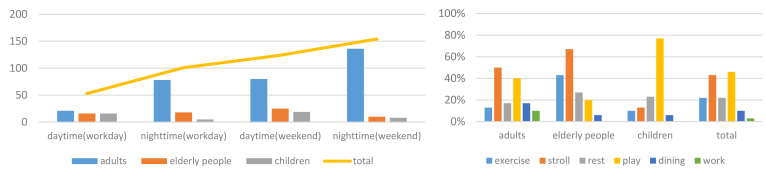

Figure 3. Composition of crowd and behavior.

3.2. SIMULATION METHOD

3.2.1. Translate environment elements into model language

The modeling platform selected in this study is Anylogic 8.6.0 Personal Learning Edition& Professional. In order to obtain a virtual environment model that reflects the real situation, the study divides the extracted environment elements into attractors and basic environment and uses the built-in environment module of the software to translate them (Table 1).

3.2.2. Translate behavior into model language

The study uses the combination of different behavior modules and environmental modules to translate behavior. Through the establishment of space-behavior unit models, the study also observes the dynamic behavior of particles to verify the feasibility of translation. The study translates static leisure behaviors into the PedWait and dynamic leisure behaviors into the PedGoTo, which are also corresponded to the environment elements. For example, rest is translated into PedWait_AreaX and corresponded to formal or informal seats (Figure 4), exercise

is translated into PedGoTo_PathwayX and corresponded to various walkways, the outdoor dining behavior is translated into PedWait_AreaX, while the indoor dining behavior is translated into PedSource & PedGoTo+PedSink.

Table 1. Model Translation of Environment Elements.

Classification	Elements	Space Markup
Attractors	restaurant/café, food truck, playground, Magic Jungle, pavement, landmark, viewing platform, toilet	Area
	waterfront promenade, shady path	Target Line
	formal and informal seat	Area + Attractor
Basic Environment	step, gentle slope	Area + Direction
	flower bed, tree pool, inaccessible building, inaccessible green space	Wall

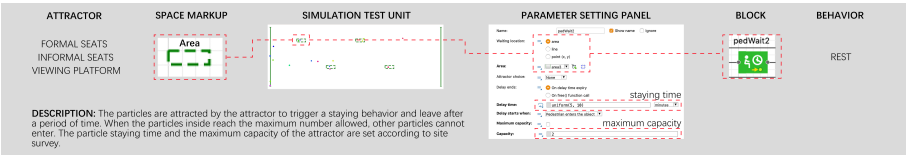

Figure 4. Model translation of rest behavior.

3.2.3. Setting preferences of behavior to environment elements

The preferences of the agent's behavior to environment elements determine to a certain extent the particle's distribution in space and the behavior types that particles conduct. This is also a key step in the study of self-organization behavior from a microscopic perspective. Through the design and distribution of questionnaires, the study enumerates the environmental elements of public space and asks respondents to rate their attractiveness. Through percentage calculations, the preferences of different age groups to different environment elements are obtained, and finally assigned into the model to ensure the initial simulation.

3.3. SIMULATION AND FITTING

On the basis of translation and preferences setting, a preliminary simulation is carried out. During the simulation process, the result of preliminary simulation showed an obvious difference with the actual situation. In order to improve the matching degree, this study uses methods such as adjusting the attractors' parameters, adding fixed routes, etc. For example, considering the actual situation that waterfront promenades are unable to provide shade during the day and users are more willing to choose shady paths to carry out activities, the study adjusts upwards the attractiveness parameter of shady paths and downwards the attractiveness parameter of waterfront promenades in daytime. Considering that some nearby residents have confirmed exercise routes, the study adds fixed routes to guide particles movement in some spaces. Through multiple rounds of parameter adjustment and simulation, there is a high similarity between the simulation results and actual situation.

4. Simulation-based analysis of the differences and their causes of day and night behavior

4.1. ANALYSIS IN DIFFERENT SPACES

At the different spaces level, the study will analyze three spaces with significant differences of day and night behavior (Figure 5).

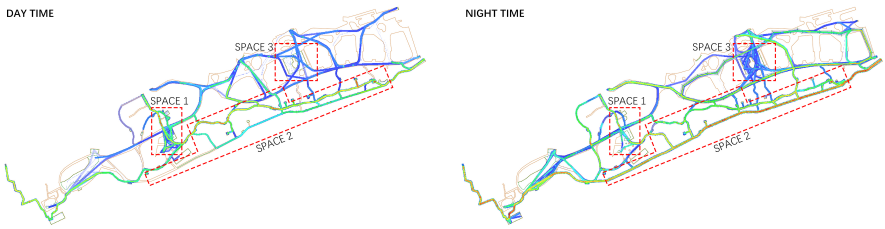

Figure 5. Simulation diagrams of day and night behavior in three spaces.

SPACE 1 is the central square which connects the entrance in the north and the waterfront promenade. The types of behavior are mostly play, rest, stroll, exercise and dining. Through the simulation, the study finds that the activity intensity in this space is greatly reduced after entering nighttime. In the process of time conversion, the changes in the function of some environment elements and the changes in the space light conditions are the main reasons that affect the above problem. Taking food trucks, playground and Magic Jungle as examples, these elements have a strong attraction to dining and play behavior of adults and children during the day. After entering nighttime, affected by business hours, these environment elements gradually lose their original functions, becoming inaccessible for users, and eventually leading to the disappearance of some types of behavior around them. In addition, due to the lack of lighting facilities, SPACE 1 is relatively dim at night, which is not conducive for users to carry out activities.

SPACE 2 includes two main spaces which are the shady path and the waterfront promenade. These two spaces are important activity spaces running through the east and west sides of the site. The types of behavior are mostly stroll, view, rest, exercise and dining. Through simulation, the study finds that the two spaces exhibited diametrically opposite behavior intensity during day and night. In the process of time conversion, the changes in the attractiveness of some environment elements and the changes in the light conditions are the main reasons that affect the above issue. The plants on both sides of the shady path are not only good visual attractions in daytime, but also can play a role in shade, which make the shady path more attractive. After entering nighttime, the attractiveness of the lush greenery is greatly reduced in the artificial lighting condition, which not only becomes an obstacle for users to watch the scenery on the other side of the Huangpu River, but also restricts the space more closed and narrower. At this time, in contrast, the waterfront promenade attracts more users because of its good view, bright environment and pleasant scale. It should be noted that the increase in activity intensity will also bring about the problem of congestion. Through simulation, it

is found that whether it is the shady path in daytime or the waterfront promenade in nighttime, there are varying degrees of congestion in places with dense attractions. The problems that are prone to occur in this kind of linear space can be alleviated by adding open space nodes around the attraction point.

SPACE 3 is enclosed by the office buildings and connects with the entrance in the north. The types of behavior are mostly stroll and exercise. Through simulation, the study finds that although the activity intensity of this space has been greatly increased after entering nighttime, only a few adults and elderly people carry out exercise here, most people just walk through. Being able to attract people but not being able to retain them is the most obvious problem in this space at night. Compared with other spaces, the base plane here is dominated by hard pavement and lacks changes in both the horizontal and vertical directions, which make the space homogeneous and boring. In addition, the office buildings not only restrict users‘ possibility of communicating with the interior space by setting the closed facades, but also uses transparent materials and indoor lighting to turn the ground floor space into a bright and boring box. These make the ground floor space unable to become a functional place that can be stepped into, nor do them have the value of viewing from outside. To a certain extent, the closed ground floor spaces also lead to the lack of functional facilities, which further affect users’ behavior.

4.2. ANALYSIS IN DIFFERENET GROUPS OF PEOPLE

Based on the ideal model, the study conducts sub-simulations on three age groups (Figure 6), and accurately analyzes the impact of environment elements on the behavior of people at different ages by exporting the simulation results (Table 2). In the sub-simulation, the study defines the number of particles at each entrance based on the pedestrian flow data obtained from the site survey, and defines the particle parameters of each age group based on the literature research (Hu, 2016) and the site survey.

Sub-simulation of the adults. During daytime, the behaviors of adults are mainly play and stroll, accompanied by a certain amount of dining. At this time, adults are mainly distributed in the central square and shady paths. During nighttime, the behaviors of adults are mainly stroll, exercise, view and dining. At this time, the distribution is more scattered, but there is a certain agglomeration on the waterfront promenade and its vicinity. Compared with other age groups, the behavior distribution of adults appears to be more discrete and random, especially at night, which shows that the attractiveness threshold of environment elements required by adults to conduct behaviors is lower. Adults are more adaptable to space. In terms of behavior distribution, it is similar between day and night, and only differs in activity intensity. In terms of behavior demands, adults show stronger demands for play in the day, and stronger demands for dining and viewing cultural landscapes in the night, which are also reflected in the changes in the attractiveness of environment elements in day and night.

Table 2. Comparison of the impact of environment elements.

		restaurant/cafe	food truck	toilet	Magic Jungle	playground	waterfront promenade	shady path	pavement	viewing platform	seat	landmark
Adults	daytime	0.04	0.10	0.04	0.05	0.09	0.09	0.32	0.04	0.10	0.07	0.05
	nighttime	0.19	0.01	0.04	0.01	0.01	0.38	0.07	0.02	0.05	0.06	0.17
Elderly people	daytime	0.04	0.08	0.06	0.04	0.03	0.10	0.38	0.04	0.09	0.09	0.06
	nighttime	0.14	0.01	0.05	0.01	0.01	0.37	0.07	0.02	0.05	0.07	0.16
Children	daytime	0.03	0.10	0.03	0.05	0.15	0.07	0.31	0.03	0.09	0.09	0.04
	nighttime	0.17	0.01	0.04	0.01	0.02	0.42	0.03	0.02	0.05	0.05	0.18

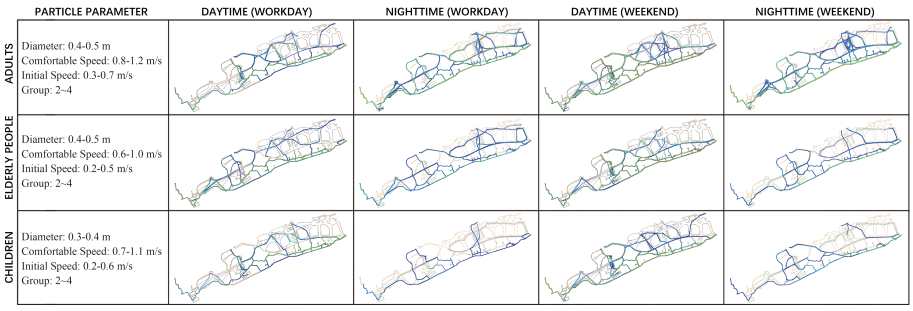

Figure 6. Particle parameters and sub-simulation results of different groups.

Sub-simulation of elderly people. During daytime, elderly people's activities are mainly distributed in shady paths and its vicinity, and the behavior types are mainly exercise, stroll and rest. At this time, shady paths and seats are more attractive to elderly people than adults and children. During nighttime, elderly people's activities are mainly distributed in the waterfront promenade and its vicinity, and the behavior types are mainly stroll, rest and exercise. Through the comparison with other age groups, it is found that the types of elderly people's behavior is relatively fewer. Stroll and exercise are the main types of elderly people's behaviors. In addition, the distribution of behaviors of elderly people at night is significantly reduced compared with that during the day, which is mainly reflected in areas with variable base heights and dim lights. This shows that elderly people have more stringent requirements for the night environment, especially the ground and lighting conditions. Elderly people are more inclined to perform activities in open, flat and bright spaces at night.

Sub-simulation of children. During daytime, children's activities are mainly distributed in the north entrance, the central square and shady paths, and the behavior type is mainly play. Environment elements as playground, food truck, etc. show a higher attraction to children in this time. After entering nighttime, the number of children has been greatly reduced, and their distribution has a higher correlation with adults. The main type of behavior is still play. During the day, children can actively choose venues to play; but in the night, affected by the closure of amusement facilities, children passively follow their caregivers and conduct activities around them. For example, when parents are dining in a restaurant or resting on a seat, children play within the visible range. In general, the current public space is not so child-friendly in the night. In the future, it can

be improved by extending the operating time of amusement facilities and adding more amusement facilities in places where adults can easily rest.

4.3. ANALYSIS IN DIFFERENT LIGHT CONDITIONS

Among light environment indicators, illuminance and color temperature are important factors that affect users' behavior (Davoudian, 2020). In order to analyze the impact of different light conditions, the study selected 13 formal seats installed in the same space type (shady paths) but under different light conditions to compare their attractiveness (Table 3).

Table 3. Comparison of the attraction of seats in different light conditions.

	seat attraction in different light conditions			
	high illumination high color temperature	high illumination low color temperature	low illumination high color temperature	low illumination low color temperature
adults	0.15	0.11	0.05	0.12
elderly people	0.18	0.16	0.04	0.09
children	0.16	0.11	0.06	0.12

Focusing on the illuminance, high illuminance environment is always more attractive to the people of different ages, especially to elderly people. Combined with the actual situation of the crowd's ability to move and perceive, elderly people need a higher illuminance to help them identify environment elements, assist decision-making, and obtain a sense of psychological security. In contrast, adults and children need less illuminance thresholds to identify environment elements and obtain a sense of psychological security than elderly people. Focusing on the color temperature, in a high illumination environment, environment elements with a high color temperature is easier to attract users than that with a low color temperature environment. However, in a low illumination environment, the results are just reversed. Combined with analysis of people of different ages, adults and children are more sensitive to color temperature changes under different illuminances, and are more likely to make corresponding behavioral responses, while elderly people are slightly slower to color temperature changes. For elderly people, it is most important to ensure basic environment illumination.

5. Summary

Research on the difference of day and night behavior in public space and its causes is an important proposition for the study of urban spatial-temporal behavior, and it is also the theoretical basis for promoting the full-time use of urban public space. With the help of multi-agent behavior simulation technology, the study can present the self-organization behavior rule behind the complex environment in a more in-depth humanistic and dynamic perspective, and reveal the logic behind the differences. The study makes up for the lack of microscopic perspective in the refined research of urban issues, provides a bottom-up design basis for the renewal and transformation of urban public spaces, and provides the possibility for the prediction of behavior after the renewal and transformation. It should be pointed out that the process of using multi-agent behavior simulation models to

study urban space problems is a process of using digital technology to analyze the interaction between behavior and the environment. Its essence is a layered analysis and discussion of the environment, individual behavior and the logic of their interaction. In future research, with the deepening of the understanding of the interaction between behavior and space, this research trend of combining analysis and practice will be promoted to develop in a more precise and in-depth direction. For example, consider the influence of group effects and social culture on behavior at the environment level, and continue to expand the influence of psychological perception on behavior at the individual level.

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