INVESTIGATION IN TO THE SOUNDSCAPE RESTORATIVE QUALITY OF URBAN PARK IN A HIGH-DENSITY CITY

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As a main content of public open space, urban park provides high-quality restorative environment for citizens. Beiling Park is a modern urban park centered on Zhao Tomb from the Qing dynasty, which is located in Shenyang, China, a typical high-density city. It is invaluable in the history, culture and urban wellbeing to Shenyang. In this study, soundscape data were collected from both acoustic measurements and perceptual assessments; ArcGIS soundscape maps were generated for spatial analysis; Soundscape walk and evaluation were taken to generate the distribution and composition of soundscape throughout the whole park; a series of Spatial Analyses by ArcGIS and correlation analyses by SPSS were carried out to confirm the relationship between the visitor’s acoustic experience and soundscape characteristics to find out problems in Restorative soundscape.

Keywords: Urban Parks, Soundscape Restorative Effects, Soundscape Mapping, Spatial Autocorrelation

1. Background

Shenyang is a typical high-density city. With the rapid development of urbanisation, pressure of life and work is increasing. People need to relieve and release pressure through some means. Urban parks serve as public spaces for citizens’ leisure activities and are the main environment for people to recover attention and release pressure[1]. Beiling Park is a combination of an ancient imperial cemetery and a modern urban park. The park has both old, traditional buildings and modern garden facilities. It got its name because it is located in the north of the city centre of Shenyang. Qing Zhaoling mausoleum was built for the Qing monarch Huangtaiji and queen consort Xiaoduanwen. It is also among the second batch of national key cultural relics protection units. Beiling Park integrated Chinese traditional culture into the garden during its refurbishment, and carried out exploration and innovation combining cultural relics protection and cultural establishments. There are all sorts of sounds in the park, which includes tourists' sounds, residents' leisure activities sounds, vendors' bawling, natural sounds of birds and roar of the traffic. These sounds combine to form a rich source of soundscapes.

The popularisation of the concept of soundscape started in 1969. Canadian composer Schafer (R.M.) conducted a series of soundscape collection activities in North America and Europe[2]. In 2014, the International Organization for Standardization (ISO) defined soundscape as the sound environment perceived by individuals or groups in a given scene[3]. The concept of soundscape is different from the traditional sound environment. Soundscape is not isolated in the environment, rather, it is inextricably linked to people and the environment. The sound, the listener and the environment combined constitute the three basic elements of soundscape[4]. Therefore, studying the influence of environment on people’s perception of acoustic environment is an important field of study in soundscape.

“Restorative Environment” refers to the environment that is conducive to people’s recovery from
their mental fatigue and negative emotions associated with stress\textsuperscript{[5]}. The quality of environmental restoration is affected by various environmental factors. We define the promotion or inhibition of soundscape as “soundscape restoration”\textsuperscript{[6]}. Studies show that urban natural environments, with natural sounds, have a positive effect on the recovery of an individuals' attention\textsuperscript{[7]}; different types of sounds present have significant divergent effects on environmental restoration\textsuperscript{[8]}. The four basic features of restorative environments: Being away, fascination, extent, and compatibility\textsuperscript{[1][9]}, in combination with the research results of the evaluation of urban soundscapes describe the restorative sensations brought by soundscapes to individuals as “a feeling of relaxation”, “a wonderful experience”, “explorability of connotation”, “happy to immerse into”\textsuperscript{[6]}.

In this paper, the soundscape status and the soundscape restoration quality of Beiling Park were investigated through on-site acoustic measurements and subjective evaluation of soundscape based on soundscape walk. The soundscape data in the park was analysed through the soundscape mapping drawn by ArcGIS. Analysis of the factors that affect the soundscape restoration was carried out through SPSS, aiming to find out the law regarding space and related factors of soundscape restoration in urban parks.

2. Subject and Methods

2.1 Research Subject and Area of interest

Beiling Park is a comprehensive park mainly consisting of historic sites. The whole park is centred on Zhaoling. It covers an area of 3.03 million square meters, of which the water surface area is 230,000 square meters. It is the largest park in Shenyang. Beiling Park Park is divided into three areas, namely, the Mausoleum is a key protected area, surrounded by the general preservation area with Gusong as the main area, and other areas are building control areas, mainly cultural entertainment. In key protected areas and general protected areas, in accordance with relevant regulations, strict protection, vigorous tree planting, and environmental protection were carried out; The construction control area, according to the functions of culture, leisure, and tourism, are divided into eight scenic spots (figure 1).

2.2 On-site measurements and audio collection

Before data collection, appropriate sampling points or plaques should be divided according to the function, landscape composition, and acoustic environment of the study area. The former applies to objective measurement data, while the latter applies to subjective evaluation indicators\textsuperscript{[10]}. According to the functional zoning and the degree of change of sound landscape in each area, the study area was divided into 8 blocks, and 205 sound pressure level measurement points were arranged. The 16 trained testers (undergraduate students from Shenyang Jianzhu University) were divided into 8 groups of 2 people each. In a weekend where the weather is fine and the wind is not greater than level 3, the groups start measuring at 10 o'clock in the morning. At this time, the richness of the soundscape in the park peaks and remains basically stable. At each measurement point, one person is responsible for the measurement: the secondary integral sound level meter was adjusted to fast gear and was placed horizontally on the same height as the chest one arm length away. The sound pressure was measured at each point for 25 seconds; another student was responsible for using the GPS function of the mobile phone for
spatial positioning to obtain the geographic coordinates of the measurement points.

2.3 Soundscape walk and subjective evaluation

Soundscape Walk \cite{11} is a way for the listener to actively and comprehensively perceive the soundscape, that is, to slowly listen to the soundscape of each area along an established route. Beiling Park was divided into 129 squares according to the functional zoning and the rate of change of soundscape. Eight pre-subjective evaluation training educators (Students from Shenyang Jianzhu University in China) were divided into 4 groups of 2 each, one male and one female, to avoid gender bias. Four groups of evaluators performed soundscape walk in the park and evaluated the soundscape experience. In order to avoid sequential effect, the four groups of assessors walked through the park in four different directions. Two of the groups proceeded from the entrance of the park, clockwise and counter-clockwise respectively; and the other two groups proceeded from the entrance of the Mausoleum, clockwise and counter-clockwise respectively.

Within each grid area, each evaluator recorded the relevant data of the area in the investigation record sheet: ① Perceived degree of significance of different types of sound, including natural sound, traffic sound, commercial sound, entertainment sound, tourists’ sound ② The soundscape recovery experience, including “attraction”, “aesthetics”, “fun”, and “harmony”, as the corresponding indicators for evaluating the four features of soundscape restoration. Indicators are used Rickett scale, plus or minus five levels.

2.4 Spatialisation of soundscape data

Visualisation of spatial data and spatial analysis based on visualisation technology are key technologies of Geographic Information System (GIS) \cite{12}. Geographic Information System (GIS) refers to the technical system that collects, stores, manages, calculates, analyses, displays, and describes geographical distribution data in all or part of the Earth’s surface space under the support of computer hardware and software systems \cite{13}. The GIS can display the processed and analysed spatial data on a map, so that various data information and spatial relationships can be displayed and analysed through image data such as maps. On the GIS platform, corresponding attributes are assigned to the vector elements with spatial coordinates, and then converted to raster data by interpolation and other spatial analysis methods and superimposed with basic geographic data. This produces a corresponding soundscape mapping.

For different types of indicators, different numerical analysis methods were used: ① The spatial distribution of sound pressure levels was calculated using the Inverse Distance Weighed method. This is because sound pressure levels are objectively measured physical data. Sound propagation has no boundaries, so points closer to the region have greater influence on the target area, and this is consistent with the basic principle of the Inverse Distance Weighed method; ② The significance of sound types and the spatial distribution of the soundscape restoration indices are calculated using Kriging interpolation. Because the significance of the sound type and the soundscape recovery index are subjective evaluation data, the subjects can only experience and perceive the sound environment of the target area during the soundscape walk, and other regions have little influence on it, the Kriging method is used. It only considers the attributes of the measuring points within the scope of influence; ③ In order to further accurately determine the spatial distribution of soundscape data, cluster analysis and anomaly analysis (Anselin Local Moran I) were used to analyse which regions have spatial autocorrelation, ie, Whether the same attribute of a regional unit and an adjacent regional unit has a correlation.

3. Results

Based on ArcGIS GIS, data exploration of sound pressure level and spatial distribution, sound category and spatial distribution, soundscape restoration index and its distribution in Beiling Park were carried out; Using SPSS statistical analysis software, related analyses were carried out for
objective factor and soundscape restoration indices, the results are as follows:

3.1 Soundscape pressure level and its spatial distribution

According to sound pressure level data, the background noise level $L_{90}$, peak value $L_{10}$ and equivalent continuous A sound level $L_{Aeq}$ of each measuring point were obtained; using ArcGIS's Inverse Distance Weighed method, three sets of sound pressure level data were calculated by the method of difference to obtain the numerical distribution of the three kinds of sound pressure levels throughout the park; Comfort based on acoustic environment and $L_{Aeq}$, the equivalent continuous sound pressure level, have a significant correlation $^{14}$ $^{15}$. Using visualisation, a spatial distribution illustration of the equivalent continuous A sound level $L_{Aeq}$ was obtained, see figure 2.

The mean values of the sound pressure level data for all regions were obtained, and the average values of the whole park of $L_{90}$, $L_{10}$, and $L_{Aeq}$ were 47.5 dB(A), 52.9 dB(A), and 55.5 dB(A), respectively. According to China's acoustic environmental quality standard $^{16}$, the daytime equivalent continuous A sound level $L_{Aeq}$ in the social living space should not exceed 55 dB(A). Statistics show that in 52.4% of the area of Beiling Park, the equivalent continuous A sound level exceeds the standard.

From the perspective of spatial distribution, the distribution of sound pressure levels in Beiling Park is basically the same as that of the planning of the park. The leisure and entertainment areas and the lake island areas conduct mainly leisure and entertainment activities, and their sound pressure levels are higher. The main tourist route on the central axis of the park has the highest $L_{Aeq}$, followed by the area around the water; the mausoleum area and the ancient pine forest area are rich in vegetation and have less people flow. The sound pressure level there is lower; At the edges near the city's major roads, the sound pressure level is higher.

3.2 Sound types and Their spatial distribution

The five main categories and the specific sound types perceived during soundscape walk in Beiling park are listed in table 1.

<table>
<thead>
<tr>
<th>category</th>
<th>sound types</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural sounds</td>
<td>bird’s voice, insect sound, wind sound, trees’ wind blown sound, bees’ sound</td>
</tr>
<tr>
<td>traffic and machinery sounds</td>
<td>vehicle sounds, plane sounds, construction sounds</td>
</tr>
<tr>
<td>tourists’ sounds</td>
<td>tour guides’ voice, footstep sound, conversation sounds, hubbub of voices, cries of children</td>
</tr>
<tr>
<td>entertainment sound</td>
<td>music sound, dance show sound, children’s playing sounds, singing sounds, entertainment facilities sounds</td>
</tr>
<tr>
<td>commercial sounds</td>
<td>Bawling sounds, radio sounds</td>
</tr>
</tbody>
</table>

According to the evaluation result of grid sound significance test, statistics are made on the number of grids for which each sound rating is positive, and the area ratios of the five types of sound scenes that are significantly perceived (evaluation scores between 0.5-2) are obtained as
follows: The activity sound was 54.7%, entertainment activity sound 36.7%, natural sound 32.8%, traffic machinery sound 24.2%, commercial sound 4.7%. It can be seen that the tours in Beiling Park have the most extensive sound distribution, followed by entertainment and natural sounds.

The Kriging difference method was used to spatially distribute the sound perception significance, and a soundscape mapping was drawn. As shown in figure 3, the distribution of the perceptual significance of natural sound, traffic sound, entertainment activity sound, tourists’ sound, and commercial sound throughout the park are illustrated.

Spatial autocorrelation reflects the degree of correlation between certain geographic attributes on a regional unit and the same attributes of neighbouring units. According to ArcGIS spatial autocorrelation analysis and clustering and outlier analysis, we can see that the above five types of acoustic landscape all have significant spatial autocorrelation. Among them, significant natural sound has significant High-High (HH) Cluster around the mausoleum, while in the densely packed road areas in front of the mausoleum there is a significant Low-Low (LL) Cluster; traffic sounds has significant High-High (HH) Cluster in the northeast and southeast of the park close to the main roads of the city. On the one side, and on the west side far from the road, there is a significant Low-Low (LL) Cluster; the sound of the tourists’ activities has significant High-High (HH) Cluster around the main road and water surface of the central axis of the park, and the entertainment has significant High-High (HH) Cluster in the mausoleum. In the first few scenic spots, commercial sounds were prominently clustered on the main roads of the park axis, while the three areas in the ancient pine forest area behind the mausoleum showed a significant Low-Low (LL) Cluster.

3.3 Analysis of the factors affecting the Quality of soundscape restoration

Using soundscape walks, a subjective assessment of the soundscape restoration experience was obtained and four indicators were used to characterise the soundscape recovery quality: attraction, aesthetics, fun, and harmony. The subjective evaluation scores of eight evaluators (different genders and different walking routes) were averaged within each grid, and the four index scores corresponding to each grid were obtained. Using the Kriging interpolation method of ArcGIS, the distribution of four indicators in the whole park can be obtained, as shown in figure 4.
From the perspective of spatial distribution, the four indicators of soundscape recovery have the same areas of significant Low-Low (LL) Cluster, and are located in the areas of northeast and southeast near the main roads of the city. They are greatly affected by traffic noise, and they are also at the time of planning and design. As a transition area between parks and urban roads, there are fewer landscape facilities and therefore less restorative effect. Secondly, the areas with significant High-High (HH) Cluster of the four indicators of soundscape recovery all include the mausoleum area. This is due to the strict management of the mausoleum area, the high walls, the shady trees, the the low flow of people, and the abundant natural sound. As a national key cultural relics protection unit, ancient buildings are well protected, so the restoration of the environment is also the highest. In addition to the attraction, the other three soundscape recovery indicators had low values around the main road and water surface around the central axis, but the attraction index has significant High-High (HH) Cluster in this area. This may be due to the rich landscape facilities in the area, the large flow of people and the relatively lively atmosphere. Although the background noise value is high and the acoustic environment is not comfortable, the high entertainment and excursion activities combined with the colourful social activities attracts people's attention.

SPSS statistical software was used to perform relevant analyses for scores and sound pressure levels. The results are shown in Table 2. The scores were correlated with soundscape category. The results are shown in Table 3.

Table 2. relevant analyses (sound pressure level and indices related to restoration)

<table>
<thead>
<tr>
<th></th>
<th>attraction</th>
<th>aesthetics</th>
<th>fun</th>
<th>harmony</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_{90}</td>
<td>0.116</td>
<td>-0.449**</td>
<td>-0.228**</td>
<td>-0.522**</td>
</tr>
<tr>
<td>L_{10}</td>
<td>0.275**</td>
<td>-0.297**</td>
<td>-0.077</td>
<td>-0.479**</td>
</tr>
<tr>
<td>L_{Aeq}</td>
<td>0.256**</td>
<td>-0.332**</td>
<td>-0.096</td>
<td>-0.504**</td>
</tr>
</tbody>
</table>

From Table 2, it can be seen that the L_{90}, representing the background noise level, is significantly negatively correlated with the aesthetics, fun, and harmony of the soundscape at the 0.01 level. The higher the L_{90} is, the lower the three indices of the soundscape restoration are, the worse the restorative experience. The L_{10} and the equivalent continuous A sound level L_{Aeq}, which represent the level of the sudden sound pressure level in the environment, are significantly positively correlated with the appeal of the sound. The higher the L_{10} or L_{Aeq}, the more likely it is to attract the individual's auditory attention, thus making the individual easier to keep away from the thinking tasks in their mind and to pay more attention to the environment in which they are living, which helps restoration; L_{10} is significantly negatively correlated to the aesthetics and harmony of the soundscape.

To sum up, in the Beiling Park where there are abundant natural resources and human activities,
the sound pressure level is significantly negatively correlated to the good experience and harmonious experience of the environmental restoration experience. The quieter the environment, the easier it is for people to immerse themselves into the beautiful soundscape experience. In the park, social sounds that contribute highly to the sound pressure level (entertainment sounds, business activities sounds, tourist’s activities sounds) are rich in content, rich in information, and accompanied by people's communicative activities, and are more likely to trigger people’s attention. Note that the performance of $L_{10}$ and $L_{A_{eq}}$ is positively correlated with the attractiveness of the soundscape; there is no correlation between interest and the $L_{10}$ and the equivalent continuous A sound level $L_{A_{eq}}$ that characterise a special sound event, demonstrating that acoustic events with large sound pressure levels, albeit easier to attract auditory attention, has no direct correlation with continuity of interest.

Therefore, if the background noise level is reduced, and the sense of aesthetics and pleasure of the soundscape are increased, people can obtain physical and mental relaxation while being able to better coexist in harmony with the environment, people's restoration in the environment can also be improved; but the attraction to individual visual attention is relying on the connotation and information of the acoustic event itself to create attractive soundscapes or acoustic events that are conducive to auditory attraction; from another perspective, noise reduction can also make other natural sounds with restorative value such as birds’ sounds, fountains and water features, etc. more easily perceived and contribute to a restorative experience.

**Table 3. relevant analyses (soundscape category feeling significance and indices related to restoration)**

<table>
<thead>
<tr>
<th></th>
<th>Natural sounds</th>
<th>commercial sounds</th>
<th>traffic sounds</th>
<th>leisure activities sounds</th>
<th>tourists’ sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>attraction</td>
<td>-0.246**</td>
<td>0.473**</td>
<td>-0.255**</td>
<td>0.556**</td>
<td>0.581**</td>
</tr>
<tr>
<td>aesthetics</td>
<td>0.288**</td>
<td>0.238**</td>
<td>-0.635**</td>
<td>0.285**</td>
<td>0.425**</td>
</tr>
<tr>
<td>fun</td>
<td>-0.04</td>
<td>0.344**</td>
<td>-0.601**</td>
<td>0.497**</td>
<td>0.559**</td>
</tr>
<tr>
<td>harmony</td>
<td>0.471**</td>
<td>-0.168</td>
<td>-0.551**</td>
<td>-0.091</td>
<td>-0.145</td>
</tr>
</tbody>
</table>

From Table 3, it can be seen that there are significant negative correlations between the four indicators of traffic sound and soundscape restorative effects, that is, the more significant the traffic sound, the worse the quality of environmental restoration; the natural sound is mixed in the park's comprehensive soundscape environment, has a weak ability to attract auditory attention; While commercial sounds, entertainment activities sounds, and the sound of excursions will significantly increase the auditory appeal of the soundscape. The sound itself is of interest; Natural sounds and social activities sounds will make people feel more beautiful. Natural sounds will make people feel quiet and relaxed. People's activities will make people feel welcoming and lively; natural sounds will significantly improve the harmony of soundscapes because natural sounds contribute less to the sound pressure level and natural sounds. The places are often quieter, matching with the natural environment of Beiling Park, and it is also easier for people to immerse themselves in the environmental experience.

**4. Conclusion and Discussion**

(1) The level of sound pressure level in Beiling Park is the main factor affecting soundscape recovery. The effective sound level $L_{A_{eq}}$ is an internationally-descriptive measure of the change of sound pressure level over time. The $L_{A_{eq}}$ in the 37.5% area in Beiling Park exceeds the 55dB(A) standard in China's environmental noise regulations. The sound pressure level of the ancient pine forest and the surrounding ancient pine forest area is the smallest, and the sound pressure level of the main road near the center axis and the main road of the city is the largest.

(2) The soundscapes in Beiling Park mainly include natural sounds, traffic sounds, tourists’ sounds, entertainment activities sounds, and commercial sounds. Among them, the most widely
distributed are tourists’ activities and natural sounds, the former mainly concentrate in the area in front of the mausoleum, the latter mainly concentrate in the mausoleum area. The sounds of excursions and entertainment activities are often accompanied by commercial sounds, and traffic sounds are mainly present near the adjacent city roads.

(3) The area with the best soundscape restorative effects in Beiling Park is the Mausoleum area, and the area near the urban traffic road is the worst. The factors affecting the restoration of soundscape in Beiling Park include sound pressure level and soundscape type. The background noise level is negatively correlated with the soundscape restoration, and traffic sound is negatively correlated with all indices of the sound restoration quality. Natural sounds are strongly positively correlated with the aesthetics and harmony of soundscape restoration; and the sounds generated by people’s tourism, entertainment, and commercial interactions are significantly positively correlated to attraction and aesthetics, and negatively correlated to harmony.

(4) The contradiction in the correlation between the social activities and the soundscape indicators, as well as the contradictions caused by the contribution by different social sound pressure levels, need to be investigated in more detail with more complex data analysis in follow-up studies for a more comprehensive assessment.

(5) In this study, the evaluators are all undergraduate students. Their preference for soundscape may lead to differences in soundscape recovery experience from ordinary citizens. Follow-up research can explore different natural and social attributes of the population. The commonalities and differences in soundscape recovery experience.

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