Characteristics of Variation of Sound Environment Perception in Urban Open Public Spaces

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Abstract

Road traffic noise is the main source of sound environment in urban open public spaces in China. Current research on sound environment perception of urban open public spaces under the influence of various sound sources has achieved fruitful results, while the research on urban open public spaces dominated by sole traffic noise need discussing further. In this paper, the square closed to the arterial road was sampled. According to the sound pressure level interval (70dBA, 60dBA, 50dBA) , three measurement areas were selected along the direction perpendicular to the arterial road. Semantic differential method was used to assess the perception of sound environment, and then factor analysis was adopted to investigate the dimensional composition of the sound environment and its variation with traffic noise attenuation. The result showed that whether analysing the three areas separately or comprehensively, two relatively stable dimensions of sound environment perception were obtained. Dimension I reflecting “Relaxation” information was the most important in all areas. Dimension II reflecting the “Spatiality” information became more and more important with the attenuation of traffic noise. The study provided reference for the design of planning and landscape in urban open public spaces.

Keywords

Urban open public spaces, traffic noise, semantic differential method.

1. Introduction

Urban open public spaces, including parks, streets, squares and green spaces, are the spatial carrier of urban public life and of great importance to citizens’ daily life. People perceive open space not only through vision but also hearing. Studies showed that acoustic comfort degree and sound pressure level were not closely related, while category of sound source, individual characteristics and non-acoustic physical factors played a key role when the sound pressure level of urban open public spaces was less than 65-70 dB[1,2,3,4].

In order to optimize the urban planning and landscape design, it is necessary to identify potential dimensions of sound environment, which has achieved fruitful results. Kang et al. [5] used semantic differential method to evaluate multiple squares and obtained four main dimensions: relaxation, communication, spatiality, and dynamics. Raimbault et al. [6] studied open spaces of different functions and obtained three main dimensions: activity, spatial attributes, and time history. Axelsson et al. [7] replayed the sound segments that recorded 50 different spatial samples and obtained three main dimensions: pleasantness, eventfulness and familiarity. Sudarsono et al. [8] obtained three main dimensions through sound environment simulators, that is, relaxation, dynamics and communication, which were basically consistent with the literature [5].

In the above literature, the sound environment perception of urban open public spaces is influenced by various sound sources, such as traffic noise, sound of human activity, birdsong, water sound, mechanical sound, etc. However, the sound environment of public open spaces in Chinese cities has some characteristics. In China, urban functions are extremely complex with high density and high floor area ratio. Many open spaces are arranged along the city's arterial roads and serve as noise buffers between roads and residential areas. At the same time, the traffic noise pollution of arterial roads is serious, and the traffic noise of 1/3 length of arterial road exceeds the national standard of 70dBA [9].Therefore, large numbers of open space sound environment are dominated by sole traffic noise, which is different from that in European cities.

In addition, the perception of traffic noise in open spaces also varies with different locations. Although existing researches have taken into account the influence of traffic noise, due to disturbance of other sound sources, variation of sound perception with traffic noise attenuation may not easy to be analyzed. Planning and landscape design should adopt targeted strategies for different areas, so it is necessary to identify the law of variation.

The aim of the study, therefore, was to: 1) explore the dimension composition of sound environment perception in urban open public space dominated by sole traffic noise; 2) discuss the variation of sound environment dimensions with the attenuation of traffic noise.

This paper took the urban open public space dominated by sole traffic noise as an example, selected multiple measurement areas according to the sound pressure level, and carried out the subjective evaluation. All the data obtained in measurement areas was analysed separately. Then, the dimension composition of sound environment perception was discussed, and the variation of which with the attenuation of traffic noise was obtained.

2. Methodology

2.1 Sample Selection

The campus square in Dalian University of Technology, China, was selected as the study sample. The square is about 200 m in length and 75 m in width, which is open without any shelter. The eastern side of the square is close to the arterial road, and the other three sides are surrounded by buildings. The arterial road has four two-way lanes. During the measurement period, there was no obvious noise source around the square except traffic noise.

The geographical information of the square site plan was obtained through the Google Maps, which was divided into 24 grids of 25 m by 25 m (Figure 1). Acoustic analysers (AWA 6291, Class I) were used on the center point of each grid cell for ten-minute sound pressure level measurement.

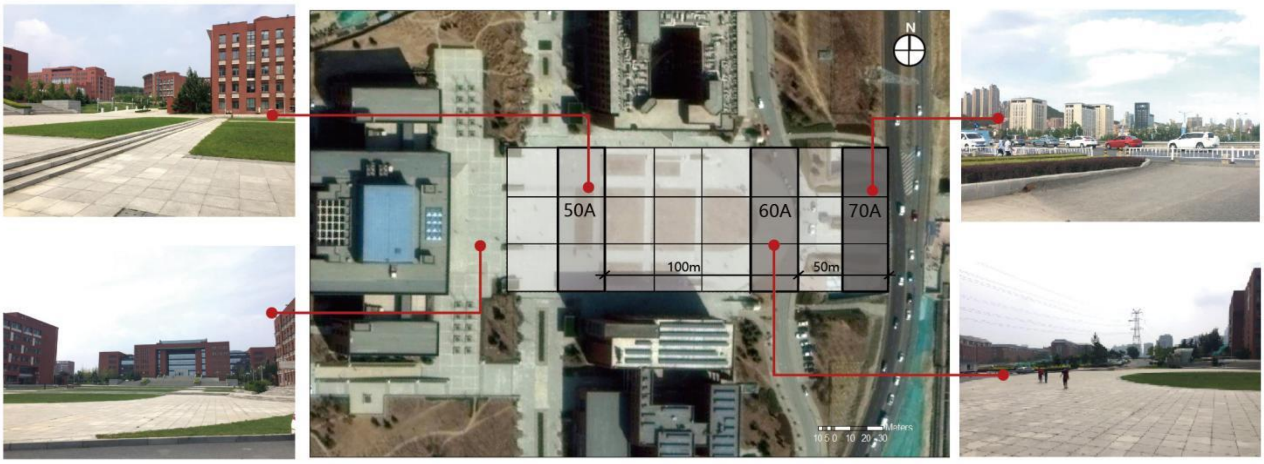

Figure 1. Three Measurement Areas

Then the distribution of sound pressure level was gained using "Kringing" interpolation method to calculate by inputting data into ArcGIS software. In the area which was perpendicular to the road, three measurement areas selected according to the interval (70dBA, 60dBA, 50dBA) of the sound pressure level were named 70A, 60A, and 50A, separately. 70A was close to the arterial road, 60A was located 50 m away from the arterial road, and 50A was 150 m away from it. The measurement route was in the order of 50A→ 60A→70A. The subjects were required to listen to the sound environment for two minutes in each area, and then carry out semantic differential evaluation.

2.2 Semantic differential method

Semantic differential method is adopted as the subjective evaluation method in this measurement. This method explain both language and psychology of subjects, originally used to determine the emotional meaning of vocabulary and later have been widely used in sound quality evaluation[10]. The subjects performed a quantitative evaluation through several adjective pairs, and then statistical methods were used to extract the perception dimension of the sound environment.

Firstly, 25 adjective pairs were selected referred to previous studies[5,1112,13]. Then, Five participants were invited to take part in the pre-measurement. And finally, 18 adjective pairs were selected, including relaxed-nervous, mild-stimulating, like-hate, fun-boring, positive-negative, pleasant-annoyed, comfortable-uncomfortable, beautiful-ugly,harmonious-conflicting,clear-mixed, concentrated-dispersed, orderly-disorderly, weak-strong, quiet-noisy, lively-deserted, pure-complex, rich-monotonous, as well as fast-slow. 7-piont bipolar rating scale was used.

A database was then established in SPSS 22.0 for further analyzing the reliability. The results of the whole area and three areas demonstrated that the Cronbach's alpha were 0.897, 0.836, 0.886, and 0.845 (>0.7) respectively, which proved that the credibility of the questionnaire was high. Simultaneously, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were 0.936, 0.824, 0.876, and 0.827 (>0.8), respectively, and the corresponding Bartlett's spherical test results (p=0.000<0.01) were also found to satisfy the validity of the questionnaire .

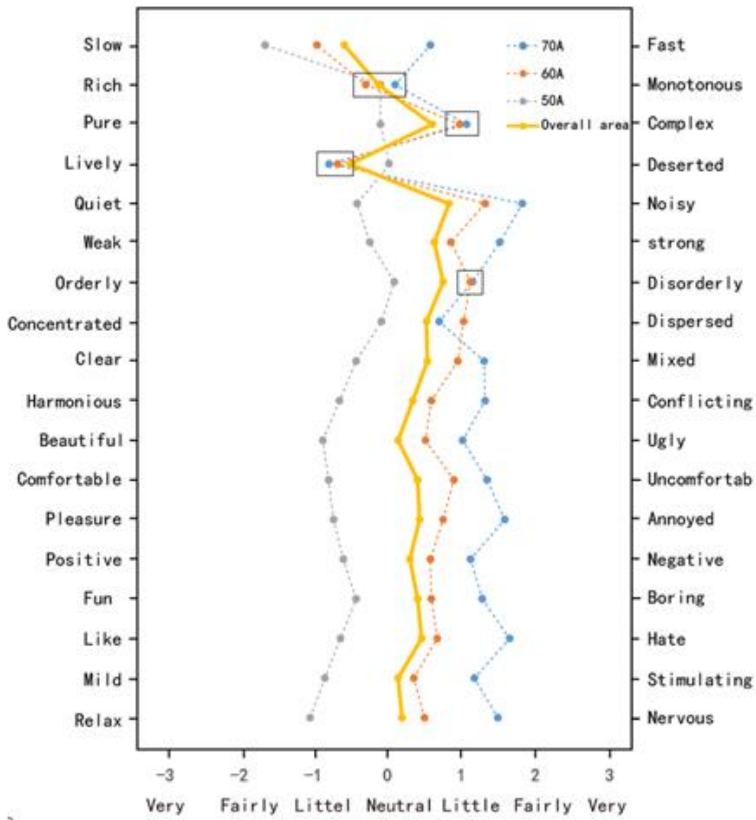

Fig. 2 SD method of acoustic environment perception : A comparison between overall area and three sound pressure level areas.

3. Results

3.1 Mean evaluation of semantic differential method

18 adjective pairs of the whole area and three areas (70A / 60A / 50A) were evaluated and the statistical average was obtained separately (Figure 2). It showed that the general average was closest to that in 60A, which indicated that the perception of sound environment in the whole area was approximate to that of 60dBA. There were differences in the mean value of the adjective evaluation of three areas. The semantic differential evaluation of 50A was distinct from the other two areas while the evaluation results in 60A and 70A were relatively close, which represented that there was a more obvious perception variation sound pressure level from 60dB to 50dB rather than from 70dB to 60dB.

In figure 4, one adjective pair (rich-monotonous) were relatively close in three regions and there were 3 adjective pairs (lively-deserted, orderly-disorderly, pure and complex) was very close in 60A and 70A, indicating that there was a non-sound energy factor affecting perception.

3.2 Dimension composition of sound environment perception in the whole area

Three dimensions were extracted in the overall area, and the total variance was interpreted as 73% (Table 1). The total variance interpretation of dimension I was 47% including 12 adjective pairs, that is, relaxed-nervous, mild-stimulating, like-hate, fun-boring, positive-negative, pleasant-annoyed, comfortable-uncomfortable, beautiful-ugly, harmonious-conflicting, weak-strong, quiet-noisy, and fast-slow. It was similar to the “Relaxation” proposed in the lliterature[5,14,15],which was related to the feeling of participants and quietness of the voice. The total variance explanation of the dimension II was 17%, including 4 adjective pairs such as clear-mixed, concentrated-dispersed, orderly-disorderly and pure-complex, which was similar to the “Spatiality” proposed in the literature[5,16]and linked with spatial scale and reverberation. The total variance of the dimension III was 9% , which contained 2 pairs of indices, that is, rich-monotonous and lively-desolated. It was similar to “Dynamics” proposed by literature[5,15,16]and mainly related to the change and rhythm of the sound.

Table 1 Factor analysis result of overall area. Kaiser–Meyer–Olkin measure of sampling adequacy:0.936 (p=0.000); cumulative %: 73; extraction method: principal component analysis; rotation method: Varimax with Kaiser normalization; N=340.

	Factor 1	Factor 2	Factor 3
Indices	47%	17%	9%
Relaxed-Nervous	.885	.229	-.121
Mild-Stimulating	.842	.230	-.196
Like-Hate	.876	.186	-.083
Fun-Boring	.847	.017	.147
Positive-Negative	.832	.160	.037
Pleasant-Annoyed	.883	.199	-.056
Comfortable-Uncomfortable	.858	.286	-.090
Beautiful-Ugly	.825	.285	.026
Harmonious-Conflicting	.813	.346	-.123
Clear-Mixed	.493	.654	-.099
Concentrated-Dispersed	.066	.858	.019
Orderly-Disorderly	.240	.749	-.155
Weak-Strong	.640	.209	-.138
Quiet-Noisy	.744	.412	-.201
Lively-Deserted	-.387	.022	.796

Pure-Complex	.325	.730	-.121
Rich-Monotonous	.184	-.216	.810
Fast-Slow	-.605	-.270	.331

3.3 Sound environment perception with the attenuation of traffic noise

4, 3 and5 dimensions could be extracted from 70A, 60A and 50A respectively, and their total variance explanations were 75%, 68%, and 74%, respectively (Table 2). The study found that there were two dimensions in the three areas, which were very similar to the dimension "Relaxation" and the dimension "Spatiality". Therefore, these two dimensions were classified as dimension I and dimension II.

Dimension I had the largest total variance interpretation in all regions. Although adjective pairs involved were slightly different, there were 8 adjective pairs that were always together (relaxed - nervous, mild-stimulating, fun-boring, positive-negative, pleasant-annoyed, comfortable-uncomfortable, beautiful-ugly, harmonious-conflicting). In the three areas，dimension II differed in the ordering of the dimension components, ranking third in 70A and second in 60A and 50A. While, four adjective pairs (clear-mixed, concentrated-dispersed, orderly-disorderly, pure-complex) included in this dimension were very stable and had no change.

The total variance explained by dimension I was 37%, 41%, and 28% in 70A, 60A, and 50A, respectively, indicating that dimension I occupied a most important position in sound environment perception evaluation. The total variance explained in dimension II decreased with traffic noise attenuation, which was 12%, 15%, and 19% respectively. This showed that the sound pressure level was reduced and the subject’s perception of the dimension II became more pronounced, which might be related to the perceived increase in sound sources.

Table 2 Factor analysis results of 70A/60A/50A. Kaiser–Meyer–Olkin measure of sampling adequacy:0.936 (p=0.000); cumulative %: 75/68/74; extraction method: principal component analysis; rotation method: Varimax with Kaiser normalization; N=92/124/124

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Indices	37%/41%/27%	17%/15%/19%	12%/11%/11%	9%/-/8%	-/-/8%
Mild-Stimulating	.635/.835/.747	.614/.126/.362	.030/-.268/.170	-.138/-/.018	-/-/.095
Like-Hate	.852/.808/.873	.325/.273/.043	-.007/-.110/.056	-.088/-/-.107	-/-/-.041
Fun-Boring	.874/.812/.549	.001/.030/-.041	-.124/.185/.156	-.030/-/.663	-/-/-.050
Positive-Negative	.833/.852/.731	.122/-.012/-.061	.226/.092/-.030	-.054/-/-.016	-/-/.219
Pleasant-Annoyed	.868/.822/.677	.187/.256/.157	-.038/-.133/.349	-.016/-/.412	-/-/.085
Comfortable-Uncomfortable	.712/.855/.546	.550/.289/.378	.063/-.067/.428	-.018/-/.340	-/-/.057
Beautiful-Ugly	.842/.759/.679	.162/.047/.445	.176/.183/.303	-.026/-/.174	-/-/.011
Harmonious-Conflicting	.797/.787/.587	.328/.304/.412	.233/-.064/.278	-.206/-/-.037	-/-/.084
Clear-Mixed	.316/.585/.225	.086/.589/.710	.625/-.005/.108	-.276/-/-.141	-/-/.280
Concentrated-Dispersed	-.137/-.010/.126	.068/.852/.833	.826/.032/-.027	-.002/-/.137	-/-/-.136
Orderly-Disorderly	.282/.240/.023	-.112/.787/.868	.543/-.095/.098	-.388/-/-.158	-/-/.052
Weak-Strong	.554/.548/.028	.368/.123/.083	.159/-.396/.017	.127/-/.054	-/-/.893
Quiet-Noisy	.524/.657/.363	.742/.381/.480	.195/-.309/.195	.058/-/-.012	-/-/.533

Lively-Deserted	-.231/-.132/-.033	-.581/.027/.021	.162/.820/-.855	.655/-/.184	-/-/-.233
Pure-Complex	.013/.154/.386	.454/.686/.667	.717/.-.222/.014	.145/-/-.126	-/-/.313
Rich-Monotonous	.081/.274/-.160	-.004/-.175/-.197	-.195/.802/-.292	.862/-/.769	-/-/.064
Fast-Slow	-.229/-.272/-.243	-.780/-.266/-.122	-.215/.347/.770	.118/-/-.022	-/-/.125

At the same time, the scatter plots of the dimensions I and II in three sound pressure level areas were studied and compared (Figure 3). The two dimensions had clear boundaries, indicating that they can well represent the two aspects of the perception of the sound environment. The load coefficients corresponding to the two dimensions were all close to 1, indicating that the dimension had a strong correlation with the contained indices, which showed that the dimension can well represent the adjective pairs contained.

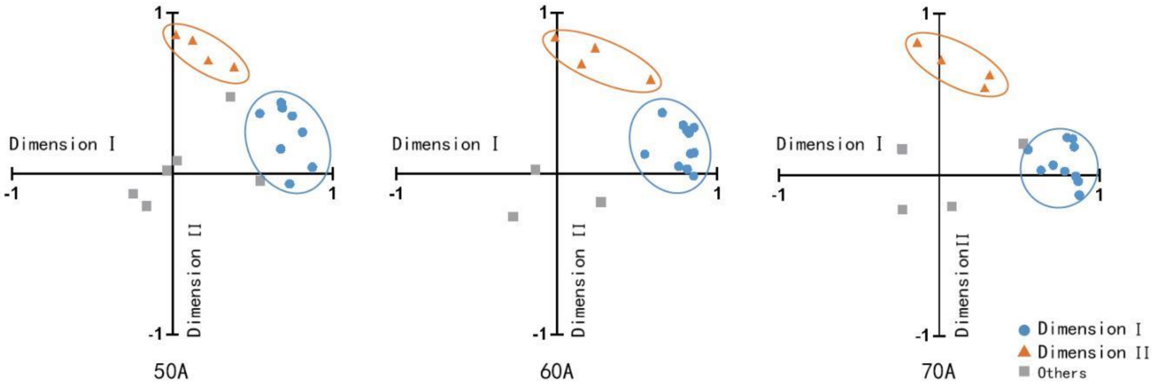

Fig. 3 Comparison of scatter plots with two public factors among three areas

4. Conclusion

In this paper, the semantic differential method was used to investigate the perception of sound environment in urban open public spaces dominated by sole traffic noise, and explore the variation of sound environment perception with the attenuation of traffic noise.

The total variance of dimension acquired through semantic differential method was as 73% in the overall area, 75%, 68% and 74% in three areas respectively, which was higher than that of previous field measurement[5,错误!未定义书签。,16]. The possible reason for the result was that the sound environment in the measurement area was dominated by traffic noise, thus the subjects might have a more clear perception of the sound source.

The analysis of the overall data and the analysis of the three areas showed that there were two similar dimensions. Dimension I had the highest interpretation of total variance in all regions, indicating that in urban open public spaces dominated by sole traffic noise, “Relaxation” was the most important in sound environment perception evaluation. The interpretation of the total variance of dimension II gradually increased with the attenuation of traffic noise, which meant that the more distant from the road, the more important “Spatiality” was for sound environment perception evaluation.

Acknowledgements

The research was supported by the Natural Science Foundation of China (51878110, 51778099，51778100).

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