Evaluation of urban space as a concept of soundscape

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ABSTRACT

Although considerable effort has been made in community noise control, reducing the sound level does not necessarily lead to better acoustic comfort in urban spaces. Therefore, it is essential to consider the environmental conditions of urban environments and how they can attract people. Recent studies on the soundscape of urban space have shown that various kinds of contexts contribute to overall perception, and ISO/TC 43/SC 1/WG 54 has started to work on standardization of evaluation procedures. The present study deals with methodologies for evaluation and improvement of urban space as a concept of soundscape. Individual soundwalk methodology has been proposed for assessment of urban space and derivation of the design elements. In addition, sound masking methodology using water sounds has been investigated for improving soundscape perception.

INTRODUCTION

Urban open spaces have contributed to the social and ecological effects of lifestyles and attitudes to nature and sustainability. The acoustical environment is a critical factor in the overall comfort of urban open spaces (Kang 2006). Therefore, considerable effort has been devoted to community noise control so as to investigate the relationship between the level of noise and the annoyance level of people. However, reducing the sound level does not always lead to improved acoustic comfort in urban spaces (de Ruiter 2004) and it is often not realistic to reduce community noises in open spaces. Therefore, the concept of soundscape has been adopted for the evaluation of the outdoor environment.

The initial concept of soundscape was proposed as an attempt to construct an analytical perspective that would describe the total acoustic environment over time and across cultures. Therefore, most soundscape studies concern the qualitative analysis of soundscapes. Schulte-Fortkamp & Fiebig (2006) adopted the Grounded Theory as a sociological approach, and Berglund & Nilsson (2006) proposed a tool for measuring soundscape quality by attribute profiling. However, the methods for evaluating a soundscape are different according to the purposes of the studies and the researchers, and thus it is difficult to directly compare the results of these studies. Even though many recent studies adopted the soundwalking methodology to identify the perception of an urban acoustic environment (Berglund & Nilsson 2006; Jeon et al. 2010a), the standardization of the procedures for assessing soundscapes are still being discussed in the ISO TC43 SC1 WG 54 (perceptual assessment of soundscape quality).

In the present study, the factors that influence soundscape perception in urban spaces were investigated through a social survey and classification of urban soundscapes was performed based on the assessment of contexts. Soundwalks were then performed for evaluation of urban soundscape. In particular, individual soundwalk was proposed to investigate the details of perceptual difference of subjects. For the improvement of urban soundscape, water sounds were introduced, and the effects of water sound on urban soundscape were investigated through auditory experiments..

CONTEXTS AFFECTING SOUNDSCAPE PERCEPTION IN URBAN SPACES

Social survey

Social surveys were performed in Seoul in order to evaluate the perception of the urban soundscape based on its context. Ten sites were chosen based on the fact that each site had a different urban environment with various combinations of buildings, road traffic, water features, and trees. Table 1 shows the main functions and sound sources for each site.

Table 1: Sites with sound sources

Site	Main function	Sound sources	Site	Main function	Sound sources
1	Commercial, office	Traffic, footsteps, music from buildings, surrounding speech	6	Office, cultural (historic building)	Traffic, footsteps, speech
2	Commercial, office	Traffic, footsteps, construction, music from buildings, surrounding speech	7	Relaxation, office	Traffic, footsteps, speech, water (stream)
3	Square, office	Traffic, water (fountain), construction, children	8	Commercial, office	Traffic, footsteps, water (stream), music from buildings
4	Square, office, cultural	Traffic, water (fountain), surrounding speech	9	Relaxation	Wind, birds, children, Traffic
5	Commercial	Traffic, footsteps, music from buildings	10	Relaxation, recreation	Wind, birds, speech, traffic

Quantitative analysis

Sound pressure levels measured at each site were strongly correlated with acoustic comfort (r=-0.85, $p<0.01$), whereas the correlation between sound pressure level and overall impression was not statistically significant (r=-0.36, $p=0.31$). The overall impression of site 4 was the highest even though its sound level was the highest; this indicates that the perception of an urban soundscape is not predominantly dependent on sound pressure level and is affected by other elements of the context. Site 9 (city park) was evaluated as the best urban space with regard to all tested contexts, whereas site 2 (with heavy road traffic and high-rise buildings) was chosen as the worst urban space. Correlation coefficients between overall impressions and the contextual evaluation results were calculated. Daylighting and fragrances and odors were significantly correlated with overall impression (0.68 and 0.65; $p<0.05$), whereas acoustic comfort, visual image, and reverberance were not (0.34, 0.52, and 0.61; $p>0.05$)

Classification of urban soundscapes

Classification of urban soundscapes was carried out through hierarchical cluster analysis on the basis of the evaluation results of the contexts, as shown in Figure 1. Based on the results, three groups (A-C) were created. Group A consisted of various types of urban spaces, including urban squares (sites 3 and 4), streets with light traffic (sites 5 and 6), a city stream (site 7), and a city park (site 10). The perceptions of the urban spaces included in Group A were not significantly different in terms of contexts. Group B contained two store-filled streets with heavy traffic (sites 1 and 2) and a pedestrian road with heavy traffic (site 8). Site 8 was categorized into Group B because sound from the small stream was rarely heard; hence, road traffic noise was likely to be dominant as it was at sites 1 and 2. Site 9 (green space) was categorized into Group C and was distinguished from the other urban soundscapes as receiving the highest subjective responses with regard to all of the contexts.

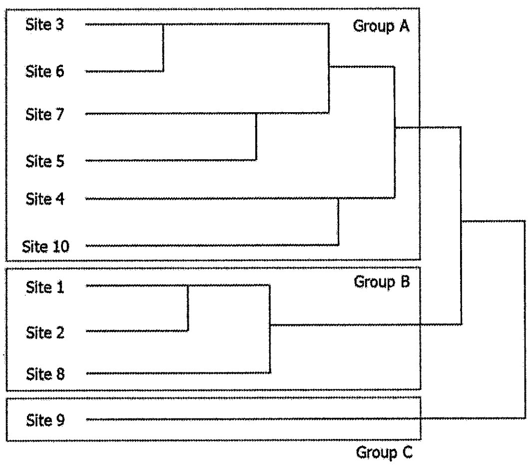

Figure 1: Classification of urban soundscapes, presented as a tree diagram (dendrogram) from a cluster analysis (the rectangles indicate Groups A-C)

Correlation coefficients between the overall impressions and the evaluation results of the contexts for Groups A-C are listed in Table 2. In the case of Group A, acoustic comfort, daylighting, and visual image were highly correlated with overall impression. Acoustic comfort and daylighting were also highly correlated with overall impression in the case of Group B, but the overall impression for Group C was correlated only with daylighting.

Table 2: Correlation coefficients between overall impression and contexts (*p<0.05, **p<0.01)

	Acoustic comfort	Visual image	Daylighting	Fragrances and odors	Reverberance
Group A	0.37**	0.55**	0.36**	0.18*	0.22**
Group B	0.44**	0.21*	0.31**	0.16	0.14
Group C	0.35	0.32	0.54**	-0.003	0.36

EVALUATION OF URBAN SPACES THROUGH SOUNDWALK

Group soundwalk

Twelve sites in Sydney were selected by considering various elements that contribute to the urban environment, such as buildings, roads, squares, and water features. Figure 2 shows the two chosen soundwalk routes, A and B. Sites 1, 6, and 12 were urban parks, and sites 2 and 9-12 were tourist attractions near the waterfront. Sites 3-5 and 8 were commercial and office districts that were exposed to heavy traffic. The soundwalk was carried out twice along two routes. Route A began at site 1 and ended at site 6, while route B passed from site 7 to site 12. Eleven participants comprised of domestic and foreign acoustics experts evaluated the urban soundscapes through questionnaires during the one-hour walks. The soundwalks were conducted in silence, and the participants were asked to concentrate on what they heard and observed about the urban environment. The questionnaire used in the soundwalk was almost the same as that used in the social survey, except for the qualitative analysis. In the soundwalk, participants were asked to describe their impressions and personal opinions.

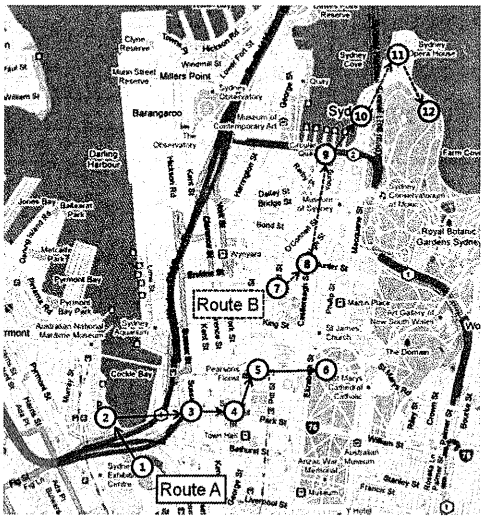

Figure 2: Soundwalk routes and evaluation sites in Sydney (source: Google Maps)

Grounded theory was used for textual analysis of the descriptions. Throughout the coding processes, perceptions of soundscapes were categorized into four themes, as shown in Table 3: 1) acoustic environment, 2) physical context, 3) psychological context, and 4) responses and outcomes.

Table 3: Categories extracted from the descriptions

Theme	Category	Subcategories	Keywords
Acoustic environment	Acoustic	Natural	Bird, wind, water sounds
		Artificial	Construction, traffic, music
		Soundmark	Identified, dominant
		Temporal features	Stationary, nonstationary
Physical contexts	Spatial aspects	Openness	Open, closed
		Density	High / low density
	Visual image	Color	Green, blue, etc.
		Brightness	Dim, bright
		Green space	Park, grass, trees, woods
		Waterfront	River, sea, stream, fountain
		Landmark	Towers, skyscrapers
	Olfactory	Unpleasant odor	Smoke
		Pleasant odor	Water, tree, clean air
Psychological contexts	Individual	Sensitivity (to)	Noise, odor
		Experience	Experience, familiarity
	Socio-cultural	Urban images	Image of city, attraction
Responses and outcomes	Responses	Positive	Favorable responses
		Negative	Unfavorable responses
		Neutral	Mixed responses
	Outcomes	Stayed	Wanted to stay
		Left	Did not want to stay
		Improve	Improvement of conditions

Individual soundwalk

Individual soundwalk methodology was proposed in order to investigate the details of subjects' perceptions. Major difference between group and individual soundwalk is a method for selection of evaluation locations. In case of group soundwalk, locations are selected by researchers, whereas those were chosen by individuals who participated in the individual soundwalks. During individual soundwalk, the subjects were given a map that indicated the area for soundwalk. They were then required to walk around that area for about an hour, stop walking and fill in the questionnaire at any locations where they noticed any positive or negative characteristics of urban environment. They also recorded environmental noise and took photographs of urban spaces simultaneously.

The urban soundscape was evaluated using a questionnaire to assess the acoustic environment and landscape, along with general questions about the participants themselves. The questions were arranged in two basic sections. The first section sought to obtain the overall impression and preference of sound source and physical conditions of the urban soundscape based on the box diagram discussed in ISO WG54. Acoustic comfort was chosen as the evaluation variable of the sound field, and visual image, daylighting, fragrances and odors, and openness were also selected for the assessment of physical conditions. These conditions were evaluated using an 11-point numerical scale (with 0 signifying not at all and 10 signifying extremely). In the second section, subjects were asked to describe soundmarks (analogous to landmarks) of the site.

Individual soundwalk was carried out in Seoul and 30 people (15 architects and 15 acousticians) were took part in. Locations that subjects stopped for the evaluation of urban soundscape were plotted in Figure 3(a). Contrary to the group soundwalk which limits the number of evaluation locations, numerous locations were selected in the individual soundwalk. This indicates that the impressions from urban spaces can be various among the subjects. As shown in Figure 3(b) the locations were grouped into 16 spots considering the number of subjects and similarity of perceptions. Blue or orange circles in different size indicate the selected numbers of locations where overall impressions were either positive or negative, respectively. The reasons why the overall impressions were different will be investigated considering the perceptions on contexts of urban soundscape.

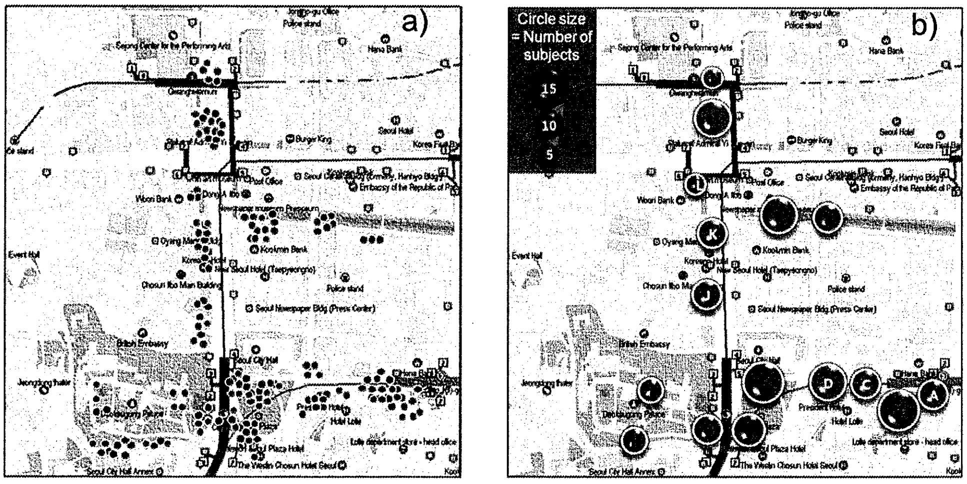

Figure 3: The locations selected by subject during individual soundwalks

ENHANCEMENT OF URBAN SOUNDSCAPE USING WATER SOUNDS

Perceptual difference of the water sound level

Auditory experiment was carried out to determine the perceptual difference in the S/N ratio between water sounds and road traffic noise. An auditory experiment with two-alternative force choice (2AFC) method was conducted to investigate the just-noticeable difference (JND) of the stimuli. The sound pressure levels (A-weighted equivalent sound pressure levels for 10 s, $L_{Aeq,10s}$) of road traffic noise were fixed at 55 or 75 dBA. When the SPL of road traffic noise was fixed at 55 or 75 dBA, the SPLs ($L_{Aeq,10s}$) of water sounds varied from 49 to 61 dBA and 69 to 81 dBA, respectively, with a step of 1 dB. During experiments, subjects were asked to select the louder stimulus of each pair. Twenty subjects, 11 males and 9 females between the ages of 22- and 32-years, participated in this experiment.

Figure 4 represents the results of auditory experiment in which road traffic noise levels were fixed at 55 and 75 dBA. The regression lines obtained from probit analysis were plotted in Figure 4. More than 75 % of the subjects correctly identified differences in S/N ratio of approximately 3 dB when road traffic noises were presented at 55 and at 75 dBA. The response in the left half (SPL of the water sounds is smaller than that of the road traffic noise) showed the similar tendency to the response in the right half.

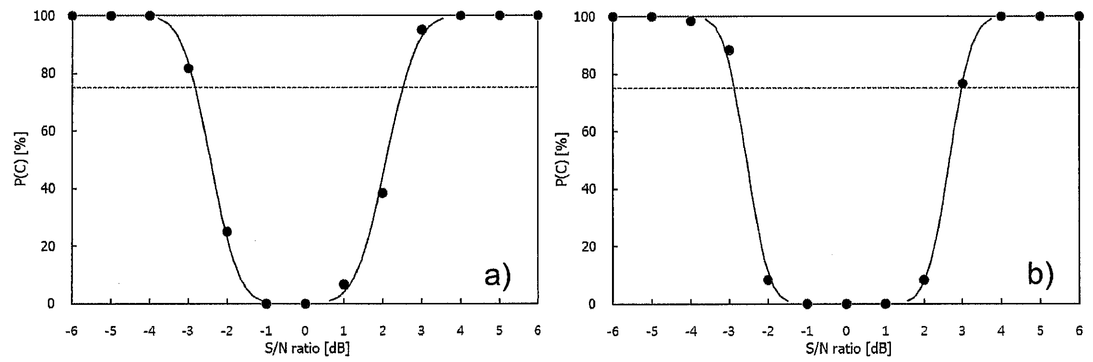

Figure 4: The results of experiment: (a) road traffic noise of 55 dBA and (b) road traffic noise of 75 dBA.

Proper level difference between water sounds and road traffic noise

The road traffic noise levels were fixed at 55 and 75 dBA ($L_{Aeq,20s}$) while the SPLs ($L_{Aeq,20s}$)of the water sounds were varied, for a total of five S/N ratios from -6 to +6 with a step of 3 dBA. Sound pressure levels of combined signal consisting of road traffic noises and the water sounds ranged from 55.9 to 61.9 dBA and from 75.9 to 81.9 dBA, respectively when the road traffic noise levels were fixed at 55 and 75 dBA. In this experiment, five water sounds, F (fountain), S1 (stream), S2 (stream), FW (falling water), and W (water fall) were presented as stimuli. Paired comparison tests were performed for stimuli (road traffic noise with water sounds) with changes in the S/N ratio. The subjects were asked to respond to the following question, "*Which stimulus would be more preferable if you were exposed to it in an urban space?*"

The results of this experiment are plotted in Fig. 5. Fig. 5 (a) represents the results in which road traffic noise was presented at 55 dBA, and Fig. 5 (b) indicates the results in which road traffic noise was presented at 75 dBA. As shown in the Fig. 5 (a), water sounds presented at a S/N ratio of -3 dB were most preferred for all five cases with different S/N ratios when the road traffic noise level was fixed at 55 dBA. A similar pattern was observed when the SPL of road traffic noise was set at 75 dBA. Subjects preferred all five water sound stimuli when the SPL of water sounds was 3 dB lower than that of the road traffic noise. S1 and FW were the most highly preferred water sounds, and S1 showed positive scale values for every case with changes of S/N ratio. Unlike S1, the scale values for F and W were negative and showed almost constant values for every case. This indicates that the sounds of the fountain and waterfall were not effective for masking road traffic noise presented at 75 dBA.

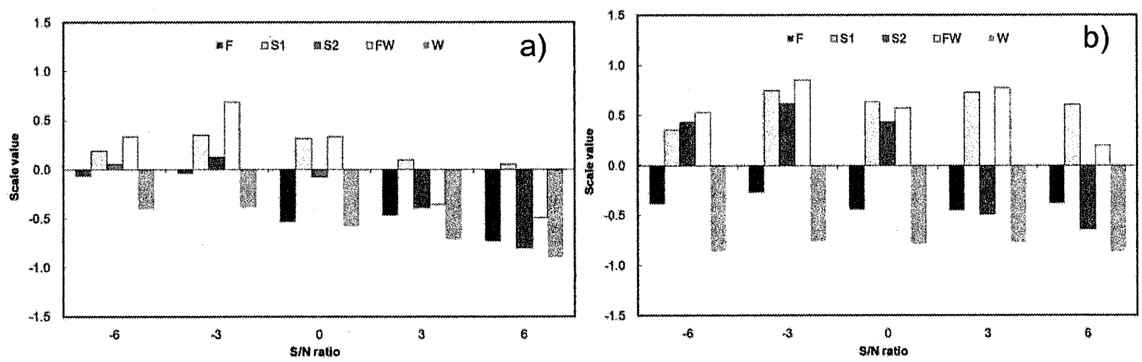

Figure 5: The results of experiment: (a) road traffic noise of 55 dBA and (b) road traffic noise of 75 dBA

Effect of audio-visual interactions

The preference test was performed to investigate, in terms of preference, the effect of water sounds on the masking of road traffic noise. In the experiments, two conditions were considered: 1) an audio-only condition and 2) a combined audio-visual condition, where, images were provided along with the sound stimuli during the experiment. A total of 14 experimental sounds were constructed: road traffic noise only and road traffic noise combined with 13 water sounds. The experiments were conducted twice with two presentation levels of road traffic noise: 55 and 75 dBA. The signal-to-noise ratios (SNR) between the water sounds and road traffic noise were set to -3 dBA so that the levels of the water sounds were 52 and 72 dBA (Jeon et al. 2010b).

The results of the preference test when the road traffic noise level was fixed at 55 dBA are shown in Figure 6(a). Preference scores obtained from the audio-only session are shown in white columns and the results from the audio-visual session are given in gray columns. All of the stimuli combining road traffic noise and water sounds were judged to be significantly better, in terms of preference ($p<0.01$), than road traffic noise alone. It was also found that improvements in the preference scores were affected by the types of water sounds. Experimental results obtained with road traffic noise of 75 dBA are shown in Figure 6(b). Similar to that at 55 dBA, water sounds led to significantly better ratings of preference ($p<0.01$).

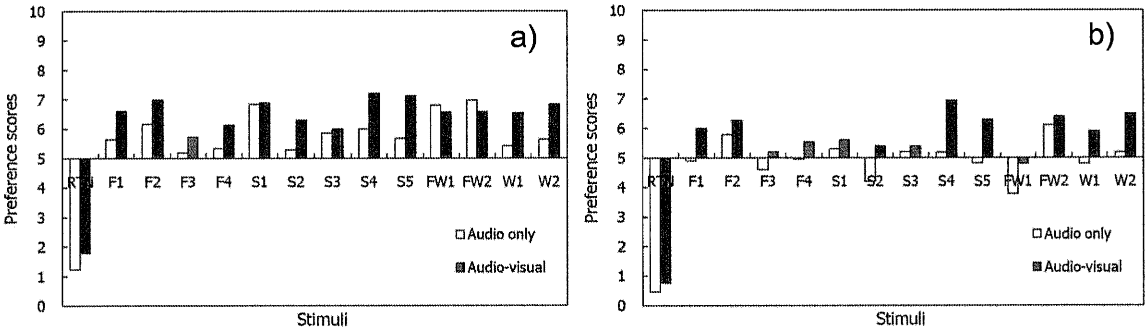

Figure 6: Experimental results for water sounds combined with road traffic noise at Leq 55 (a) and 75 dBA (b)

CONCLUSIONS

In this study, urban soundscapes were evaluated using a social survey in order to investigate the effects of contexts on soundscape perception. In the social survey, urban soundscapes were classified into Groups A-C based on the context evaluation results. In addition, urban soundscapes were assessed by soundwalks. From group soundwalks, it was found that spatial impressions such as openness and density of urban spaces influenced soundscape perception. The results of individual soundwalk also showed that locations that the subjects perceived positive or negative impressions were different. Furthermore, the results of auditory experiment represented that the perceptual difference of the water sound level was around 3 dB with noises from road traffic in the background, the water sound, which had 3 dB less sound pressure level, was evaluated as preferable when the levels of road traffic noise were 55 or 75 dBA, and preference scores for the urban soundscape were affected by the acoustical characteristics of water sounds and visual images of water features.

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