Sound-masking technique for combined noise exposure in open public spaces

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ABSTRACT

A sound-masking technique was applied to minimize the annoyance in open public spaces exposed to combined noise sources. The noises were recorded binaurally through artificial head microphones from the building construction sites with nearby roads. Sound quality (SQ) parameters as well as spectral and temporal characteristics of the noises were investigated. For the auditory tests to evaluate the presence of the sound-masking system, sound maskers were manipulated and presented in the open public spaces. Psychoacoustical factors affecting subjective responses to the combined noise exposure were investigated and the effectiveness of the sound-masking system was examined.

INTRODUCTION

Demands on favorable acoustic environment in open public spaces have been increasing with the increase of outdoor activities. Overall sound pressure level in the area has been thought as the most important aspect affecting the amenity of the environment. However, most of the open areas are necessarily accompanied with heavy flux of transportation and people so that excessive noise threatens soundscape of the environments.

Many studies investigated the acoustical environment of exterior spaces in order to define the relationships between sound characteristics and subjective responses (Anderson et al. 1983; Skanberg & Ohrstrom 2002). Although classifying the characteristics of soundscape in open public space is important, active treatment on the sound environment is often needed to improve quality of the acoustical amenity of the areas. As an actual method to control the soundscape, several nature sounds were introduced with speaker systems to the open public spaces (Jang et al. 2003; Lee et al. 2005; Jeon et al. 2007). As most of the studies applied nature sounds without manipulation, hence masking effects on the environmental noise have been deficient.

In the present study, the characteristics of combined exterior noises from road traffic and construction site were investigated. The preferences on the soundscape were sought before and after the application of the sound-masking system. Sound quality attributes of the combined noise were determined and sound maskers (to enhance the acoustical amenity) were produced.

MEASUREMENTS

Sounds from building construction and nearby roads were recorded in eight open public areas which were chosen according to the volume of road traffic and the distance from construction sites (see Table 1). Measured noise level ranged from 55.8 to 78.0 dBA during 10 minutes. Sites B and F were chosen and, as shown in Figure 1, HATS (Head and Torso simulator) was located at 33 m, 15 m from the roads in Sites B and F, respectively. Therefore, in Site F, HATS was located at 50 m apart from the construction site. The height of microphone was set at 1.5 m from the ground. The noises were recorded as 'wav' format using Adobe Audition software, through AD/DA converter.

Table 1: Categorization of open public spaces for noise measurements

Place	Road traffic volume	Number of construction sites
A	Low	0
B	High	0
C	Low	1
D	High	1
E	Low	1
F	High	1
G	Low	2
H	High	2

(a) Site B

(b) Site F

Figure 1: Binaural recordings in Sites B and F

As shown in Figure 2, frequency characteristics of the noise for both sites were compared. Both site B and F showed relatively high levels at low frequencies due to road traffic, but harmonic components appeared in Site F because of the noises from construction machinery. Site B showed lower levels at low and mid-low frequency ranges, and the level difference between Sites B and F was increased at mid-low frequency range.

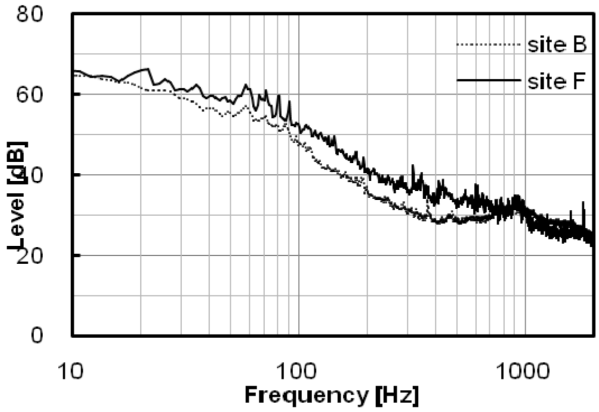


Figure 2: Frequency characteristics of recorded noise

EXPERIMENTS AND RESULTS

In the laboratory and actual sound fields, three experiments were undertaken to evaluate the subjective attributes of the maskers. First, masker sound among various nature sounds was selected by preference tests. Second, signal to noise ratio between masker and maskee was determined and finally, the SQ characteristics of the masker were manipulated in order to enhance the effectiveness of masking.

Experiment 1: Selection of maskers

Sound-maskers were evaluated by an auditory experiment which was designed to select the sounds from the combined sounds with various maskers (nature sounds). Ahn (2002) found that nature sounds from fountain and bird are preferred in open public spaces. In the present study, nine nature sounds as shown in Table 2 were used to investigate the preferred sound masker. Paired comparison method was used: each of the stimuli pair consisted of a site noise with one sound masker and the noise from the same site with another sound masker. All the subjects were asked to select one in each pair. Duration of each sound was 7.0 s with an interval of 3.5 s (total 17.5 s). All the pairs were randomly presented to the subjects. Visual image of the actual site was presented to subjects before the auditory tests begin.

Twelve subjects – aged from 20 to 30 – evaluated the sounds through headphones in a sound proof chamber. Presentation level of the sound stimuli was set to 58 and 60 dBA for road traffic and construction noise, respectively, by considering the actual sound level.

Consistency tests indicated that 11 out of 12 subjects showed significant responses ($p<0.05$). As shown in Figure 3, ‘Stream’ and ‘Lake’ sounds were highly preferred in both cases of road traffic and construction noise. ‘Rainfall’, ‘Seagulls in port’ and ‘Wind sound’ showed relatively lower scale values of preference.

Table 2: Stimuli in Experiment 1

No.	Road traffic noise	Construction noise
1	-	-
2	Waterfall	Waterfall
3	Rainfall	Rainfall
4	Stream	Stream
5	Lake	Lake
6	Birds in forest	Birds in forest
7	Seagulls in port	Birds in port
8	Insects	Insects
9	Church bell	Bell of church
10	Wind sound	Wind sound

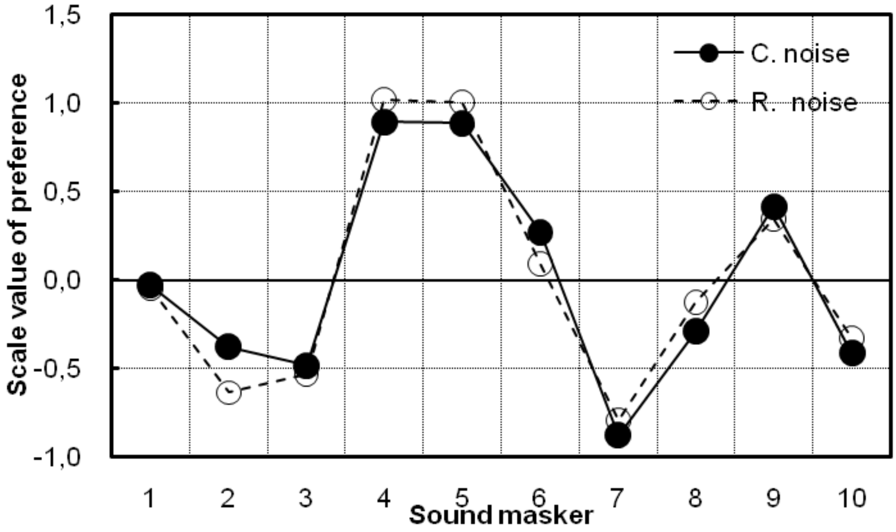


Figure 3: Scale value of preference of sound maskers

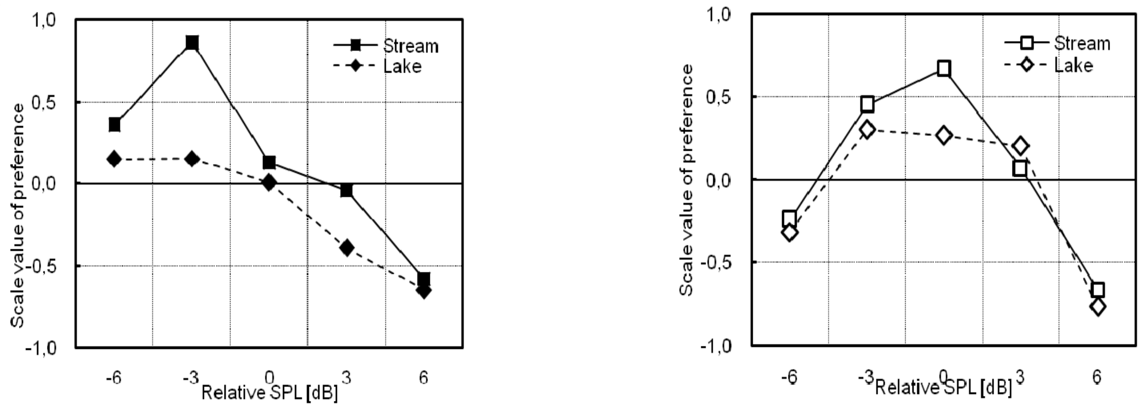
Experiment 2: Investigation of effective signal to noise ratio

Effective signal to noise ratio between masker and maskee was investigated for 'Stream' and 'Lake' sounds which were determined as sound maskers in Experiment 1. As shown in Table 3, the relative sound pressure levels of the sound maskers were varied. The signal to noise ratio between each of the neighboring stimuli was 3 dB and maximum level difference was 6 dB. Paired comparison method was also employed and ten subjects participated for the evaluations.

Consistency tests indicated that 9 out of 10 subjects showed significant responses ($p<0.05$). As shown in Figure 4, in the case of construction noise, the scale value showed high preferences when the sound masker was presented 3 dB lower than that of the noise. In the case of road traffic noise, the scale value was high when the 'Stream' and 'Lake' were presented as the same level and 3 dB lower than the noise, respectively. The scale value was decreased when the level of sound masker was increased over the level of site noise.

Table 3: Stimuli of experiment 2

No.	Road traffic noise	Construction noise
1	Stream 52 dBA (-6 dB)	Stream 56 dBA (-6 dB)
2	Stream 55 dBA (-3 dB)	Stream 59 dBA (-3 dB)
3	Stream 58 dBA (0 dB)	Stream 62 dBA (-0 dB)
4	Stream 61 dBA (+3 dB)	Stream 65 dBA (+3 dB)
5	Stream 64 dBA (+6 dB)	Stream 68 dBA (+6 dB)
6	Lake 52 dBA (-6 dB)	Lake 56 dBA (-6 dB)
7	Lake 55 dBA (-3 dB)	Lake 59 dBA (-3 dB)
8	Lake 58 dBA (0 dB)	Lake 62 dBA (0 dB)
9	Lake 61 dBA (+3 dB)	Lake 65 dBA (+3 dB)
10	Lake 64 dBA (+6 dB)	Lake 68 dBA (+6 dB)



(a) Construction noise (b) Road traffic noise

Figure 4: Scale value of preference according to relative presentation level

Experiment 3: SQ characteristics of effective sound maskers

The stimuli which were varied in sound quality characteristics were investigated in this experiment with the same experimental conditions as in Experiments 1 and 2. Psychoacoustical characteristics of the noise and sound masker are shown in Table 4. 'Masker A' and 'Masker B' are the sound maskers which were preferred in the previous experiments for construction noise and road traffic noise, respectively.

Table 4: Psychoacoustical characteristics of the stimuli used in Experiment 3

	SPL [dBA]	Loudness [sone]	Sharpness [acum]	Roughness [asper]	Fluctuation Strength [vacil]
Construction noise	62	17.6	1.41	1.67	1.05
Masker A	59	11.1	2.01	2.46	1.2
White noise A	59	12.3	3.14	1.43	0.74
Road traffic noise	58	12.1	1.43	1.34	0.76
Masker B	58	10.2	1.99	2.51	1.22
White noise B	58	11.5	3.15	1.44	0.75

Evaluation of sound masking system in actual condition

Evaluations on the soundscape were conducted to verify the effectiveness of the sound masking system in actual condition. Subjects evaluated the sound masking system in the eight actual fields in order to validate the sound maskers in laboratory conditions.

DISCUSSION AND CONCLUSIONS

Sound maskers have been applied in urban public spaces exposed to construction and road traffic noises. Subjective evaluations have been made to investigate noise annoyance to different combination of soundscape. Results which were taken both in laboratory and actual conditions, show that sound maskers such as 'Stream' and 'Lake' are effective for both road traffic and construction noises. When the presentation level of the sound masker is up to 3 dB lower than that of the combined noise sources, the scale values of preferences actually increase.

Analyses of Zwicker's parameters reveal that higher loudness factors in the presented noises are perceptually lessened by other higher psychoacoustical factors in the maskers. The effectiveness of the sound masking-system will be further examined in actual situations.

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