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SUITABILITY OF NATURAL SOUNDS TO ENHANCE SOUNDSCAPE QUALITY IN URBAN RESIDENTIAL AREAS

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Masking noise by introducing pleasant natural sounds is one of the soundscape design approaches to improve soundscape quality. In order to achieve good soundscape quality, it is necessary to consider both pleasantness and suitability of maskers. This study aims to investigate the effects of main functions of places on suitability of natural sounds to mask traffic noises. Thirteen natural sounds including birds, insects and water sounds were used as acoustic stimuli. Spherical panoramic pictures of six locations in residential areas were captured for laboratory experiment. The laboratory experiments consisted of audio-only, visual- only, and audio-visual conditions. In the audio-only session, pleasantness of natural sounds were assessed, and suitable behavioural activities in the six locations were evaluated in the visual-only session. In the audio-visual session, suitability of the natural sounds as maskers were evaluated in the six different locations. The results showed that suitability of masker is significantly influenced by the contexts of the places in residential areas.

Keywords: soundscape, residential area, masking, natural sounds, urban activities

1. Introduction

Unlike the conventional noise control perspective, the soundscape approach does not primarily aim to reduce noise levels, but concentrates on what sounds are appropriate and desired in a place. Soundscape approaches treat sounds as a ‘resource’ rather than as a ‘waste’ to design acoustic environments in places. Auditory masking is a representative soundscape approach considering sounds as resources [1]. Introducing pleasant sounds as resources could enhance perceived acoustic quality by energetically masking noise or diverting the listener’s attention from urban noises [2]. Many studies on soundscape masking using natural sounds have been conducted [3–5]. However, the previous studies have not considered the appropriateness of soundscape in a place. Appropriateness of soundscape is one of the important perceptual descriptors of soundscape which is largely dependent on the context of the given place [6]. To choose appropriate sound maskers, not only pleasantness but also suitability of sound sources should be taken into account. Thus, this study aims to evaluate both preference of natural sounds and suitability sound maskers within the contexts in the urban residential areas. In order to achieve these goals, laboratory experiments were conducted using various types of natural sounds.

2. Methods

2.1 Acoustic and visual stimuli

In this study, Road traffic noise was chosen as a representative urban noise. Natural sounds including bird, insect and water sounds were selected positive sound sources in urban spaces. In total, thirteen natural sounds (5 birds, 3 insects, and 5 water sounds) were chosen as maskers considering various acoustical characteristics. Road traffic noise recorded from the real urban environment was used as a stimulus. For the laboratory experiment, 10 second audio recordings of road traffic noise and natural sounds were used. Similar to previous studies [5,7], mono acoustic stimuli were made in order to avoid the possibility of spatial unmasking effects.

Outdoor open and public spaces in the residential areas in Singapore are classified into six categories considering main functions and typologies: 1) active zone 2) passive zone 3) common green 4) rooftop garden 5) small park and 6) park connector. According to the six categories of urban spaces, spherical panoramic images of each category in a residential area was captured with clear weather using Google street view application as shown in Figure 1.

Figure 1: Spherical panoramic images of the six locations in residential areas

2.2 Subjective evaluation

The laboratory experiments consist of three sessions: 1) an audio-only condition, 2) a visual-only condition, and 3) a combined audio-visual condition. For the audio-only condition, 14 acoustic stimuli (10 s each) were constructed, namely, one road traffic noise (RTN), five bird (B1 to B5), three insect (I1 to I3) and five water (W1 to W5) sounds. The signal-to-noise-ratio (SNR) between RTN and natural sounds were set to 0 dBA because findings in previous studies show that natural sounds should be similar or not less than 3 dB below the RTN level to be most preferable [3,8]. The A-weighted equivalent sound pressure level ($L_{Aeq,\ 10s}$) of the acoustic stimuli was fixed at 55 dBA. In the audio-only session, the subjects were asked to rate their preferences for each stimulus using an 11-point scale (0: not at all pleasant and 10: extremely pleasant).

In the visual-only session, subjects were asked to evaluate suitable social and recreational activities in the given location using a 5-point scale (‘Not at all’, ‘Slightly’, ‘Moderately’, ‘Very’, ‘Perfectly’). Social and recreational activities that may frequently happen in residential areas were listed based on the previous studies [9,10] and the list is presented in Table 1.

In the combined audio-visual session, 84 audio-visual stimuli (13 combination of RTN and natural sounds × 6 locations) were created and the suitability of sound sources in the given locations were assessed using an 11-point scale (0: not at all pleasant and 10: extremely pleasant).

Table 1. List of social and recreational activities in residential areas

No.	Description
1	Walking the dog
2	Informal outdoor games (e.g. Frisbee, other self-organised sports)
3	Spending time with friends or family
4	Walking, jogging or running
5	Using electronic devices (e.g. mobile phones)
6	People-watching
7	Nature appreciation (e.g. flowers, shrubs, trees)
8	Experiencing peace and quiet in general
9	Socialising/conversing/chatting
10	Children's play
11	Gardening/food-growing

In total, 43 subjects (male: 20 and female 23) with normal hearing took part in the experiments. The subject age distribution ranged from 19 to 25 years. The acoustic, visual and audio-visual combined stimuli were uploaded in YouTube and presented through headphones (Beyerdynamic Custom One Pro) and a PC monitor screen (HP z23n), respectively. Subjects assessed stimuli one-by-one in audio-only, visual-only, and combined audio-visual sessions and they were allowed to replay sounds and visual stimuli as many times as they wanted to answer the questions.

3. Results

3.1 Preference of acoustic stimuli

Mean pleasantness rating scores for the acoustic stimuli are shown in Figure 2. Overall, pleasantness scores of natural sounds are higher than that of traffic noise except for B3. Among the natural sounds, water sounds are highly preferred than other natural sounds. In particular, W4 (stream) and W5 (waves of lake) were judged as most pleasant sounds supporting the findings in previous studies [8,11]. There were no significant differences between bird and insect sound in terms of pleasantness. Among the bird songs, pleasantness scores of B2 and B4 were relatively higher than those of other bird songs. I2 obtained highest pleasantness score among the insect sounds.

One-way analysis of variance (ANOVA) was conducted to examine the statistical mean differences in preference score among the acoustic stimuli. The results of the ANOVA showed that there were significant differences among the natural sounds in terms of pleasantness ($F(13,588)=15.09$, $p<0.01$). Post hoc Tukey's tests were performed to compare the mean differences between traffic road and natural sounds. It was found that there were significant mean differences in I2, and W1 to W5. This implies that there are no significant difference between road traffic noise and bird songs. The L_{Aeq} values of the road traffic noise ranges from 55 and 70 dBA in most urban spaces [12]. The road traffic noise at 55 dBA in the present experiment might be considered as acceptable noise level so that the subject might evaluate the RTN less annoying. In particular, Singapore is highly dense city so that Singaporeans might be used to higher road traffic levels.

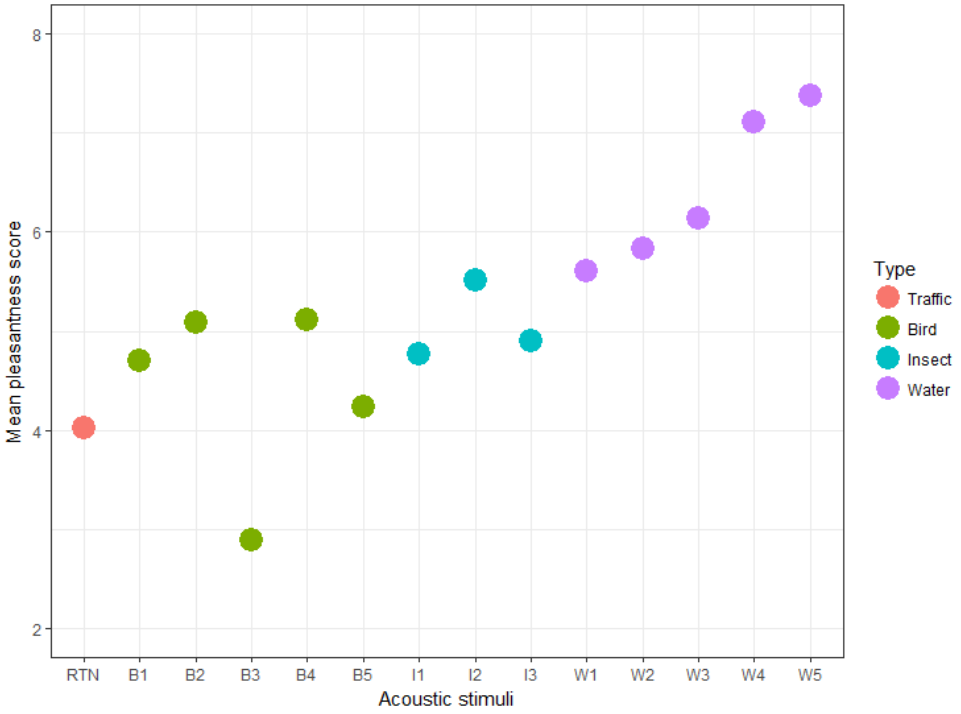

Figure 2: Mean pleasantness rating scores for the acoustic stimuli.

3.2 Socio-recreational activities in residential areas

Principal component analysis (PCA) was conducted to extract main components of social and recreational activities in urban residential areas based on the responses from the visual-only session. Varimax rotation method was applied to identify the orthogonal components. Three components with Eigenvalues larger than 1 were obtained. Components 1 that explained 38.4% of variance was highly correlated with personal exercises such as walking, jogging or running. Component 2 showed 14.7% of explained variance was associated with activities including Children's play, informal outdoor games, socialising, conversing and chatting. Component 3 explained 9.51 % of variance and closely related to the activities such as Gardening/food growing and experiencing peace.

As shown in Figure 3, mean component scores of the three components are calculated for the six different locations in order to characterize the main socio-recreational functions of the places. Active zone had higher component scores of component 1 and 2. This indicates that active zone usually serves for personal exercise and children's play. Passive zone obtained highest score of component 2 implying that socializing or chatting are main behavioural activities in a passive zone. Park and park connector showed similar tendency in terms of functions that personal exercise and experiencing peace and nature are considered as main functions of those places. Common green shows neutral values for the all components. This indicates that common green is considered as a rather multiuse place. In the rooftop garden, component 3, experiencing peace and nature, was slightly higher than other components.

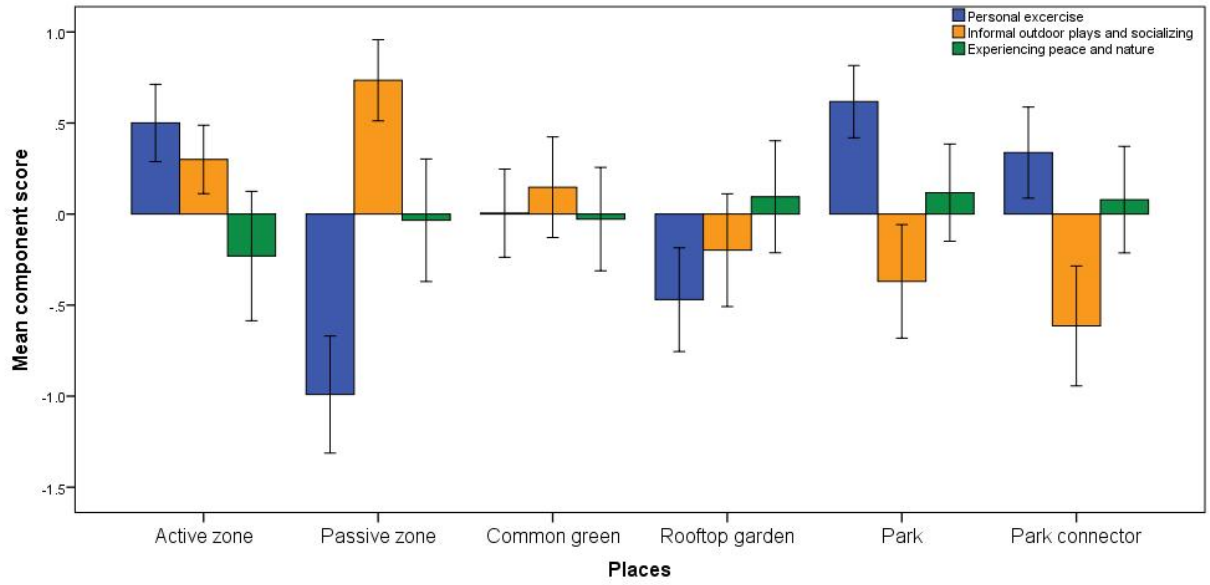

Figure 3: Mean component scores for the six locations.

3.3 Appropriateness of sounds in residential areas

In audio-visual combined session, suitability of soundscape was evaluated within the six locations. As illustrated in Figure 4, large variances of suitability of soundscape were found across the different places. This finding indicates that functions of space play important role to judge suitability of soundscape [2,6]. In general, bird sounds were considered as more suitable in residential areas as masker sounds due to their coherence within the contexts of the places. The bird sounds were suitable in the common green, park, active zone, and park connector. The water sounds were evaluated as less appropriate than bird and insect sounds in the places. The subject assessed that water sounds were only suitable in the Park and Park connector. This is because of visibility of water features in the park and park. In contrast, visibility of birds and insects is not critical factor to judge suitability of their sounds because normally, people usually hear bird or insect sounds even though they do not know where the bird and insects are located.

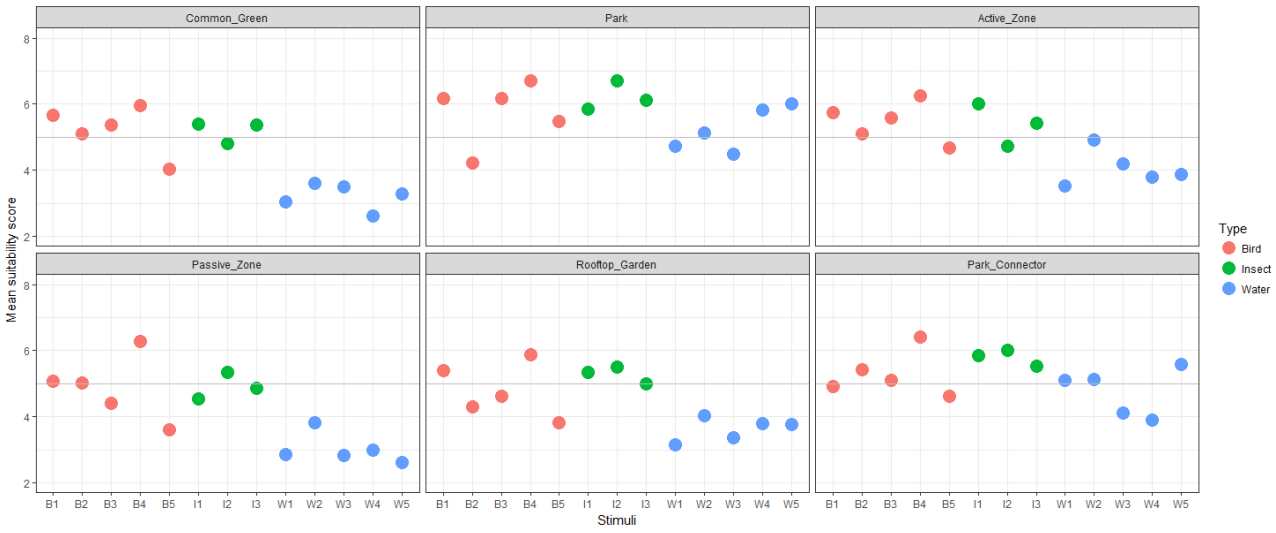

Figure 4: Mean component scores for the six locations.

4. Conclusions

In the present study, natural sounds were evaluated as maskers to traffic noise in the perspective of preference and suitability of the soundscapes. In terms of the pleasantness of sound, water sounds were more preferable than bird sounds for Singaporean. Outdoor open and public spaces in residential areas were characterized with the main functions: personal exercise, informal outdoor plays and socializing, and experiencing peace and nature. In terms of suitability of soundscape in different places with different functions, there are significant differences in water sounds across the places. It can be deduced that visibility of water features is important factor to use water sounds as maskers, while visibility of birds and insects is not important factor to evaluate suitability of bird sounds. In general, the park is the most suitable place for all natural maskers.

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