

ANN models for sound preference evaluations International Congress on Acoustics, ICA 2010

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ABSTRACT

Subjective evaluation of individual sounds is an important aspect of soundscape research. In this paper, a study of sound preference evaluations in urban open spaces is discussed while artificial neural network (ANN) models for predicting the subjective evaluations of sound preference are developed. The impact of various factors on sound preference evaluations is statistically analysed based on indoor experiments and outdoor surveys. The importance of various sounds' physical and psychological factors, and listeners' social and behavioural situations for sound preference evaluations are examined. With respect to such importance, input variables for ANN models are selected. A number of ANN models are explored in terms of complicated relationships between various factors and sound preference evaluations according to different study cases. Four kinds of models have been built, namely general, individual, group, and lab models. The results show that the lab models make good predictions whereas the prediction performance of the other models is not satisfactory. No significant differences of predictions have been found among general, individual and group models, indicating that the impact of different locations is trivial on sound preference evaluations. Furthermore, a mapping technique is proposed in order to directly assist urban planners/designers.

INTRODUCTION

There is no doubt that a sound plays an important role to determine the quality of sonic environment [1-2]. Physically, sound is a kind of waveform vibrating in an elastic medium [3]. Psychologically, sound effects on human perceptions cause an informative aural sensation in our brains through the auditory mechanism [4]. Sound is also realised as a social element in our life that is associated with reminding dangers, searching for foods or religious ceremonies [5]. Sounds with the 'scape' they enclose are essential parts in a physical environment. From this point of view, Schafer coined the item 'soundscape' in 1960s to describe an acoustic environment and the way people are feeling it [6]. Sound is essential element in a soundscape that can carry various messages to a certain circumstance. Sound preference is an aesthetic response of people reacting to a sonic environment. In relation to soundscape research, the subjective evaluations of sound preference have been focused by various studies [7-11].

Although sound preference has been broadly studied, systematic research of various factors on sound preference evaluations is rather limited. Meanwhile, there is a lack of a link between the sound preference study and the soundscape planning/design. In this study, the importance of various factors on the sound preference evaluations in urban open spaces is therefore explored. Artificial Neural Networks (ANNs) is introduced as an innovative method to study sound preference evaluations. In terms of single sounds, ANN models are largely developed to predict the subjective evaluations of sound preference in order to aid soundscape planning/design. Moreover, a mapping method is proposed for visually helping planners/designers.

FIELD STUDIES

In order to study subjective evaluation of sound preference in urban open spaces, a series of field studies were carried out in EU and China. Following the field studies, laboratory experiments were also undertaken.

The field studies were firstly carried out in two urban squares in each of seven European cities, including Athens, Thessaloniki, Milan, Fribourg, Cambridge, Sheffield, and Kassel [12]. Parallel studies were then undertaken in five Chinese urban squares, two in Beijing and three in Shanghai.

The questionnaires were initially developed in English, and then translated into other languages. In total, nineteen urban squares were chosen in the study, while approximately 10,000 people were interviewed. The interviewees, usually the space users than passers-by, were selected randomly. Among the nineteen case study sites, there was a wide range of variation in terms of physical conditions and social users. Based on the geographical locations, the case study sites can generally be categorised into four kinds of area, namely city centre, residential area, tourist spot and railway station [13]. In terms of sound sources, three sorts of sounds were examined, namely natural, human and mechanical.

Table 1 shows the noticed sounds in the studied squares when carrying out interviews. In the field studies, a 3-point scale (-1: favourite, 0: neutral, 1: annoyance) was used for subjective evaluation of sound preference as pilot studies have shown that this scale is more efficient in distinguishing the preference differences of people on sound effects.

Table 1. Noticed sounds (marked by ✓) in the case study sites

Site	Natural sounds			Human sounds			Mechanical sounds			Construction
	Bird	Water	Insect	Speaking	Footstep	Children shouting	Traffic			
							Car	Bus	Parking	
Site 1		✓		✓	✓		✓	✓		
Site 2				✓	✓		✓			
Site 3				✓	✓	✓	✓			
Site 4				✓	✓	✓	✓			
Site 5				✓		✓	✓	✓		✓
Site 6						✓	✓	✓		✓
Site 7		✓		✓			✓	✓		
Site 8				✓		✓	✓			
Site 9	✓			✓		✓	✓			
Site 10				✓	✓		✓	✓		
Site 11	✓			✓			✓	✓		
Site 12		✓		✓	✓		✓	✓		
Site 13				✓	✓		✓	✓		
Site 14		✓		✓		✓	✓	✓	✓	✓
Site 15	✓		✓	✓			✓	✓		
Site 16			✓	✓	✓		✓	✓	✓	
Site 17				✓	✓		✓	✓		
Site 18		✓		✓			✓	✓	✓	
Site 19	✓	✓	✓	✓			✓	✓		

The grey areas indicate where the variables are not available

LABORATORY EXPERIMENTS

In order to examine more factors influencing subjective evaluation of sound preference, laboratory experiments were undertaken following the field studies. This is because some factors, such as psychoacoustic indices, were not easy to be studied in outside, whereas the sounds recorded in the case study sites could be used in the laboratory experiments.

The experiment was designed as three parts, with 56 participants. In Part I, nine sounds similar to the sounds examined in the field studies were listed, and the participants were asked to give assessments of sound preference according to literal meanings of the sounds. In Part II, ten pre-recorded sounds, most from case study sites, were presented to the participants. Among them, six were from different sound sources, whereas the four remaining ones were repeating two of the above six sounds but at different sound levels. The participants were required to give their evaluations after listening to each sound. In Part III, five sounds with video recordings were presented to the participants. The audio recording of a sound was firstly played back to the participants, and then the video recording with the same sound was played. The sounds were played back in random order to the participants with a 4.5 seconds gap, and the participants were asked to evaluate these sounds based on their listening or watching experience.

In Table 2 all the studied sounds in laboratory are summarised. Generally speaking, these sounds can be classified into two categories, single sounds and combined sounds. Single sounds can also be divided into natural sounds, human sounds and mechanical sounds. In total, sixteen sounds were studied in the laboratory experiments. Eleven of them were single sounds, while five of them were combined sounds.

Table 2. Studied sounds in the laboratory experiments

Sounds	Part I	Part II	Part III
	Natural sounds	Bird	Bird
Insect		Bird -10dBA	
		Bird + 10dBA	
Human sounds	People speech	Children shouting	Skateboard
	Children shouting		
	Music played in a street		
	Church bell		
	Skateboard		
Mechanical sounds		Car passing	
		Car passing - 10dBA	
	Traffic	Car passing + 10dBA	
	Construction	Traffic	
Combined sounds		Birdsong & Car passing	Fountain & Song
		Church bell & Speaking	Fountain & Children shouting
			Fountain & Construction

The grey areas indicate where the variables are not available

INFLUENCING FACTORS ON SOUND PREFERENCE EVALUATION

Based on field studies and laboratory experiments, the effect of various factors, including sound meanings, psychoacoustic parameters (loudness and sharpness), social/demographic characteristics, physical conditions, behavioural, psychological status, and home sound experience, on the sound preference evaluation has been systematically studied, for three sound types, namely natural, human and mechanical sounds.

The effects of sound meanings on the sound preference evaluations have been studied based on sound category. In terms of sound category, natural sounds (bird, water, insect) are the most preferred sounds, while human sounds (speaking, footstep, children shouting) are more preferred than mechanical sounds (car passing, buses passing, vehicle parking and construction), as shown in Figure 1. In terms of cultural difference, the study compared the preference evaluations between Chinese and Europeans. The result shows that Chinese people are more annoyed by the sound of children shouting and buses passing than the EU people as it can be seen in Figures 2 and 3. In terms of the visual effect, the result indicates that a positive view can improve preference feeling of a sound whereas negative scenery does the opposite.

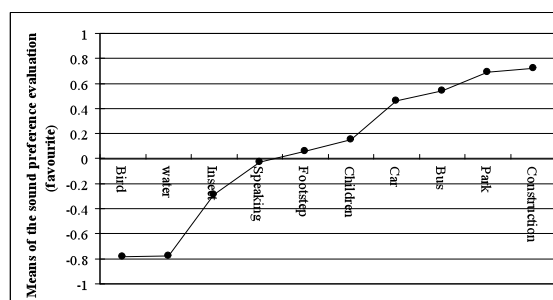


Figure 1. Means of sound preference evaluations for all sound samples

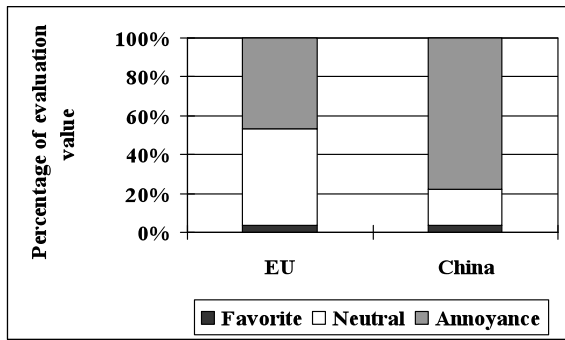


Figure 2. The differences of sound preference evaluation between the EU and China in terms of children shouting

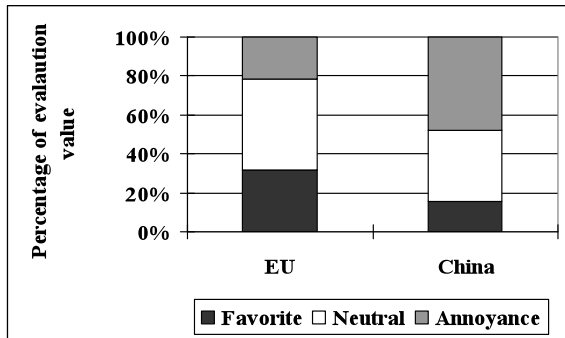


Figure 3. The differences of sound preference evaluation between the EU and China in terms of bus passing

Figures 4 and 5 show that loudness affects preference evaluation of single as well as combined sounds [14]. It can be seen that the correlation between loudness and the subjective evaluations of single sounds is higher than that of the combined sound as R^2 is usually higher for the single sounds. Further Pearson correlation has been made in the study, and significant correlation has been found between loudness and the preference evaluations for single sound. A sound with higher loudness has been found to be with less preference, especially for the single sounds. However, the effect of loudness on the evaluations of combined sounds is relatively less than that of single sounds, as shown in Figure 5. In relation to the same sound with different sound levels, it is found that a negative relationship exists between loudness and the subjective evaluations, as expected [14].

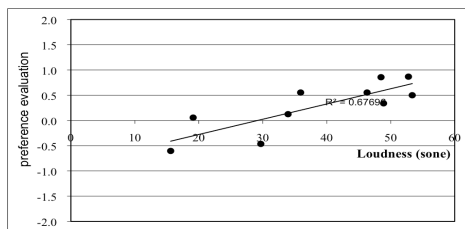


Figure 4. Relationships between loudness and sound preference evaluations for single sounds

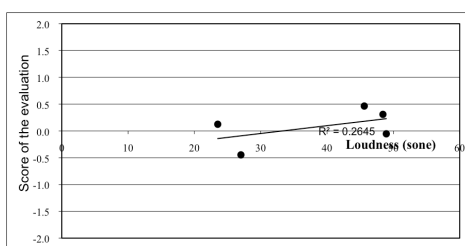


Figure 5. Relationships between loudness and sound preference evaluations for combined sounds

In Figure 6 and 7, the influence of sharpness on sound preference evaluation is shown. Unlike loudness, within the range of the studied sounds, a sound with a higher sharpness level was perceived with a higher preference but this is not true for the combined sounds. In relation to the combined sounds, it is found that a sound is less preferred if sharpness is higher but it is noted that this was only with five studied sounds.

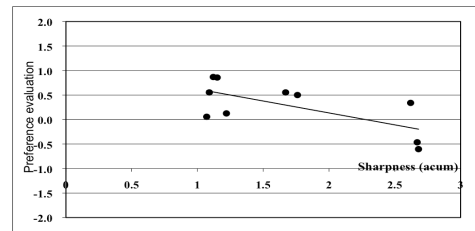


Figure 6. Relationships between sharpness and sound preference evaluations for single sounds

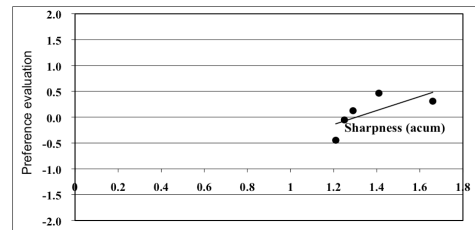


Figure 7. Relationships between sharpness and sound preference evaluations for combined sounds

In terms of social/demographic factors, the results suggest that age and education are related to the sound preference evaluations more than others [15]. However, the correlation may vary with different types of urban open spaces and sounds. It is interesting to note that with increasing age or education level, people tend to prefer natural sounds more and to be annoyed by mechanical sounds. As to physical/behavioural/psychological factors, generally speaking, their importance for sound preference evaluation is insignificant, except for a limited case study sites and certain sound types. Among these factors, the reason for visiting the site has the weakest relationship with the sound preference evaluations, whereas the site preferences are most related. The importance of home sound environment for sound preference has been found to be generally insignificant, except for certain sounds. For example, those people who hear birdsongs at home may often tend to prefer birdsongs in urban open spaces too.

ANN MODELS FOR SOUND PREFERENCE EVALUATION

Modelling subjective evaluation of sound preference is more sophisticated than that of sound level and acoustic comfort [16]. Based on the study of impact factors on sound preference evaluation, it can be seen that the subjective evaluations varied significantly according to three sound sources, namely natural, human and mechanical, and therefore, three sounds representing these three sound sources have been selected to develop ANN models, which are birdsong, children shouting, and car passing. The input variables for all models are statistically significant. As shown in the above section, sound meanings, loudness and sharpness are important factors in sound preference evaluation, which have been selected to be input factors for all models. However, for other factors, they were selected as inputs, only if there is statistically significant correlation with the sound preference evaluations [15]. Using NeuroSolutions software [17], four types of ANN models were developed in this study, as illustrated in Table 3.

From Table 3 it can be seen that general, EU, China and Lab models were developed for the models of birdsong, children shouting and car passing. In addition, an individual model was developed for site 9- Jardin de Perolles, Frobourg, Switzerland, which has been used in all four types of models, so that a comparison can be made. These models were built for representing a general situation, individual site, group sites and laboratory case that covers various possibilities of studied cases. For all models, after a number of optimisations of the training process, the optimal networks were obtained, as shown in Table 4.

Table 3. ANN models of predicting subjective evaluation of sound preference

Types	Model	Inputs	Outputs
Models for all three sounds	Lab	Age, Gender, Loudness, Sharpness, Sound category	Evaluations of birdsong, children shouting, and car passing
	Jardin de Perolles (JdP)	Age, Occupation, Education, Sound category	
Models for birdsong	General-bird	Age, Gender, Occupation, Education	Evaluations of birdsong
	Jardin de Perolles (JdP)-bird	Age, Occupation, Education, Time of day	
	EU-bird	Age, Gender, Occupation, Education	
	China-bird	Age, Education	
	Lab-bird	Age, Gender, Loudness, Sharpness	
Models for children shouting	General-children	Age, Occupation, Education	Evaluations of children shouting
	Jardin de Perolles (JdP)-children	Age, Occupation, Education, View assessment	
	EU- children	Age, Occupation,	
	China-children	Age, Gender	
Models for car passing	General-car	Age, Gender, Education, Residential status, Season	Evaluations of car passing
	Jardin de Perolles (JdP)-car	Time of day, Age, Occupation, Education, Site preference	
	EU-car	Age, Education, Season, Frequency of visiting the site, Site preference	
	China-car	Age, Education	
	Lab-car	Age, Gender, Loudness, Sharpness	

From Table 4 it can be seen that there is no difference between the general, individual (site 9- Jardin de Perolles, Frobourg), and group (EU, China) models for predicting the subjective evaluations of sound preference (birdsong, children shouting, or car passing). All of the general, individual and groups presented a poor prediction performance, with a <0.3 low correlation coefficient for the test set. This result is rather different from the result obtained from the sound level and acoustic comfort models, where the individual models gave much better predictions than the general models [16]. However, considerable difference has been found between the lab models and the other models for predicting the subjective evaluations of birdsong and sound of car passing. It is interesting to note that the lab models, in which loudness and sharpness are available to be used as inputs, made considerably better predictions. A possible reason for this is the close relationship between loudness and sound preference evaluation as well as between sharpness and sound preference evaluation, as shown in the above section. This shows again that the subjective evaluations of sound preference are more related to the sound itself rather than the sites where it was heard. However, further study is still needed to follow this up, considering more psychoacoustic parameters, sounds and situations. In Table 4, it is interesting to note that the models developed for all three sounds make much better predictions than the models developed for one sound. A possible reason might be that sound category, which was found significantly related to the subjective evaluations of sound preference, is an input variable for the models of all three sounds, whereas it is not an input variable for the other models.

Nevertheless, in this study, all of the models developed were for the prediction of single sounds. For combined sounds, according to their complicated compositions, the prediction models might be sophisticated and rather different from the models for single sounds, for which further detailed studies are required.

Table 4. Prediction results of sound preference models

Types	Model	Results			
		Coefficient		MSE	
		Train	Test	Train	Test
Models for all three sounds	Lab	0.53	0.52	0.08	0.05
	Jardin de Perolles (JdP)	0.71	0.67	0.06	0.06
Models for birdsong	General-bird	0.18	0.11	0.04	0.04
	Jardin de Perolles (JdP)-bird	0.34	0.23	0.03	0.03
	EU-bird	0.27	0.23	0.03	0.04
	China-bird	0.20	0.10	0.00	0.02
	Lab-bird	0.71	0.60	0.08	0.08
Models for children shouting	General-children	0.13	0.12	0.11	0.11
	Jardin de Perolles (JdP)- children	0.32	0.15	0.07	0.09
	EU- children	0.10	0.09	0.11	0.11
	China- children	0.17	0.16	0.10	0.11
Models for car passing	General-car	0.16	0.06	0.07	0.07
	Jardin de Perolles (JdP)-car	0.19	0.11	0.05	0.05
	EU-car	0.14	0.11	0.06	0.08
	China-car	0.34	0.23	0.06	0.06
	Lab-car	0.64	0.46	0.06	0.07

MAPPING SUBJECTIVE EVALUATION OF SOUND PREFERENCE

In order to map subjective evaluation of sound preference, a hypothetical urban open space with a soundscape containing birdsong, children shouting and car passing was assumed in this study, as can be seen in Figure 8. The distribution of hypothetical sounds and their locations in the open square are shown in Figure 9. It can be seen that a >100 metre distance was assigned between each sound, because with such a distance, the effect of other single sounds could be ignored. In Figure 9, the notable sound and its dominated area is marked with four colours (A, B, C), while the grey area D is dominated by combined sounds. The potential users in this space were assumed from two age groups: the younger group (from 18 to 24), and the older group (from 55 to 65).

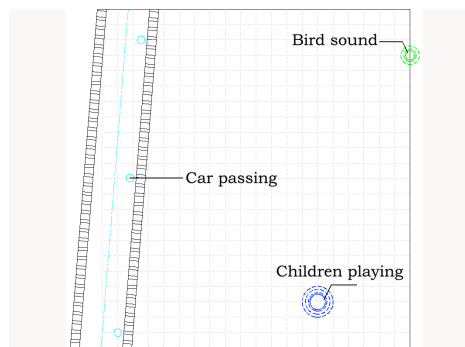


Figure 8. A hypothetical space with a soundscape containing birdsong, children shouting and car passing

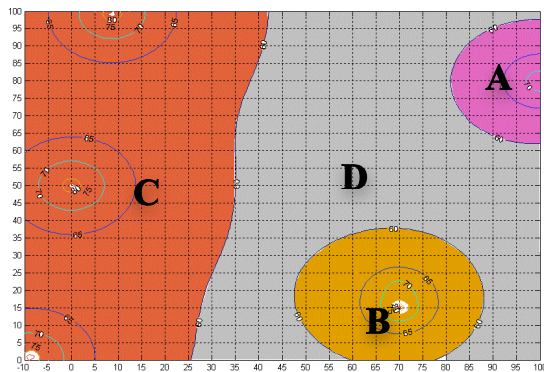


Figure 9. The distribution of hypothetical sounds and their locations

As subjective evaluation of preference for combined sounds is rather complicated and has not been examined in this study, the maps produced below are only for the evaluations of birdsong, children shouting and car passing. In order to draw maps for showing the potential users' evaluations of birdsong, children shouting, and car passing, the JdP model was used to make predictions, as it is the best model developed by the data from field studies. Although the JdP model was developed based on a typical case study site, it might be appropriate to use for a universal situation. A possible reason is that the above findings showed that only a tiny difference exists between the predictions of general, individual, and group models with respect to their location differences. Figures 10 and 11 show the maps of the prediction results made by the JdP model for the two age groups, respectively. The maps were drawn according to the average values of the prediction outputs and coloured according to the degree of sound preference evaluations for birdsong, children shouting, and car passing. With the colour from purple to red, the subjective evaluation moves from favourable to noisy.

By comparing Figure 10 with Figure 11, it is interesting to note that: (1) different colour is presented in area A and B; (2) a similar colour is shown in area C; (3) a significant colour difference is presented in area A. This result suggests that the younger age group preferred the birdsong and children shouting less than the older age group; however, the differences of preference between the younger and the older groups for children shouting were less than that for birdsong. With respect to the sound of car passing, the preference evaluations of both age groups were rather similar.

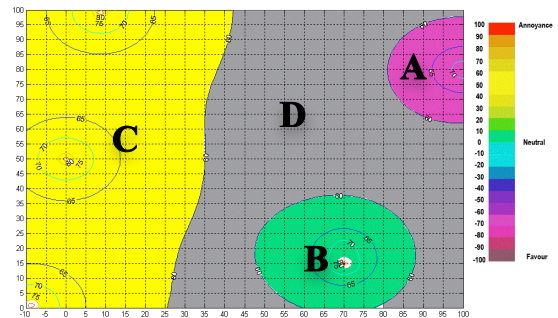


Figure 10. Evaluation map for younger age group, 18-24

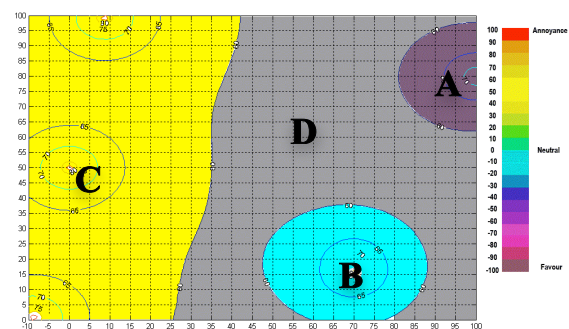


Figure 11. Evaluation map for older age group, 55-64

CONCLUSIONS

The study of factors influencing the sound preference evaluations demonstrates that the effect of various factors on the sound preference evaluations varied corresponding to the sound sources, including natural, human or mechanical sounds. The results show that the important factors influencing sound preference evaluation are sound meanings and psychoacoustic parameters, loudness and sharpness. With regard to the social/demographical factors, age affects more on natural sounds, whereas education has a greater influence on mechanical sounds. In terms of physical, behavioural and psychological factors, generally speaking, their influence on the sound preference evaluations is insignificant, except in a limited case study sites and certain sound sources. These results are also important in determining the input variables for ANN models to predict the subjective evaluations of sound preference.

A number of ANN models for predicting the subjective evaluations of birdsong, children shouting and car passing have been made. Good predictions have been made by all the lab models, whereas poor ones have been made by the other models including general, individual and group models. No significant differences of predicting the subjective evaluations of sound preference have been found among general, individual and group models, indicating that the location difference may not have much impact on the subjective evaluations of sound preference. Based on a successful model, prediction maps have been developed to provide a feasible approach to connect the decision-makers and the space users at the design/planning stage.

It is noted that in all the models developed for predicting the soundscape evaluations, their test coefficients between outputs and targets are generally not very high, all less than 0.8. A possible reason is that subjective evaluations are rather varied between individual users, which cannot be completely represented by computer models. On the other hand, only loudness and sharpness were used as inputs in ANN models, whereas other psychoacoustic parameters, e.g. roughness, was not included. It is then expected that further improvements could be made for ANN models of predicting subjective evaluation of sound preference if more psychoacoustic parameters could be used as inputs in building ANN models.

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