Soundwalk for evaluating community noise annoyance in urban spaces

Pyoung Jik Lee, Jin Yong Jeon*

Department of Architectural engineering, Hanyang university, Seoul, 133-791, Korea

* corresponding author: e-mail: jyjeon@hanyang.ac.kr

ABSTRACT

Community noise annoyance has been investigated in open public spaces exposed to construction and road traffic noises. Sixteen field surveys were conducted as soundwalking using 5-point verbal and 11-point numerical scales according to ISO 15666 (2003). The questionnaire contains demographic factors, dwelling types, health-related symptoms and noise sensitivity. The noise levels in the chosen areas were also measured in terms of A-weighted equivalent level (L_{Aeq}) using binaural microphones. Synthesis curves for the relationship between noise levels and percentage of highly-annoyed (%HA) for the combined noise sources were derived.

INTRODUCTION

Many studies have been carried out to investigate noise exposure-annoyance relationships for various noise sources such as transportation noise, industry noise and impulsive noise. Based on the previous study of Schultz (1978), Miedema and Vos (1998) reported synthesis curves for transportation noise, applying 95 % confidence intervals around the exposure-annoyance curves. Total annoyance caused by combined noise sources was investigated and prediction models such as energy summation model and energy equivalent model were proposed (Miedema 2004). However, most of the studies have investigated noise annoyance of indoor environment and dealt with stationary noise.

Studies of outdoor environment such as urban spaces were initiated by Schafer (1977) as a concept of soundscape. Recently, soundwalking methodology has been adopted for identifying perception of the urban acoustic environment (Semidor 2006; Berglund & Nilsson 2006). However, the procedure for assessing urban environment has not been standardized yet and more discussions are needed. The methodology for evaluating the noise annoyance and dose-response function in urban soundscape has not been a major issue in the environmental studies.

In this study, noise annoyance in urban spaces was investigated by soundwalking; construction noise as well as road traffic noise was dealt as a combined noise source. Questions to investigate the noise annoyance were used and the synthesis curves for the relationship between noise exposure and annoyance were derived.

QUESTIONNAIRE

As the ICBEN team 6 recommends the use of two questions to measure annoyance reactions for comparison between social surveys (Fields et al. 2001), both 5-point verbal and 11-point numerical scales were used in this study. The questions addressed in the ISO 15666 were translated into Korean and, as shown in Table 1, the standardized noise annoyance modifiers (Jeon et al. 2003) used in the 5-point verbal scale questions.

Table 1: Modifiers for 5-point verbal scale

1	2	3	4	5
Junhyu	Jogum	Jebupp	Mewoo	Umchungnagae

The questionnaire was comprised of questions to assess road traffic and/or construction noises, as well as general questions about the correspondents themselves, even if they are not exposed to noise. The questions were arranged in two basic sections. The first section sought to obtain annoyance from the noise sources, which contained three questions: to assess the overall impression on their sound environment and two responses to road traffic and construction noise. The second section dealt with demographic data (age, sex), dwelling type, health condition, noise sensitivity and noise annoyance at home. Noise sensitivity was asked in the 11-point scale questions to evaluate how easily they were annoyed by noise.

Annoyance responses from the two types of questions were translated into a scale from 0 to 100 for assessment of %HA (percentage of highly annoyed). %HA is the percentage of annoyance responses which exceeds a certain cutoff point. Schultz (1978) used a cutoff at 72 in his synthesis to define %HA, and same cutoff point was chosen in this study.

SOUNDWALKING

Site selection

Soundwalking was performed in sixteen urban areas in Seoul and Bundang (biggest satellite city of Seoul). The dominant noise source of the sites was road traffic noise. Twelve sites were exposed to construction noise as well as road traffic noise. The sites can be categorized into two groups: residential areas and open public spaces according to their usage. The sites selected in this study are listed in Table 2 and the picture examples are shown in Figure 1.

Table 2: Categorization of sites

Noise source	Number of site	
	Residential	Open public
Road traffic	2	2
Road traffic / Construction	6	6
Total	8	8

In the selected sites, construction types were varied due to excavation and rock removal work, hammering, drilling and grinding.

Figure 1: Selected sites: residential area (left), open public space (right)

Procedure

Sixteen field surveys were conducted all in the afternoon (13:00-18:00) on the basis of the assumption that the outdoor activities are most frequent at that period. The field survey continued for 4 days (four sites per each day), and 15 subjects (7 female and 8 male) between 20 and 30 years of age participated. The subjects were chosen when consistent responses for 4 days were obtained.

Soundwalk was conducted in silence and participants were asked to concentrate on what they could hear as they walked and observed the urban environments. After soundwalking for 30 minutes in each site, participants were asked to evaluate the annoyance from the noise sources.

Noise metrics

The L_{Aeq} for ten minute was used as a descriptor of the noise exposure. The sound pressure levels were measured using a binaural microphone (B&K Type 4101) while one subject walked around each site. In addition, the visual image was captured using a camcorder (Sony DCR-HC90) to investigate the effect of visual information on the judgement of the soundscape in the auditory test.

Frequency characteristics and sound levels of measured sounds in each site are shown in Figure 2.

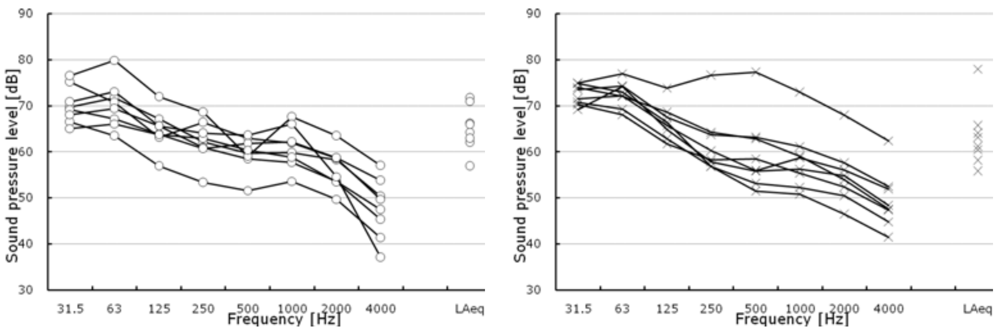

Figure 2: Measured sound pressure levels: residential area (left), open public space (right)

RESULTS

Exposure-response relationship

Exposure-response relationships were obtained as a function of L_{Aeq} from 5-point verbal and 11-point numerical scales. As shown in Figure 3. The %HA from 5-point verbal scale question was slightly higher than that from 11-point verbal scale at the same noise exposure level.

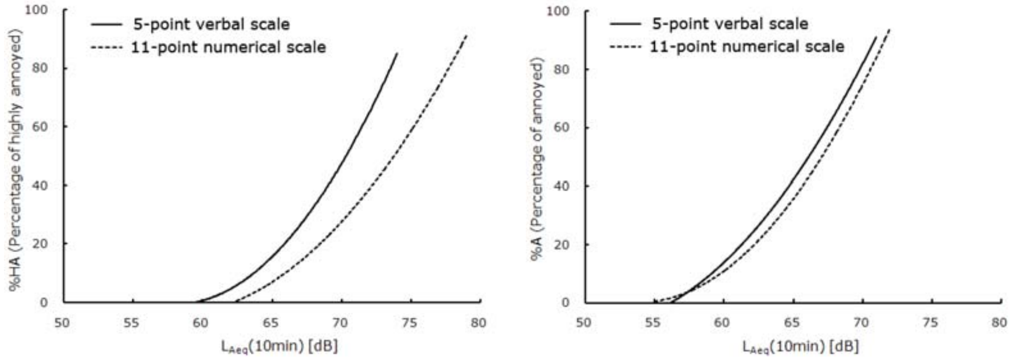

Figure 3: The percentages highly annoyed (%HA) and annoyed (%A) as a function of L_{Aeq}

The differences of %HA curves for the two scales were statistically significant as shown in Table 3. However, the %A curves from 5-point verbal and 11-point numerical scales were almost same in contrast to the results of %HA.

Table 3: The difference between %HA curves from 5-point verbal scale and 11-point numerical scale

Difference					t	df	Sig.
Mean	Std.	Std. error mean	95 % Confidence Interval of the Difference				
			Lower	Upper			
-1.59	1.13	0.28	-2.19	-0.99	-5.63	15	0.00

Polynomial approximations for road traffic noise with construction noise are given in Eq. (1) and (2), here quadratic functions are sufficient to get very close approximations. These polynomials were forced through zero at 60 and 62 dBA (%HA) and 57 and 55 dBA (%A), respectively, are based on model curves fitted to data in the L_{Aeq} range 55-80 dBA.

5-point verbal scale : $\%HA = 1191 - 40.77\,L_{Aeq} + 0.349\,L_{Aeq}^2$

$$\%A = 538 - 22.06\,L_{Aeq} + 0.222\,L_{Aeq}^2 \quad (1)$$

11-point numerical scale : $\%HA = 696 - 24.25\,L_{Aeq} + 0.21\,L_{Aeq}^2$

$$\%A = 993 - 35.81\,L_{Aeq} + 0.324\,L_{Aeq}^2 \quad (2)$$

The influence of L_{Aeq} and other factors on annoyance

A simple model with L_{Aeq} as the only predictor can be extended with addition of extra independent variables as a same manner in the previous study (Miedema, 2004), the prediction model is as follows:

$$Annoyance = \beta_0 + \beta_1 L_{Aeq} + \beta_2 X_1 + \cdots \beta_n X_n + C \quad (3)$$

Comparisons of model from 5-point verbal and 11-point numerical scales are listed in Table 4. Using other parameters as well as L_{Aeq}, the total coefficients of the models from 5-point verbal and 11-point numerical scale were 0.52 and 0.72 ($p<0.01$), respectively. In the prediction model from 5-point scale, L_{Aeq}, dwelling type, and vibration annoyance are statistically significant. L_{Aeq}, vibration annoyance and noise annoyance are also statistically significant in the prediction model with 11-point numerical scale. The reason why age and noise sensitivity do not affect annoyance is because the number of subjects is much less than previous studies.

SUMMARY AND FURTHER STUDIES

The noise annoyance was evaluated in urban spaces on the basis of a simple field survey known as ‘soundwalk’. The standardized questions and procedures to obtain the annoyance measure, such as %HA (highly annoyed) and %A (annoyed), were applied. A model of the distribution of noise annoyance as a function of the noise exposure was presented for road traffic noise with construction noise.

Table 4: Prediction models from 5-point and 11-point scales (*p<0.05, **p<0.01)

	5-point verbal scale	11-point numerical scale
Constant	-182.41**	-192.04**
L_{Aeq}	2.73**	3.38**
Age/100	135.51	-1.92
Dwelling	-5.6*	-3.71
Sensitivity	0.07	0.09
Dust	-0.15	0.16
Vibration	0.33*	0.29*
Annoyance-home	0.04	0.13**

Dependent variables		
Annoyance	0-100	11-point scale for annoyance
Predictor variables		
L_{Aeq}	55-78	Noise exposure
Age	24-30	Age of respondent in years
Dwelling	0-1	0=other, 1=apartment
Sensitivity	0-100	11-point scale for noise sensitivity
Dust	0-100	11-point scale for annoyance from dust
Vibration	0-100	11-point scale for annoyance from vibration
Annoyance-home	0-100	11-point scale for annoyance at home

In case of %HA, questions with 11-point numerical scale caused less annoyance than 5-point verbal scale, as the subjects rarely chose '8', '9' and '10' in the 11-point scale even though they were exposed to higher noise levels. However, it was found that the %A curves from 5-point scale and 11-point scale were almost same. It appears that most subjects chose '3' in the 5-point scale when they exposed to wide range of noise levels.

In the prediction model from different annoyance scales, some factors except sound pressure levels were not able to relate to annoyance since the number of subjects was not enough. Thus auditory experiments with more subjects should be further conducted to investigate the annoyance from road traffic noise and construction noise.

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