Predicting the Effects of Noise Exposure on Activity Disturbance

*Jin-Yong Jeon

Abstract

The aims of this study were to investigate the covariation between the extent of activity disturbances and general annoyance, and to study the relation between the extent of annoyance reactions and noise sensitivity. This paper presents a description of a model developed by taking into account self-rated noise sensitivity and noise rating (*i.e.*, annoyance) for road traffic. The results indicate that there are large variations in noise sensitivity which is independent on the level of noise. It is also found that the extent of all activity disturbances decreased with decreased general annoyance. The paper suggests a normative approach to predicting individual's reaction to noise exposure, based on a periodically observed relationship between the prevalence of activity disturbance and annoyance. The model also predicts a road traffic-noise adaptation level for each individual.

Ⅰ. Introduction

Individual reactions caused by noise disturbance are influenced by susceptibility, personality traits and attitudes, but are furthermore dependent on interference with daily life activities. These may be referred to as specific noise effects, and they appear directly in connection with the actual noise exposure. For these specific effects, the general annoyance caused by noise may be seen as a composite reaction, built up after some time of exposure.

Through a number of models of individual annoyance, it has been found that non-noise (non-stimulus) factors, especially sensitivity to noise, had a stronger effect on annoyance than did the noise factor itself [1-2]. The large amount of variance in individual annoyances which has been unexplained so far could lead to a number of hypotheses about personal and other attitudinal factors which might be associated with individual noise annoyance responses.

Many traffic noise studies have been undertaken in which noise level have been related to residents' annoyance with the object of establishing community reactions. The studies depend upon specifying what is tolerable to the majority of the population, but people's disturbance patterns, derived from individual response to noise, have not been established. The aims of the present analysis were to longitudinally study the covariation between annoyance and disturbances reported by respondents who were exposed to different levels of noise, and to compare different noise situations with reference to the specific disturbances caused.

Ⅱ. Background

A. Individual Response to Noise

In most field studies performed on effects of transportation noise on man, the effects are expressed in terms of 'annoyance'. The concept of annoyance is in itself a subjective measure, and hence is characterized by large individual differences. The standard definition of noise as unwanted sound also indicates that there is a subjective component in the evaluation of the degree of the 'unwantedness' of the sound.

Individual dissatisfaction scores correlate poorly with physical measures [3], because of wide individual differences in susceptibility and experience of noise, as well as in patterns of living likely to be disturbed by noise. Although there are many factors in addition to the noise measures which affect subjective annoyance to traffic noise, attitude surveys have shown that the correlation between individual annoyance and noise level is relatively insensitive to noise measures [4]. Edwards [5] indicated that it is not noise measurements and noise indices that cause the poor correlation, but measures of human response. It has been found that there are considerable differences between people in how they react to the same level of noise [6]. Therefore, it is necessary to pay special attention to individual differences when selecting noise criteria for residential areas.

*Department of Architectural Engineering, Youngdong Institute of Technology

Manuscript Received 96. 11. 13

B. Sensitivity, Annoyance and Disturbance

Noise level is known to correlate with annoyance. However, reactions (also termed as 'disturbance') to changes in noise environments have been different. Langdon and Griffiths [7] found that reductions in noise results in changes in annoyance, whereas Fidell and Jones [8] reported no change in residents' reactions after a severe reduction in night-time aircraft noise levels. In most studies of the effects of noise on communities, measures of noise exposure incorporate corrections for certain time operations.

Fields [2] found that noise annoyance is not strongly affected by demographic variables, but is related to the attitudinal variables. The acoustical factors affecting annoyance are;numbers of individual noise events [9], day/night-time noise levels [8, 10-13], residential noise environments (ambient noise) [3, 14-16], and changes in noise environments [7-8]. Sensitivity to noise (or noise annoyance susceptibility) does not appear to depend upon personal factors such as age, sex, education, job responsibility [6], length of residence [13] and type of housing [12].

Annoyance is generally higher for people who are fearful that some danger to themselves or other people in the local area may be associated with the transportation activities which they can hear. The attitude of 'fearfulness' has proved to be important for road traffic noise as well as aircraft and railway noise. Things disliked about the area, from neighbourhood evaluation to evaluations of the quality of the public services, are related annoyance [17]. The people who believe that their health is affected by noise from the particular source are also likely to be annoyed by the source [18].

C. Adaptation (Habituation)

'Adaptation' (or 'Habituation') is another matter to be reviewed in relation to any sort of annoyance surveys to road traffic noise. How the annoyance of an individual changes with time (adaptation) is also important and is one of the main objects of the present work.

Since almost all noise research has used a cross-sectional survey design, most conclusions about the survey results have been lacking sufficient evidence for adaptation/non-adaptation. Longitudinal studies are needed to provide a more realistic model of noise reactions and adaptation. Some available noise researches have provided little evidence that people adapt to road traffic noise in residential settings [e.g., 19-20]. Surveys have found that longtime neighbourhood residents are at least as bothered by noise as more recent arrivals;longitudinal studies find more disturbance at the end of the study period than at the beginning [21-22].

It has been reported that total habituation in sleeping against noise does not occur after years of exposure [23-27]. However, it could be possible that the studies misled and that people do adapt to noise. After a while, they might pay less attention to the noise and fall asleep more quickly, but their survey responses might continue to reflect their original feelings about the noise rather than their current reactions. If the method of habituation measurements is changed to a continuous judgement method, the duration of "no response" to noise can be an index of habituation [28]. Some low-anxiety residents always adapt to a certain level of noise [19], whereas high-anxiety residents do not [29]. Furthermore, acoustical parameters such as regularity of the noise, which characterizes noise, may also contribute to a more rapid habituation than is the case for fluctuating noise, represented by road traffic.

Aircraft noise surveys show rather favourable opinions on residents' adaptation to noise;although there is variability of annoyance response due to aircraft noise, models [e.g., 30] of aircraft noise adaptation with limits have existed. Attitude-personality variables were found to account for varying annoyance judgements and an adaptation level could be represented for each individual [30]. Dempsey and Cawthorn [31] found that the use of an aircraft-noise adaptation level (human tolerances, noise threshold) improved prediction accuracy of annoyance responses and simultaneously reduced response variation. Vallet et al. [32] found an adaptation to the noise in habituated sleepers when they investigated the quality of sleep of persons living near a French airport.

The usual procedure of most noise adaptation studies has been to investigate exposed population groups on the assumption that they constitute a "general population". Such an assumption is not automatically correct in view of the fact that the population studied has been exposed over a lengthy period and has presumably developed clear norms, evaluations and attitudes in relation to the source of annoyance [21]. The differences within the population are the movements into and out of the area, and the possibility of habituation to the exposure. Habituation can be studied by investigating a population after the start of exposure to a noise source and on one or more later occasions. If no reduction in the intensity and incidence of the reactions has occurred, this indicates that no habituation has taken place. If, on the other hand, a reduction of the reactions is found, this may be because an actual habituation has occurred or because the individuals' acceptability level has changed.

Ⅲ. Study methods

There are three aspects of studies of the response of people to traffic noise. They are: (1) the study of subjective annoyance to traffic noise as a function of traffic noise measures as well as other non-noise parameters, (2) the study of interference with various activities and possible forms of health impairment, and (3) an evaluation of the merits of various noise measures as predictors of adverse responses [12]. These aspects can be termed annoyance, disturbances, and noise measures. A large number of noise surveys have been reported in the areas. As Fields and Hall [18] mentioned in the literature, low-investment research programmes may not provide any more useful information about the dose-response relationship than is available in existing research publications and so the initial part of the present study has been to evaluate previous studies.

A. Assessing annoyance to noise

Even though actual noise-related effects are experienced, the degree of subjective annoyance is likely to be determined by the type of noise environment causing the effects. Factors such as capacity to influence and avoid the noise exposure, experience of the noise source in terms of usefulness and necessity, and experienced fear in connection with the noise source have been considered to be of importance in analyses of annoyance reactions. Although taking responses of 'complaints' (reactions to noise) from subjects is one way of assessing annoyance to noise, questions related to 'complaints' were not likely to be separately treated.

The answers given in the so-far noise surveys probably reflect a mixture in behavioral interruptions or emotional reactions. Even if investigators deliberately formulate questions in attempts to separate these components of dissatisfaction, respondents may be unable to make the discriminations requested. Therefore, a clear conception of the kinds of noise reactions that can occur should help to develop more precise models of the noise response process. Although Cohen and Weinstein [33] mentioned that noise research should require less reliance on self-report measures, no direct observations of the physiological, behavioral, and interpersonal consequences of noise exposure are realistic and reliable. Self-reported noise appraisal is the only possible measure of the impact of noise on individuals.

B. Selection of survey criteria

The main problem faced in choosing a sample for surveys is normally one of eliminating as much bias as possible. As the survey variables are interrelated and it is difficult to provide strong evidence for the nature of the causal relationships between variables, caution must be exercised in making survey plans and findings about sensitivity and disturbances:

(1) If the sensitivity is correlated with noise level then part of the relationship of the sensitivity with noise annoyance may be caused by the noise level effect.

(2) The sensitivity variable must be investigated with a question which is clearly distinct from a noise rating or disturbance question.

(3) Some of the high correlation between annoyance and these disturbances should be discounted because both are measured at the same time in a single questionnaire under similar conditions and thus may be subjected to such correlated errors in measurement as 'response set' (the tendency for people to give answers that follow the form rather the content of the question).

(4) Also of concern is that the position of the 'disturbances' section may suggest that the medical symptoms are attributable to road traffic noise.

(5) In order to predict an individual's annoyance to a particular noise it is necessary to know not only the level of the noise but also his/her personality [6]. Certain personality traits are responsible for differences in noise annoyance sensitivity.

(6) Models for biases in judging sensory magnitudes should be eliminated.

C. Hypotheses

It seems that there are three reasons for variations in annoyance caused by noise: differences in situations of the noise source, differences in situation-specific attitudes (nonauditory effects of noise) and personality differences (sensitivity). Individuals' responses to the same noise vary considerably even though the averages of these responses are systematically related to noise level. In addition to the actual noise exposure, the development of annoyance is dependent on such factors as sensitivity, personality and attitudes. Therefore the hypotheses of this study are: (1) There are individual differences in sensitivity to road traffic noise. (2) People's reaction to noise varies in incidence. (3) Noise sensitivity, noise rating and disturbances are three major factors which will contribute to an individual's rating of noise annoyance in a given situation.

D. Outline of survey

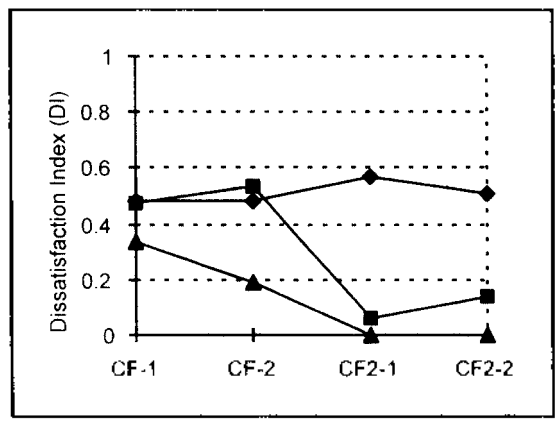
The surveys dealing with residents' attitudes and opinions consist of;(1) various sorts of disturbance which might be expected to result from noise, (2) a scale of dissatisfaction with the acoustic environment, (3) a study of nuisance caused by noise from motorways (room usage, sleep disturbance, preferred siting of the house in relation to the road, and seasonal or meteorological effects on the perceived noisiness of traffic), (4) sources of noise nuisance, (5) a scale of susceptibility to noise nuisance, (6) demographic characteristics.

The present questionnaire delivered to the respondents was originally aimed at discovering the attitude of the population to housing and housing areas. The questions using a Likert-style format developed by Weinstein [22] were modified to assess self-reported sensitivity to noise. The questionnaire commenced with questions concerning the following;(1) Housing conditions, (2) Respondents' backgrounds including the spending hours a day at home, (3) Questions concerning the attitude to road traffic noise ;Part A-Noise Sensitivity;Part B-Annoyance;Part C-Disturbance. Most items were presented on a 6-point scale ranging from 'agree strongly' to 'disagree strongly'.

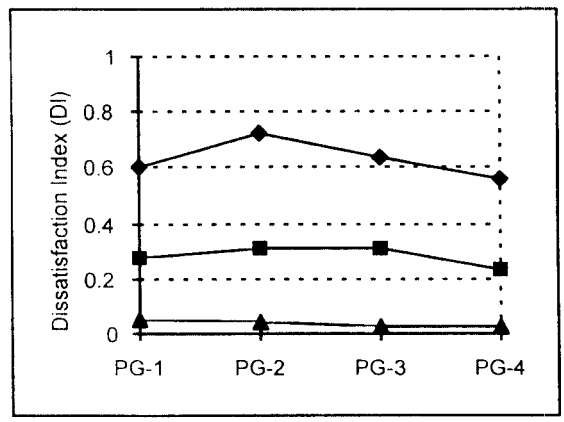
This investigation was to have a repeated measures design. The survey was presented to four respondents (three male and a female in their 30's and 40's) at intervals of 3-4 months for period of one year. It was a satisfaction survey aimed at discovering the attitude to the respondents' noise environments. Respondents were asked to indicate whether or not they were annoyed and, if so, to what degree they were annoyed. In addition to attempting to find the degree of general annoyance, questions were also asked on noise-related interference with such activities as listening to radio/TV, conversation, rest and relaxation and sleep.

Ⅳ. Results

Subjective responses were periodically obtained, giving attention to noise sensitivity, annoyance (dissatisfaction or noise rating), and disturbance as previously indicated. Fig. 1 shows the variation of individual annoyance. As shown in Fig. 1, the individual sensitivities to road traffic noise were almost invariable, whereas noise rating (annoyance) and reaction (disturbance) varied with survey time. The respondents are all noise-sensitive (normally more than 0.5).



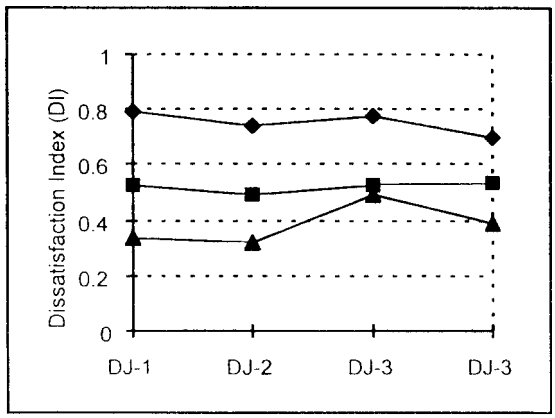
(a)



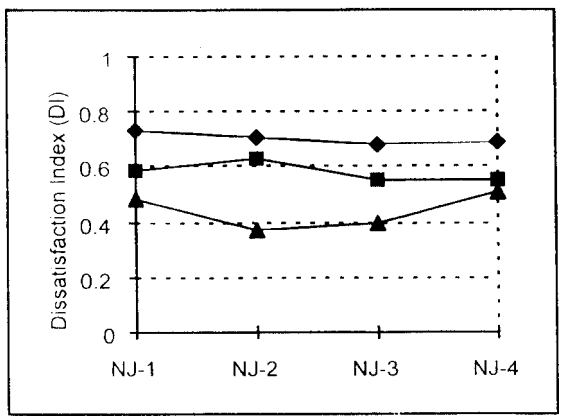
(b)

Table 1. Development of medical symptom for the period (Percentage of time or incidence, %)

Medical symptom	Subject CF				Subject PG				Subject DJ				Subject NJ			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tiredness	0	0	0	0	0	0	0	0	0	0	20	20	40	20	20	40
Headache	60	0	0	0	0	0	0	0	0	0	40	0	20	20	20	40
Nervousness	0	0	0	0	0	0	0	0	60	40	40	60	20	20	20	40
Tension	0	0	0	0	0	0	0	0	20	20	60	60	20	40	20	40
Irritability	60	40	0	0	0	0	0	0	60	20	60	20	20	40	20	60



(c)



(d)

Figure 1. The relation between the individual indices of four subjects for sensitivity (-◆-), annoyance (-■-) and disturbance (-▲-), obtained from repeated measures: (a) Subject CF, (b) Subject PG, (c) Subject DJ, and (d) Subject NJ.

Medical symptoms were reported by the respondents when their disturbance index (DI) is above 0.30. As shown in Table 1, subject CF reported headache and irritability (DI = 0.33) at first. Headache discontinued in the second survey (DI = 0.19). After that, CF moved to a quieter place, where his DI decreases to nil, as shown in Fig. 1(a). His irritability also discontinued (see Table 1). Subject PG had lived in a quiet street for a long time, but showed high sensitivity. As shown in Fig. 1(b), PG's average annoyance rating and disturbance index are about 0.30 and 0.04, respectively. Subject DJ continuously reported nervousness, tension and irritability (the lowest DI = 0.33). As shown in Fig. 1(c), the third DI is exceptionally high. The third survey was the occasion when he spent more time at home for his writing and was severely affected by road traffic noise. As shown in Fig. 1(d) and Table 1, subject NJ reported most of the medical symptoms and provided variations in her disturbance.

A relation between annoyance and disturbance was found. The respondents' annoyance and disturbance indices are all plotted in Fig. 2. It is found that there is a breakpoint of 0.45 in annoyance rating. Up to this point, the responses to noise were not reported although annoyance increased. The responses to noise (disturbance patterns) seem apparent after this point. This could be a 'threshold of annoyance' for responding to road traffic noise in this noise model.

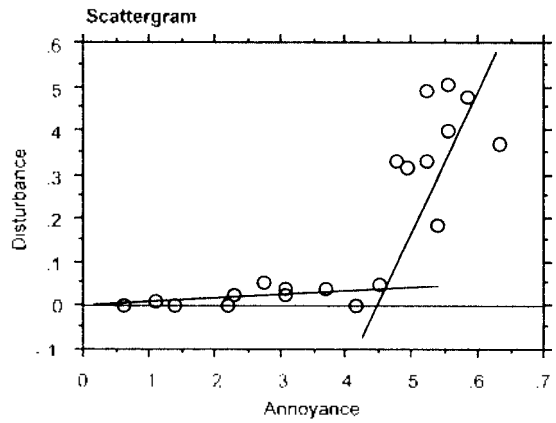


Figure 2. The relation between annoyance and disturbance in the present model.

V. Discussion and conclusions

As the actual noise levels (Leq 24 hours) are not likely to vary significantly throughout the present survey, it can be concluded that noise level is not the only variable that can be used to control annoyance levels over long periods of time. There is individual variability in the measured reactions at any one noise level due to acoustical, situational, attitudinal and personal factors. The results suggest that adaptation does not occur over the period studied on the subjects. However, if there exists adaptation to noise, the disturbance index (0.3) can be proposed as a reference to the individual degree of adaptation to a new noise environment.

From the results of this study, it is found that the individual sensitivity to road traffic noise remains unchanged. Sensitivity to noise is not associated with decreased environmental noise level. The results obtained may be dependent upon differences in respondents' attitudes towards the various noise situations. No significant relationship between sensitivity and annoyance was observed. People's annoyance caused by noise is not affected by their noise sensitivity but by the noise measure itself. (*i.e.*, 'annoy-

ance' or 'noise rating'). However, there is a relationship between annoyance and disturbance. It is confirmed that a more direct approach to the noise problem is to measure disturbance rather than annoyance [4].

There is a suggestion for a way forward in the future: As the relationship between sensitivity, annoyance and disturbance is unique for each individual, neural network analysis would be a useful method of implementing the aim of the this study, *i.e.*, predicting individual disturbance in a noise environment. In order to carry out a neural network analysis the adaptive learning procedure has to be set up through the characteristics of input data (sensitivity, annoyance and disturbance), which make a network model undertake the process of calculation. Input data will be later obtained from the correlation between self-rated noise, field measurements and laboratory annoyance tests. Then the correlation between these values will be used for training the neural network. Laboratory tests should be added to investigate whether the magnitude and direction of change of annoyance with traffic noise exposure correspond closely to the actual changes in physical exposure. Estimates should be made of time constants for the rate of change of attitudes toward traffic noise. Consequently, weighting all activity interferences into an index and applying this universally for road traffic noise will decrease the precision of the response description and hence influence the accuracy of the dose-response relationship.

'Disturbance' is what needs to be determined and it can be obtained directly from Leq, annoyance and sensitivity. The use of individual adaptation levels and personality types may improve prediction accuracy of disturbance index. People's disturbance rates to traffic noise can be predicted from their noise sensitivity and noise evaluation. It should be further reviewed how intensity, duration and frequency composition of noise affects the auditory, annoyance, sleep and speech interference, psychological and sociological responses in man.

Acknowledgment

Funding for this research project was provided by the New South Wales RTA (Roads and Traffic Authority) of Australia to the author.

References

1. S. M. Taylor, "A path model of aircraft noise annoyance," *J. Sound Vib.* 96, pp. 243-260, 1984.
2. J. M. Fields, "Effects of personal and situational variables on noise annoyance in residential areas," *J. Acoust. Soc. Am.* 93, pp. 2753-2763, 1993.
3. I. D. Griffiths and F. J. Langdon, "Subjective response to road traffic noise," *J. Sound Vib.* 8, pp. 16-32, 1968.
4. J. B. Ollerhead, "Scaling aircraft noise perception," *J. Sound Vib.* 26, pp. 361-388, 1973.
5. R. M. Edwards, "A social to examine the variance of aircraft noise annoyance," *J. Sound Vib.* 41, pp. 41-51, 1975.
6. N. M. Moreira and M. E. Bryan "Noise annoyance susceptibility," *J. Sound Vib.* 21, pp. 449-462, 1972.
7. F. J. Langdon and I. D. Griffiths, "Subjective effects of traffic noise exposure, II: comparisons of noise indices, response scales, and the effects of changes in noise levels," *J. Sound Vib.* 83, pp. 171-180, 1982.
8. S. Fidell and G. Jones, "Effects of cessation of late-night flights on an airport community," *J. Sound Vib.* 42, pp. 441-427, 1975.
9. J. M. Fields, "The effect of numbers of noise events on people's reactions to noise: An analysis of existing survey data," *J. Acoust. Soc. Am.* 75, pp. 447-467, 1984.
10. N. S. Yeowart, D. J. Wilcox and A. W. Rossall, "Community reactions to noise from freely flowing traffic, motorway traffic and congested traffic flow," *J. Sound Vib.* 53, pp. 127-145, 1977.
11. F. J. Langdon and I. B. Buller, "Road traffic noise and disturbance to sleep," *J. Sound Vib.* 50, pp. 13-28, 1977.
12. J. S. Bradley and B. A. Jonah, "The effects of site selected variables on human responses to traffic noise, Part I: Type of housing by traffic noise level," *J. Sound Vib.* 66, pp. 589-604, 1979.
13. J. Nemecek, B. Wehrli and V. Turrian, "Effects of the noise of street traffic in Switzerland, a review of four surveys," *J. Sound Vib.* 78, pp. 223-234, 1981.
14. D. W. Robinson, "Towards a unified system of noise assessment," *J. Sound Vib.* 14, pp. 279-298, 1971.
15. C. G. Rice, "Subjective assessment of transportation noise," *J. Sound Vib.* 43, pp. 407-417, 1975.
16. T. J. Schultz, "Synthesis of social surveys on noise annoyance," *J. Acoust. Soc. Am.* 64, pp. 377-405, 1978.
17. F. L. Langdon, "Noise nuisance caused by road traffic in residential areas: Part III," *J. Sound Vib.* 49, pp. 241-256, 1976.
18. J. M. Fields and F. L. Hall, "Community effects of noise," in *Transportation Noise Reference Book*, edited by P. M. Nelson, (Butterworths, London), pp. 3/1-27, 1987.
19. M. Vallet, M. Maurin, M. A. Page, B. Favre and G. Pachiaudi, "Annoyance from and habituation to road traffic noise from urban expressways," *J. Sound Vib.* 60, pp. 423-440, 1978.
20. N. D. Weinstein, "Community noise problems: Evidence against adaptation," *J. Environ. Psychol.* 2, pp. 87-97, 1982.
21. E. Jonsson and S. Sörensen, "Adaptation to community

noise-A case study," *J. Sound Vib.* 26, pp. 571-573, 1973.

22. N. D. Weinstein, "Individual differences in response to noise: a longitudinal study in a college dormitory," *J. Appl. Psychol.* 63, pp. 458-466, 1978.
23. G. J. Thiessen, "Disturbance of sleep by noise," *J. Acoust. Soc. Am.* 64, pp. 216-222, 1978.
24. M. Vallet, J. M. Gagneux, V. Blanchet, B. Favre and G. Labiale, "Long term sleep disturbance due to traffic noise," *J. Sound Vib.* 90, pp. 173-191, 1983.
25. R. T. Wilkinson and K. B. Campbell, "Effects of traffic noise on quality of sleep: Assessment by EEG, subjective report, or performance the next day," *J. Acoust. Soc. Am.* 75, pp. 468-475, 1984.
26. B. Griefahn and E. Gros, "Noise and sleep at home, a field study on primary and after-effects," *J. Sound Vib.* 105, pp. 373-383, 1986.
27. J. L. Eberhardt, "The influence of road traffic noise on sleep," *J. Sound Vib.* 127, pp. 449-455, 1988.
28. S. Namba and S. Kuwano, "Measurement of habituation to noise using the method of continuous judgement by category," *J. Sound Vib.* 127, pp. 507-511, 1988.
29. B. A. Jonah, J. S. Bradley and N. E. Dawson, "Predicting individual subjective responses to traffic noise," *J. Appl. Psychol.* 66, pp. 490-501, 1981.
30. T. K. Dempsey, G. D. Coates and J. M. Cawthorn, "Model of aircraft noise adaptation," *NASA TM-74052*, 1977.
31. T. K. Dempsey and J. M. Cawthorn, "Variability of annoyance response due to aircraft noise," *NASA TP-1335*, 1977.
32. M. Vallet, F. Simonnet and J. M. Gagneux,. "The psychoacoustic effects of aircraft noise on sleep-An in situ study (In French)," *Revue d'Acoustique* 12, pp. 79-81, 1979.
33. S. Cohen and N. Weinstein, "Nonauditory effects of noise on behavior and health," in *Environmental Stress*, edited by G. W. Evans (Cambridge University Press, Cambridge), pp. 45-74, 1982.

▲Jin -Yong Jeon

Jin Yong Jeon completed his Bachelor of Architectural Engineering (1982) at Hanyang University and Master of Building Science (1991) and PhD in Architecture (1994) at the University of Sydney. His post-doctoral research at the University of Sydney was on people's annoyance and adaptation to traffic noise. He is also interested in developing an evaluation method in the acoustical quality of rooms for music. Currently, he is lecturing at Youngdong Institute of Technology.