Effects of non-acoustic factors on annoyance caused by floor impact sounds: A structural equation analysis

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Summary
Previous research studies have addressed the relevance of non-acoustic factors in the perception of noise. However, the majority of these studies have focused on environmental noise, such as road traffic, railway and aircraft noises, and no attempt has been made to investigate the impact of building noises. In this paper, a conceptual model which explains the annoyance caused by floor impact sounds in apartment buildings was proposed based on previous findings and is subject to empirical testing. Online and paper questionnaire surveys were conducted in Korea and the questionnaire included questions designed to assess the impact of non-acoustic factors on annoyance caused by floor impact sounds, such as noise sensitivity and neighbourhood satisfaction. The structural equation model developed from the survey indicated that a negative relationship with neighbours resulted in greater annoyance, while a greater sensitivity to noise leaded to a greater perception of disturbance from noise. The various types of noises also produced different effects on relationship between noise annoyance and relationship with neighbours.

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1. Introduction

Floor impact noise has become a big social issue in South Korea. Earlier survey [1] indicated that floor impact noise from neighbouring apartments was found to be the most annoying sound source. Recent survey [2] confirmed this finding and emphasised how the noise of children running and jumping on the floors of neighbouring apartments was more annoying than the noise from overhead aircraft or road traffic.

Although considerable technical and governmental efforts have been made to control floor impact noise, reducing the sound pressure level (SPL) has not always provided the most satisfactory solution for less noise annoyance or better acoustic comfort in apartment buildings. Previous studies [3, 4] also have shown that perceived annoyance from noise arose not only because of sound levels but also because of the effects of various non-acoustic factors. As most studies in this field have focused mainly on the acoustic characteristics of floor impact noise, [5, 6], it is vital; therefore, that consideration should now be given to the influences of non-acoustic factors, through a socio-acoustic approach.

The aim of this study is to investigate these non-acoustic influences and to develop a conceptual model of perceived noise annoyance. In-depth interviews were conducted to examine which factors influenced the residents' perception of floor impact noise. Socio-acoustic surveys were then performed to explore key indicators of perception of floor impact sounds and to investigate the relationships between them.

Based on the literature review [3, 7-9] and in-depth interview [10], the following hypotheses were developed. Figure 1 shows a theoretical framework developed based on proposed hypotheses.

Hypothesis 1. *Noise disturbances in apartments are related to noise annoyance and health symptoms.*

Hypothesis 2. *Attitude to noise problems is related to coping behaviour.*

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Hypothesis 3. *Noise disturbances and annoyance caused by floor impact sounds are related to coping behaviour.*

Hypothesis 4. *Mediator variables such as noise sensitivity and relationship with neighbours are related to noise disturbance and annoyance*

2. Methods

2.1. Participants

An online survey was conducted through Google Forms from September to October 2014. Recruitment was via social media and community sites used by residents of the apartment complex. The paper survey also performed for those who were unfamiliar with internet questionnaires. A total of 803 responses were collected. However, of these, 311 did not live in apartments or hadn't heard or experienced noise from their neighbours. Therefore, 492 questionnaires (472 from online and 20 from paper surveys) were used for analysis. The majority of the participants (77.6%) ranged in age from 20 to 40 and around 70% were educated to university degree level or higher. Most of the participants were married (55.1%), followed by single people (43.1%) and those divorced, separated, or widowed (1.8%).

2.2. Questionnaire

The questionnaire was developed as a means to examine the theoretical framework shown in Figure 1.1 and to investigate the effects of non-acoustic factors on perceptions of floor noise in apartment buildings. The questionnaire was in three parts. The first section sought socio-demographic information, such as age, gender, education level, marital status, years in residence, dwelling type, and sensitivity to noise. The second part included questions about residents' satisfaction with their living environment, their relationship with neighbours, attitudes to noise problems and coping behaviour. The last part sought to obtain the participants' perceptions of annoyance, disturbance, and health symptoms. The ISO standard five-point verbal scale (1: not at all and 5: extremely) was used in the questionnaire.

2.3. Structural equation modelling

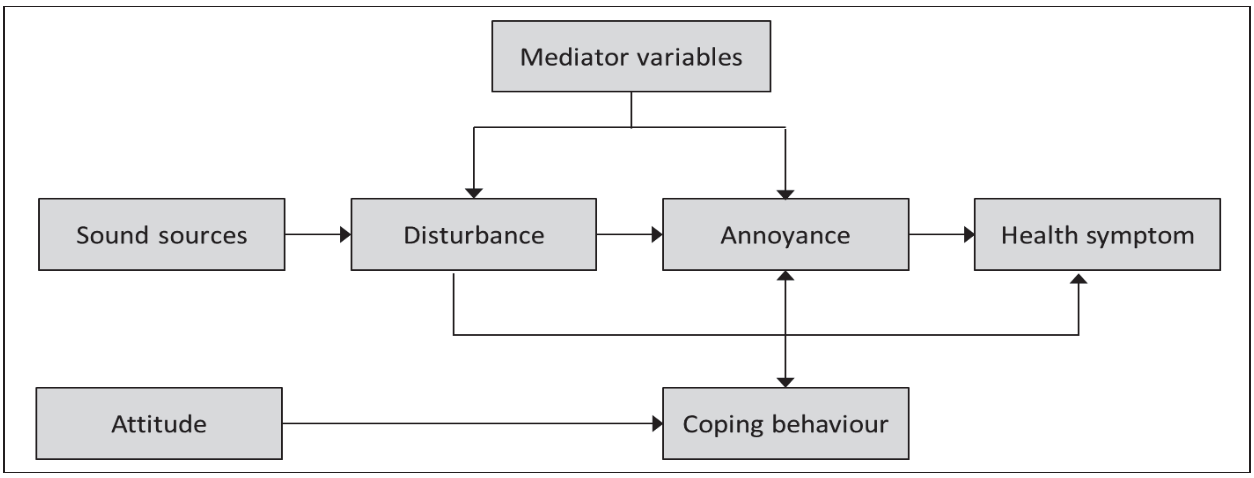
In the present study, the structural equation modelling (SEM) procedure was employed to illustrate the relationship between noise annoyance and non-acoustic factors. The SEM models consist of observed variables and unobserved variables (also called underlying or latent variables) that can be independent (exogenous) or dependent (endogenous). The latent variables are hypothetical constructs that cannot be directly measured, and they are typically represented by multiple observed variables. The SEM model is an a priori hypothesis about a pattern of linear relationships among a set of observed and unobserved variables. There are different types of software for the SEM and in the present study, we used AMOS version 22.0.

3. Results

3.1 Confirmatory factor analysis

Confirmatory factor analysis was conducted to examine the construct validity and reliability. The reliability coefficients (Cronbach's alphas) were calculated in order to assess the internal consistency of the subscale. The reliability coefficients were all higher than 0.6. Convergent validity was also assessed in terms of factor

Figure 1. Proposed structural model.



loading, composite reliability (CR) and average variance extracted (AVE). The factor loading of each individual measure with its respective construct were statistically significant (p<0.01). Factor loadings were found to be greater than 0.5. The composite reliability ranged from 0.756 to 0.912, exceeding the cut-off value of 0.7 for good reliability. The AVE ranged from 0.517 to 0.809; therefore, it was confirmed that the CFA model has good construct reliability and adequate convergent validity.

3.2 Path analysis

Figure 2 shows the structural equation model, describing the relationship between the non-acoustic factors and annoyance caused by floor impact sound. According to the acceptable thresholds described in Table I, the model showed a reasonable fit to data. For instance, RMSEA was less than acceptable threshold level, 0.07 and CFI was greater than 0.95.

With regard to H1, a significant relationship was found between noise disturbance and annoyance, whereas noise disturbance was not a factor in perceived health symptoms. The participants' attitudes to noise sources were found to have a significant effect on coping behaviour (H2). Regarding H3, noise disturbance had a positive effect on coping behaviour, although the relationship between noise annoyance and coping behaviour was not found to be significant. With Hypotheses 4, only two paths were found to be statistically significant: a) noise sensitivity and disturbance and b) the relationship with neighbours and noise annoyance.

Table I. Results of path analysis.

Paths	Estimates[a]
Noise disturbance – Noise annoyance	**0.727***
Noise disturbance – Health symptoms	0.115
Attitude – Coping behaviour	**0.141***
Noise disturbance – Coping behaviour	**0.922***
Noise annoyance – Coping behaviour	-0.028
Noise sensitivity – Noise disturbances	**0.510***
Noise sensitivity – Noise annoyance	0.026
Relationship with neighbours – Noise disturbances	0.045
Relationship with neighbours – Noise annoyance	**-0.19***

[a] Standardized *$p<0.05$

3.3 Effects of other non-acoustic factors

Additional path analyses were conducted to investigate the effects of other non-acoustic factors. The non-acoustic factors examined in these analyses are shown in Table II. They include major noise sources, predictability, living with children and knowing upstairs neighbours. The respondents were divided into two groups and path analyses were then performed separately. For example, the respondents were categorised in two groups according to major noise sources. The first group claimed that the sound of footsteps upstairs was a major noise source, while the sources of noise for the other group related to objects being dropped on the upper floor or dragging chairs.

Figure 2. Structural equation model.

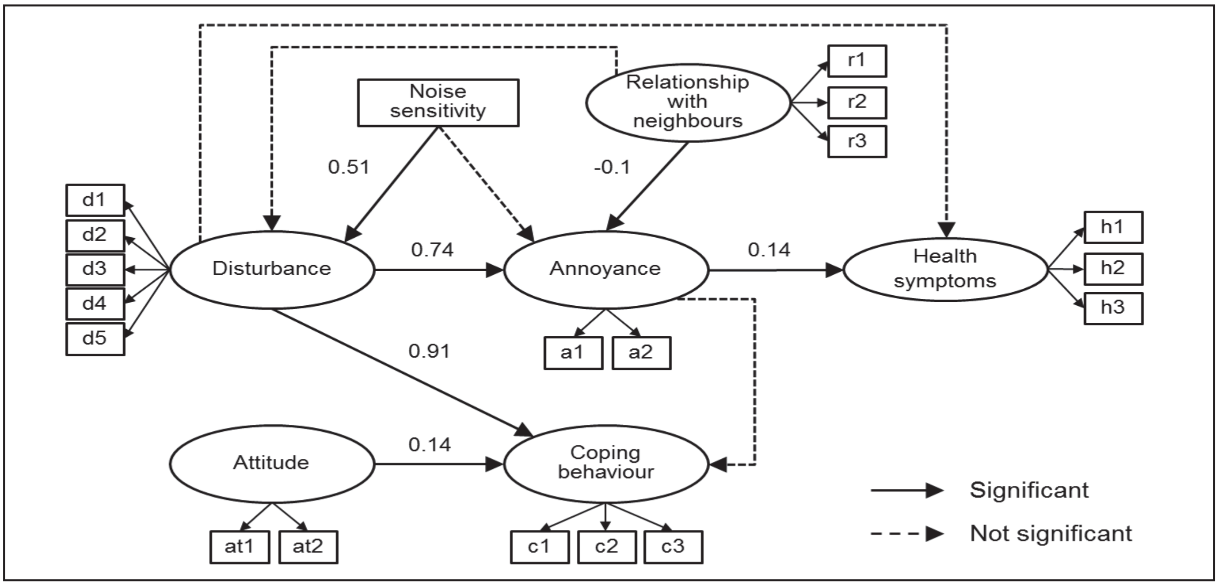


Table II. Non-acoustic factors for path analyses.

Non-acoustic factors		Number of participants
Major noise source	Footsteps	254
	Other sources	233
Predictability	Can predict when a noise will occur	251
	Cannot predict when a noise will occur	236
Living with children (residents)	With children (3-19 years old)	215
	Without children	272

3.3.1 Major noise source

The structural equation models were slightly different according to major noise source. For footsteps, the impact of relationships with neighbours on nose annoyance was found to be significant, whereas it was not the case for other noise sources. This indicates that relationships with neighbours contributed to decrease of noise annoyance only when residents are exposed to footstep noises. Another difference between two groups was found in the relationship between attitude and coping behaviour. In contrast with the results for footsteps, the influence of attitude on coping behaviour was not found to be significant for other noise sources.

3.3.2 Predictability

The differences between the groups were highlighted by two paths. The effect of noise annoyance on health was significant for the group who claimed that they could predict noise occurrences; this was not the case for the other group. Another difference was shown in the path from attitude to coping behaviour. The relationship between attitude and coping behaviour was significant in the model. However, it was not observed to be significant for the group who said that they could not predict the occurrence of noises.

3.3.3 Living with children (residents)

It was assumed that those with children would be more tolerant of noise coming from the upper floor than residents without children. The differences between the groups were mapped by two paths: a) relationship with neighbour-annoyance and b) attitude-coping behaviour. For residents with children, the impact of noise on their relationships with neighbours was not significant, whereas the opposite was true for the other group. Different effects of attitude on coping behaviour also were discovered.

4. Conclusions

Social surveys were conducted to investigate the hypothesised relationships between non-acoustic factors and perceived noise annoyance. It was observed that a negative relationship with neighbours resulted in greater noise annoyance, and greater sensitivity to noise leaded to an increased perception of noise disturbances. Attitudes to the sources of noise influenced coping behaviours, and impact of relationship with neighbours on noise annoyance was affected by types of major noise source.

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