Relationships between non-acoustic factors and subjective reactions to floor impact noise in apartment buildings

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Abstract

The aim of this study was to provide an understanding of how residents in apartment buildings perceive and react to impact sounds coming from their upstairs neighbours' dwellings. Based on existing theoretical and empirical studies on environmental noise, a conceptual model was developed to explain relationships among noise annoyance and non-acoustic factors. The model was then tested using structural equation modelling with survey data from residents living in apartment buildings (N = 487). The findings showed that the conceptual model was consistent with other models developed for environmental noises. The results indicated that annoyance induced by floor impact noise was associated with perceived disturbance, coping, and self-reported health complaints. Noise sensitivity had a direct impact on perceived disturbance and an indirect impact on annoyance, and moderating variables affected the non-acoustic factors. Exposure to footstep noises increased the impact size of noise sensitivity to disturbance. Predictability, marital status, and house ownership were found to influence the relationship between attitudes towards authorities and coping. In addition, a negative attitude towards neighbours (i.e., the noise source) moderated the positive relationship between annoyance and coping.

I. Introduction

Noise from neighbouring apartments and flats is one of the most prevalent sources of annoyance in European countries (Maschke and Niemann, 2007). Noise in apartment buildings has also become a social issue in Korea, as the number of people living in apartment housing has increased rapidly over several decades (Lee *et al.*, 2007). In particular, complaints and concerns regarding indoor noise focus on noise produced by children's or adults' footsteps. Floor impact sounds were found to be the most annoying source of noise in apartment buildings (Jeon *et al.*, 2010), and children aged 6–9 years were found to be the primary source of floor impact sound (Jeon *et al.*, 2006).

In addressing the issue of noise annoyance, recent studies have places an emphasis on the acoustic features of floor impact sounds in terms of an autocorrelation function (Jeon and Sato, 2008), the magnitude of interaural cross-correlation (Jeon *et al.*, 2009), spectral characteristics (Ryu *et al.*, 2011), and temporal decay (Kim *et al.*, 2013). A few studies have used social survey to examine subjective responses to floor impact sounds. Jeon et al. (2010) conducted a survey study to explore dissatisfaction with indoor noise environment in residential buildings. They measured the participants' overall dissatisfaction with indoor noise environment as well as dissatisfaction and annoyance of individual noise sources (floor impact sounds, airborne, drainage, and traffic noise). It was found that the contribution of dissatisfaction with floor impact noise to overall dissatisfaction with the indoor noise environment was the highest, followed by airborne noise and drainage noise. Ryu and Jeon (2011) carried out surveys and laboratory experiments. They investigated the relationship between noise sensitivity and annoyance caused by indoor residential noises and by outdoor traffic noise. It was found that noise sensitivity had a significant influence on annoyance level caused by both indoor and outdoor noises; in particular, noise sensitivity had a stronger impact on annoyance with indoor noise than with outdoor noise.

Annoyance caused by environmental noises - such as road traffic, aircraft, and wind turbines - has been examined mainly through the use of social surveys (Job, 1988; Fields, 1993; Guski, 1999; Pedersen and Persson Waye, 2007; Paunović *et al.*, 2009; Elmenhorst *et al.*, 2012). Most previous studies suggested that noise annoyance could not be explained by noise exposure alone. For example, Job (1988) reported that noise exposure could account for approximately only 20% of the variation in reactions to noise; attitude to the noise source and noise sensitivity explained more variation in reaction than did noise exposure. Pedersen and Persson Waye (2007) argued that noise annoyance caused by wind turbines was also linked to the visibility of wind turbines and negative attitudes towards them. Guski (1999) classified non-acoustic factors affecting annoyance into personal and social variables. The personal variables included noise sensitivity, personal evaluation of the source, and coping capacity, while social variables included general attitude, history of noise exposure, and residents' expectations. Paunović *et al.* (2009) stressed that subjective noise sensitivity was a significant indicator of annoyance, confirming that noise sensitivity had a greater effect on annoyance than demographic factors (Fields, 1993). Recently, Laszlo *et al.* (2012) reviewed a number of previous studies examining reactions to environmental noise exposure, and they classified the moderating variables into four groups: demographical, personal, social, and situational.

Based on the previously conducted theoretical and empirical research (Guski, 1999; Stallen, 1999; Kroesen *et al.*, 2008; Pennig and Schady, 2014), this study aimed to develop and test a causal model of annoyance arising from floor impact noise. A survey was conducted to assess reactions to floor impact noise, and the relationships between non-acoustic factors and annoyance were investigated via structural equation modelling (SEM). The structure of this paper is as follows. The second section presents the hypothesised conceptual model and explains the background, in relation to previous studies, of each hypothesised path. The third section shows how and with whom, the research was conducted

and analysed. In the fourth section, the results are shown; the fifth section discusses the findings with some reflective commentaries. The last section concludes the paper by presenting the main conclusions.

II. Conceptual model

Previous studies (Guski, 1999; Stallen, 1999; Kroesen *et al.*, 2008; Pennig and Schady, 2014) have developed conceptual models to provide insights into the relationships between noise annoyance and relevant variables. Guski (1999) proposed a model of individuals' reactions to environmental noises, and suggested that personal and social factors influence disturbance, annoyance, and somatic effects. In particular, noise sensitivity was shown to affect actual and reported disturbance. A number of studies have also confirmed that noise sensitivity is one of the key indicators of noise annoyance and sleep disturbance (Job, 1988; Nivison and Endresen, 1993; Lercher and Kofler, 1996; van Kamp *et al.*, 2004; Paunović *et al.*, 2009; Fyhri and Aasvang, 2010; Kang and Zhang, 2010). Therefore, it was assumed that noise sensitivity would have direct impacts on perceived disturbance and annoyance.

Stallen (1999) developed a theoretical framework for environment noise annoyance based on a psychological stress theory (Lazarus, 1966) and suggested that perceived disturbance (primary appraisal) was a major determinant of noise annoyance, which accords with the suggestion that actual interferences affect one's reported annoyance (Guski, 1999). This relationship between perceived disturbance and noise annoyance was later empirically tested in an aircraft noise study by Kroesen *et al.* (2008) who tested a structural equation model for aircraft noise annoyance and found that perceived disturbance had a positive impact on annoyance. The present study also hypothesised a positive impact of perceived disturbance on annoyance caused by floor impact noise.

Stallen (1999) argued that coping and perceived control might be major determinants of noise annoyance. Moreover, a number of studies have reported a close link between coping and noise annoyance (Lercher, 1996; Guski, 1999; Stallen, 1999; Hatfield *et al.*, 2002; Haines *et al.*, 2003; Park and Lee, 2015). Haines *et al.* (2003) reported various coping strategies that children used when they were exposed to environmental noises. Recent empirical studies on aircraft and railway noise confirmed the relationship between noise annoyance and coping; it was found that annoyance positively affects individuals' coping capacity (Kroesen *et al.*, 2008; Pennig and Schady, 2014). In the present study, therefore, coping was hypothesised to be positively affected by annoyance.

Noise exposure has been proposed to cause physical and mental problems (Lercher, 1996; Guski, 1999). The relationship between noise annoyance and subjective health complaints has also been confirmed in empirical studies (Pedersen and Persson Waye, 2007; Fyhri and Klæboe, 2009; Bluyssen *et al.*, 2011; Bakker *et al.*, 2012). Road traffic noise annoyance was found to be associated with self-reported health complaints such as sleep disturbance, nervousness, and headache (Fyhri and Klæboe, 2009). Recent questionnaire surveys have also reported that wind turbine noise annoyance has significant impacts on self-reported health complaints and psychological distress (Pedersen and Persson Waye, 2007; Bakker *et al.*, 2012). Thus, annoyance induced by floor impact noise was hypothesised to be here positively associated with health complaints.

Attitudinal variables have been emphasised in explanations of subjective reactions to noise (Fields, 1993; Lercher, 1996; Guski, 1999; Stallen, 1999; Elmenhorst et al., 2012). For instance, Guski (1999) introduced social factors and stated that individuals who were aware of the importance and necessity of the source showed low noise annoyance. Pedersen et al. (2009) also found that residents reported relatively lower levels of annoyance if they benefited economically from wind farms as owners or co-owners of wind turbines. On the

other hand, several researchers have connected attitudinal variables to coping. A close link between attitude and coping was theoretically suggested by Stallen (1999). In Stallen's framework (1999), it was hypothesised that non-noise related attitudes is a potential coping resource because coping is related to attitudes towards stressors (Shaw et al., 1993). Subsequent empirical studies on aircraft and railway noise (Kroesen et al., 2008; Pennig and Schady, 2014) then confirmed that attitudes toward noise sources (social evaluation of a noise source) influences perceived control. Therefore, attitudinal variables were considered to be related to coping rather than annoyance, and it was hypothesised that attitudinal variables would affect coping positively. A recent study of floor impact noise suggested that closeness with neighbours (i.e., a positive attitude to the noise source) could influence the degree of annoyance and decrease the level of noise complaints (Park and Lee, 2015). Thus, closeness with neighbours was chosen as the attitudinal variable along with attitudes to authorities (Lercher, 1996; Guski, 1999; Stallen, 1999; Kroesen et al., 2008; Pennig and Schady, 2014).

Based on the literature review and the proposed hypotheses, a theoretical framework was constructed to explain the relationships among non-acoustic factors and annoyance caused by floor impact noise. As shown in Figure 1, there are seven endogenous factors; noise sensitivity, disturbance, annoyance, health complaints, coping, attitudes towards authorities, and closeness with neighbours.

Figure 1

III. Methods

A. Sample

Both online and paper surveys were developed because it was assumed that older people are less familiar with online surveys. The online survey was designed using Google forms.

Survey invitations were sent via email or letters and only those who were residents of apartment buildings and have heard floor impact sounds from their upstairs neighbours were invited to take part in the study. The participants were asked to respond using their preferred method, and the majority selected the online survey. The online survey allows researchers to recruit large samples, and its reliability has been validated in comparison to paper methods in psychology and epidemiological studies (Gosling *et al.*, 2004; Ekman *et al.*, 2006). The surveys were conducted in Korea in October and November 2014, and 527 questionnaires (505 online and 22 on paper) were completed and collected. Of the 527 completed questionnaires, 40 were excluded since they involved outliers or were completed by individuals with no experience of hearing floor impact noise. As listed in Table I, 66.9% of the respondents were female and 33.1% were male. Most participants (77.8%) were in their 20s, 30s, or 40s, and approximately 70% were educated to university degree level or higher. In addition, almost half of the participants were married (54.8%) and almost half of them were homeowners (54.2%).

Table I

B. Measurements

The questionnaire consisted of questions about participants' demographic characteristics, attitudinal factors (e.g., closeness with their upstairs neighbours), and perceptions of floor impact noise (e.g., annoyance). As shown in Table II, latent variables in the conceptual model were assessed and they were evaluated using 5-point scales ranging from 1 ("Not at all") to 5 ("Extremely").

Table II

1. Annoyance and disturbance

Two questions were used to measure annoyance: one concerning perceived annoyance and the other pertaining to changes in annoyance relative to that experienced a year earlier. Kroesen *et al.* (2008) evaluated noise annoyance using three different scales (i.e., 5-point, 7-point, and 11-point scales), while Pennig and Schady (2014) evaluated noise annoyance at different times (day, evening, and night). Instead, the present study developed the second question based on the finding that adaptability could influence noise annoyance (Lercher, 1996). It was assumed that annoyance might be reduced as people become adapted to noise. Measurement items for disturbance were determined according to previous studies (Griffith and Langdon, 1968; Guski *et al.*, 1978; Fidell *et al.*, 2002; Öhrström, 2004; Kroesen *et al.*, 2008). Fidell *et al.* (2002) used two items to determine whether aircraft noise had disturbed participants' sleep or interfered with conversation or listening to the radio. Öhrström (2004) measured indoor disturbances caused by road traffic noise and considered conversation, radio/television, concentration, rest/relaxation, difficulties in falling asleep, and being woken by noise. Recently, Kroesen *et al.* (2008) also assessed perceived disturbance caused by aircraft noise and considered five activities including sleep, conversation, and resting. The present study asked respondents to rate the extent to which they had been disturbed by noise with respect to five different types of activity: sleeping, watching television or listening to the radio/music, having conversations, quiet activities, and resting.

2. Coping

Hatfield *et al.* (2002) used a single-item question to assess perceived control; they asked participants how much personal control they felt they had when they heard aircraft noise overhead. Kroesen *et al.* (2008) measured coping capacity using three questionnaire items (e.g., feeling of powerlessness). Folkman and Lazarus (1988) identified avoidant coping as the most common coping strategy: for instance, when exposed to noise, individuals

concentrate on something else or increase the volume of their music or televisions when they were exposed to noise (Haines *et al.*, 2003) rather than direct attention to the problem in order to prevent or control it (Folkman and Lazarus, 1988). The present study took into account three avoidant coping behaviours which were the most frequently used by the interviewees (Park and Lee, 2015): going out, increasing the volume of the television or music, and concentrating on other activities.

3. Health complaints

Previous studies have suggested the influence of noise annoyance on subjective health complaints (Nivison and Endresen, 1993; Guski, 1999; Fyhri and Klæboe, 2009; Bakker et al., 2012). Guski et al. (1978) earlier proposed some self-report question items to measure health effects such as tiredness and headaches. Fyhri and Klæboe (2009) invited participants to answer questions about their physical symptoms including tiredness and headaches arising from road traffic noise. More recently, Bakker et al. (2012) used a standardised health questionnaire to assess the relationship between self-reported psychological distress and wind turbine noise. The present study set the participants questions regarding three common physical symptoms (headache, stomach ache, and tiredness) that, in a recent study (Park and Lee, 2015), were found to evaluate subjective health complaints affected by floor impact noise.

4. Attitudinal variables

In their aircraft noise annoyance study, Kroesen *et al.* (2008) measured attitudes towards authorities by asking respondents about attitudes to the airport (Schiphol) and the government. Similarly, general attitudes to the responsible authorities and railway institutions were assessed in a recent study (Pennig and Schady, 2014). In the present study, the government and the construction company were selected as the relevant authorities regarding noise issues

because residents asserted that policy makers' neglect and poor sound insulation performance were major causes of floor impact noise problems (Park and Lee, 2015).

For measuring attitudes to the noise source, Fields (1993) suggested considering fear of danger from the noise source and beliefs about the social importance of the noise source. Pedersen and Persson Waye (2007) asked participants whether they held negative or positive attitudes toward wind turbines. Kroesen *et al.* (2008) measured negative attitudes to the noise source by asking participants to rate the extent to which they agreed with several statements regarding personal beliefs and attitudes toward the noise source. In this study, individuals' relationships with their neighbours were measured to assess their attitudes to the noise source, since the occurrence of floor impact sounds depends largely on neighbours' activities and living patterns. In other words, noisy neighbours are considered as noise source of floor impact noise. Park and Lee (2015) also reported that residents in apartment buildings frequently described relationships with their upstairs neighbours when they described floor impact noise. Three questions were employed to assess the participants' closeness with their neighbours. The first question aimed to assess the participants' overall closeness with their upstairs neighbours. The other two items were included to determine how often the participants had shared gifts or food with their upstairs neighbours and how frequently they had visited them. These two items were included on the assumption that sharing gifts or food and visiting neighbours are common activities only between close neighbours in apartment buildings.

C. Statistical analysis

Structural equation modelling (SEM) was employed to test the hypothesised model (Figure 1). This statistical procedure is beneficial since it estimates multiple and interrelated relationships simultaneously, calculates measurement error in the estimation process, and

describes a model which explains the entire set of relationships (Hair *et al.*, 2010). In the present study, the conceptual model was tested using AMOS 22.0 (SPSS Inc., Chicago, IL). The validity and reliability of each set of questions was assessed by confirmatory factor analysis (CFA) in AMOS 22 and Cronbach's alphas were calculated in SPSS for Windows, version 21.0 (SPSS Inc., Chicago, IL).

SEM is an extension of several multivariate techniques that examines a series of dependence relationships simultaneously. It is useful to test relationships among latent variables which cannot be directly measured. Estimates of error variables and confirmatory factor analysis (CFA) provide researchers with tools to determine both how much each of the observed variables represent the latent variables and how much each latent variable is represented differently from each other. Further, it is of use to test theories which contain dependence relationships (Hair et al., 2010). Using SEM was expected to be helpful since there is a lack of studies testing the relationships between non-acoustic factors and noise annoyance caused by floor impact noise based on stress theory (Lazarus, 1966; Stallen, 1999).

IV. Results

A. Reliability and validity measures

Before testing the path model, validity and reliability of the items were assessed using Confirmatory Factor Analysis (CFA). As summarised in Table III, convergent validity was assessed via factor loadings and Average Variance Extracted (AVE), and reliability was examined via Composite Reliability (CR) and Cronbach's alpha. All factor loadings were statistically significant (p<0.001) and greater than 0.6, which were acceptable values. Hair *et al.* (2010) suggested cut-off values for AVE (0.5) and CR (0.7) to explain adequate convergence and good reliability. The calculated AVE ranged from 0.518 to 0.751 and the

reliability estimates measured via CR and Cronbach's alpha ranged from 0.756 to 0.912. Discriminant validity refers to the degree to which a construct is truly distinct from other constructs. According to Hair *et al.* (2010), high discriminant validity provides evidence that a construct is unique and captures some phenomena that other measures do not. One of the ways to assess discriminant validity is to compare the Average Shared Variance (ASV) values for the constructs with their AVE values. ASV values, which are lower than AVE values, indicate good discriminant validity (Hair *et al.*, 2010). As shown in Table III, therefore, the CFA results confirmed that internal consistency exists, and the model's construct validity was good.

Table III

B. Results of the path analysis

The fit of the structural model was tested using maximum likelihood estimation. The adjusted root mean square error of approximation (RMSEA) was 0.055, which is lower than the normal cut-off limit for a good RMSEA value (Hu and Bentler, 1999). The value of the goodness of fit index (GFI) was 0.932 and the comparative fit index (CFI) was 0.967; values for both fit indices were close to 1, indicating a good fit. In addition, the normed Chi square (χ^2/df) was 2.479, which is within the acceptable range (Hair *et al.*, 2010). Overall, the fit indices suggested that the tested model was a good fitting model.

Figure 2

As shown in Figure 2, four of six hypothesised paths were statistically significant (p<0.01). The standardised estimates were plotted in Figure 2. It was found that noise sensitivity positively affected disturbance (β=.511, p<0.001), indicating that those who were sensitive to noise were more easily disturbed by floor impact noise. However, the impact of noise sensitivity on annoyance was not significant. This indicates that noise sensitivity does not have a direct effect on annoyance in the causal relationship even though the correlation coefficients between them were statistically significant (r = 0.38 for AN1 and r = 0.31 for AN2, p<0.01 for both). This is because the correlation between two variables can be decomposed into four components: direct effect, indirect effect, spurious association, and an unanalysed component (Olobatuyi, 2006). In this study, the correlation between noise sensitivity and annoyance was explained only by the indirect effect via disturbance (β = 0 496, p<0 001). In addition, noise sensitivity had indirect effects on health complaints (β = 0.460, p<0.001) and coping (β = 0.468, p<0.001) via disturbance and annoyance. This finding confirms that noise sensitivity is one of the key variables in understanding subjective responses to building noise as well as to environmental noises (Fields, 1993; van Kamp *et al.*, 2004; Paunović *et al.*, 2009; Ryu and Jeon, 2011). Perceived disturbance was also positively associated with noise annoyance and the effect size was very large (β=.942 p<0.01); it had indirect effects on health complaints and coping, at 0.888 and 0.905, respectively (p<0.001). This result shows that more frequent disturbance leads to increased annoyance. Recent empirical studies reported a reciprocal relationship between disturbance and noise annoyance (Kroesen *et al.*, 2008; Pennig and Schady, 2014). The unbiased estimate of the reciprocal effects can be obtained when both factors (disturbance and annoyance) have at least one instrumental vairable (Smith-Lovin and Tickamyer, 1978; Wong and Law, 1999); this is because the estimation of the reciprocal relationship requires estimating the error covariance between the instrumental variables. However, the model tested in this study had one

instrumental variable (noise sensitivity) for disturbance but no instrumental variable connected to annoyance; therefore, it was not appropriate to assess the reciprocal relationship in the present study. Noise annoyance significantly affected both coping (β=.955 p<0.01) and health complaints (β=.926 p<0.01), and the standard estimates of these relationships were all positive. These findings imply that increased noise annoyance led the participants to employ avoidant coping behaviours more frequently and to report more health complaints. On the other hand, it was found that two attitudinal variables (attitudes towards authorities and closeness with neighbours) had no significant impacts on coping.

C. Moderation and mediation

Moderating variables were introduced to investigate whether such variables might moderate the relationships between the major factors used in our model. The moderating variables that are of interest fall into two groups: a) categorical variables (type of noise source, predictability, marital status, and house ownership) and b) a continuous variable (negative attitude towards neighbours). The impacts of moderating variables on the relationships were examined through both multiple-group analysis and two-way interaction analysis. First, multiple-group analyses were performed in order to compare the structural models across different groups. In each model, all paths were constrained to be invariant for multiple-groups. The participants were categorised into two groups according to moderating variables. For example, one group had footsteps as a major source of floor impact sound; the other group had other types of noise source such as furniture being dragged or light objects being dropped. The fit indices of each model were found to be within the acceptable range, and path analysis results were consistent with the results plotted in Figure 2. As listed in Table IV, significant differences between groups across moderating variables were observed only in two paths; noise sensitivity-disturbance and attitudes to authorities-coping. Footsteps were found to increase the impact size of noise sensitivity on disturbance. This indicates that

noise sensitivity is more critical for predicting perceived disturbance if the residents are exposed to footstep noises. The other three moderators (predictability, marital status, and house ownership) moderated the path between attitudes towards authorities and coping. Even though the impact sizes were relatively small, the attitude towards authorities had a positive influence on coping when 1) the noise events were predictable, 2) the residents were married, and 3) the residents lived in their owned apartments.

Table IV

Two-way interaction analysis was also carried out in order to examine whether a negative attitude towards neighbours was associated with an increase or decrease in the use of coping strategies among the residents with different annoyance levels. The negative attitude towards neighbours was assessed using a 5-point scale ranging from 1 ("*Not at all*") to 5 ("*Extremely*") with the following instruction: "How much do you think that lack of consideration between neighbours is a major reason for the floor impact noise problem?" Before the test, all variables were mean-centred (the variable averages were subtracted from the data) to reduce multicollinearity. As shown in Figure 3, constructs for the interaction terms were computed individually, and each moderator was then multiplied by each observed variable (e.g., AN1 × NA and AN2 × NA).

Figure 3

The impact of negative attitudes towards neighbours on the relationship between annoyance and coping was found to be statistically significant ($\beta = -.123$, $p<0.01$). In order to interpret the moderating effects, Figures 4 was plotted for different levels of the attitude

towards neighbours. One standard deviation above and below the mean value was chosen to classify each moderator into two groups: those with strong or weak negative attitudes towards neighbours (Dawson, 2014). When perceived annoyance was low, those who had strong negative attitudes towards neighbours used more coping strategies than did those with weak negative attitudes. However, the level of coping became almost the same when they were highly annoyed. This implies that negative attitudes towards neighbours weakened the positive relationship between annoyance and coping; in other words, the belief that inconsiderate neighbours are responsible for the noise problems moderates the impact of annoyance on avoidant coping strategies. Thus, stronger negative attitudes towards neighbours can be assumed to increase the level or frequency of vigilant coping as against avoiding exposure to the noise.

Figure 4

In the path model, coping was considered as a dependent variable in the relationship between annoyance and coping. In addition, coping can be a mediator in direct relationships as shown in Figure 5. In other words, mediating relationships might occur when coping plays an important role in relationships such as disturbance – annoyance and annoyance – health complaints. Therefore, additional tests were conducted to investigate the mediation effects of coping on two direct relationships. The impact size of disturbance on annoyance (β=.959 $p<0.01$) and that of annoyance on health complaints (β=.927 $p<0.01$) were earlier estimated in the path analysis in the absence of a mediator (i.e., coping). It was found that coping partially and negatively mediates the relationships (disturbance – annoyance and annoyance – health complaints). The direct impact of disturbance on annoyance significantly decreased to 0.502 ($p<0.01$), while the effect size of annoyance on health complaints was also reduced to

0.434 ($p<0.05$) when coping was added as a mediator. These results imply that 1) disturbance leads to coping, then less annoyance may be reported, and 2) annoyance leads to coping, then less health complaints may be reported.

Figure 5

V. Discussions

Previously developed conceptual models have focused mainly on environmental noise (Guski, 1999; Stallen, 1999; Kroesen *et al.*, 2008). In particular, in recent empirical studies, conceptual models were developed to explain the relationships between non-acoustic factors and annoyance caused by aircraft and railway noise (Kroesen *et al.*, 2008; Pennig and Schady, 2014). In contrast, the present study examined noise annoyance induced by floor impact sounds, which are categorised as building noise. Therefore, this approach extended the explanation of issues surrounding building noise provided by environmental noise research. The findings from this study confirm that the theoretical model for environmental noise is applicable to other noises sources. Consistent with previous studies (Stallen, 1999; Kroesen *et al.*, 2008), the present study shows that perceived disturbance has a positive impact on noise annoyance. The relationship between annoyance and coping demonstrated here supports the findings of environmental noise studies (Stallen, 1999; Kroesen *et al.*, 2008; Pennig and Schady, 2014); the negative effects of noise annoyance on health that are shown here also confirm previous research (Lercher, 1996; Guski, 1999). Contrary to Kroesen *et al.* (2008) who could not find any significant impact of noise sensitivity on perceived disturbance, this study revealed that noise sensitivity has a direct impact on disturbance.

However, the findings concerning attitudinal variables were not consistent with other empirical studies (Kroesen *et al.*, 2008; Pennig and Schady, 2014). As shown in Figure 2,

attitudes towards authorities and closeness with neighbours were found to have no significant impact on coping in the present study. Inconsistency between previous studies and the present study might be explained by three factors. First, the measurement of coping was different. Kroesen *et al.* (2008) assessed cognitive coping strategies rather than measuring behavioural coping that can have both positive and negative outcomes. Pennig and Schady (2014) also measured cognitive coping with behavioural coping strategies, using six questions which had been previously developed for assessing subjective coping capacity regarding environmental noise (Guski *et al.*, 1978). Contrary to the previous studies, this study focused on behavioural coping strategies because these were the ones predominantly selected by the residents who had been exposed to floor impact noise in their dwellings (Park and Lee, 2015). Although the residents reported more behavioural coping than cognitive coping, setting appropriate questions for assessing cognitive coping strategies would yield further insights into the relationships between attitudes and coping; this would be a fruitful area for future research. Second, the noise sources were entirely different. The present study measured attitudes to noise source with which people can have personal relationships, whereas the noise sources that the previous studies focused on (Kroesen *et al.*, 2008; Pennig and Schady, 2014) were aircraft and railway noises with which people cannot have personal relationships. Kroesen *et al.* (2008) and Pennig and Schady (2014) measured attitudes to noise sources by asking their respondents about the importance or financial benefits of the noise sources. Since such social evaluations cannot be made of a person's upstairs neighbours, the present study instead employed questions that assessed the respondents' closeness with their neighbours. Third, the relationships between authorities and the noise sources were different. The attitudes towards authorities assessed in the present study were not of the kind that Kroesen *et al.* (2008) and Pennig and Schady (2014) measured. The occurrence of aircraft and railway noise can be ascribed to relevant authorities such as airports, railway institutes, or the governments since

the noise sources are regarded as being run by the authorities; in contrast, the sources of floor impact noises are simply the upstairs neighbours.

In general, behavioural coping strategies can be classified into avoidant or vigilant coping. The questions concerning coping that were used in the present study dealt with avoidant coping strategies that aim to divert one's attention from a stressful situation in order to cope with it (Folkman and Lazarus, 1988); vigilant coping directs attention towards the source of the stress in order to prevent or control it - complaining about noise is the most common strategy that people select. The relationship between noise annoyance and complaining has been previously examined by many researchers (e.g., Hume *et al.*, 2002; Maziul *et al.*, 2005; Nykaza *et al.*, 2013). People are more likely to use avoidant coping strategies in preference to lodging complaints when they are exposed to problematic environmental noises but believe their noise complaints to authorities will not lead to significant change (Hume *et al.*, 2002). However, noise complaints were commonly observed in cases of floor impact noises (Park and Lee, 2015); this may be because residents of apartments are able to contact their neighbours (i.e., the noise source) directly to attempt to resolve such problems. Therefore, it would be useful to collect data regarding participants' experiences of making complaints. Further research examining complaints concerning building noises may be expected to extend current scientific knowledge regarding coping mechanisms. A limitation of the present study is its cross sectional design which could introduce bias due to cohort effects. Household income was not evenly distributed and some apartments may have a high exposure to transportation noise which causes another noise annoyance. Even though multiple-group moderation and interaction moderation were carried out in this study, it is unlikely to have entirely eliminated the bias due to the cohort effects. Therefore, more studies are needed using comparable measures across the population.

A number of studies have concentrated on the theoretical modelling of perception of noise (Lazarus, 1966; Guski, 1999; Stallen, 1999). Along this line of investigation, several studies (Kroesen *et al.*, 2008; Pennig and Schady, 2014) have proven that theoretical models are reliable to understand annoyance induced by environmental noise, but little attempt has been made to explore perception of building noise with a theoretical basis. Similarly to previous studies on environmental noise (Kroesen *et al.*, 2008; Pennig and Schady, 2014), this study introduced a structural equation modelling to understand the relationships between non-acoustic factors and annoyance caused by floor impact noise. As a result, contrary to previous works on floor impact noise (Jeon and Sato, 2008; Jeon *et al.*, 2009; Ryu *et al.*, 2011), the developed model provides theoritical and empirical insight into perception of building noise. In addition, this study expanded the use of the SEM to investigate the impacts of moderating and mediation variables on the model. The findings from multiple-group and two-way interaction analysis suggest that there are significant moderation effects in the two paths (i.e., noise sensitivity-disturbance and attitudes to authorities-coping) and attitudes towards neighbours influence the relationship between annoyance and coping. Overall, the findings contribute to the literature by highlighting the psychological mechanisms underlying the associations between non-acoustic factors and perception of floor impact noise.

VI. Conclusions

A conceptual model was developed and tested using social survey data to explain the relationships between non-acoustic factors and annoyance caused by floor impact noise in apartment buildings. The findings of this study confirmed the conceptual models relating to environmental noises. Noise sensitivity was found to have a positive influence on perceived disturbance. Disturbance had a positive relationship with annoyance, while annoyance was found to affect individuals' coping and health complaints. However, contrary to the findings

of previous studies (Kroesen *et al.*, 2008; Pennig and Schady, 2014), the relationships between coping and attitudinal variables (attitudes towards authorities and closeness with neighbours) were not significant. It was observed that several factors moderated the paths in the conceptual model. In particular, a negative attitude towards neighbours was found to weaken the positive relationship between annoyance and coping; therefore, promoting relationships between neighbours could lead to the solving of conflicts arising from floor impact noise. However, the present study focused on only floor impact noise; further empirical studies are required to examine whether the conceptual model is valid for other building noises (e.g. airborne noise).

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Table I. Participants' personal characteristics (N = 487)

		N	%
Gender	Male	161	33.1
	Female	326	66.9
Age	Teens	42	8.6
	20s	134	27.5
	30s	145	29.8
	40s	100	20.5
	50s	45	9.2
	60s or older	21	4.3
Education	High school or equivalent	93	19.1
	Studying at a university or college	52	10.7
	University or college graduate	272	55.9
	Postgraduate or above	70	14.4
Marital status	Married	267	54.8
	Single	211	43.3
	Divorced, widowed, etc.	9	1.8
House ownership	Owned	264	54.2
	Rented (deposit rent)	174	35.7
	Rented (monthly rent)	44	9.0
	Other	5	1.0
House age	<5 y	95	19.5
	5–10 y	109	22.4
	10–15 y	103	21.1
	15–20 y	92	18.9
	>20 y	88	18.1

Table II. Overview of latent variables, observed variables, and questions

Latent variable	Observed variable	Questions
Annoyance	AN1	How annoyed are you by hearing the floor impact sounds from upstairs?
	AN2	Compared with 1 year ago, how different is your annoyance with the noise from upstairs?
Disturbance		How much has floor impact noise interfered with these aspects of your home life?
	D1	Sleeping
	D2	Watching television and listening to the radio and music
	D3	Having a conversation (incl. on the telephone)
	D4	Reading, studying, and other quiet activities
	D5	Resting
Coping		How often have you taken these actions to avoid the noise from upstairs?
	C1	Gone out (e.g., make an appointment with friends)
	C2	Increased the volume up of the television or music
	C3	Concentrated on other activities
Health complaints		How much does the noise from upstairs influence these aspects of your health?
	H1	Headache or dizziness
	H2	Stomach-ache or indigestion
	H3	Tiredness or sense of fatigue
Noise sensitivity	NS	How sensitive are you to noise in general?
Attitudes to authorities		What would you say is the major reason for the floor impact sound problem?
	AT1	Lack of policies on floor impact sound
	AT2	Poor construction
Closeness with neighbours	R1	On the whole, how close are you to your upstairs neighbours?
	R2	How often do you share gifts or food with your upstairs neighbours?
	R3	How often do you visit your upstairs neighbours or invite them to your apartment?

Table III. Results of confirmatory factor analysis (RMSEA=0.050; GFI=0.932; CFI=0.966; χ^2/df=2.492)

Latent Variable	Observed variable	Factor loading	Average variance extracted (AVE)	Composite reliability (CR)	Average Shared Variance (ASV)	Cronbach's alpha
Annoyance	AN1 AN2	.960 .762	.751	.856	0.315	.843
Disturbance	D1 D2 D3 D4 D5	.794 .830 .741 .852 .859	.666	.909	0.447	.912
Health complaints	H1 H2 H3	.840 .790 .926	.729	.889	0.443	.904
Coping	C1 C2 C3	.686 .790 .677	.518	.762	0.433	.756
Attitudes to authorities	AT1 AT2	.919 .576	.588	.731	0.120	.690
Closeness with neighbours	R1 R2 R3	.689 .959 .799	.678	.861	0.005	.839

Table IV. Results of multi-group moderation (** $p<.01$ * $p<.05$)

Moderator variable	Group	Path	Standardised estimates
Noise source	Footsteps (*N*=254)	Noise sensitivity –	0.58**
	Others (*N*=233)	Disturbance	0.44**
Predictability	Predictable (*N*=251)	Attitudes to authorities –	0.17*
	Unpredictable (*N*=236)	Coping	0.02
Marital status	Married (*N*=267)	Attitudes to authorities –	0.15*
	Single (*N*=211)	Coping	0.02
House	Owned (*N*=264)	Attitudes to authorities –	0.13*
ownership	Rented (*N*=218)	Coping	-0.001

Figure captions

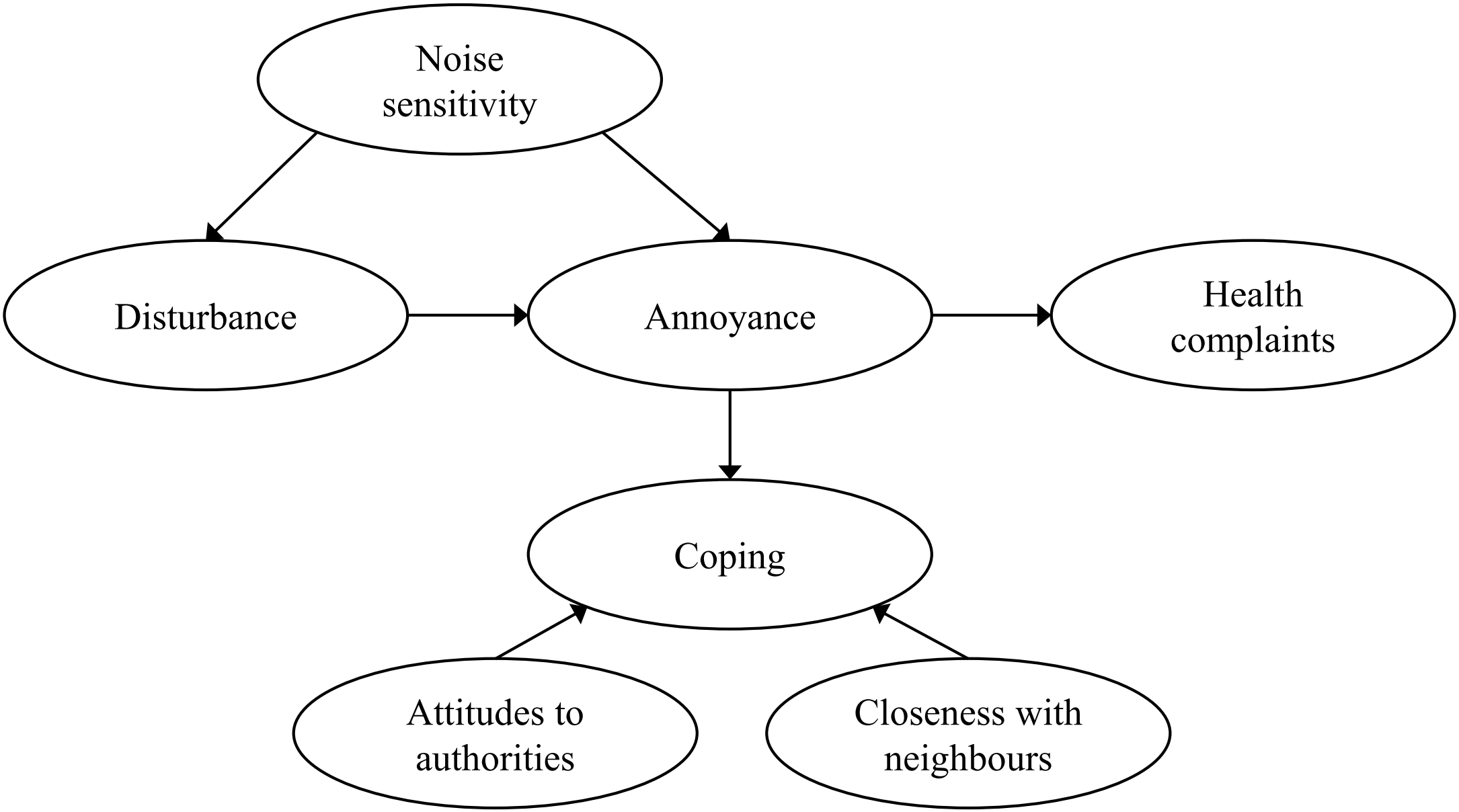
Figure 1. Conceptual model

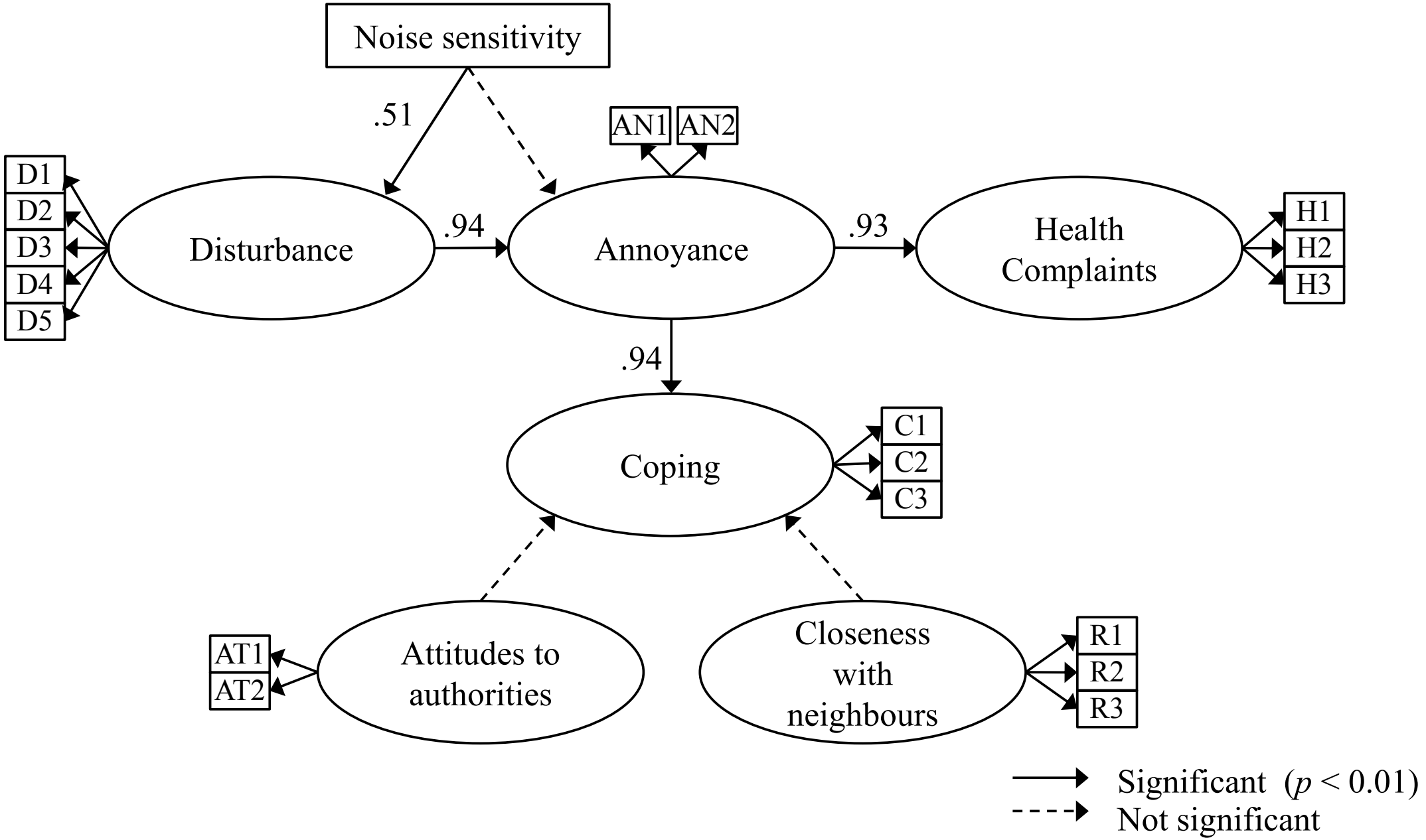
Figure 2. Estimated structural equation model (standardised)

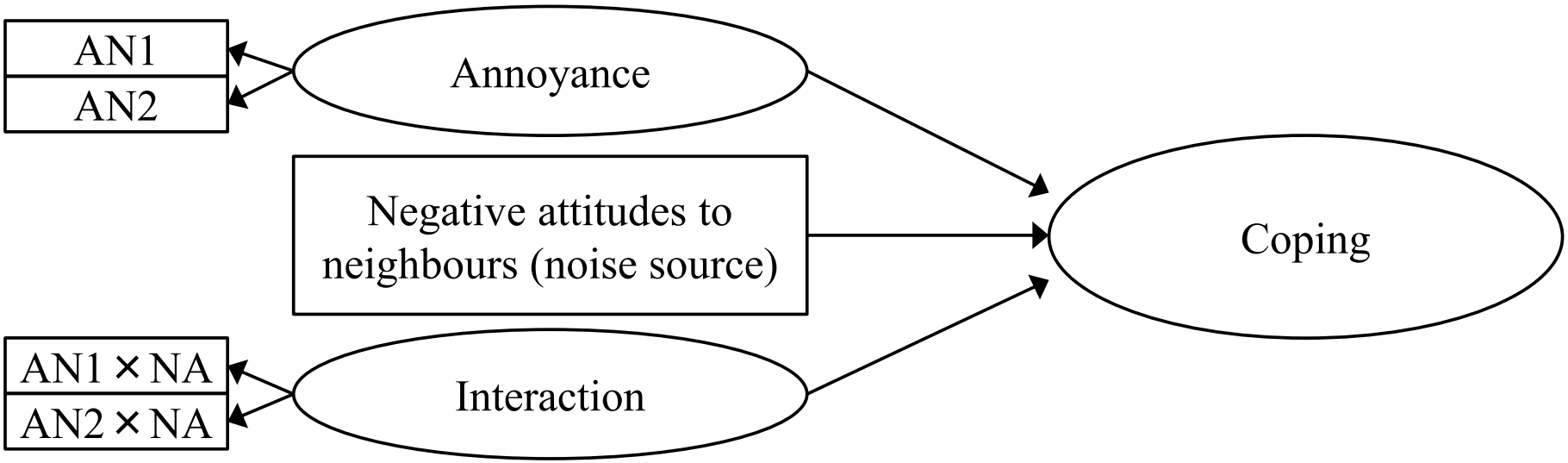
Figure 3. Path model for the interaction test

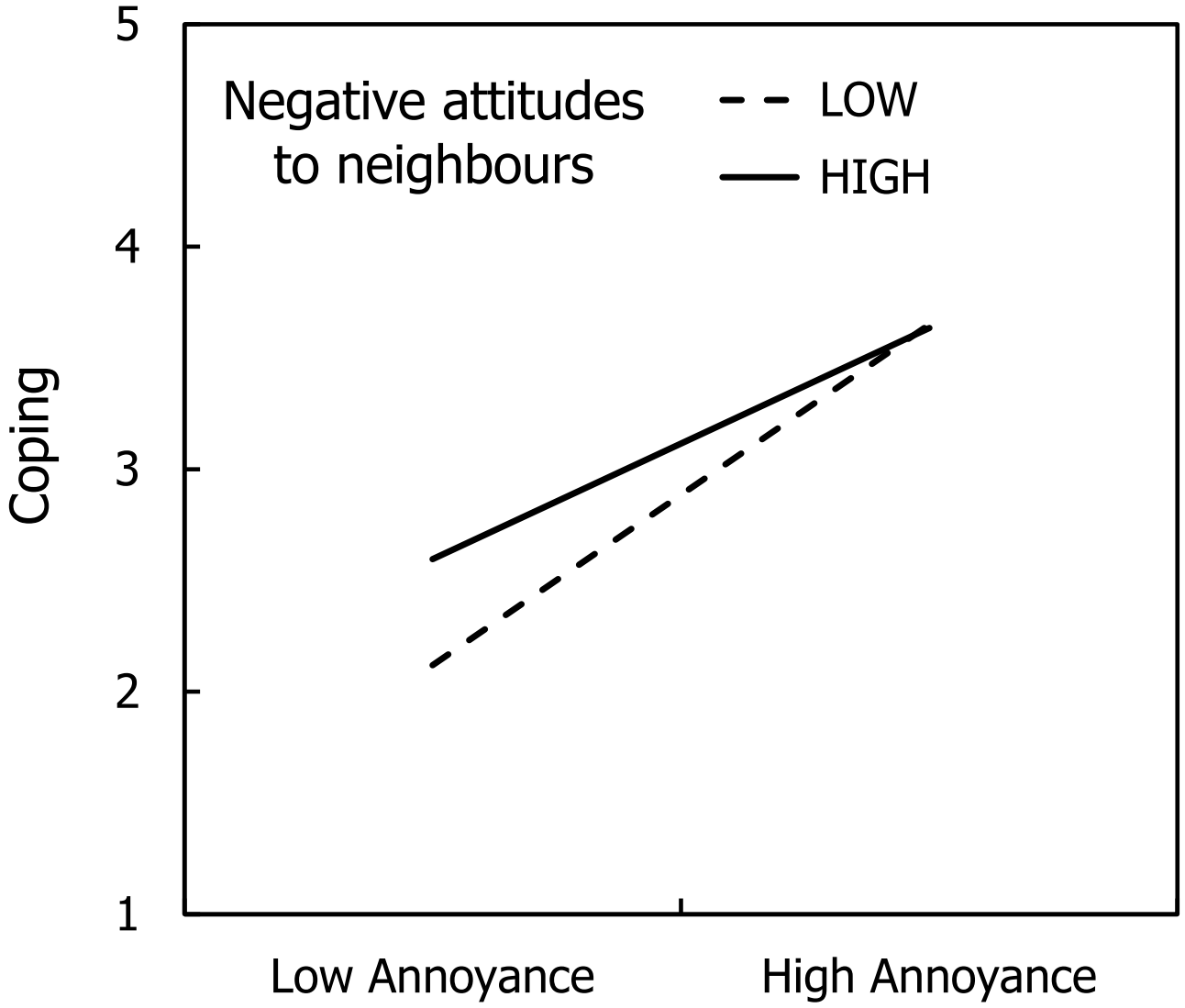
Figure 4. Interaction effects of negative attitude to neighbours

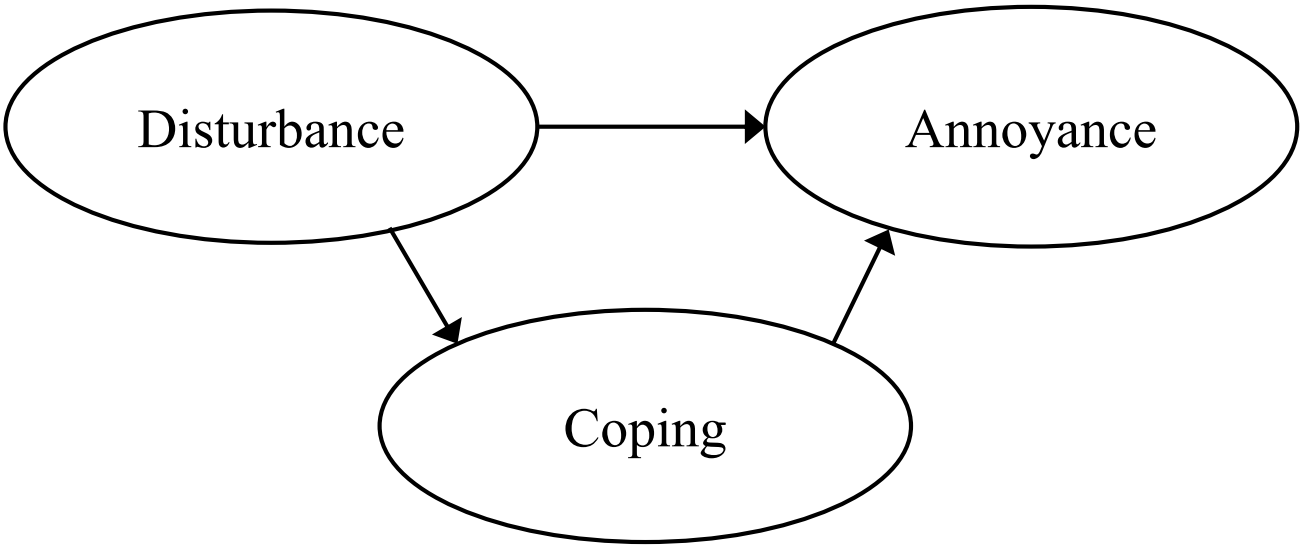
Figure 5. Mediation effects of coping on (a) the relationship between disturbance and annoyance and (b) the relationship between annoyance and health complaints.


Noise sensitivity
Disturbance
Annoyance
Health complaints
Coping
Attitudes to authorities
Closeness with neighbours

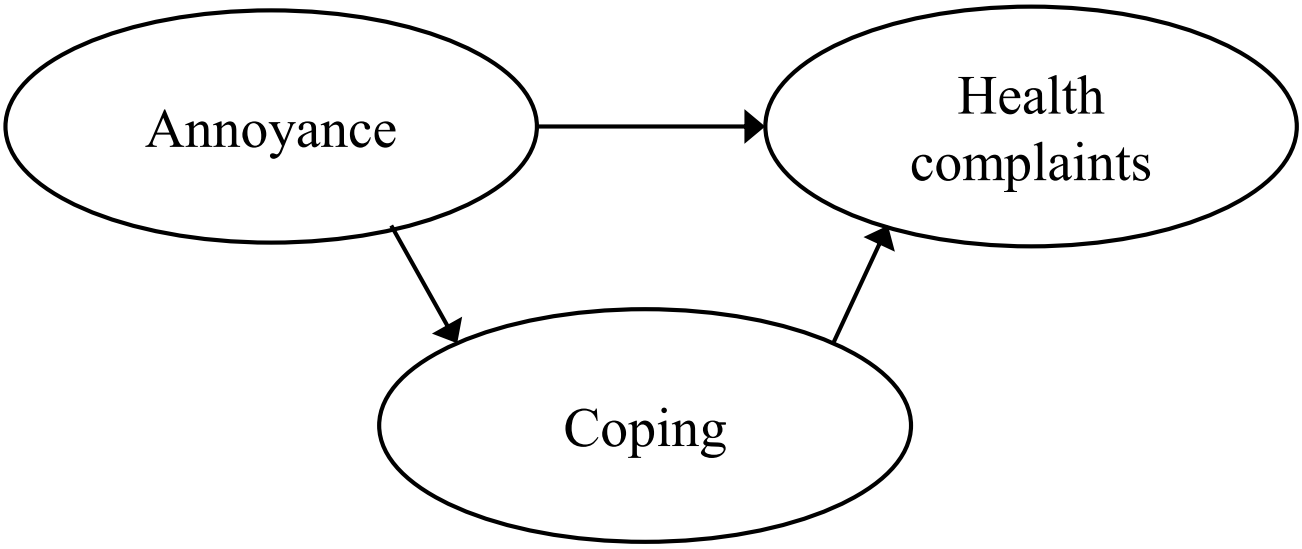

Noise sensitivity
.51
AN1
AN2
D1
D2
D3
D4
D5
Disturbance
.94
Annoyance
.93
Health Complaints
H1
H2
H3
.94
Coping
C1
C2
C3
AT1
AT2
Attitudes to authorities
Closeness with neighbours
R1
R2
R3
Significant ($p < 0.01$)
Not significant


AN1
AN2
Annoyance
Negative attitudes to neighbours (noise source)
AN1 × NA
AN2 × NA
Interaction
Coping


5
4
3
2
1
Coping
Negative attitudes
to neighbours
LOW
HIGH
Low Annoyance
High Annoyance


Disturbance
Annoyance
Coping

(a)


Annoyance
Health
complaints
Coping

(b)