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Impact of Noise on Self-rated Job Satisfaction and Health in Open-plan offices: A Structural Equation Modeling Approach

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Abstract

This study uses a structural equation model to examine the effects of noise on self-rated job satisfaction and health in open-plan offices. A total of 334 employees from six open-plan offices in China and Korea completed a questionnaire survey. The questionnaire included questions assessing noise disturbances and speech privacy, as well as job satisfaction and health. The results indicated that noise disturbance affected self-rated health. Contrary to popular expectation, the relationship between noise disturbance and job satisfaction was not significant. Rather, job satisfaction and satisfaction with the environment were negatively correlated with lack of speech privacy. Speech privacy was found to be affected by noise sensitivity, and longer noise exposure led to decreased job satisfaction. There was also evidence that speech privacy was a stronger predictor of satisfaction with environment and job satisfaction for participants with high noise sensitivity.In addition, fit models for employees from China and Korea showed slight differences.

Practitioner Summary: This study is motivated by strong evidence that noise is the key source of complaints in open-plan offices. Survey results indicate self-rated job satisfaction of workers in open-plan offices was negatively affected by lack of speech privacy and duration of disturbing noise.

Key words: Noise, Open-plan office, Job satisfaction, Health, Structural equation model
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1. Introduction

It is commonly believed that open-plan offices promote teamwork and communication, making it the most commonly used layout (Kupritz, 2003). However, recent studies have reported various negative influences of open-plan office layouts on speech privacy, occupant health, job satisfaction, and performance (Sundstrom *et al.*, 1982; Brennan *et al.*, 2002; Danielsson and Bodin, 2008; Kaarlela-Tuomaala *et al.*, 2009; Lee and Jeon, 2014). Longitudinal studies have reported that the perceived performance of the occupants and their feelings of privacy were reduced after relocating from traditional offices to open offices (Sundstrom *et al.*, 1982; Brennan *et al.*, 2002). In addition, the self-rated loss of work time due to noise in open-plan offices was twice that of private offices (Kaarlela-Tuomaala *et al.*, 2009). Furthermore, the overall health status and job satisfaction for workers in open-plan offices were lower than for workers in individual offices (Danielsson and Bodin, 2008). Recent study reported that a significant excess risk of sickness absence was found in open-plan offices (Bodin Danielsson *et al.*, 2014).

The related literature has consistently demonstrated that noise is the key source of dissatisfaction with physical environments of open-plan offices (Boyce, 1974; Kaarlela-Tuomaala *et al.*, 2009; Kim and de Dear, 2012; Zhang *et al.*, 2012; Kim and de Dear, 2013). More than half of the occupants in an open-plan office were found to be disturbed by noise (Boyce, 1974), and workers experienced noise disturbance more frequently than any other disturbances from a multitude of indoor environmental factors (Kaarlela-Tuomaala *et al.*, 2009). A recent survey on open-plan offices also reported that the perceived quality of the acoustics was the lowest among six physical factors, including temperature and lighting (Zhang *et al.*, 2012). Similarly, satisfaction ratings for noise level and sound privacy were lower than ratings for any of the other indoor environmental quality (IEQ) factors in open-plan offices (Kim and de Dear, 2013). These findings indicate that acoustics might pose potential problems for occupant psychological well-being and health in open-plan offices.

A number of studies have focused on the relationship between the physical conditions found in offices and psychological perceptions, such as job satisfaction and performance (Oldham and Fried, 1987; Crouch and Nimran, 1989; Lee and Brand, 2005). However, these studies have tended to ignore the potential impact of noise itself on psychological well-being and health. Klitzman *et al*. (1989) reported that there was a negative correlation between ratings of excessive noise and job satisfaction. Sundstrom *et al*. (1994) also found a significant, inverse relationship between noise disturbance and job satisfaction. However, these studies (Klitzman and Stellman, 1989; Sundstrom *et al.*, 1994) used data obtained from both conventional and open-plan offices and did not focus specifically on the open-plan layout. Furthermore, no attempt has been made to investigate the influence of speech privacy on psychological well-being and health in open-plan offices, despite various evidence that speech privacy contributes to overall workplace satisfaction (Kim and de Dear, 2013). Moreover, cognitive performance was more impaired when subjects understood more speech and conversation (Haka *et al.*, 2009).

The present study was designed to investigate the impacts of noise in open-plan offices on occupant psychological well-being and health. Noise disturbance and speech privacy were introduced to assess the noise in the office. This study also aimed to develop a path model identifying the multiple relationships among the latent variables of noise disturbance, speech privacy, satisfaction with workplace environment, job satisfaction, and health. A structural equation model (SEM) was adopted to simultaneously test these multiple relationships.

2. The conceptual model

Prior research has revealed that noise disturbance influences environmental satisfaction in offices (Sundstrom *et al.*, 1994). Disturbances due to noise, such as telephones ringing and people talking on the phone, are inversely correlated with environmental satisfaction. Among a total of 15 factors, the negative impact of noise level on workplace satisfaction ranked third for open-plan offices (Kim and de Dear, 2013). In addition, Sundstrom *et al*. (1994) reported that job satisfaction had a negative correlation with disturbances produced by six specific offices noises. Furthermore, office noise showed adverse impacts on occupant health. There is a significant correlation between acoustic environment and health (Zhang *et al.*, 2012), and additional noise exposure in offices is directly related to increase in worker stress levels (Evans and Johnson, 2000). Furthermore, poor perception of the noise in workplace led to poorer health (Brauer *et al.*, 2008). Based on the well-established tendency of office workers to report noise and noise disturbances as problematic, the following hypothesis was proposed:

Hypothesis 1. *Noise disturbances in open-plan offices are negatively correlated to satisfaction with workplace environment (H1a), self-reported job satisfaction (H1b), and health symptoms (H1c).*

In addition to noise, speech privacy also has potential negative impacts on both workplace and job satisfaction. Kim and de Dear (2013) identified satisfaction with speech privacy as one predictor of overall workplace satisfaction. Although there is no empirical evidence showing the impact of speech privacy on job satisfaction, speech privacy, as a negative attribute, is likely to be related to occupant psychological well-being. Accordingly, the following hypothesis was proposed:

Hypothesis 2. Lack of speech privacy in open-plan offices is negatively correlated to satisfaction with workplace environment (H2a) and self-reported job satisfaction (H2b).

Research has shown that noise sensitivity has a strong relationship with perceived annoyance caused by indoor noises as well as environmental noises (Fields, 1993; Job, 1999; Miedema and Vos, 2003; Jakovljevic *et al*., 2009; Ryu and Jeon, 2011; Pierrette *et al*., 2014). Miedema and Vos (2003) found a significant difference in conversation disturbances between low and high sensitivity groups at high noise exposure levels. A recent study reported that noise sensitivity was related to subjective health complaints such as sleep problems and nervousness (Fyhri and Aasvang, 2010). The existing literature has not definitively established whether noise sensitivity has any influence on speech privacy. However, there is research showing that the effect of irrelevant speech on recall was affected by noise sensitivity (Ellermeier and Zimmer, 1997). Based on these considerations, the following hypothesis was proposed:

Hypothesis 3. Noise sensitivity is related to noise disturbance (H3a) and speech privacy (H3b).

The literature shows that noise has a negative impact on job satisfaction and health when the occupants are chronically exposed to high-intensity sounds (Melamed *et al.*, 2001; Raffaello and Maass, 2002). Evans and Johnson (2000) reported that chronic low-level noise exposure in offices may also have adverse effects on health, self-reported job stress, and satisfaction with work environment. Furthermore, a recent study (Peter *et al.*, 2014) reported that noise in open-plan offices influences occupant stress. In light of these findings, the following hypothesis was proposed:

Hypothesis 4. The duration of noise exposure is related to self-reported job satisfaction (H4a) and health symptoms (H4b).

Based on our literature review and proposed hypotheses, a theoretical framework was developed. Most of the relationships between the factors were based on these four hypotheses. Additionally, it was assumed that there is a significant relationship between worker satisfaction with the environment and job satisfaction (Lee and Brand, 2005; Veitch *et al.*, 2007). An additional relationship between job satisfaction and overall health was derived from the conceptual model used in a previous study (De Croon *et al.*, 2005). As shown in Figure 1, exogenous factors include noise sensitivity and duration of noise exposure, while endogenous factors comprise speech privacy, noise disturbance, satisfaction with the environment, job satisfaction, and health symptoms.

Figure 1

3. Method

3.1 Offices and participants

Questionnaire surveys were performed in two Asian mega cities: Beijing, China and Seoul, Korea. In both cities, the majority of the offices are located in high-rise buildings. Six open-plan offices were selected for the surveys (four in China and two in Korea). All of the open-plan offices were in the business districts of the cities and were close to main roads with heavy traffic. As shown in Table I, three of the four offices in China specialized in research and development (R&D) or engineering, with the fourth being a customer service department. The two offices in Korea were an R&D department and an architectural design department. All offices were rectangular and floor areas (m^2) ranged between 203 and 1305. Floor area per number of people varied from 5.8 to 8.6. This variation is because each office has a different layout with a variety of communal and service spaces (e.g. kitchen, comfortable furniture, and lounge-like space). Ceilings of the Chinese offices were absorbent materials with an air space behind and this typically occupies 80-90% of the whole ceiling areas. This is because office workers complained about noise so that the company added acoustic treatments to the ceilings. Office 3 had perforated plasterboard and others had plasterboard. Similarly, the two offices in Korea had non-perforated gypsum board. Offices 1 and 4 had floor tiles and thick carpets were installed in offices 2 and 3. The offices in Korea had soft textile plates (carpet) on the floor.

Short-term measurements of acoustic environments at each office are also summarized in Table I. Background noise levels were measured during the day when occupants were present. Twenty-minute sound recordings were made during the busiest time of day (2 pm - 3 pm) in Korea, while measurements in China were performed for 15-minutes. The sound pressure levels of the background noises were analyzed in terms of A-weighted equivalent sound pressure levels (L_{Aeq}). The measured noise levels of the offices varied from 47.0 dBA to 62.4 dBA and this result is consistent with the previous study (Tang, 1997) reporting that background noise levels for five-minute of 26 open plan offices ranged between 45 dB and 70 dB. The noise levels of the offices in China were greater than the levels of the offices in Korea, and this is mainly because the noise levels from the air conditioning system in China were greater than those in Korea. The values of L_{A10}–L_{A90}, which is a measure of the temporal variability of the sounds, ranged from 6.3 to 13.5 and there was no significant difference between the offices in Korea and China. A variety of sound sources were observed in the offices; common sources were colleague chatting, telephone conversation, telephone ringing, ventilation, and road traffic. Office equipment such as printer and coping machine was also identified but noise levels varied across the office due to the location and sound insulation. Two offices in Korea had service rooms for office equipment at the furthest corners, whereas printers were located in the middle of the offices in China. This also contributed to the noise level differences between the offices in China and Korea.

Full-time employees were randomly selected and given questionnaires, which were distributed via physical distribution of hard copies. A total of 333 valid questionnaires were collected from the six offices. As listed in Table II, of the respondents, 66.4% were males and 33.6% were females. The majority of the respondents in China were between 25 and 38 years of age, while the majority of the Korean participants were aged 25-45 years. There was a difference in the job positions held, as more than 80% of the Chinese participants were staff, followed by line managers (11.7%), and general managers (1.5%). However, the majority of the Korean participants were line managers (69.3%). This difference may be due to the different job titles and levels in the two countries.

Table I

Table II

3.2 Measures

The questionnaire was developed based on a social survey that addressed the impacts of noise in open-plan offices (Zhang *et al.*, 2012) and was translated into Korean. The questionnaire consisted of items concerning job satisfaction, health symptoms, satisfaction with the environment, noise disturbance, speech privacy, and noise sensitivity.

3.2.1 Job satisfaction and health symptoms

In the current study, a three-item job satisfaction scale was drawn from a recent survey (Zhang *et al.*, 2012). The items included: “I like what I am doing at work,” “I enjoy working with my colleagues,” and “I care about the future of my work unit.” Participants responded using a five-point scale, ranging from “very much unlike me” to “very much like me.” The eight items were used to measure health symptoms in the private and open-plan offices (Kaarlela-Tuomaala *et al.*, 2009). They include the following problems: 1) concentration, 2) memory, and 3) motivation, 4) tiredness and overstrain, 5) negative feeling such as feeling displeased, 6) headache, 7) neck pain, and 8) shoulder pain. Among them, fatigue was determined to be the most common symptom, followed by headache, neck, and shoulder pain (Kaarlela-Tuomaala *et al.*, 2009). In addition, depression has also been noted as one of the subjective health complaints (De Lange *et al.*, 2002). Therefore, items about fatigue and depression were included in the present study. The questions related to health symptoms comprised three items, which asked participants if they experienced any of the following three office symptoms: hypersensitivity to loud sounds, fatigue, or depression. The responses were measured using a five-point scale ranging from “never” to “frequently.”

3.2.2 Satisfaction with the environment

Several studies have used social surveys to examine worker perceptions of the physical environments of open-plan offices (Lee and Guerin, 2010; Kim and de Dear, 2013). Lee and Guerin (2010) assessed worker satisfaction with indoor air quality, temperature, and lighting quality. A recent study (Kim and de Dear, 2013) also used a total of eight questions to investigate worker satisfaction with the IEQ of open-plan offices. These questions included overall satisfaction and focused on seven physical aspects of the office, including thermal comfort, lighting, and acoustic quality. In the present study, five questions taken from previous studies (Lee and Guerin, 2010; Kim and de Dear, 2013) were used to evaluate the participants’ degrees of satisfaction with the overall environment, as well as their satisfaction related to lighting, humidity, acoustics, and temperature. Participants were asked to evaluate their satisfaction on a seven-point scale (1: very good and 7: very poor).

3.2.3 Noise disturbance and speech privacy

The 11-items were used to assess self-rated disturbance caused by noise in the office (Kaarlela-Tuomaala *et al.*, 2009). They include the following distractions: 1) voices and laughter from general areas, 2) voices and laughter from neighbouring workstations, 3) telephone ringing tones, 4) movement in the corridors, 5) voices and laughter from your own workstation, 6) shared office equipment, 7) radio, 8) air-conditioning and ventilation, 9) construction sounds, 10) your own computer, and 11) traffic outside. Unnecessary speech from general areas and neighbouring workstations were cited most frequently, followed by ringing telephones. Tang *et al*. (1996) also reported that and colleagues were major source of noises in open plan offices. In the present study, three-item scales were adopted to assess noise disturbance. Participants rated disturbances due to telephone conversation, colleagues chatting, and telephone ringing using a five-point scale (1: “hardly noticeable” to 5: “very disturbing”). The two questions used to assess speech privacy were “How many words/phrases in a usual conversation can you overhear while you are working?” and “How much of your colleagues’ overheard conversations can you understand?” The questions were rated using a five-point scale (1: “none” to 5: “all”).

3.2.4 Duration of disturbing noise

The exposure to disturbing noise was assessed rather than exposure to noise because not all the noise in the office is disturbing. Disturbing noise was defined as noise that might cause disruptions of work and task. The duration of disturbing noise was evaluated using the following question: “How many hours in a day are you exposed to disturbing noise?” Participants were asked to evaluate the duration of disturbing noise exposure using a five-point scale (1: rarely, 2: less than 30 min., 3: less than one hour, 4: less than two hours, and 5: more than two hours).

3.2.5 Noise sensitivity

Similar to previous studies (van Kamp *et al.*, 2004; Fyhri and Klæboe, 2009; Ryu and

Jeon, 2011; Lee and Griffin, 2013), noise sensitivity was assessed using a single response statement: “I am very sensitive to noise.” A five-point scale was used to assess noise sensitivity (1: “very much unlike me” and 5: “very much like me”).

3.3 Data analysis

Previous research examining the multivariate aspects of the adverse effects of open-plan office layout on occupants (De Croon *et al.*, 2005; Pejtersen *et al.*, 2006; Lee, 2010; Kim and de Dear, 2013) has commonly used multiple regression analysis (Pejtersen *et al.*, 2006; Kim and de Dear, 2013). Multiple regression analysis is useful when investigating relationships between perception and several variables; however, simple regression analysis only explains the direct impact of the variables on the participants’ perceptions; therefore, it is difficult to fully comprehend the underlying relationships between the observed and latent (unobservable) variables. A few studies (Brauer *et al.*, 2008, Lee and Brand, 2005; Veitch *et al.*, 2007) have employed structural equation modeling to promote better understanding of various complex interrelationships. Structural equation modeling allows for causal pathways to be tested and estimates both the indirect and direct effects. The SEM also allows for the use of all of the potential variables, rather than eliminating those that might be considered potential confounders (Kroesen *et al.*, 2008; Tse *et al.*, 2012). Therefore, in the present study, the SEM was used to explain the routes of noise disturbance and the participants' psychophysiological reactions. A theoretical initial model included both latent and manifest variables in order to delineate between the hypothesized pathways, and the initial model was then tested against the empirical dataset obtained in the current study.

The data were analyzed using AMOS version 21.0 in order to simultaneously examine the multiple relationships. Confirmatory factor analysis (CFA) was conducted to validate a set of tentative constructs, employing a maximum likelihood estimation. The fit of the structural model was assessed using the goodness-of-fit index (GFI), the adjusted root mean square error approximation (RMSEA), and the relative Chi square (χ^2/df). The sample size for the SEM analysis was slightly reduced (N=314) due to missing questionnaire responses.

4. Results

4.1 Confirmatory factor analysis

Factor constructs were developed through exploratory factor analyses, and a confirmatory factor analysis (CFA) was then performed to examine the construct validity and reliability. The results of the confirmatory factor analysis are summarized in Table III. 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, corresponding to the acceptable cut-off value (Nunnally *et al.*, 1967). Convergent validity was assessed using the three measures factor loading, composite reliability (CR) and average variance extracted (AVE). The factor loading of each individual indicator with its respective construct were statistically significant (p<0.01). Factor loadings were all greater than 0.3, which is a recommended value (Sellin and Keeves, 1997), and they were considered ‘practically significant’ because they were all greater than 0.5 (Hair *et al.*, 2006). The composite reliability ranged from 0.81 to 0.88, exceeding the cut-off value of 0.7 for good reliability (Hair *et al.*, 2006). The AVE indicates the overall amount of variance in the indicators accounted for by the latent construct (Abdullah *et al.*, 2013). The AVE should exceed 0.5 for adequate convergence (Hair, 2009). In this study, the AVE ranged from 0.53 to 0.72. Therefore, it was confirmed that the CFA model has good construct reliability and adequate convergent validity.

Table III

4.2 Proposed structural equation model test

The structural model shown in Figure 1 was tested, and the final results of the path model are illustrated in Figure 2. As listed in Table IV, seven of the 11 paths were statistically significant. The RMSEA was lower than the normal cut-off limits of 0.06 (Hu and Bentler, 1999) and 0.07 (Steiger, 2007). The GFI was greater than 0.9, which is acceptable, and the relative Chi square (χ^2/df) was also within an acceptable range (Kline, 2005; Tabachnick and Fidell, 2007).

Figure 2
Table IV

Then, Hypotheses 1-4 were tested based on the results of the path analysis (shown in Table IV). In regard to H1a, it was found that the relationship between noise disturbance and job satisfaction was not statistically significant. This is inconsistent with one previous study (Sundstrom *et al.*, 1994), which reported that noise disturbance was negatively correlated with job satisfaction. However, the previous study conducted field surveys in 58 offices, including private offices, and the correlation coefficients between the noise disturbance and job satisfaction were very low (less than 0.2). Conversely, the proposed model supported a relationship between noise disturbance and health symptoms (H1b), confirming the findings of other previous studies (Evans and Johnson, 2000; Peter *et al.*, 2014). This indicates that the increased noise disturbance in open-plan offices leads to more frequent negative experiences, which relates to health symptoms. It was also observed that noise disturbance had a significant, negative influence on satisfaction with the environment (H1c). These results correspond to the findings of Lee and Brand (2005), which argued that perceived distraction level, including noise disturbance, was negatively related to worker satisfaction with the environment.

Speech privacy had previously been shown to have a significant relationship with job satisfaction (H2a was supported). Consequently, a lack of speech privacy in open-plan offices results in lower job satisfaction. Open-plan office layouts also have a negative impact on worker job satisfaction (Evans and Johnson, 2000; De Croon *et al.*, 2005; Veitch *et al.*, 2007). Furthermore, the relationship between speech privacy and satisfaction with the work environment was found to be statistically significant (H2b). Lee and Brand (2005) measured distractions using five items, including lack of privacy, reporting that distractions were negatively related to satisfaction with the physical environment. Therefore, a lack of speech privacy negatively affects worker satisfaction with the physical environment.

There was no significant relationship between noise sensitivity and noise disturbance (H3a). This is not consistent with one previous study (Miedema and Vos, 2003), which demonstrated that noise sensitivity negatively impacts and disturbs conversations. However, there are significant differences between this study and the previous study in terms of the location of noise exposure and the noise sources. Participants in the previous study (Miedema and Vos, 2003) assessed perceived disturbance in a home environment, with the noise sources representing transportation noise, such as road traffic and aircraft noises. Moreover, it was also found that noise sensitivity had a positive relationship with speech privacy (H3b).

The present result shows that the duration of disturbing noise had a significant influence on job satisfaction (H4a). Previous research showed that job satisfaction was negatively associated with noise exposure (Van Dijk *et al.*, 1987). In particular, chronic noise exposure reduced the job satisfaction of participants with complex jobs (Melamed *et al.*, 2001); however, these studies examined the high ambient noise existing in various industries. The results of this analysis may extend the finding of previous studies to open-plan offices with relatively low ambient noise levels, confirming that longer duration of disturbing noise leads to a decrease in job satisfaction. H4b was not supported by the proposed model, indicating that the duration of disturbing noise had no significant effect on health symptoms.

It was observed that the relationship between satisfaction with the environment and job satisfaction was not significant even though the direction of the relationship was positive. This finding does not correspond to previous studies, which reported that environmental satisfaction had a significant effect on job satisfaction for office workers (Zalesny *et al.*, 1985; Sundstrom *et al.*, 1994; Carlopio, 1996; Veitch *et al.*, 2007). This may be due, in part, to the fact that previous studies conducted questionnaire surveys in enclosed and private offices, as well as open-plan offices. There was one study, from Lee and Brand (2005), that found no significant relationship between environmental satisfaction and job satisfaction. Their study was conducted using a questionnaire and analyzed both individual and open-plan offices.

4.3 Moderation effects of noise sensitivity

In this study, it was found that noise sensitivity has an indirect effect on satisfaction with environment and job satisfaction through speech privacy. Previous studies (van Kamp *et al.*, 2004; Fyhri and Klæboe, 2009) also treated noise sensitivity as an influential variable for annoyance and health problems rather than a moderating variable. However, a few researchers suggested the possibility that noise sensitivity could be a moderator (Job, 1988; Lercher, 1996). Therefore, as shown in Figures 3(a) and 3(b), we proposed two possibilities that the relationship between speech privacy and constructs (satisfaction with environment and job satisfaction) will be moderated by noise sensitivity. In order to examine the moderation effects of noise sensitivity, a two-way interactions technique was employed (Dawson, 2014). Each latent variable of satisfaction with environment and job satisfaction was first mean-centered and the interaction terms were then computed (speech privacy × noise sensitivity) to avoid multicollinearity.

Figure 3

The results showed that the interaction term (speech privacy × noise sensitivity) were statistically significant ($p<0.05$) confirming that the noise sensitivity moderated the effects of speech privacy on satisfaction with environment and job satisfaction. For interpreting the moderating effects of noise sensitivity, Figures 4 and 5 were plotted under different levels of noise sensitivity. One standard deviation above and below the mean was chosen to divide noise sensitivity scores to high and low levels (Dawson, 2014). As shown in Figure 4, participants with high noise sensitivity less satisfied with office environment at low speech privacy ($p<0.05$), and the effect of speech privacy on satisfaction with environment was stronger at high noise sensitivity than at low noise sensitivity. Figure 5 represents that the effect of speech privacy on job satisfaction was much stronger at high noise sensitivity compared to low noise sensitivity. It was also observed that the participants with high noise sensitivity reported less job satisfaction at high levels of speech privacy ($p<0.01$).

Figure 4
Figure 5

4.4 Cross-cultural comparison

Since social surveys were conducted in both China and Korea, it was imperative to determine whether cultural differences played a role in the findings. Therefore, the proposed models were re-tested using separated data for China and Korea (N=192 for China and N=122 for Korea). It was assumed that the sample sizes for China and Korea were adequate, because previous studies had reported that a sample size of 100 is usually sufficient for convergence (Anderson and Gerbing, 1984; Iacobucci, 2010). Fit indices for both path models for the two countries showed acceptable levels (RMSEA = 0.06, GFI =0.90, and χ^2/df=1.14 for China and RMSEA = 0.03, GFI =0.91, and χ^2/df=1.89 for Korea). As listed in Table V, differences between the final models of the two countries were observed in the four paths. Regarding H3a, the duration of disturbing noise had a significant influence on job satisfaction in Korea but did not affect job satisfaction in China. Hypothesis 4 was supported in Korea; however, noise sensitivity showed no significant impact in China. Another difference was found in the relationship between job satisfaction and health symptoms. Job satisfaction was only significantly associated with health symptoms in the Chinese model.

These results might be due to the differences in the working environments and physical conditions. Most Chinese participants worked 6-8 hours per day, whereas around 80% of the participants in Korea worked more than 8 hours per day. In addition, the short-term background noise levels of the offices in China were higher than those in Korea. The measured 15-minute sound pressure levels ($L_{Aeq,15min.}$) from the four Chinese open- plan offices ranged between 56.9 dB and 62.4 dB, whereas the measured levels ($L_{Aeq,20min.}$) for the two offices in Korea were 48.1 and 47.0 dB. However, short-term measurements of the sound pressure level alone are not sufficient to comprehensively describe the noise level in workplaces.

5. Discussions

The main aim of this study was to test four hypotheses using the structural equation approach. Of the 11 paths related to the hypotheses, seven showed statistical significance. In addition, fit indices, such as RMSEA, supported the proposed model. However, this study's application of SEM has several limitations. The SEM requires a mature theory for the exogenous factors tested in order to draw unambiguous predictions for the endogenous outcomes. In the present study, several of the relationships between speech privacy, duration of noise exposure, and job satisfaction were not based on the findings of previous studies; therefore, these aspects were investigated only exploratively and without empirical evidence. Furthermore, the factors tested in this study did not have a sufficient set of measurements. For instance, the endogenous factors of speech privacy only had two measures. The measurement of the duration of noise exposure was also limited. Future research can help improve the proposed model by using a larger number of measurement items to evaluate speech privacy and duration of noise exposure.

There are two approaches to measure perceived noise sensitivity; multiple item scale and single item question. Many field studies used a single item to measure self-reported noise sensitivity (Miedema and Vos, 2003; Fyhri and Klæboe, 2009; Fyhri and Aasvang, 2010). In particular, Miedema and Vos (2003) investigated the relationship between noise sensitivity and reactions to noise through a meta-analysis of 28 field studies. All the study assessed noise sensitivity using a single item question. Another way to measure the noise sensitivity is using the multiple item scale (Weinstein, 1978; Zimmer and Ellermeier, 1999; Schütte *et al*., 2007). Zimmer and Ellermeier (1999) reported that multiple item scales produced more reliable and valid results rather than single item scales. In their study, two multiple item scales (Weinstein’s and their own) satisfied psychometric criteria of reliability and validity, whereas the single item questions did not. Ryu and Jeon (2011) also compared 20 multiple questions with a single question, and found that the sensitivity scores obtained from the multiple questions had a more symmetrical distribution than the scores by single item. Recently developed the Noise-Sensitivity-Questionnaire (NoiSeQ) consists of 35 items and it was aimed to measure global noise sensitivity as the sensitivity of five domains of daily life such as leisure, work, habitation, communication, and sleep (Schütte *et al*., 2007). Griefahn (2008) shortened the NoiSeQ to 12 items for thee subscales (sleep, habitation, and work) and it was applied to a recent questionnaire survey in open space offices (Pierrette *et al.*, 2014). In the present study, the relationship between noise sensitivity and noise disturbance was significant only in Korean offices. One of the possible reasons might be because the self-reported noise sensitivity measured using the single item question was limited to interpret a wide range of the context in which people are exposed to noise (Zimmer and Ellermeier, 1999). However, the multiple item scales developed by previous studies (Weinstein, 1978; Zimmer and Ellermeier, 1999; Schütte *et al*., 2007) focused on various reactions to noises that occur in daily life and did not include items describing reactions to noises at workplaces. Therefore, it is necessary to propose questions to assess workers' reaction to noises, which are heard at workplaces in the future.

There are also non-acoustic factors that affect the perception of noise and the working environment (Laszlo *et al.*, 2012). For instance, Sundstrom *et al.* (1994) reported that there was mutual influence between environmental satisfaction and job characteristics that could aid in clarifying the relationship between job satisfaction and physical working environment. They measured participants' job titles and duties, subsequently classifying them into three categories (managerial, professional-technical, and secretarial-clerical). In general, the job characteristics were determined using multiple questions about various attributes such as variety, autonomy, task identity, and feedback (Hackman and Lawler, 1971); however, questions concerning job characteristics were not included in the questionnaire. Alternatively, in this study, three of the Chinese offices (offices 1, 2, and 4) were compared with the third one, assuming that the job characteristics of the customer service department would differ from those of the other departments. It was found that there were no significant differences between the two groups, and their path models showed almost identical results. These results confirm that job characteristics cannot be simply determined based on type of department making a multidimensional approach necessary to define job characteristics (Hackman and Lawler, 1971). Therefore, future research is needed in order to identify any potential impact of job characteristics on the relationship between noise disturbance and psychophysiological reactions using multiple questions.

6. Conclusions

In this research, noise disturbance, speech privacy, satisfaction with the workplace environment, and occupants' psychophysiological reactions in open-plan offices have been successfully modeled using a set of structural equations in pre-existing knowledge-based pathways. It was found that noise disturbance affected satisfaction with the environment and health, whereas the relationship between noise disturbance and self-rated job satisfaction was not significant. Lack of speech privacy was found to be inversely correlated with environment and job satisfaction. The relationship between noise sensitivity and speech privacy was significant, and longer noise exposure resulted in less job satisfaction. Noise sensitivity had moderating effects on two relationships (speech privacy - satisfaction with environment and speech privacy – job satisfaction). In addition, there was a difference in the fit models for China and Korea due to the different working and acoustics environments. However, given the paucity of research in the two countries, a robust conclusion on cultural differences would require further empirical studies and cross-cultural research is also required to compare work practices and psycho-social factors in Asian countries with Western countries in the future.

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Table I. Job characteristics, physical characteristics of the offices, and measured sound pressure levels

		Job characteristic	Floor area [m^2]	Floor are per person	Number of participants	L_{Aeq} [dBA]	L_{A10} – L_{A90} [dBA]
China	1	Design department	203	6.2	30	57.9	6.3
	2	Product research and development department	449	5.8	34	60.9	13.5
	3	Customer service department	1305	8.0	106	62.4	6.9
	4	Engineering department	618	8.6	36	56.9	7.5
Korea	5	Research and development department	571	6.9	68	48.1	8.3
	6	Architectural design department	590	8.2	59	47.0	7.4

Table II. Survey respondents' personal characteristics

Personal characteristics		China	Korea	Total
Gender	Male	128	93	221
	Female	78	34	112
Age (years)	18-24	3	1	4
	25-31	29	34	63
	32-38	152	63	215
	39-45	18	27	45
	46-55	3	2	5
	56-65	1	-	1
Job position	Staff	179	28	207
	Line manager	24	88	112
	General manager	3	11	14

Table III Results of confirmatory factor analysis

Construct	Measurement items	Cronbach's alpha	Factor loading	Convergent validity: Composite reliability[a]	Convergent validity: Average variance extracted[b]
Job Satisfaction	JS1: Like to work	0.941	0.92	0.88	0.72
	JS2: Working with colleagues		0.87		
	JS3: Future of work unit		0.90		
Health Symptoms	HS1: Hypersensitivity to sound	0.702	0.91	0.85	0.53
	HS2: Easily fatigued		0.71		
	HS3: Depression		0.53		
Satisfaction with Environment	SE1: Temperature	0.812	0.81	0.82	0.70
	SE2: Lighting		0.67		
	SE3: Humidity		0.60		
	SE4: Acoustics		0.61		
	SE5: Overall environment		0.84		
Speech Privacy	SP1: Overheard words/phrases	0.791	0.78	0.81	0.60
	SP2: Overhead conversation		0.73		
Noise Disturbance	ND1: Telephone conversation	0.761	0.96	0.82	0.62
	ND2: Colleagues' chatting		0.64		
	ND3: Telephone ringing		0.60		

All t-values are significant at $p<0.0001$
a Composite reliability = (square of the summation of the factor loadings) / {(square of the summation of the factor loadings) + (summation of error variances)}
b Averaged variance extracted = (summation of the square of the factor loadings) / {(summation of the square of the factor loadings) + (summation of error variances)}

Table IV Results of path analysis

Path	Estimates[a] (All data)	Hypothesis
Noise disturbance-Satisfaction with environment	**-0.47****	H1a
Noise disturbance-Job satisfaction	-0.19	H1b
Noise disturbance-Health symptoms	**0.21***	H1c
Speech privacy-Satisfaction with environment	**-0.29****	H2a
Speech privacy-Job satisfaction	**-0.30***	H2b
Noise sensitivity-Noise disturbance	0.11	H3a
Noise sensitivity-Speech privacy	**0.35***	H3b
Duration of disturbing noise-Job satisfaction	**-0.30****	H4a
Duration of disturbing noise-Health symptoms	0.02	H4b
Satisfaction with environment-Job satisfaction	0.15	-
Job satisfaction-Health symptoms	**-0.21***	-

[a] Standardized

*p<0.05, **p<0.01

Table V Results of path analysis for China and Korea

Path	Estimates[a]		Hypothesis
	China	Korea	
Noise disturbance-Satisfaction with environment	**-0.45****	**-0.48****	H1a
Noise disturbance-Job satisfaction	-0.14	-0.21	H1b
Noise disturbance-Health symptoms	**0.22***	**0.23***	H1c
Speech privacy-Satisfaction with environment	**-0.21****	**-0.47****	H2a
Speech privacy-Job satisfaction	**-0.21****	**-0.30***	H2b
Noise sensitivity-Noise disturbance	0.11	**0.35***	H3a
Noise sensitivity-Speech privacy	**0.28***	**0.65***	H3b
Duration of disturbing noise-Job satisfaction	-0.18	**-0.26****	H4a
Duration of disturbing noise-Health symptoms	0.07	**0.65****	H4b
Satisfaction with environment-Job satisfaction	0.17	0.04	-
Job satisfaction-Health symptoms	**-0.27***	-0.1e	-

[a] Standardized

*p<0.05, **p<0.01

Figure captions

Figure 1. Structural model of the a priori hypotheses
Figure 2. Structural equation model (standardized)
Figure 3. Model for testing the moderation effects of noise sensitivity: (a) Relationship between speech privacy and satisfaction with environment and (b) Relationship between speech privacy and job satisfaction
Figure 4. Interaction between speech privacy and noise sensitivity on satisfaction with environment
Figure 5. Interaction between speech privacy and noise sensitivity on job satisfaction

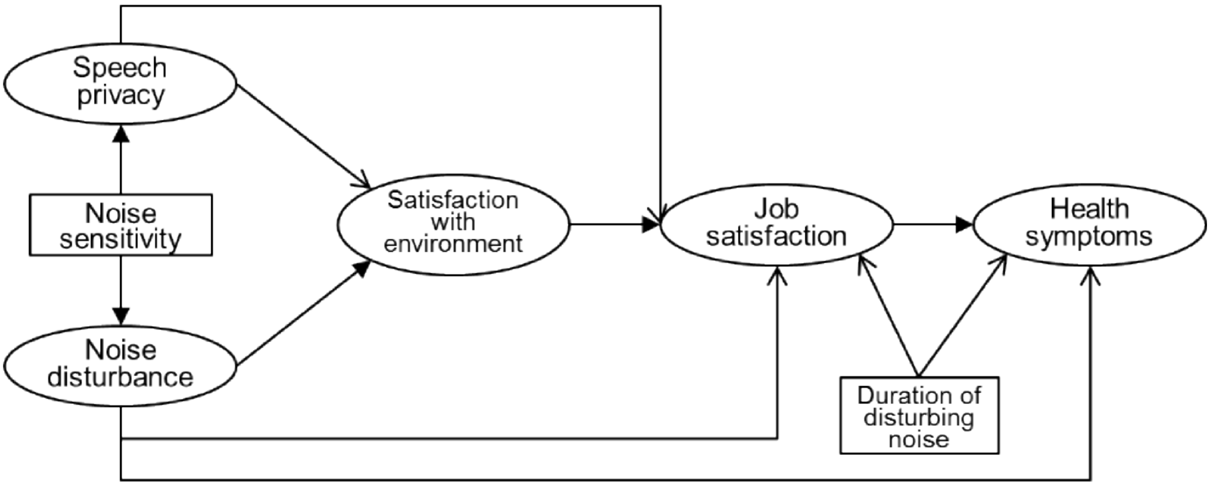


Figure 1

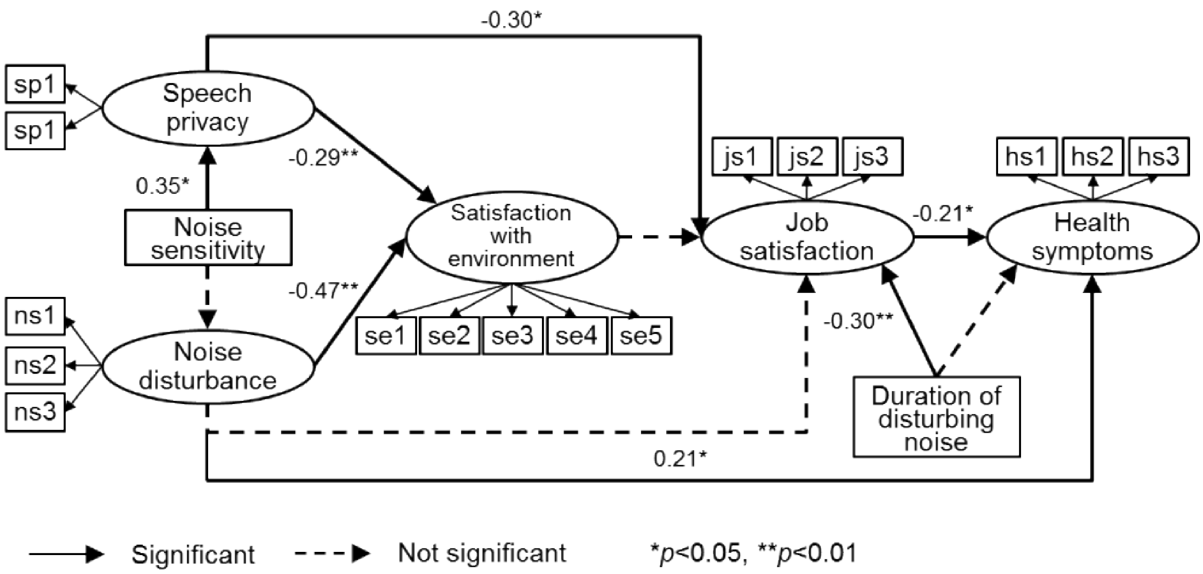
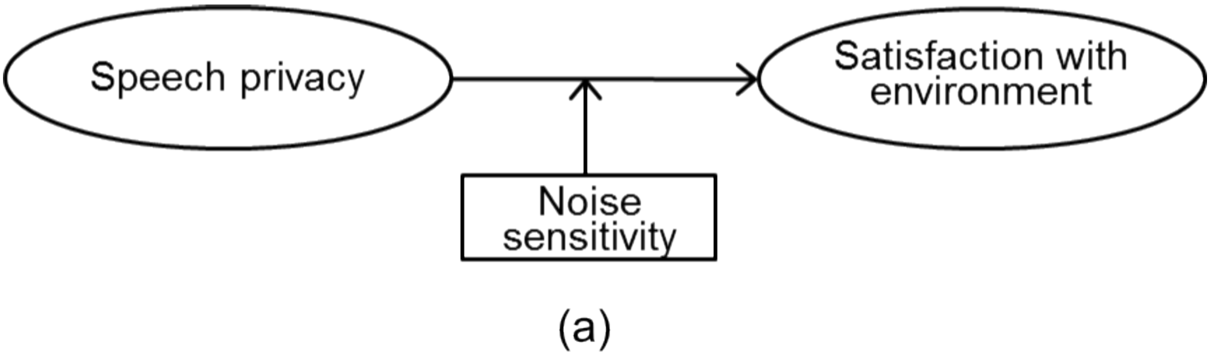


Figure 2


Speech privacy
Satisfaction with environment
Noise sensitivity
(a)

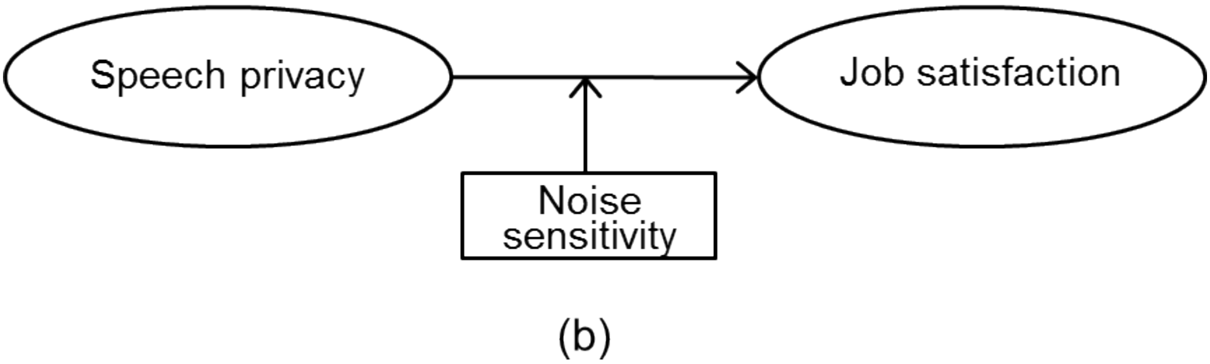

Speech privacy
Job satisfaction
Noise sensitivity
(b)

Figure 3

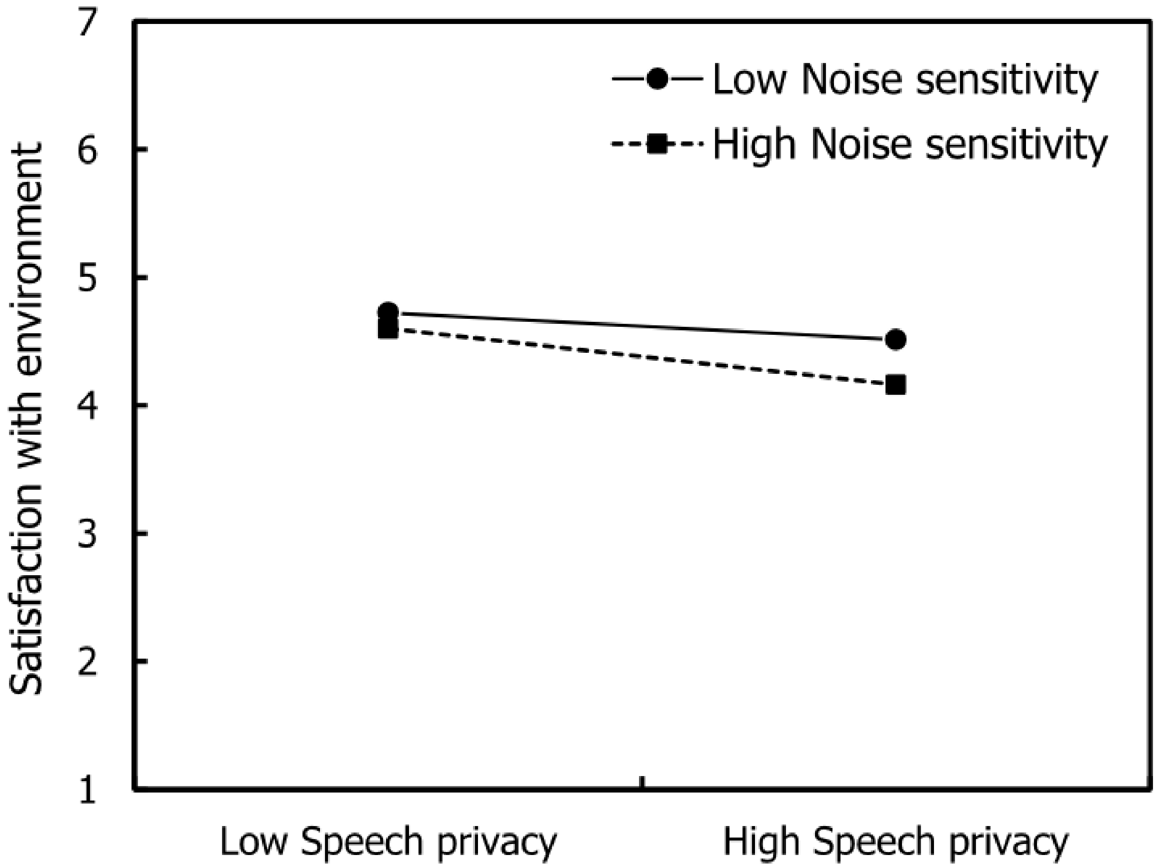

Low Noise sensitivity
High Noise sensitivity
Satisfaction with environment
7
6
5
4
3
2
1
Low Speech privacy
High Speech privacy

Figure 4

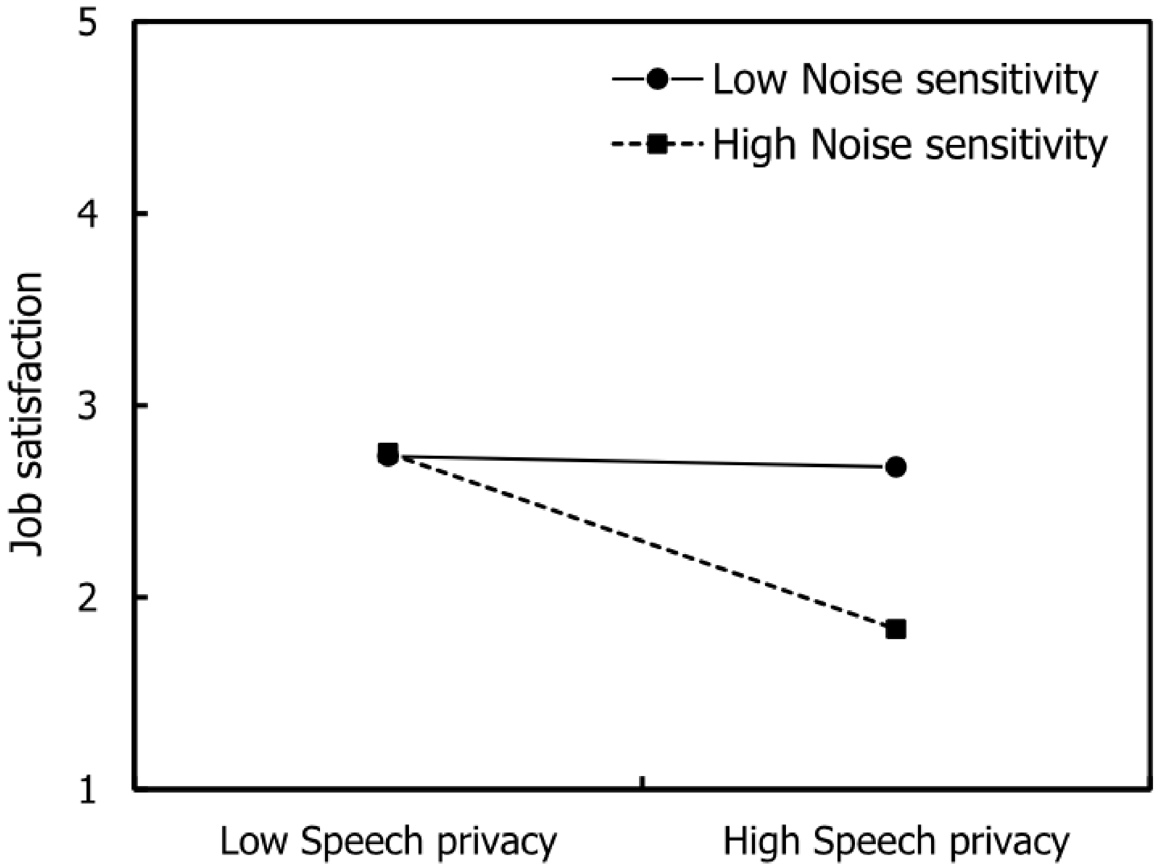

5
4
3
2
1
Job satisfaction
Low Noise sensitivity
High Noise sensitivity
Low Speech privacy
High Speech privacy

Figure 5