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Associations between job satisfaction, job characteristics, and acoustic environment in open-plan offices

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Abstract

This study aimed to investigate the associations between physical acoustic factors, job characteristics, and job satisfaction. Acoustic measurements and questionnaire surveys were conducted in 12 open-plan offices. Active noise levels ($L_{Aeq,8\text{-hour}}$), reverberation time (T_{20}), and speech privacy-related measures such as $D_{2,S}$ and $L_{p,A,S,4m}$ were measured at each office. A total of 324 employees then completed the online questionnaire surveys. The questionnaire assessed perceived speech privacy, noise disturbance, job characteristics, and job satisfaction. The measures of job characteristics involved skill variety, task identity, task significance, and autonomy. The results showed that active noise level ($L_{Aeq,8\text{-hour}}$) was negatively correlated with job satisfaction. Also, job satisfaction showed a negative correlation with speech privacy, whereas the relationship between job satisfaction and noise disturbance was not significant. It was also observed that the relationship between task identity and job satisfaction was moderated by the active noise level and speech privacy.

Keywords: acoustic environments; acoustic perceptions; job characteristics; job satisfaction

1 Introduction

Open-plan offices were introduced in the 1950s and have become popular from the early 1970s [1]. This type of office is cost-effective to create and be rearranged to meet the changing needs of groups and whole departments [1, 2]. In addition, it allows better access to daylight than a conventional arrangement [3]. Moreover, it has been known to help co-workers be near to each other and have efficient communication [4-6]. However, a growing number of studies have demonstrated that such office environments have negative impacts on employees in many ways [7, 8]. Contrary to the original argument that open-plan office promotes efficient communication between co-workers [4], some researchers have reported that it does not facilitate communication among co-workers because employees are likely to feel such offices prohibit confidential conversations [9-11]. Adverse impacts of open-plan offices on employees' perceived satisfaction have also been reported. Brennan, Chugh [1] compared traditional offices to open offices during relocation and found that satisfaction with the physical environment, team member relations, and perceived job performance decreased after the relocation. It was also reported that poor physical environments (e.g., lighting, temperature, and noise) reduced job satisfaction of employees in open-plan offices [12, 13]. In particular, lack of perceived privacy and increase of noise distractions have been observed in open-plan offices [14-16].

1.1 Design parameters of open-plan office

Several studies have proposed design guidelines of open-plan offices for designers as well as acousticians. Kjellberg and Landstrom earlier recommended general strategies to deal with major noise sources in the offices [17] and highlighted the effects of noise on occupants' perception and performance [18]. Later Bradley [19] investigated the effect of office design parameters on Speech Intelligibility Index (SII) using a mathematical sound propagation model. The office design parameters were ceiling absorption, partition height, partition absorption,

workstation plan size, floor absorption, screen transmission loss, ceiling height, lighting fixture, speech level, and making noise level. Among the parameters, the ceiling absorption, partition height, and workstation plan size were most important in improving speech privacy. Recently, Rindel and Christensen [20] confirmed that the ceiling absorption was critical in improving speech privacy in open-plan offices in terms of speech privacy-related measures in ISO 3382-3. A laboratory experiment [21] also showed that the Speech Transmission Index (STI) decreased with increasing masking sound level, partition height, and room absorption. Different types and levels of speech maskers were also adopted as a design parameter to improve speech privacy in the offices [22, 23]. Other researchers [24] have also considered several features of open-plan offices to maximise employees' productivity and satisfaction as well as to fulfil the following needs: physical and task needs (e.g., furnishing, storage), privacy needs (e.g., partition shape and height, workstation size), and recognition needs (e.g., space for displaying personal items). For example, more than 80% of interviewees answered that they preferred increases of partition height and degree of enclosure [25]. Recently, Lee and Aletta [26] developed key performance indicators of acoustic environments including space planning principles. Duval *et al.* [27] highlighted that higher-density might harm employees' satisfaction although further investigation with empirical evidence is needed. Newsham *et al.* [28] also found that workstation size significantly increased the risk of dissatisfaction with privacy and acoustics. Moreover, Yildirim *et al.* [29] reported higher satisfaction with a workspace from those with higher partitions, implying better privacy led to higher satisfaction. Haapakangas *et al.* [30] suggested that quiet workspaces in open-plan offices might provide better coping and improve the work environment.

1.2 Effects of acoustics environment of open-plan offices on occupants

Research has demonstrated that poor acoustic quality of open-plan offices causes employees' disturbance, and adversely affects work performance, job satisfaction, and health.

Boyce [31] found that more than half of the survey respondents in open-plan offices reported disturbance caused by telephone ringing, conversation, and some machinery noises. Kraemer [32] demonstrated significant noise disturbance in open-plan offices by highlighting the increase of noise disturbance with decreasing masking sound level. Kaarlela-Tuomaala *et al.* [33] found that the negative acoustic environment in the open-plan offices increased disturbance, concentration difficulties, and the use of coping strategy from the longitudinal study during relocation. Haapakangas *et al.* [34] investigated the relationships between an acoustic measure (distraction distance) and perceived disturbance using data from 21 open-plan offices. The study found that increasing distraction distance was associated with an increase in noise disturbance. Smith-Jackson and Klein [35] carried out a laboratory study to examine how irrelevant speech in open-plan offices contributed to employees' mental workload, performance, stress, and fatigue. They found that irrelevant speech had impacts on performance (e.g., false alarms and completion rates) and workload. Di Blasio et al (2019) also highlighted the negative effect of irrelevant speech on work performance, mental health and well-being in shared and open-plan offices based on the questionnaire survey. Similarly, a Swedish laboratory study [36] showed the high noise level condition resulted in lower performance, higher tiredness, and lower motivation with work. Furthermore, the poor acoustic environment of open-plan offices may adversely affect employees' health [32, 37]. Hackman and Lawler [38] showed that employees in open-plan offices had the lowest health status and those working in the medium-sized open-plan offices had second-lowest job satisfaction. In addition, Pejtersen *et al.* [39] found that sickness absence significantly increased in open-plan offices compared to other office types such as private offices. More recently, Lee *et al.* [40] conducted questionnaire surveys in open-plan offices to examine the effects of noise on job satisfaction and health problems. They found that employees' health symptoms were associated with perceived speech privacy and self-rated job satisfaction.

1.3 Job satisfaction and job characteristics

Given that job satisfaction is one of the crucial factors affecting organisations' outcome [41], many researchers have described the term in their own words. Hoppock [42] described it as any combination of psychological, physiological and environmental circumstances that cause a person truthfully to say, 'I am satisfied with my job'. Besides, Spector [43, 44] defined it as the extent to which people like (satisfaction) or dislike (dissatisfaction) their jobs. There has been a lot of research on job satisfaction in relation to job design and job characteristics. Substantial research has reported that enriched and complex jobs improved employees' job satisfaction. More specifically, the job characteristics model of Hackman and Oldham [45], developed based on earlier methodologies [46, 47], proposed that positive work outcomes (e.g., high job satisfaction) are obtained once employees experience the fulfilment of three critical psychological states (e.g., experienced meaningfulness of the work). Later, several studies supported this job characteristics model by reporting positive correlations between job characteristics and job satisfaction [48]. However, it is still unknown how the association between job characteristics and job satisfaction is affected by the acoustic environment in open-plan offices and only few studies have examined this issue. Sundstrom *et al.* [49] analysed subjective ratings of employees' environmental satisfaction, job satisfaction, and job performance before and/or after office renovation into an open-plan office. A significant relationship between noise disturbance and employees' dissatisfaction with the job was found. Based on this finding, the study hypothesised a model between environmental features (e.g., noise), environmental satisfaction, job characteristics, and job satisfaction. The model showed mutual impacts between environmental satisfaction and job characteristics. However, the associations were not empirically validated. Recently, Lee, Lee [40] highlighted that speech privacy was associated with self-rated job satisfaction. However, only subjective ratings of acoustics (e.g., speech privacy and noise disturbance) were used in the questionnaire surveys

and physical acoustic data was not introduced. Lee, Lee [40] also noted that there was a need for further consideration into non-acoustic factors such as job characteristics in explaining employees' job satisfaction.

1.4 The aims

This study aimed to investigate the relationships between acoustic factors, job characteristics, and job satisfaction of employees in open-plan offices through the data collected by questionnaire surveys and acoustic measurements in the open-plan offices. The acoustic factors covered both physical acoustic environments as well as perceptions of acoustics in order to broaden the understanding of the relationship between the physical and perceived acoustic environment and job satisfaction. Furthermore, moderation effects of acoustic and non-acoustic factors on the relationship between job characteristics and satisfaction were examined.

2 Methods

2.1 Sites

As listed in Table 1, questionnaire surveys and acoustic measurements were conducted at 12 open-plan offices. Among them, six offices (offices #1-#6) were located within the same building of a construction company. Those offices were chosen to investigate the perceived acoustic environment and job satisfaction of employees who are working in almost identical environmental conditions. The offices in the building were a mixture of R&D, design, sales, technical support, and IT support. Each office had 74 workstations which were almost always occupied. They were located on different floors with the same floor design, finishing materials, and workstation arrangement; thus, similar acoustic environments were expected across the floors. On the other hand, the other six offices were branches of an energy service company located in different buildings. Office #7 was a Network Operations Centre (NOC) where the

employees were mainly communicating on the phone. There were 30 workstations in the office which were nearly always occupied. The employees in office #8 were mostly consultants; there were 90 workstations in this area and approximately 60 employees occupied the space. Office #9 was a call centre where 150 workstations were located and around 80 callers mainly communicated on the phone. The employees in office #10 were in human resources, finance, and various administrative teams. There were 90 workstations and around 70 were occupied. Around 50 of 70 workstations were occupied in office #11 and the employees in this area were mainly in finance and quotes teams. In office #12, there were 140 workstations and around 100 employees were working on call-handling. Most offices were in rectangular shapes except for offices #8, #10, and #12. Floor areas varied from 150 to 680 m^2, while ceiling heights ranged between 2.4 and 3.0 m. Partitions with heights of 1.1 and 1.2 m were installed between workstations in 10 offices. The pictures of the offices are presented in Figure 1.

Table 1

Figure 1

2.2 Participants

A total of 324 employees took part in the questionnaire surveys. As listed in Table 2, more than a half (61.4%) were between 18 and 35 years old, 30.2% of them were between 36 and 50 years old, and 8.3% were between 51 and 64 years old. No respondent was more than 65 years old. In addition, 67.3% were males and 31.2% were females. Five respondents reported that they preferred not to answer on their gender identity.

Table 2

2.3 Acoustic measurements

Active noise levels were measured in an occupied condition for eight hours using sound level meters (B&K Type 2236) with half-inch free-field microphones (B&K Type 4188).

Single measurements were conducted in the rectangular offices because the workstation arrangements were almost the same, whereas three sound level meters at different workstations were placed in the non-rectangular offices. The measurements were carried out on weekdays during the working hours from 09:00 to 17:00 (A-weighted equivalent sound pressure levels, $L_{\mathrm{Aeq,8\text{-}hour}}$). One minute equivalent sound pressure levels ($L_{\mathrm{Aeq,1\text{-}min}}$) were then stored to obtain sound profiles.

Additional measurements were performed at night-time when people were absent in order to determine room acoustics [50] and speech privacy-related measures [51]. The night-time measurement was conducted at one of offices #1-#6 because all the offices had almost identical acoustic conditions when they were vacant. During the measurements, the air conditioner was operated as during typical working hours. An omni-directional source was adopted as a sound source and half-inch microphones were used to record the signals. Measurements were carried out along a line which crossed over workstations. Two measurements were conducted in two different zones in the non-rectangular offices with different workstation arrangements, while one measurement was done in the rectangular offices with similar workstation arrangements. The sound source was placed at the end of the line at a height of 1.2 m and microphones were located at the position of each workstation, 1.2 m above the floor. From the measurements, reverberation time (T_{20}) and speech privacy-related measures were determined. The speech privacy-related measures included spatial decay rate of speech ($D_{2,\mathrm{S}}$), A-weighted sound pressure level of speech at a distance of 4 m ($L_{\mathrm{p,A,S,4m}}$), distraction distance (r_{D}), and background noise level ($L_{\mathrm{p,A,B}}$).

2.4 Questionnaire

The questionnaire measured speech privacy, noise disturbance, job characteristics, and job satisfaction. First, the following question was used to assess perceived speech privacy: “How much do you hear the content of following sounds?” Two options (colleagues chatting

and telephone conversation) were given and each option was rated using 5-point scales (1 = *"None"* ~ 5 = *"All"*). Second, perceived disturbance caused by different noises was assessed using 7-point scales (1 = *"Not at all"* ~ 7 = *"Extremely"*). Haapakangas, Hongisto [34] introduced the proportions of highly disturbed by noise (%HD) with a cut-off point of 75 on a scale from 0 to 100. Similarly, the %HD was computed in this study by computing the percentage of the responses exceeding the cut-off point (i.e. 6 and 7 on the 7-point scale). Third, four job characteristics (skill variety, task identity, task significance, and autonomy) were measured by the Job Diagnostic Survey (JDS) developed by Hackman and Oldham [52]. Skill variety, task identity, and task significance were to measure the 'psychological states of the experienced meaningfulness of the work', and autonomy was to measure the 'psychological states of the experienced responsibility for outcome of the work' [52]. The following instruction was given: "Please choose the number indicating whether each statement is an accurate or inaccurate description of your job." and each statement was rated using 7-point scales (1 = *"Very inaccurate"* ~ 7 = "*Very accurate"*). A total of eleven statements (three for measuring each of skill variety, task identity, and autonomy, and two for task significance) were used to measure the job characteristics. Fourth, job satisfaction was measured with the Global Job Satisfaction (GJS) developed by Pond and Geyer [53]. Following the instruction ("Please indicate your agreement with the following statements."), three statements were given with 7-point scales (1 = *"Strongly disagree"* ~ 7 = "*Strongly agree"*) for assessing job satisfaction. Lastly, the questionnaire also contained some question items concerning personal details such as age, gender, and self-reported noise sensitivity. In particular, noise sensitivity was measured using 6-point scales (1 = *"Strongly disagree"* ~ 6 = "*Strongly agree"*) given to five statements which followed the instruction "Please indicate your agreement with the following statements." Table 3 shows the sample question items used in the questionnaire

survey and their Cronbach's alpha. The Cronbach's alpha ranged between 0.71 and 0.91, indicating internal consistencies of the questions.

Table 3

2.5 Procedure

Employees of the 12 offices were invited to participate in the online survey. Survey invitations were sent via email with information of the study and only those who reported they did not have any hearing disability were invited to take part in the survey. At the first page of the online survey, the study information and a consent form were presented on the screen and it proceeded only when the participants agreed with the consent. If for any reason during the questionnaire, they needed to leave the website, their answers were deleted. The responses were stored only after the participants filling in all required fields and clicking the 'submit' button. This study was ethically approved by the School of the Arts Committee on Research Ethics, University of Liverpool (Approved on the 23.04.2018, Ethics application No. 3079).

2.6 Data analysis

The data were analysed using SPSS version 24.0 and AMOS version 24.0. Since the survey responses were measured using different numerical scales as they were adopted from the existing measures, all of the data were translated to the minimum score of 0 to the maximum score of 100. It was assumed that the categories divide the range from 0 to 100 in equally spaced intervals. Each category was positioned on a scale from 0 to 100 using a simple equation: $\text{category}_i = (i\text{-}1)*100/(m\text{-}1)$, where i is the number of category and m is the number of the categories. For example, the translated scores using seven categories from 1 to 7 are 0, 17, 33, 50, 67, 83, and 100. Shapiro-Wilk normality test showed that $L_{\text{Aeq,8-hour}}$ and speech privacy were not normally distributed. Thus, Spearman rank correlation coefficients were computed to examine the bivariate correlations between the variables. The independent samples *t*-tests were

performed to compare groups (e.g., differences between the low and high skill variety groups' job satisfaction). Main effect of the offices on the $L_{Aeq,1\text{-}min}$ was assessed using a one-way analysis of variance (ANOVA) because the $L_{Aeq,1\text{-}min}$ were normally distributed. Finally, the structural equation modelling (SEM) method was used to test the effects of moderating variables (e.g., low and high speech privacy) on the relationships between the latent variables (job characteristics and job satisfaction). Before testing the path model, validity and reliability of the items were assessed using Confirmatory Factor Analysis (CFA). As summarised in Table 4, convergent validity was assessed via factor loadings and Average Variance Extracted (AVE), and reliability was examined via Composite Reliability (CR). All factor loadings were statistically significant ($p < 0.01$) and greater than 0.6, which were acceptable values. Hair *et al.* [54] suggested cut-off values for AVE (0.5) and CR (0.7) to explain adequate convergence and good reliability. The calculated AVE ranged from 0.56 to 0.76 and the reliability estimates measured via CR ranged from 0.79 to 0.90. Moreover, Fisher's r to z transformation [55] was used to compare correlation coefficients. This study considered *p* values of less than 5% ($p < 0.05$) as statistically significant.

Table 4

3 Results

3.1 Descriptive results

3.1.1 Offices

Figure 2 shows the boxplots of the active noise levels during working hours ($L_{Aeq,8\text{-}hour}$) measured at each office. The mean of $L_{Aeq,8\text{-}hour}$ of the offices ranged between 44.7 and 60.3 dB. In particular, the active noise levels from the offices in the same building (#1-#6) varied between 44.7 and 51.2 dB, showing a good agreement with a previous study [33]. This result

implies that active noise levels vary according to the employees' jobs and working environments even though room acoustic conditions are almost identical. On the other hand, the other offices (#7-#12) had slightly greater noise levels, varying from 49.1 to 60.3 dB. This might be because the working environments and job characteristics of these offices were different from those of offices #1-#6. For example, the employees were mainly communicating on the phone in offices #7, #10, and #12. In addition, offices #7-#12 had higher ceiling heights and more reflective materials on walls than the others. The result of ANOVA confirms that the $L_{\text{Aeq-1min}}$ values were statistically different across the offices [$F(8640, 17) = 942.774$, $p < 0.01$]. *Post hoc* comparisons via Tukey's test indicated that the $L_{\text{Aeq-1min}}$ values of the offices #1-6 were significantly lower than those of the offices #1-7 except for the office #4 which was not different from the office #11. Among the offices #1-6, three non-significant differences were found (#2 and #3, #2 and #5, and #3 and #6) because they have almost identical environmental conditions. On the other hand, the $L_{\text{Aeq-1min}}$ values of the offices #7-12 were all statistically different.

Figure 2

Room acoustics and speech privacy-related measures are listed in Table 5. Offices #1-#6 showed a shorter reverberation time (T_{20}) than offices #7-#12 due to the lower ceiling height and smaller room volumes. The $D_{2,S}$ results, varying from 4.2 to 7.9 dB, were quite small because the partition heights were not high. Offices #1-#6, the second measurement line of office #8, and office #9 showed smaller $D_{2,S}$ values due to the stronger reflections from columns and windows. Results of $L_{\text{p,A,S,4m}}$ were opposite; offices #1-#6 showed larger value than the other offices similarly due to the sound reflections from the room boundaries. $L_{\text{p,A,S,4m}}$ of offices #7-#12 varied from 45.8 dB to 49.4 dB showing, a quite small variation. Offices #1-#6 showed

the largest r_D because of the lowest background noise level ($L_{p,A,B}$), whereas office #7 with the largest background noise level showed the smallest r_D.

Table 5

3.1.2 Perceptions and job characteristics

The mean perceived speech privacy, %HD, and job satisfaction ratings are listed in Table 6. Speech privacy ratings ranged from 43.1 to 59.9, where the minimum and maximum ratings were from offices #2 and #10, respectively. The %HD varied from 5.0 (office #5) to 43.5 (office #9). The mean job satisfaction ratings ranged from 53.3 to 73.9 where the minimum and maximum ratings were from offices #12 and #6, respectively. The participants from the IT support team (office #6) showed the highest job satisfaction rating, whereas those from the call-centre (office #12) had the lowest rating. Skill variety ranged from 53.2 to 75.8 across the 12 offices, where the minimum and maximum ratings were from offices #12 and #1, respectively. Task identity ranged from 54.6 (office #7) to 79.3 (office #3) and five offices showed lower ratings than the mean of the whole. Task significance ranged from 66.5 (office #5) to 87.8 (office #10), while autonomy varied from 56.7 (office #5) to 82.5 (office #9).

Table 6

3.2 Relationships between acoustic factors and job satisfaction

Table 7 shows the correlations between perceived speech privacy, %HD, active noise level ($L_{Aeq,8\text{-hour}}$) and job satisfaction. It was found that job satisfaction was significantly correlated with perceived speech privacy and $L_{Aeq,8\text{-hour}}$, whereas the relationship between %HD and job satisfaction was not significant. This indicates that the increase of speech privacy and active noise level led to a decrease in job satisfaction. It was also observed that $L_{Aeq,8\text{-hour}}$

showed a significant correlation with %HD, indicating the impact of active noise level on perceived noise disturbance.

Table 7

3.3 Moderation effects on job satisfaction

The structural equation modelling (SEM) was computed to assess the effects of the moderating variables on the path between job characteristics and job satisfaction. In order to test the moderation effects, multi-group analyses were carried out. The participants were grouped into 1) low and high active noise level ($L_{Aeq,8\text{-hour}}$) groups, 2) low and high speech privacy groups, 3) low and high noise disturbance groups, and 4) low and high noise sensitivity groups. Table 8 shows the standardised estimates of the paths from the four job characteristics (skill variety, task identity, task significance, and autonomy) to job satisfaction across the moderating variables. First, job characteristics showed weaker relationships with job satisfaction for those with high active noise levels ($L_{Aeq,8\text{-hour}}$) except for autonomy which showed the opposite tendency. However, only the path between task identity and job satisfaction showed a significant difference among the four paths. It implies that the influence of task identity on job satisfaction became weaker in the offices with a high noise level. Second, job satisfaction's relationships with skill variety, task identity, and autonomy became stronger with higher speech privacy but only that with task identity significantly increased. In contrast, the associations between job satisfaction and task significance were almost the same for the low and high speech privacy groups. This presents that the effect of task identity on job satisfaction is stronger in better speech privacy conditions. Third, the impact of job characteristics on job satisfaction was not significantly changed across the level of noise disturbance. For instance, the association between task identity and job satisfaction was weakened for those with high noise disturbance but the difference between the groups was not

significant. This result confirms that noise disturbance might not moderate the associations between job characteristics and job satisfaction. Fourth, for the low and high noise sensitivity groups, job satisfaction's paths with skill variety and autonomy remained the same. The effect of task identity on job satisfaction was slightly declined, while that of task significance increased. However, Fisher's r to z transformation showed that there was no significant difference between groups for all measures, indicating that self-reported noise sensitivity does not have any moderation effect on the relationship between job characteristics and job satisfaction.

Table 8

4 Discussion

4.1 Physical acoustic environments and subjective acoustic perceptions

Sundstrom, Town [49] previously highlighted the potential contribution of the physical environment to perceived noise disturbance and job satisfaction in a conceptual model. In particular, they proposed a hypothetical model, indicating the relationship between physical environment conditions and environmental satisfaction. In order to validate their model, the present study investigated the relationships between acoustic measures and perceived noise disturbance as a form of percentage of highly disturbed by noise (%HD) by assuming that the acoustics is one of the physical environmental conditions. Confirming the hypothesis, it was found that active noise level ($L_{\mathrm{Aeq,8\text{-}hour}}$) was highly correlated with %HD. However, other speech privacy-related measures in the ISO 3382-3 did not show any significant correlation with %HD. This result is not consistent with the finding of Haapakangas, Hongisto [34], in which most speech privacy-related measures (r_{D}, $L_{\mathrm{p,A,S,4m}}$, and $L_{\mathrm{p,A,B}}$) were significantly correlated with %HD. The disagreement may be attributed to the ranges of acoustic environments of the open-plan offices. Haapakangas, Hongisto [34] studied 21 open-plan

offices with greater variations of acoustics; for instance, r_D ranged from 2.5 m to 14 m. It was observed that job satisfaction ratings had negative correlations with $L_{Aeq,8\text{-hour}}$ and perceived speech privacy, indicating that lower active noise level and less speech privacy are helpful to improve job satisfaction. This is consistent with existing findings which reported the negative correlation between noise exposure level and job satisfaction [56]. Moreover, those with high active noise levels showed a weakened association between task identity and job satisfaction (Table 8), supporting the hypothesis of Sundstrom, Town [49].

Lee, Lee [40] reported that job satisfaction was significantly influenced by perceived speech privacy. The present study confirmed this by showing the significant correlation between speech privacy and job satisfaction. In addition, this study showed that speech privacy had some moderation effects on the paths between job characteristics and job satisfaction. Particularly, the association between task identity and job satisfaction became significantly stronger with high speech privacy. However, the percentage of highly disturbed by noise (%HD) did not have any significant effect on job satisfaction. Moreover, noise disturbance did not have any moderation effect on the paths between job characteristics and job satisfaction. These results are in line with previous findings in which the inverse relationship between noise disturbance and job satisfaction was not very strong or not statistically significant [40, 49]. In their path model, Lee, Lee [40] found a non-significant association between noise disturbance and job satisfaction (β = -.19) and Sundstrom, Town [49] also reported a weak correlation between noise disturbance and job satisfaction (r < .20). Both studies suggested that further evaluation of job characteristics may yield a better understanding of the link between noise perception and job satisfaction. However, the present study found that job satisfaction was not well explained by noise disturbance and job characteristics. In addition, noise disturbance did not have any significant moderation effect on the paths between job characteristics and job satisfaction. These results imply that perceived satisfaction cannot be predicted only by noise

and thus, better understanding would be obtained with other environmental variables covering both physical and subjective data [49].

4.2 Job characteristics and job satisfaction

Lee, Lee [40] discussed that there is a need for further investigation into the diverse components of job characteristics and their mutual associations with job satisfaction and acoustic factors. The present study tested how the relationships between job characteristics and job satisfaction were affected by moderating variables such as acoustic and personal factors. It was observed that the impact of task identity on job satisfaction significantly changed across the groups with low and high speech privacy ratings and active noise levels. Task identity represents "the degree to which the job requires completion of a whole and identifiable piece of work [45]". This dimension also evaluates how much employees do a job from beginning to end and clearly identify the result of their efforts [57]. Its significant changes may imply that this particular job characteristics index has more sensitive links to acoustic environments. Furthermore, Loher, Noe [48] earlier reviewed 28 studies on the relationship between job characteristics and job satisfaction, and reported that the sample-weighted correlation coefficient between job characteristics index and job satisfaction was about .39. In the present study, the standardised estimates of the path from task identity to job satisfaction were .33 and .35 for those who perceived low speech privacy or high active noise level, respectively. The estimates significantly increased with improvements in speech privacy (i.e. high speech privacy) and active noise level (i.e. low active noise level). This tendency agrees well with Locke [58] who earlier emphasised that "dissatisfaction accompanies unpleasant or stressful physical working conditions, but employees take favourable working conditions for granted and experience positive gains in satisfaction only through other job characteristics such as job autonomy or task variety [49, 58]". In agreement with Locke [58], job characteristics did not have significant impacts on job satisfaction with poor physical conditions of office

environments. In other words, the impacts of job characteristics on job satisfaction became significant in the offices with favourable acoustic conditions. Moreover, noise sensitivity did not have any moderation effect on the association between job characteristics and job satisfaction. It is in agreement with Lee, Lee [40] who also reported a non-significant impact of noise sensitivity on job satisfaction in their path model. However, they found an interaction effect of noise sensitivity on the influence of speech privacy on job satisfaction. Employees who had high noise sensitivity reported lower job satisfaction when speech privacy was poor, indicating noise sensitivity would be an appropriate measure to predict acoustic-related responses. The present study followed the idea of job satisfaction defined in earlier studies [42-44]. As Hoppock [42] stated, job satisfaction is a combination of psychological, physiological and environmental circumstances affecting a person to say that he/she is satisfied with his/her job. The present study particularly focused on the environmental circumstance by assessing the acoustic environment and examined how it is associated with the way the employees like (satisfaction) or dislike (dissatisfaction) their jobs [43, 44]. To measure this, the present study used the Global Job Satisfaction which assesses respondents' job satisfaction in general. Since there are different kinds of questionnaires on job satisfaction designed for various purposes, future research may consider using these instruments depending on its research aim. For instance, some questionnaires (e.g., Job Descriptive Index [59]) examine specific dimensions (e.g., satisfaction with coworkers, pay, promotional opportunities etc.) considering them as crucial determinants of job satisfaction.

4.3 General discussion

Limitations in the present study can be supplemented in future research. First, the variation of the partition heights in the present study was smaller compared to previous studies. For example, Virjonen *et al.* [60] studied open-plan offices with partition heights ranging from 1.2 m to 1.7 m and Utami *et al.* [61] estimated how privacy and disturbance in open-plan offices

were affected by partitions with different heights ranging from 1.25 m to 1.85 m. Given that the speech privacy-related measures in the present study, in particular, $D_{2,S}$ and r_D, showed a small range, the offices with various partition heights and speech privacy conditions could be examined. Second, the acoustic parameters did not correspond to each participant; thus, future research could obtain physical data and predict how the acoustic environment at each workstation associates with individuals' subjective responses. This study found that acoustic factors are limited to fully explain job satisfaction. Therefore, additional physical environmental variables (e.g., temperature and lighting) would be helpful to further explain job satisfaction. Third, Hackman and Oldham [45] introduced five core dimensions (skill variety, task identity, task significance, autonomy, and feedback from the job itself) to measure the critical psychological states and later added two supplementary dimensions (i.e. feedback from agents and dealing with others). Given that the present study only used four out of the five core dimensions measuring two critical psychological states, the use of the full scale would be helpful to extend the understanding of the associations between the concerned variables.

In the present study, the $D_{2,S}$ values were quite small due to the low partition heights (< 1.2 m). In addition, the offices #9-#12 had only front partitions and the offices #7 and #8 did not have any partition between workstations. Consequently, perceive speech privacy ratings were not satisfactory and it resulted in a decrease of job satisfaction. Several studies [19-21] have demonstrated the importance of the partition height to improve physical and perceptual speech privacy. Thus, the offices of the present study could adopt this strategy to enhance speech privacy. The offices #1-#6 with identical environments showed a variation of active noise levels, which led to fluctuations of perceptual ratings such as speech privacy and noise disturbance. Thus, noise masking system could be introduced in the offices #1-#6 in the future.

5 Conclusions

The relationships between physical and subjective acoustic factors, employees' job characteristics, and perceived job satisfaction have been investigated through the acoustic measurements and questionnaire surveys. The moderation effects on the relationship between job characteristics and job satisfaction have also been examined. Several acoustic parameters showed significant correlations with job satisfaction. In particular, job satisfaction showed negative correlations with active noise level for 8 hours ($L_{\mathrm{Aeq,8\text{-}hour}}$) and perceived speech privacy. On the other hand, noise disturbance (%HD) did not have a significant influence on job satisfaction. The active noise level was highly correlated with %HD, implying its significant impact on noise disturbance. Active noise level and speech privacy showed significant moderation effects on the relationship between task identity and job satisfaction. Future research is required to further understand job satisfaction by considering other environmental variables.

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Figure captions

Figure 1.Pictures of the offices.

Figure 2. Boxplots of the active noise levels ($L_{Aeq,1\text{-}min}$) for eight hours in the 12 offices. The box plot shows the median (bold line), the first quartile (lower border of the box) and the third quartile (upper border of the box); the whiskers indicate 1.5 times the interquartile range above and below the 75th and 25th percentiles. The circles indicate the outliers.

Table 1. Characteristics of the participated offices

Offices	Floor plan	Floor area [m^2]	Ceiling height [m]	Partition height [m]	Number of workstations	Estimated percentages of Occupied workstations [%]	Employees' duties
#1	Rectangular	418	2.4	1.2	74	90-100	Design
#2							Sales planning and support
#3							Technical support
#4							Technical support
#5							R&D
#6							IT support
#7	Rectangular	150	3.0	-	30	90-100	Network Operations Centre
#8	Non-rectangular	570	3.0	-	90	65-75	Consulting
#9	Rectangular	415	2.7	1.1	150	50-60	Call-center
#10	Non-rectangular	680	2.7	1.1	90	75-85	HR; finance; other administrative teams
#11	Rectangular	250	2.5	1.1	70	70-80	Finance; quotes
#12	Non-rectangular	650	2.5	1.1	140	70-80	Call-center; planners

Table 2. The number of survey respondents from each office

Offices	Age			Gender			
	18-35	36-50	51-64	Male	Female	Prefer not to answer	*Total*
#1	15	7	-	17	5	-	*22*
#2	14	11	1	23	3	-	*26*
#3	15	11	2	18	10	-	*28*
#4	18	6	3	25	2	-	*27*
#5	15	6	2	22	1	-	*23*
#6	12	7	2	18	3	-	*21*
#7	5	5	3	6	6	1	*13*
#8	21	13	2	28	8	-	*36*
#9	12	10	2	11	13	-	*24*
#10	13	10	3	9	13	4	*26*
#11	25	3	3	21	10	-	*31*
#12	34	9	4	20	27	-	*47*
Total	*199*	*98*	*27*	*218*	*101*	*5*	*324*

Table 3. Sample question items for measuring each scale and Cronbach's alpha. The number in the bracket indicates the number of questions used to measure the scales.

Scale	Range	Sample question items (sub-scale)	Cronbach's alpha
Job satisfaction (3)	1=strongly disagree, 7=strongly agree	I find real enjoyment in my work.	.90
Job characteristics (11)	1=very inaccurate, 7=very accurate		
Skill variety		The job requires me to use a number of complex or high-level skills.	.71
Task identity		The job is arranged so that I can do an entire piece of work from beginning to end.	.75
Task significance		The job is one where a lot of other people can be affected by how well the work gets done.	.76
Autonomy		The job gives me considerable opportunity for independence and freedom in how I do the work.	.81
Acoustic perceptions (5)			
Speech privacy	1=none, 5=all	How much do you hear the content of following sounds? (e.g., colleagues chatting)	.88
Noise disturbance	1= not at all, 7= extremely	How disturbing do you find the following noises in your office? (e.g., colleagues chatting)	.85
Noise sensitivity (5)	1=strongly disagree, 6=strongly agree	I am sensitive to noise.	.89

Table 4. Results of the confirmatory factor analysis (CFA)

Factor	Question item	Factor loading	AVE	CR
Job satisfaction	Enthusiasm about my work	0.777	0.759	0.904
	Enjoyment in my work	0.898		
	Satisfaction with my present job	0.930		
Skill variety	Variety in my job	0.785	0.562	0.792
	Requirements of complete/high-level skills	0.638		
	Simpleness/repetitiveness of the job	0.815		
Task identity	Whole/identifiable piece of work	0.792	0.599	0.871
	Chance to completely finish the work I begin	0.692		
	Arranged to do an entire piece of work from beginning to end	0.831		
Task significance	A lot of other people can be affected	0.755	0.625	0.769
	Significance and importance in the broader scheme	0.820		
Autonomy	Autonomy in my work	0.666	0.604	0.820
	Independence/freedom in how I do the work	0.839		
	Chance to use my personal initiative/judgment	0.740		

Table 5. Acoustic parameters measured from each office. T_{20} was averaged over 500Hz and 1kHz octave bands.

Offices	T_{20} [s]	$D_{2,S}$ [dB]	$L_{p,A,S,4m}$ [dB]	r_D [m]	$L_{p,A,B}$ [dB]
#1-#6	0.30	5.7	51.9	16.5	33.9
#7	0.44	7.4	48.6	9.7	40.3
#8	0.54, 0.52	7.9, 4.2	48.3, 49.4	10.8, 10.8	38.5, 39.2
#9	0.45	5.7	47.9	12.2	36.5
#10	0.43, 0.42	6.9, 7.2	47.3, 47.8	12.2, 15.0	35.5
#11	0.46	7.9	47.2	12.0	34.8
#12	0.34, 0.37	7.0, 7.7	47.6, 45.8	12.7, 10.6	35.6, 37.7

Table 6. Mean ratings of perceptions and job characteristics.

Offices	Speech privacy	%HD	Job satisfaction	Job characteristics			
				Skill variety	Task identity	Task significance	Autonomy
#1	43.2	15.8	71.4	**75.8**	75.5	77.6	65.8
#2	**43.1**	23.1	69.8	71.4	79.1	77.2	72.0
#3	45.1	25.0	72.5	74.5	**79.3**	81.4	72.4
#4	45.3	19.2	64.5	66.3	76.9	76.2	71.3
#5	48.8	**5.0**	65.6	67.1	71.4	**66.5**	**56.7**
#6	45.9	5.3	**73.9**	73.9	73.9	75.9	61.5
#7	49.5	33.3	64.4	68.5	**54.6**	76.9	68.1
#8	49.4	22.6	69.2	72.5	72.2	81.0	75.9
#9	44.9	**43.5**	64.7	75.0	70.0	**87.8**	**82.5**
#10	**59.9**	29.2	53.7	59.0	62.7	74.7	62.5
#11	52.3	20.0	61.8	53.8	63.9	73.5	63.7
#12	48.6	30.6	**53.3**	**53.2**	61.9	78.3	62.5

Table 7. Correlation coefficients between acoustic parameters, acoustic perceptions, and job satisfaction (**$p < 0.01$ and *$p < 0.05$).

	Speech privacy	%HD	$L_{\text{Aeq,8-hour}}$ [dB]	Job satisfaction
Speech privacy	1	0.077	0.483	-.608*
%HD	0.077	1	.734**	-0.476
$L_{\text{Aeq,8-hour}}$ [dB]	0.483	.734**	1	-.734**
Job satisfaction	-.608*	-0.476	-.734**	1

Table 8. Standardised estimates of the structural equation models showing the effects of the moderating variables on the paths from job characteristics to job satisfaction (**$p < 0.01$; *$p < 0.05$). Underlined estimates showed there were significant differences between the compared groups.

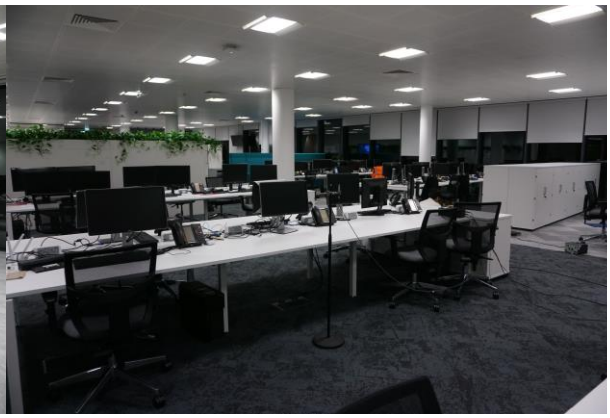
	Acoustic factors						Non-acoustic factor	
	$L_{\text{Aeq,8-hour}}$		Speech privacy		Noise disturbance		Noise sensitivity	
	Low	High	Low	High	Low	High	Low	High
Skill variety – job satisfaction (RMSEA = .020; GFI = .965; CFI = .986; χ2/df = 1.667)	.76**	.61**	.60**	.72**	.70**	.73**	.70**	.70**
Task identity – job satisfaction (RMSEA = .016; GFI = .977; CFI = .993; χ2/df = 1.436)	.64**	.35**	.33**	.59**	.49**	.47**	.51**	.43**
Task significance – job satisfaction (RMSEA = .021; GFI = .984; CFI = .993; χ2/df = 1.721)	.54**	.39**	.43**	.42**	.41**	.45**	.32**	.53**
Autonomy – job satisfaction (RMSEA = .016; GFI = .977; CFI = .993; χ2/df = 1.434)	.48**	.53**	.46**	.52**	.49**	.48**	.50**	.50**

Figure 1

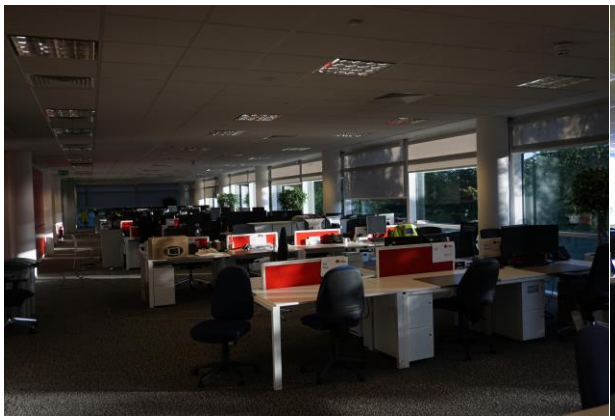
Office #1

Office #3

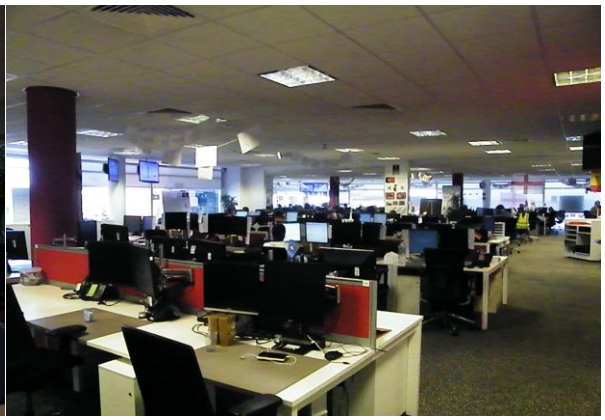
Office #7



Office#8



Office #9

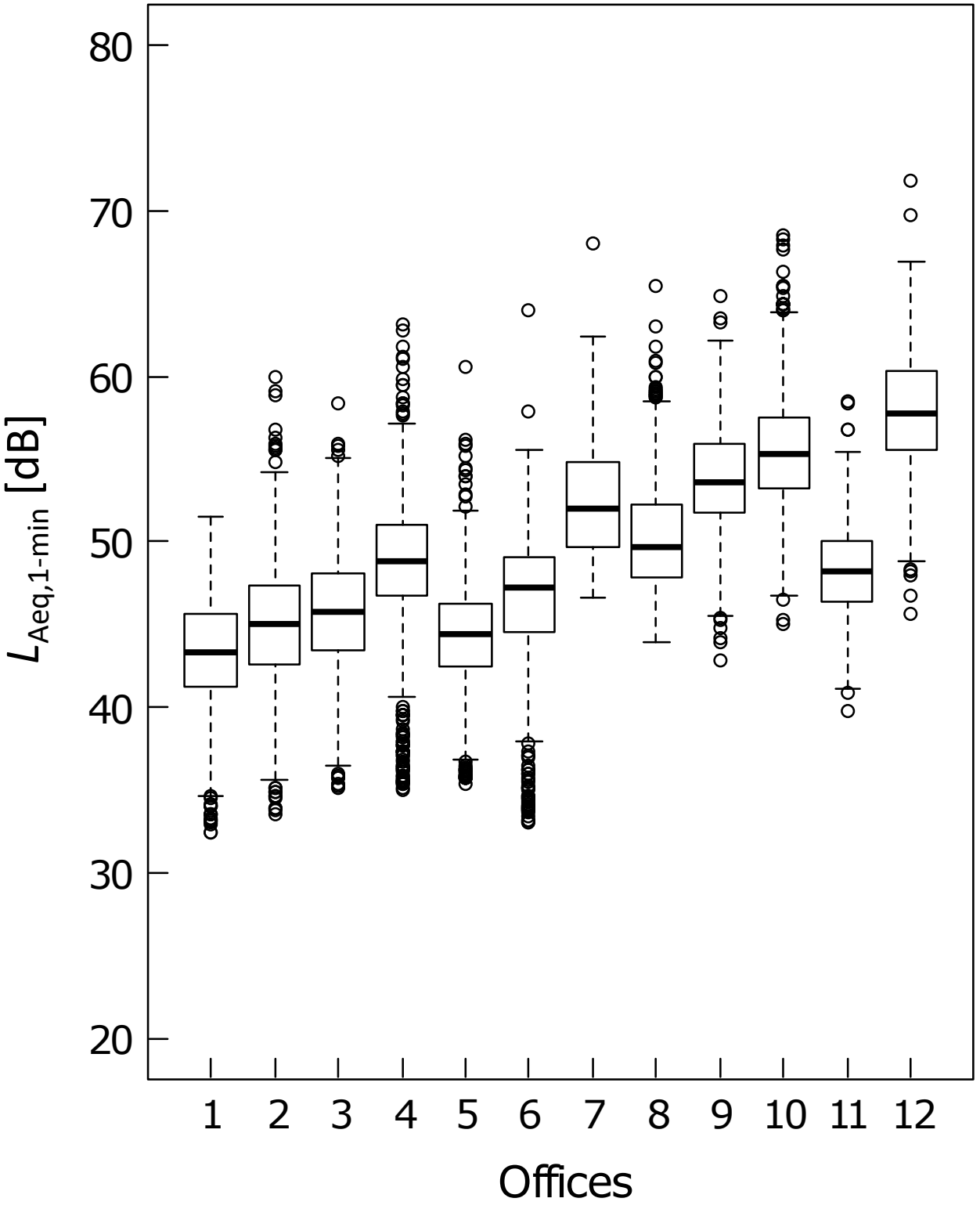


Office #10

Office #11

Office #12

Figure 2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$L_{Aeq,1\text{-}min}$ [dB]
1
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Offices