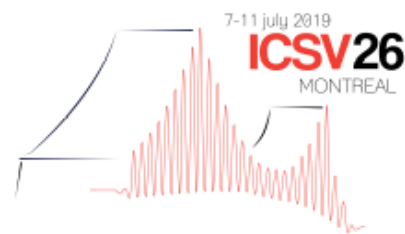


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## IMPACT OF ACOUSTIC ENVIRONMENT ON WORK IN OPEN-PLAN OFFICES ACROSS JOB CHARACTERISTICS

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This study aims to investigate the impacts of acoustic environment on the relationship between job characteristics and job satisfaction. Acoustic measurements and questionnaire surveys were conducted in open-plan offices in the UK and Korea. Background noise levels were recorded for 8 hours in each office and speech transmission index (STI) and sound pressure levels were measured for quantifying the single number quantities in ISO 3382-3. A total of 324 employees from 12 offices completed a questionnaire survey. The questionnaire included questions assessing noise disturbances and speech privacy, as well as job satisfaction and job characteristics. The result confirmed the strong impacts of job characteristics on self-rated job satisfaction. Background noise levels during working hours and reverberation time were negatively associated with job satisfaction; however, there were little influences of speech privacy and noise disturbance on job satisfaction. It was also observed that speech privacy, noise disturbance, background noise level, and cultural difference (Korea and UK) had moderating effects on the relationship between job characteristics and job satisfaction. In particular, greater speech privacy and lower background noise level increased the impacts of job characteristics on job satisfaction.

Keywords: open-plan office, speech privacy, job satisfaction, job characteristics

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### 1. Introduction

Open-plan offices have been a popular layout because they promote teamwork, social relations, communication, and knowledge-sharing between workers. However, recent studies have reported that the ambient features in office environments such as noise and temperature influence workers attitude, behaviour, satisfaction, and performance [1-3]. Lee and Brand [4] reported that more personal control over the physical workspace led to higher job satisfaction. Lee *et al.* [5] also demonstrated that job satisfaction and satisfaction with the environment were negatively correlated with lack of speech privacy. In addition, speech privacy was affected by noise sensitivity and longer noise exposure led to decreased job satisfaction.

Many researchers have argued that employee's performance and satisfaction can be improved by enriching the employee's job. Thus, many efforts have been made to characterise the jobs. For example, Hackman and Oldham [6] developed the job characteristics model consisting of skill variety, task identity, task significance, and autonomy. Based on the job characteristics theories, many studies have investigated the relationships between job characteristics and job satisfaction. For example, Loher *et al.* [7] conducted a meta-analysis using Hackman and Oldham's job characteristics model and reported a moderate relationship between job characteristics and job satisfaction. Sundstrom *et al.* [8] also demonstrated that noise disturbance affected job satisfaction through job characteristics. However, the participants of their study were from private as well as open-plan offices.

This study aims to investigate the impacts of acoustic environment on the relationship between job characteristics and job satisfaction. More specifically, the following three hypotheses were tested through questionnaire surveys in Korea and the UK.

1. Job characteristics might affect job satisfaction of the employees.
2. Acoustic environment office might influence job satisfaction of the employees.
3. Acoustic environment might affect the relationship between job characteristics and satisfaction

## 2. Methodology

### 2.1 Sites

Twelve open-plan offices (six in Korea and six in the UK) were selected for the questionnaire surveys and acoustic measurements. The offices in Korea were within the same building of the construction company and were a mixture of R&D, design, finance and HR departments. They were located on different floors with same floor design, finishing materials, and workstation arrangement; thus, it was expected that acoustic environments are similar across the floors. The offices in the UK were located in three different buildings and some of the employees were mainly communicating on the phone. All the offices in Korea were rectangular but half of the UK offices were not rectangular. Floor areas varied from 150 to 680 m<sup>2</sup>, 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 and two offices didn't have a partition. Ceiling heights of the UK offices (2.5-3.0 m) were slightly higher than those of the offices in Korea (2.4 m).

### 2.2 Participants

A total of 324 employees (147 from Korea and 177 from the UK) took part in the questionnaire surveys. 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. In addition, 67.3% were males and 31.2% were females.

### 2.3 Acoustic measurements

Background noise levels were measured in an occupied condition using a sound level metre (B&K Type 2236). Single measurements were conducted in the rectangular offices because the workstation arrangements were almost 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 ( $L_{Aeq,8-hour}$ ). One minute equivalent sound pressure level samples ( $L_{Aeq,1-min}$ ) were then stored to obtain sound profiles. Additional measurements were performed at night-time when people were absent to determine room acoustics and Speech Transmission Index (STI) in open-plan offices [9, 10]. Contrary to the UK offices, the additional measurement was conducted at one office in Korea because all the offices had similar acoustic conditions. During the measurements, 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 crosses over workstations. Two measurements were conducted in the non-rectangular offices in two zones with different furniture design and workstation arrangement, while one measurement was done in the rectangular offices with similar workstation arrangement and ceiling material. The sound source was placed at the end of the measurement line at a height of 1.2 m and microphones were located at the position of each worker, 1.2 m above the floor. From the measurements, room acoustics measures ( $T_{20}$  and EDT) about reverberation time were analysed and speech privacy-related measures were also determined: spatial decay rate of speech ( $D_{2,s}$ ), A-weighted sound pressure level of speech at a distance of 4 m ( $L_{p,A,S,4m}$ ), distraction distance ( $r_D$ ), and background noise level ( $L_{p,A,B}$ ).

## 2.4 Questionnaire

The questionnaire consisted of items concerning job satisfaction, job characteristics, speech privacy and noise disturbance. First, job satisfaction was measured with the Global Job Satisfaction (GJS) developed by Pond and Geyer [11]. Second, four job characteristics (skill variety, task identity, task significance, and autonomy) were measured by the Job Diagnostic Survey (JDS) developed by Hackman and Oldham [12]. A total of eleven statements were used to measure the four types of job characteristics. Third, the following question was used to assess speech privacy: “How much do you understand the following when you over-hear them?” Two options were 1) colleagues chatting and 2) telephone conversation) were given and each option was rated using 5-point scales. Lastly, self-rated disturbance caused by noise nine times was assessed using a five-point scale (1 = “Not at all” ~ 5 = “Extremely”). Noise sources were 1) colleague chatting, 2) telephone conversation, 3) telephone ringing tones, 4) keyboard typing, 5) office equipment, 6) ventilation systems, 7) noise from outside, 8) footsteps, and 9) door opening. All the ratings were then converted to percentage values varying 0 to 100%.

## 2.5 Data analysis

The data were analysed using SPSS version 24.0 and using AMOS version 24.0. Pearson correlations were tested to examine the bivariate correlations between the variables. The one-way analyses of variance (ANOVA) were tested to examine the effects of variables. The independent samples *t*-tests were performed to compare groups. Finally, the structural equation modelling (SEM) method was used to test the relationships between the variables. This study considered *p* values of less than 5% ( $p < 0.05$ ) as statistically significant.

## 3. Results

### 3.1 Acoustics

As listed in Table 1, background noise levels during working hours in Korea ranged between 44.7 and 51.2 dB and the offices in the UK had slightly greater noise levels, varying from 49.1 to 60.3 dB. The differences in background noise levels between Korea and the UK might be because employees in the UK were more frequently talking to their colleagues and customers over the phone than Korea. In addition, the UK offices were higher ceiling heights and had more reflective materials on walls.

Table 1: Measured background noise levels for 8 hours

Offices	Korea						UK											
	#1	#2	#3	#4	#5	#6	#7	#8			#9	#10			#11	#12		
								1	2	3		1	2	3		1	2	3
$L_{Aeq,8-hr}$ [dB]	44.7	47.1	47.2	51.2	46.1	48.3	54	52.3	51.3	50.9	54.9	55.3	58.4	56.7	49.1	58.3	58.4	60.3

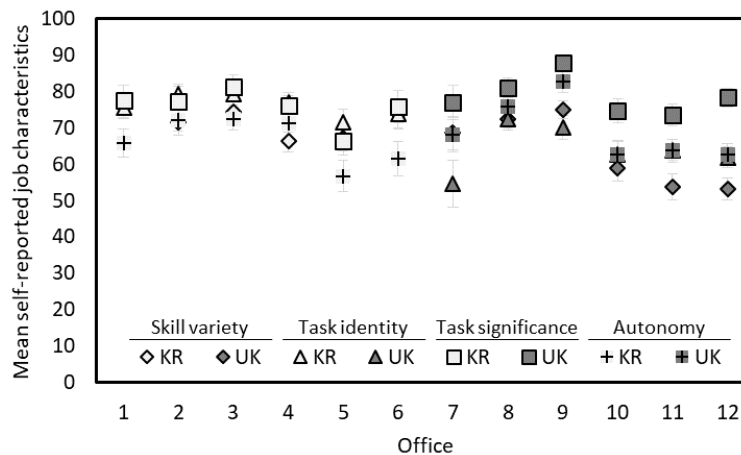
Room acoustics and speech privacy-related measures are listed in Table 2. The offices #1-6 showed slightly shorter reverberation times ( $T_{20}$  and EDT) than offices #7-12 due to the low ceiling height and small room volume. The  $D_{2,S}$  results varying from 4.2 to 7.9 dB were quite small because the partition heights were not high and two offices even had no partitions. The offices #1-6 and the second measurement line of the office #8 showed smaller  $D_{2,S}$  values due to the strong reflections from columns and windows. Results of  $L_{p,A,S,4m}$  were opposite; the offices #1-6 showed much larger value than other offices similarly due to the sound reflections from room boundaries. The variation of  $L_{p,A,S,4m}$  across the offices #7-12 was quite small, varying from 45.8 dB to 49.4 dB. The offices #1-6 showed the largest  $r_D$  because of the lowest background noise level ( $L_{p,A,B}$ ), whereas the office #7 with the largest background noise level showed the smallest  $r_D$ .

Table 2: Measurement results of room acoustics and speech-privacy related parameters of each office.

Offices	$T_{20}$ [s]	EDT [s]	$D_{2,S}$ [dB]	$L_{p,A,S,4m}$ [dB]	$r_D$ [m]	$L_{p,A,B}$ [dB]
#1-6	0.30	0.25	5.7	51.9	16.5	33.9
#7	0.44	0.39	7.4	48.6	9.7	40.3
#8	0.54, 0.52	0.50, 0.32	7.9, 4.2	48.3, 49.4	10.8, 10.8	38.5, 39.2
#9	0.45	0.38	5.7	47.9	12.2	36.5
#10	0.43, 0.42	0.38, 0.35	6.9, 7.2	47.3, 47.8	12.2, 15.0	35.5
#11	0.46	0.45	7.9	47.2	12.0	34.8
#12	0.34, 0.37	0.39, 0.45	7.0, 7.7	47.6, 45.8	12.7, 10.6	35.6, 37.7

### 3.2 Self-rated job characteristics and job satisfaction

Figure 1 shows the self-rated job satisfaction and job characteristics. The employees of Korea offices had greater skill variety and task identity than the UK offices, whereas those working at the UK offices showed greater task significance and autonomy ratings than Korean employees.



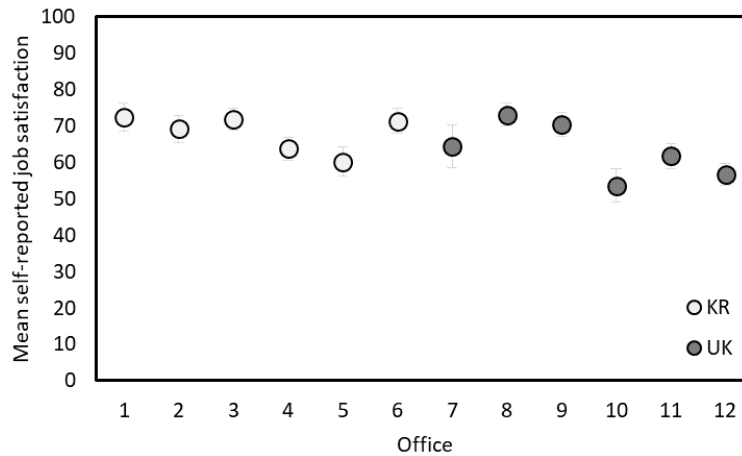


Figure 1: Averaged job characteristics (top) and job satisfaction (bottom)

Correlation coefficients between job characteristics and job satisfaction are listed in Table 3. Four categories of job characteristics were positively correlated with job satisfaction. For example, the skill variety showed the greatest correlation coefficient with job satisfaction ( $r = .56$ ). This implies that employees with higher skill variety, task identity, task significance, and autonomy had greater job satisfaction.

Table 3: Correlation coefficients between job characteristics, job satisfaction, speech privacy, and noise disturbance (\*\* $p < 0.01$  and \* $p < 0.05$ ).

Job characteristics	Job satisfaction	Speech privacy	Noise disturbance
Skill variety	.56**	-.09	.04
Task identity	.40**	-.12*	.03
Task significance	.36**	-.11	.03
Autonomy	.41**	-.05	.07

In order to further examine the effect of job characteristics on job satisfaction, the participants were classified into two groups (low and high) based on their ratings of job characteristics. The classification was conducted using their median scores as cut-off points. The median scores of skill variety, task identity, task significance, and autonomy were 66.7, 71.4, 78.6, and 71.4, respectively. If the scores were smaller than the cut-off points, they were grouped as low and those which were equal to or higher than the cut-off points were grouped as high. Figure 2 illustrates the comparisons of job satisfaction ratings across low and high groups of job characteristics. It was found that high groups showed greater job satisfaction. The results of the independent samples  $t$ -test confirmed that the differences in job satisfaction were statistically significant across four job characteristics. This indicates that those with high skill variety, task identity, task significance, and autonomy reported higher job satisfaction compared to other groups.

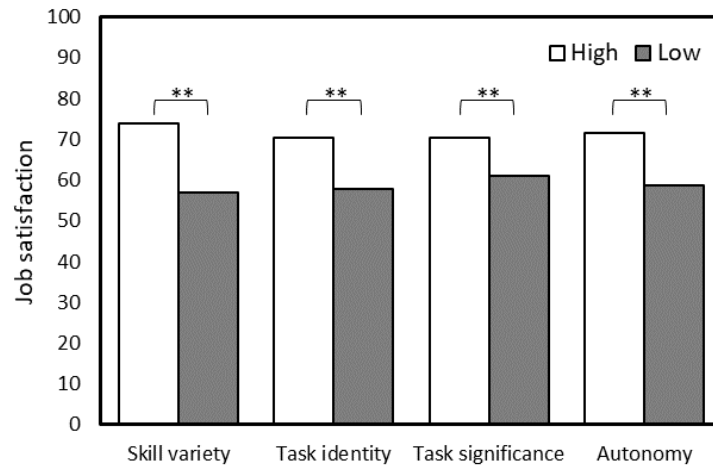


Figure 2: Job satisfaction ratings for low and high groups of job characteristics

### 3.3 Relationships between acoustics and job satisfaction

Table 4 represents the correlation coefficients between job satisfaction and acoustic related subjective and objective variables. The relationship between job satisfaction and speech privacy was not significant. Job satisfaction also did not have any significant correlation with the noise disturbance. Job satisfaction had significant negative correlations with  $L_{Aeq,8-hour}$  and EDT. This implies that lower background noise level and shorter reverberation time were helpful to improve job satisfaction.

Table 4: Correlation coefficients between subjective ratings (job satisfaction, speech privacy, noise disturbance) and acoustic parameters (\*\* $p < 0.01$  and \* $p < 0.05$ ).

	Job satisfaction	Speech privacy	Noise disturbance	$L_{Aeq,8-hour}$ [dB]	$T_{20}$ [s]	EDT [s]
Job satisfaction	1	-.04	-.10	-.21**	-.00	-.14**
Speech privacy	-.04	1	-.18**	.14*	.15**	.14*
Noise disturbance	-.10	-.18**	1	-.04	.05	-.03

Figure 3 shows comparisons of job satisfaction ratings for two independent groups with low and high speech privacy, noise disturbance, and background noise levels ( $L_{Aeq,8-hour}$ ). Classification of groups was made based on their median score as a cut-off point. Median scores of speech privacy, noise disturbance and  $L_{Aeq,8-hour}$  were 46.4, 36.5, 51.2 dB, respectively. The participants with values below than the cut-off points were grouped as the low group and those equal to or higher than the cut-off points were grouped as high group. High speech privacy group ( $n = 178$ ) showed slightly lower job satisfaction and low speech privacy group ( $n = 146$ ) but the difference between groups was not statistically significant. It was observed employees who experienced greater noise disturbance ( $n = 165$ ) reported slightly lower satisfaction than those with lower noise disturbance ( $n = 159$ ) but the difference was not significant. Furthermore, those who were exposed to high background noise level ( $n = 164$ ) presented significantly lower job satisfaction than those in low  $L_{Aeq,8-hour}$  ( $n = 160$ ).

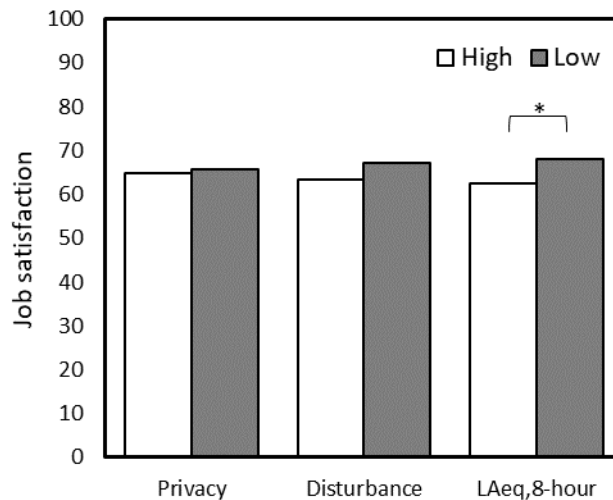


Figure 3: Job satisfaction ratings for low and high groups of speech privacy, noise disturbance, and background noise level

#### 4. Conclusion

In this research, the relationship between job characteristics and job satisfaction was examined by highlighting the moderation effect of the acoustic environment. It was found that job characteristics had strong impacts on self-rated job satisfaction. Higher skill variety, task identity, task significance, and autonomy led to greater job satisfaction. Background noise levels during working hours and reverberation time were negatively associated with job satisfaction; however, there were little influences of speech privacy and noise disturbance on job satisfaction. It was also found that speech privacy, noise disturbance, background noise level, and cultural difference (Korea and UK) had moderating effects on the relationship between job characteristics and job satisfaction. In particular, greater speech privacy and the lower background noise level increased the impacts of job characteristics on job satisfaction.

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