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REVIEW OF THE WORKS ON THE EFFECT OF SOUND ON OFFICE PRODUCTIVITY

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Noise in offices is related to an employee's comfort, health and productivity. This paper has briefly reviewed two recent works on office productivity. For the work of Mak and Lui, a seven-part questionnaire survey was conducted. Two hundred and fifty-nine office workers in thirty-eight air-conditioned offices in Hong Kong were recruited to participate in this survey. It was found that sound and temperature were the principal factors affecting office productivity. The most irritating noises were conversations, ringing phones and machines. The study also revealed that the environment mattered least to the younger participants. An extended analysis revealed that the female workers were found to be more sensitive to the environmental and office design factors including office layout, temperature and sound and the office should be more carefully designed especially for the female office workers. For the work of Kang et al., a questionnaire analysis was based on survey responses collected from two hundred and thirty-one people who were working in university open-plan research offices (UOROs) from nineteen universities in China. The results showed a clear picture of how office productivity was affected by the key IEQ aspects (such as acoustic environment) and how these key IEQ aspects were affected by their sub-factors (such as conversation noise).

Keywords: noise, office productivity, offices, university open-plan research offices (UOROs)

1. Introduction

There is a growing concern about noise in offices since noise is related to an employee's comfort, health and productivity. A large number of investigations have been sought to study noise problems in indoor air-conditioned spaces [1-5]. Indoor environment and office design can enable or impede office work. A review of past work conducted by Mak and Lui [6] suggested that a possible correlation exists between noise and office productivity and a questionnaire is a direct and useful method for measuring productivity using a self-assessment approach. This paper reviews the previous work of Mak and Lui [6] and the previous work of Kang et al. [7] on productivity in offices.

2. Work of Mak and Lui

2.1 Methods

In the work of Mak and Lui [6], two hundred and fifty-nine office workers in thirty-eight air-conditioned offices in Hong Kong were recruited to participate. The workers completed a seven-part questionnaire themselves. The questionnaire was used to examine the effect of sound on office productivity and to assess the relationship between office productivity and office noise sources as well as five environmental and office design factors, namely temperature, air quality, office layout, sound and lighting. Data were coded and analysed using the software package SPSS for Windows 17.0 (SPSS Inc., Chicago, IL, USA). The SPSS is a widely used program for statistical analysis in social science. It is also used by researchers in the fields of health, engineering, built environments and other fields.

2.2 Results

It was found that there was no statistical differences appeared for gender between the high- and low-productivity groups. Differences in age groups between the low- and high-productivity participants were found to be significant, meaning that the environment impacts on the productivity of the younger age group (below 45) to a lesser degree. The further analysis of the questionnaire survey was later conducted [8].

2.2.1 Office environmental factors and office productivity

Table 1 shows the grades of the mean score and the standard deviation (SD) of the environmental factors. Strong and significant differences for gender were found with respect to temperature and air quality (P-value < 0.01), implying that the female participants were more unsatisfied with these factors. Although there are not significantly positive correlations between changes in office productivity and air quality [6], it is still worth noting that the mean score of air quality by female participants was smaller than 3, indicating that female workers are not satisfied with the air quality in offices in Hong Kong.

Table 1: Mann-Whitney U tests between gender groups, Mean (SD)

	Environmental factor	Male	Female	*P*-value
1	Office layout	3.37 (0.68)	3.35 (0.85)	0.936
2	Temperature	3.33 (0.63)	3.13 (0.63)	0.008
3	Air quality	3.11 (0.77)	2.66 (0.90)	0.000
4	Lighting	2.74 (0.87)	2.77 (0.87)	0.888
5	Sound	3.23 (0.61)	3.22 (0.62)	0.952

The relationships of the rank orders between changes in office productivity and scores of environmental factors according to different genders were analyzed using Spearman rank correlations as shown in Table 2. It shows the effects of different environmental factors on office productivity of male and female. Only one factor (temperature) was found to be significantly positive correlated (*P*-value<0.01) to office productivity for male, while three factors (Temperature, office layout and sound) were found to be significant for female. This means the female workers were more sensitive to the environmental and office design factors including office layout, temperature and sound and the office should be more carefully designed especially for the female office workers.

Table 2: Spearman rank correlation coefficients of office productivity and environmental and office design factors according to different genders

		Office layout	Temperature	Air quality	Lighting	Sound
Male	Productivity	0.086	0.280**	0.147	0.117	0.109
Female	Productivity	0.280**	0.195*	0.057	0.120	0.285*

*Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

2.2.2 Sound and office productivity

Participants were separated into low- and high-productivity groups with the mean productivity score (3.18) of all participants as the cut-point. In order to perform further analysis, participants were similarly separated into sound satisfaction and sound dissatisfaction groups with the mean score of sound factor (3.23) of all participants as the cut-point. Table 3 shows that no statistical differences appeared for age (and gender) between the sound satisfaction and sound dissatisfaction groups (P >0.05).

Table 3: Demographic characteristics of participants

Demographic characteristics	Sound satisfaction	Sound dissatisfaction	*P*-value
Age			
Under 25	17 (43.6%)	22 (56.4%)	0.186
25 to 34	60 (50.4%)	59 (49.6%)	
35 to 44	31 (54.4%)	26 (45.6%)	
45 to 55	13 (50.0%)	13 (50.0%)	
over 55	14 (77.8%)	4 (22.2%)	
Gender			
Male	58 (46.8%)	66 (53.2%)	0.734
Female	66 (48.9%)	69 (52.1%)	

[a]score for sound factor is larger than the mean score for sound factor of all participants.

[b]score for sound factor is not larger than the mean score for sound factor of all participants.

Their analysis [6] showed that strong and significantly positive correlations (P-value < 0.01) between changes in office productivity and office layout, temperature and sound were found. In addition, it was found that among the environmental and office design factors, the temperature and sound factors had a principal influence on office productivity. The relationship of the rank orders between productivity group (low- and high-productivity groups) and sound group (sound dissatisfaction and sound satisfaction groups) were analyzed using Spearman rank correlations as shown in Table 4. Strong and significantly positive correlations (P-value<0.01) between productivity group (changes in low- and high-productivity groups) and sound group (changes in sound dissatisfaction and sound satisfaction groups) were found, meaning that an office worker who is not satisfied with the sound environment in the office is more likely to have low office productivity while an office worker who is satisfied with the sound environment in the office is more likely to have high office productivity. This indicates again the sound environment has important effects on the office productivity.

Table 4: Spearman rank correlation coefficients of productivity group (low- and high-productivity groups) and sound group (sound dissatisfaction and sound satisfaction groups)

	Sound group
Productivity group	0.192**

*Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

3. Work of Kang, Ou and Mak

3.1 Methods

The work of kang, Ou and Mak focused on a special type of open-plan offices, university open-plan research offices (UOROs), and aimed to study how the IEQ of this type of offices affects the occupants' productivity. The analysis was based on survey responses collected from two hundred and thirty-one people who were working in UOROs from nineteen universities in China. The data were also analyzed with SPSS software.

3.2 Results

The results showed the qualities of the five key IEQ aspects, including layout, air quality, thermal comfort, lighting and acoustic environment, had significantly positive correlations with office productivity. The results also emphasized the quality of acoustic environment has the greatest influence on the occupants' productivity in UOROs.

3.2.1 Evaluation of IEQ aspects and their impacts on office productivity

The Spearman rank correlation coefficients were calculated to determine whether there was an association between work productivity and each of the five key IEQ aspects, as shown in Table 5. The larger the absolute value of the coefficient, the stronger the relationship between the variables. As seen in Table 5, the qualities of all these five key IEQ aspects had significantly positive correlations (P-value<0.01) with office productivity, which demonstrates again the importance of these five aspects to office productivity in UOROs. The correlation coefficients of layout, air quality, thermal environment, lighting environment and acoustic environment were 0.341, 0.231, 0.256, 0.282 and 0.432, respectively. It is worth noting that the correlation coefficient of acoustic environment is much larger than those of the other aspects, which means the acoustic environmental quality of the UORO has extremely significant effects on occupants' productivity.

Table 5: Spearman rank correlation coefficients (r_s) of work productivity and IEQ aspects

	Layout	Air quality	Thermal environment	Lighting Environment	Acoustic environment
Work productivity	0. 341**	0. 231**	0.256**	0.282**	0.432**
** Correlation is significant at the 0.01 level (two-tailed)					

3.2.2 Noise sources and office productivity

For further analysis of how noise sources affect office productivity, Mann-Whitney U Tests were utilized again to identify differences in the disturbance scores of noise sources between the low- and high productivity participants, as shown in Table 6. Participants were separated into low- and high- productivity groups according to the mean productivity score (3.30) of all participants as the cut-point. Except for noises of construction, machines and traffic, significant differences between the low- and high-productivity participants were found with respect to all noise sources, implying that the lower productivity participants are more likely influenced and distracted by these noise sources.

Table 6: Mann-Whitney U tests between low and high productivity groups with respect to the perception of noise sources

Noise source	Mean perceived disturbance level		P-value
	Low productivity	High productivity	
Construction	2.90	2.79	0.532
Conversation	3.26	2.63	0.000**

Entertainment	2.87	2.47	0.019*
Phone ringing	2.82	2.35	0.002**
Door closing	2.54	2.16	0.008**
Machines	2.35	2.15	0.159
Footsteps	2.47	2.05	0.003**
Traffic noise	2.25	2.10	0.178
Human activity	2.61	2.30	0.009**
Keyboard sound	2.37	1.90	0.002**
Mean scores and P-values are given in the table; * Correlation significant at the 0.05 level (two-sided); ** Correlation significant at the 0.01 level (two-sided).			

4. Conclusion

In the work of Mak and Lui [6], it was found that sound and temperature were the principal factors affecting office productivity. The most irritating noises were conversations, ringing phones and machines. The study also revealed that the environment mattered least to the younger participants. Those over 45 were more sensitive to it, and factors such as noise and temperature had a bigger effect on their productivity. The extended analysis [8] revealed that the female workers were found to be more sensitive to the environmental and office design factors including office layout, temperature and sound and the office should be more carefully designed especially for the female office workers. Besides, an office worker who is not satisfied with the sound environment in the office is more likely to have low office productivity while an office worker who is satisfied with the sound environment in the office is more likely to have high office productivity.

In the work of Kang et al. [7], the qualities of the five key IEQ aspects, including layout, air quality, thermal comfort, lighting and acoustic environment, had significantly positive correlations with office productivity. Among these five aspects, the quality of acoustic environment had the greatest influence on productivity in UOROs. The lower productivity participants were more likely influenced and distracted by the noises of conversation, entertainment, phone ringing, door closing, footsteps, human activity, and keyboard sound.

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REFERENCES

1 Mak, C.M., A prediction method for aerodynamic sound produced by multiple elements in air ducts, *Journal of Sound and Vibration*, **287**, 395–403, (2005).

2 Mak, C.M., Development of a prediction method for flow-generated noise produced by duct elements in air ducts, *Applied Acoustics*, **63** (1), 81–93, (2002).

3 Mak, C.M., and Au, W.M., A turbulence-based prediction technique for flow-generated noise produced by in-duct elements in a ventilation system, *Applied Acoustics*, **70**, 11–20, (2009).

4 Mak, C.M., Wu, J., Ye, C., and Yang, J., Flow noise from spoilers in ducts, *Journal of the Acoustical Society of America*, **125**, 3756–3765, (2009).

5 Ayr, U., An experimental study on noise indices in air conditioned offices, *Applied Acoustics*, **62**, 633–643, (2001).

6 Mak, C.M., and Lui, Y.P., The effect of sound on office productivity, Building Services Engineering Research and Technology, **33**(3), 339–345, (2012).

7 Kang, S.X., Ou, D.Y., and Mak, C.M., The impact of indoor environmental quality on work productivity in university open-plan research offices, submitted to Building and Environment, (2017)

8 Mak, C.M., The effect of sound on productivity in offices, *Proceedings of the 11th International Congress on Noise as Public Health Problem*, Nara, Japan, 1–5 June, (2014).