DOI: 10.61782/fa.2023.0689

forum acusticum 2023

CORRELATION OF SOUND LEVEL OF MASKING SOUNDS WITH THE ANNOYANCE AND OVERALL UNPLEASANTNESS OF OCCUPANTS IN OPEN-PLAN OFFICES

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ABSTRACT

The present study aims to investigate the optimum level of masking sounds which can satisfy with both the occupants and acoustical privacy. In order to this, prior investigation was accomplished to know real condition of open-plan offices using questionnaire survey to 115 people. Also, acoustic listening experiments were done to 30 people with 5 scale points questionnaires. Recorded voice was played with the output sound level of 57 dB at 1m from the directional speaker. Artificial masking sound was also radiated from the ceiling speaker using pink noise. Masking sound used in the experiments consisted of 5 different sound levels which have SNR of 10, 13, 16, 19 and 22 dB. Using questionnaire, three responses from occupants were received including speech intelligibility, annoyance of masking sounds, and overall unpleasantness.
As a result, it was found that SNR 22 is appropriate for the decrease of annoyance of masking sounds and overall unpleasantness while SNR 16 to SNR 19 is considered to be suitable for the reduction of speech intelligibility and the annoyance of masking sounds.

Keywords: *open-plan office, speech privacy, masking sounds, SNR, listening experiment*

1. INTRODUCTION

Business efficiency is most major important factor when designing office space [1]. Open-plan office is a way to make an efficient business environment. It gives high efficiency of communication among people, high rate of space use, and flexible use of space [2-3]. Especially in open-plan offices, securing speech privacy between workers is acoustically very important since it can influence the working concentration and productivity. However, there are some disadvantages concerning speech privacy caused by exposure to neighbor's talk and various noises [4]. Currently, in order to maintain the speech privacy in open-plan offices, various methods are being used including sound absorption, office partition and sound masking [5].
Normally, sound masking is used to maintain the speech privacy in many ways. Recently, sound masking is used, as a design method of soundscape, to reduce road traffic noise and community noise in public spaces [6-8]. Also, recent study showed that sound masking system can be utilized to reduce the variability of sound feature in rooms in order to secure speech privacy [9]. Uniformity of sound masking system in open-plan office was assessed using computer modeling [10].
However, masking sounds can cause the unpleasantness and annoyance of occupants. The present study aims to investigate the optimum level of masking sounds which can satisfy with both the occupants and acoustical privacy. In order to this, prior investigation was accomplished to know real condition of open-plan offices using questionnaire. Also, acoustic experiments were done to people in order to find suitable sound level of masking sound in open-plan office.

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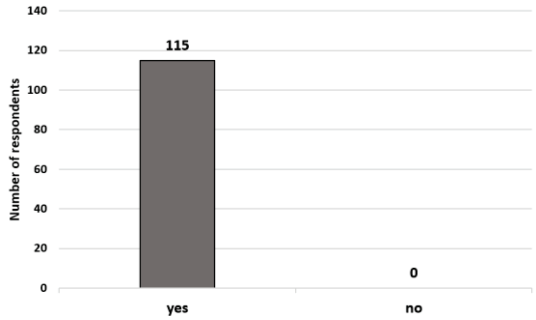
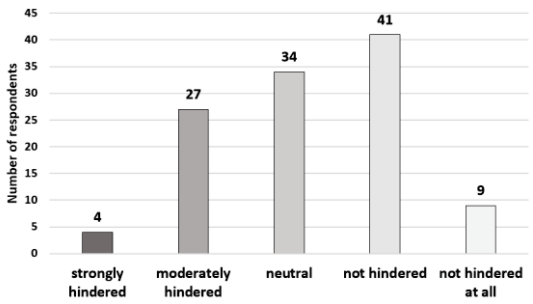
2. QUESTIONNAIRE SURVEY

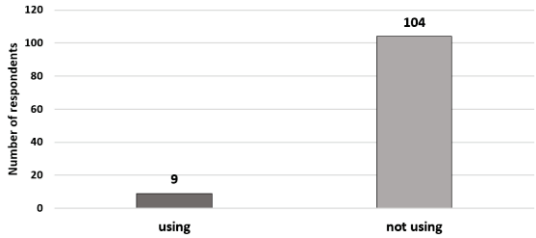
Questionnaire survey was undertaken to 115 occupants in 51 open-plan offices in order to investigate their responses to sound masking system. Through the investigation, it was found that all the occupants have experienced noise during working time, and 56.5% of respondents though that their working was somehow disrupted by noise. Also, it was found that 34% of subjects responsed that sound masking would be helpful for sound environment and hope to use it even though only 8% of respondents are using masking sounds in their office. The results of the questionnaire survey were displayed in Fig. 1.



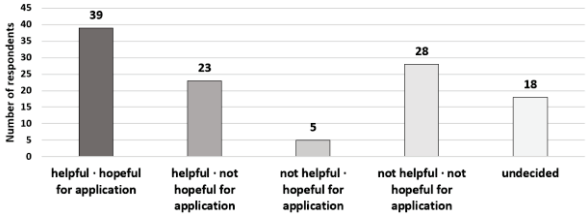
(a) Has noise from others ever been conveyed to you?



(b) How much does noise from others disrupt your work?



(c) Are you currently using masking sounds in your office?



(d) Do you think sound masking would be beneficial for the acoustic environment in your office?

Figure 1. Results of prior questionnaire survey

3. LISTENING EXPERIMENTS

Listening experiments were done to 30 subjects for a day in a lab creating similar environment of open-plan office. All the subjects were adults with normal hearing ability and consisted of 5 groups i.e., 6 people for each group.

Recorded announcer's voice was played with the output sound level of 57 dB at 1 m from the omnidirectional speaker [11]. The background noise level was about 30 dB. Artificial masking sounds were also radiated from the ceiling speaker using pink noise. Masking sounds used in the experiments consisted of 5 different sound levels which have SNR of 10, 13, 16, 19 and 22 with interval of 3 dB, the just noticeable difference (JND) of sound levels [12]. Sound levels used for experiment are listed in Tab. 1.

Omnidirectional speaker was installed at the height of 1.2m from the floor corresponding the location of worker's mouth. Locations of sound source and listeners in the experiments are displayed in Fig. 2. Listening experiments were carried out 5 times with 6 people for each time.

Three questions were asked in five-point scale to evaluate the speech intelligibility of announcer voice, annoyance of masking sound from ceiling speaker, and overall unpleasantness. The contents of the announcer's voice were the materials used for Korean Language Proficiency Test organized by the Korean Broadcasting System. Evaluation items of listening experiment are listed in Tab. 2.

Table 1. Sound levels of listening experiment.

Recorded announcer voice	$L_{p,A,s,1m}$	57 dB
Pink noise	SNR 10	47 dB
	SNR 13	44 dB
	SNR 16	41 dB
	SNR 19	38 dB
	SNR 22	35 dB

Table 2. Evaluation items of listening experiment

(a) Speech intelligibility of announcer voice				
very intelligible	intelligible	neutral	unintelligible	very unintelligible
(b) Annoyance of masking sound				
very pleasant	pleasant	neutral	annoyed	very annoyed
(c) overall unpleasantness				
very pleasant	pleasant	neutral	unpleasant	very unpleasant

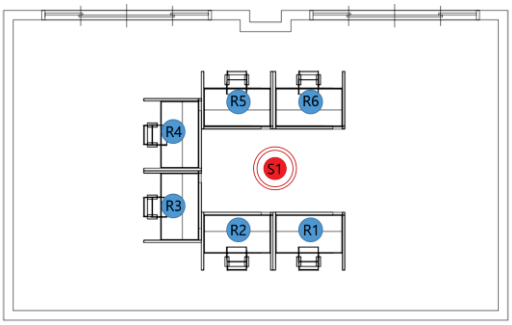
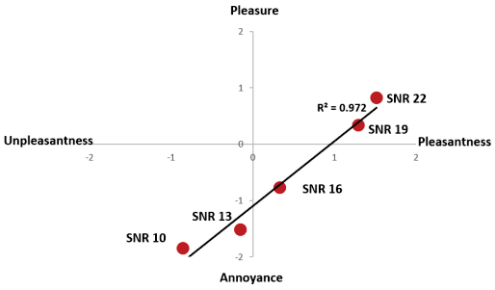


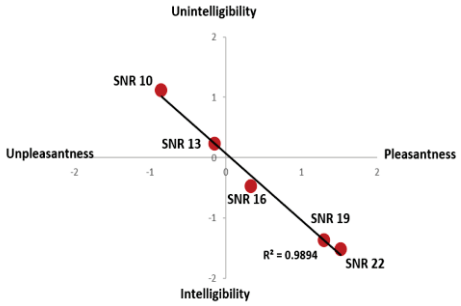
Figure 2. Location of sound source and listener
s

4. RESULTS

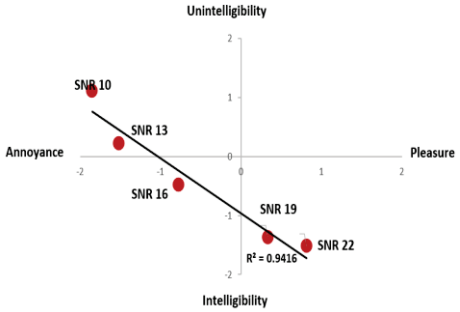
5 scale point response of all the answers were analyzed and transformed to an arithmetic mean value. Also, correlation of every two evaluation factors were plotted. Correlations of each evaluation factor are shown in Fig. 3 according to the various SNR. As a result, it was found that speech intelligibility and overall pleasantness are increasing with the SNR increase which means low level of masking sound and low speech privacy.
Meanwhile, annoyance is increasing with the SNR decrease which means higher level of masking sound.
it was revealed that SNR 22 is appropriate for the decrease of annoyance of masking sounds and overall unpleasantness while SNR 16 to SNR 19 is considered to be suitable for the reduction of speech intelligibility and the annoyance of masking sounds. Also, SNR 13 to SNR 16 were suitable considering speech intelligibility and overall unpleasantness of masking sounds.



(a) Annoyance - Unpleasantness



(b) Intelligibility - Unpleasantness



(c) Intelligibility - Annoyance

Figure 3. Correlation of each evaluation factor a
ccording to the SNR

5. DISCUSSION

In Korea, sound masking is not commonly used in open-plan office due to the resistance of masking noise. So, Annoyance by masking sound should be considered preferentially rather than other factors. Thus, considering annoyance and pleasantness of masking sound, rational sound level of masking sounds can be suggested as SNR 16 ±2 which means signal sound level -16±2 dB.

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