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The Effect of Office Layouts and Ambient Office Sounds on the Simple Tasks of White Collar Workers

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Abstract

The purpose of this study is to scrutinize the effect of office layouts and ambient office sounds on the performance of office workers involved with a proof-reading test (simple task). Twenty subjects, who were professional researchers and computer programmers, were from three different office layouts: 1) Nine subjects from a combined office type with open meeting places and closed individual offices; 2) five from an open office with rectangular individual workstations, and 3) six from an open office with triangular individual workstations. Architects and consultants working in the field of office have reported from interviews and their own observations that occupants' satisfaction differs as their office layouts vary although the sizes are the same. This finding leads to the hypothesis of this experiment. Proof-reading test results were obtained from three different office layouts (combined office type, rectangular and triangular individual workstations in open offices) under two different sound conditions (quiet background sound and ambient sound of their own workplace) for 10 minutes. The test analysis shows the mean test score of subjects from the triangular individual workstations in open offices is significantly different from the mean test scores of subjects from the combined office type and the rectangular individual workstations in open offices.

Keywords: Office Layout, Performance, Simple Task, Office Sounds

1. INTRODUCTION

Since the early 1990s, the open workplace has reappeared due to an effort to encourage collaboration between workers in companies or institutes as mentioned by Horgen, et al. (1999). Many companies have realized that it is crucial to use all of each worker's knowledge in combination with all of the knowledge of his or her co-workers in order to compete with other companies in an efficient manner. The open workplace provides such an environment for sharing knowledge informally and naturally by the studies of Davenport, et al. (1998). However, in spite of the many advantages of the open workplace (such as the flexibility to change the workplace setting, a lower initial construction cost than the closed workplace, and the sharing of knowledge between workers), continuous complaints about poor visual and acoustic (speech) privacy in the open workplace have been the main problems as described by De Chiara, et al. (2001).

Sound in the workplace is often considered to be noise when it is unwanted even though it is not loud (refer to Figure 1). In other words, sound is noise when it is unexpected, uncontrolled, happening at the wrong time, or contains unwanted information such as an adjacent telephone conversation as noted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2001). According to the survey results of the American Society of Interior Design (ASID), et al. (1996), noise in the open workplace contributes to 71% of overall workplace distractions.

As workers can not control the sound from co-workers' activities, this sound can be either information or noise. When examining the open workplace and knowledge sharing, there are two opposite aspects of sound to be observed from the workplace. One aspect is that people say that they need to have a quiet environment to work in, especially for very demanding tasks. The other aspect is that people need a certain magnitude of sound to work. Many workers want to know what is happening in their workplace and what others are doing when their work does not require total concentration. Absolute quietness, therefore, does not necessarily mean a comfortable and stimulating work environment for office workers. However, at the same time, they need to keep their own privacy and territories as explained by Cavanaugh, et al. (1998).

Sound Pressure Level (SPL) is widely used with a sound level meter to measure sound levels in offices, although there are two methods related to speech privacy in the open workplace. One is the Articulation Index (AI) which was standardized by the American National Standards Institute in 1969 and revised in 2002, and the other is the Speech Privacy Noise Isolation Class (NIC', Noise Isolation Class Prime) which was adapted from the Noise Isolation Class (NIC) by the U. S. General Services Administration (GSA) in 1978. However, AI and NIC' are more complex to use than SPL. In addition, normal or satisfactory speech privacy is rarely achieved in open offices and is highly dependant on background sound levels. That is the main reason why many architectural acousticians have recommended sound masking devices as a remedy for speech privacy in open offices. Therefore, it is important to measure the ambient background sound level in offices. The sound level in open offices recommended by Cavanaugh, et al. (1998) is between 40-45 dBA. Regardless of the need to have a study on the effects of ambient sound, few studies exist due to the complexity of regenerating a realistic ambient noise situation.

In addition to the need for the study of sound with ambient noise, the open workplace raises issues worthy of investigation in terms of workers' performance. The open workplace is intended to increase workers' performance by creating an informal and seamless knowledge-sharing environment. However, it is also known to decrease workers' performance because they are annoyed or distracted by the sound from the workplace. Therefore, it is highly questionable whether or not the performance of workers in an open workplace is increased or decreased with ambient noise when their performance in the open workplace is compared with their performance with quiet background sound. The question has led the purpose of this study, which is to analyze the effect of office layouts and ambient office sounds on the performance of office workers with a simple task. Among the many variables of open workplace types, office sounds and task types that office workers perform in their normal business days, in this current study we experiment with real office workers from three different office layout types with their own normal background office sounds with a simple office task.

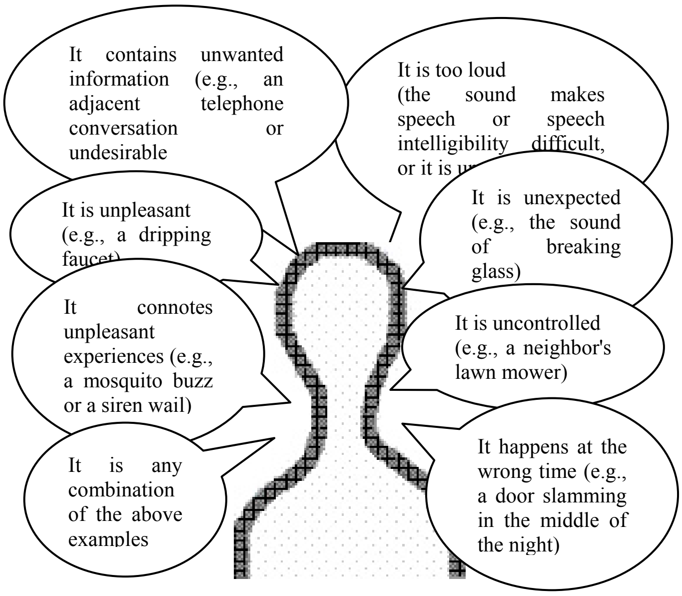


Figure 1. Sound characteristics which people consider being noise in offices.

2. SITES

Three sites were used for comparison in the experiment: A combined office with open meeting places and closed individual offices in an educational institute in Massachusetts, and two types of open offices in a software engineering company in Toronto, Canada; one with rectangular individual workstations and one with triangular individual work-stations, (refer to Figure 2, Figure 3, and Figure 4).

The educational institute in Massachusetts was renovated in 1997 to break down the barriers between teachers and students and to increase their natural contact. The open spaces have been used as small class spaces and a graduate student lounge. The institute evaluated the space to be a success. The software engineering company in Toronto made a pilot space to study proper workplace settings for a new building that it is planning to build. They provided three different types of workplaces in the pilot space: 22 people in closed individual offices (as they are currently situated in a rental building), 31 people in an open office with rectangular individual workstations, and 21 people in an open office with triangular individual workstations.

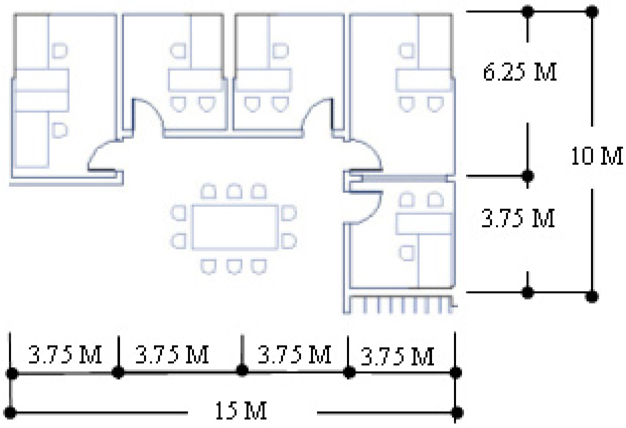


Figure 2. A combined office with open meeting places and closed individual offices. The dimensions of the two types of closed individual offices are 3.75M x 6.25M and 3.75M x 3.75M respectively. In the middle of these units, there is an open meeting area for small classes and conferences.

Picture 1. A photo of the combined office from the corner of the open meeting area.

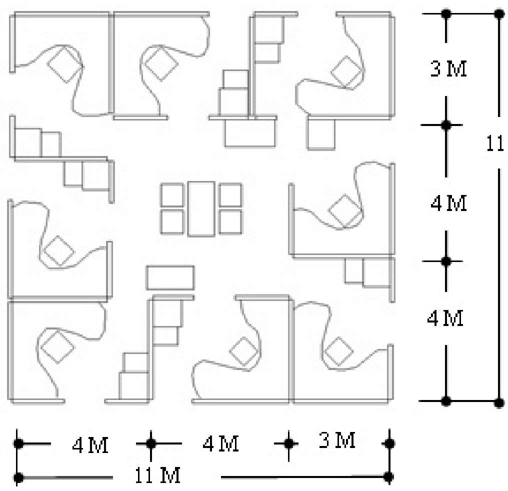


Figure 3. An open office with rectangular individual workstations. The dimension of the individual workstation is 3M x 4M. In the middle of these units, there is an open meeting area for this group. Each workstation has two entrances: one is to the corridor and the other is to the central meeting area. The height of the partitions is 1.8 M.

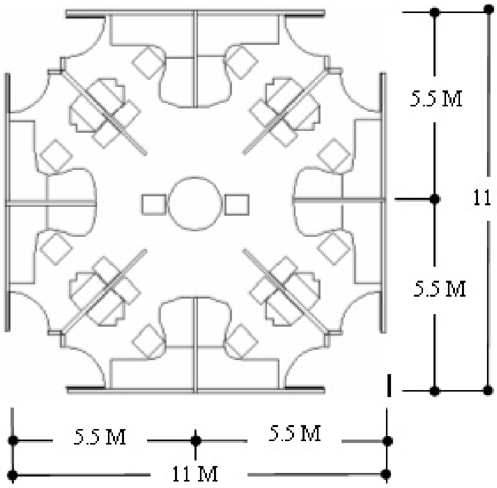


Figure 4. An open office with triangular individual workstations. The dimension of the individual workstation is 5.5 M x 5.5 M. In the middle of these units, there is an open meeting area for this group. Each workstation has two entrances: one is to the corridor and the other is to the central meeting area. The partitions are from floor to ceiling.

Picture 2. The left photo depicts the open office with rectangular individual workstations from the open meeting area, while the right photo depicts the office with triangular individual workstations from the open meeting area.

According to the measurements of the sound levels in the three different offices in December 1999 and in January 2000, the overall sound levels were between 35 dBA and 65 dBA. The magnitudes of the typing sound and talking in the corridors were between 35 dBA and 40 dBA while conversations in the conference areas were between 45dBA and 50dBA. Whenever an entrance door to the workplace was closed and a shared printer was working, the sound levels were about 60 dBA and about 50 dBA respectively. The sound magnitudes in the three places were not dramatically different. People in the three open workplaces commented that the most disturbing aspect of the sound from their workplaces was that they could not help hearing others' private phone conversations or conversations with other workers. In other words, other workers were hearing coworkers' conversations all the time and vice versa. This comment was similar to the comments on office noise from the research of Sundstrom, et al. (1994).

3. METHOD

(1) Questionnaire

A questionnaire to evaluate acoustic quality was distributed to only one of three workplaces, the educational institute. The questionnaire was modified from the Indoor Environmental Quality Survey of the Environment Protection Agency (EPA) and focused on the attitude of employees toward their work and the acoustic environment. This questionnaire was divided into four sections: workplace information, information about acoustics and well being, description of workplace conditions, and characteristics of the job.

The total number of the workers in the combined office with open meeting places and closed individual offices was fourteen, excluding students and visitors. Seven people, three females and four males, returned the questionnaire. According to the results, 85.7% had worked in the workplace for two years, while 14.3% had worked there for three years. This means they have had enough time to be habituated to this workplace. 71.4% had a single personal private office, 14.3% had a shared private office with one coworker, and 14.3% worked in an open space without partitions with three persons or more. The ambient sound for this space was recorded in one of the single personal private offices. All of them had profess-sional jobs and graduate degrees. 71.4% said that their jobs had required them to work very fast fairly often or very often and that their work objectives have been well defined. So, they could be said to have highly demanding and stressful jobs. Sound generating devices such as telephones (85.7%), answering machines (71.4%), photocopiers (28.6%) and printers (28.6%) were used in their workplace several times a day. 57.1% said they have had somewhat or very uncomfortable conversational privacy, although 71.4% rarely or occasionally had closed the door to block the sound from the open space coming into their work place. People said in the interviews that they were satisfied with this combined office, although they have often done major writing at home due to the distractions of the office. These replies may show workers feel distracted due to the open space, but they do not want to disconnect themselves from the sound and the space.

T he company in Toronto had conducted its own questionnaire to ascertain its workers' satisfaction and preferences in their pilot offices; closed individual offices, an open office with rectangular individual workstations with human height partitions, and an open office with triangular individual workstations with floor to ceiling partitions. Through the results of the questionnaires and the interviews, the closed individual office type is considered to provide the most satisfactory workplace out of the three types of workplaces, while the open office with triangular individual workstations had the highest complaints about acoustics. Talking among coworkers, the sound of movement, and telephone conversations in adjacent workstations were the main acoustic noise sources, according to the interviews. A manager in the Toronto office said that although white noise generating devices had been installed, complaints had not been reduced, and the devices had been shut off owing to an aversion to them. Consequently, the complaints about acoustics may have come from the contents of the sound, not from the sound magnitude. Therefore, it may be meaningful to use the ambient sound from each workplace with subjects from the workplace where the ambient sound was recorded. Considering this, the research question seeks to find if the proofreading test scores of subjects in three different types of workplace settings are different under two different sound conditions.

Hypothesis: Proof-reading test results in three different workplaces (a combined office with open meeting places and closed individual offices, an open office with rectangular individual workstations, and an open office with triangular individual workstations) under two different sound conditions (quiet background sound and ambient sound of their own workplace) will be better in the order of combined office, rectangular and then triangular individual workstations.

(2) Sound Recording

To record the ambient sound from each workplace, a binaural artificial head measurement system with a DAT recorder was used. This system, as shown in Figure 5, is comparable to human hearing from two recording directions, which resemble the left and right ears. In addition, it can be configured to give results compatible with conventional measurements and to regenerate the locations of the sound events as a human hears the sound with two ears. Since the recorded sound will be replayed in the proof-reading test with a headphone that reproduces sound coming from the direction it came from originally, this system would be a proper method for the sound reproduction. These signal components for noise annoyance can also be found as mentioned by Genuit (1994). The binaural head measurement system was placed in the three different offices to record their ambient sounds. The two microphones in the system were placed in the ears of a dummy. This dummy figure was intended to reduce any unusual quietness or avoidance near this system and to give more comfort to workers in the space while the sound was recorded. The height of the dummy was similar to that of a worker sitting and working in the workstation.

Each ambient sound was recorded inside of a workstation (see Picture 2). In the case where there was a door to the workstation, such as in the combined office and in the triangular individual workstation, the sound was recorded while the door was open. According to the results of the questionnaire, which asked when was the most disturbing time in the workplace, 10am to 2pm was commonly reported as the most disturbing time. This four-hour period was set as a recording time in each workplace. After the recording, 5 minutes of the recorded time was selected which contained the best components such as conversation between workers and telephone conversations inside the worker's own workstation and in adjacent workstations, shared printer sounds, and the sound of the entrance door slamming.

(3) Proof-reading Test

A simple task test, a proof-reading test, was chosen as it required a short time to complete, and the numbers used in the test were a universal language. Twenty subjects were volunteers from the three different offices and the native languages of some of them were not English. Therefore, a numerical test was chosen. Five subjects were from the open office with rectangular individual workstations, 6 were from the open office with triangular individual workstations, and 9 were from the combined office with open meeting places and closed individual offices. Before the test, subjects were informed that this test did not intend to measure their intelligence and that there were two different sound conditions. One sound condition was 5 minutes ambient of sound (35 dBA - 60 dBA, unsteady state) from the workplace where each subject worked. The other condition was 5minutes of quiet sound that was recorded in a well-soundproofed room with 30 dBA of steady HVAC sound. A DAT recorder and a headphone were provided in the test. The recorder was a Sony TCD-D8 and the headphones were Sony MDRNC20. Subjects used the headphones in the test in one of their closed conference rooms. The order of the background sound and the active sound were changed to reduce the learning effect.

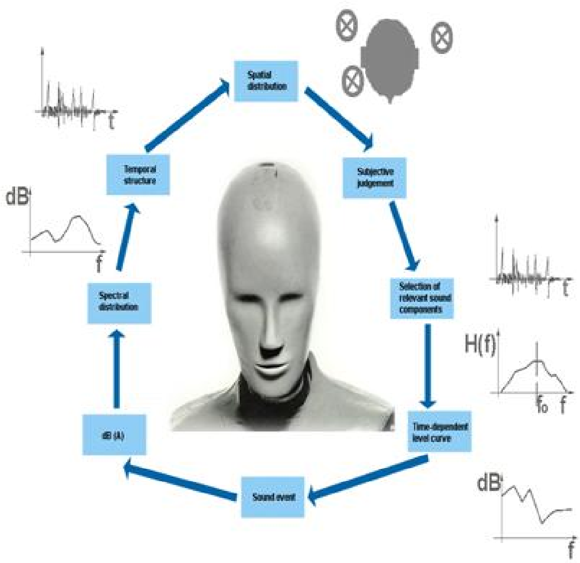
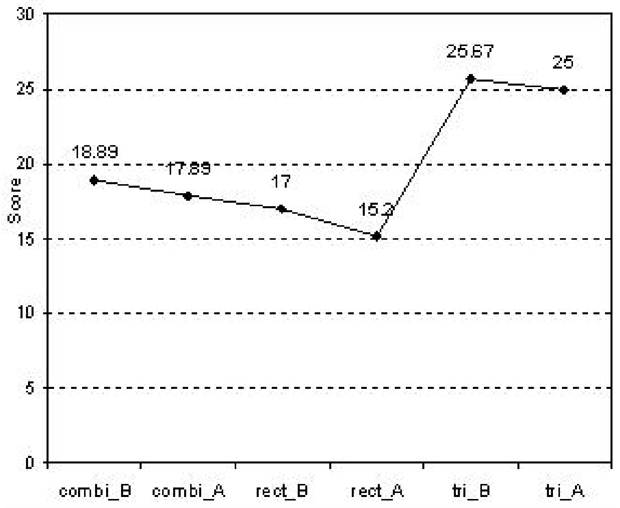


Figure 5. The process of recording and analyzing the ambient sound with the binaural head measurement system in an office.

4. RESULTS

'combi_B' denotes the test scores of the subjects from the combined office with open meeting places and closed individual offices under the background sound while 'combi_A' denotes the test scores of the subjects from the combined office under the ambient sound recorded from one of the closed individual offices with an open door. In the same way, 'rect_B' represents the proof-reading test score of the subjects from the open office with rectangular individual workstations under the 35 dBA steady background sound. ‘rect_A’ represents the test scores of the subjects from the open office with rectangular individual workstations under the ambient sound recorded from one of the rectangular individual workstations. Correspondingly, ‘tri_B’ indicates the test scores of the subjects from the open office with triangular individual workstations under the background sound. ‘tri_A’ indicates the test scores of the subjects from open office with triangular individual workstations under the ambient sound recorded from one of the triangular individual workstation with an open door. The mean scores of the proof-reading test are summarized in Figure 6.



combi_B: the combined office with open meeting places and closed individual offices under the background sound
combi_A: the combined office under the ambient sound
rect_B: the open office with rectangular individual workstations under the background sound
rect_A: the open office with rectangular individual workstations under the ambient sound
tri_B: the open office with triangular individual workstations under the background sound.
tri_A: the open office with triangular individual workstations under the ambient sound.

Figure 6. The mean scores of the proof-reading test as a simple task ($F=3.05$, $p<0.05$).

A one way analysis of variance showed a significant difference between the test results from the combined office with open meeting places and closed individual offices, the open office with rectangular individual workstations, and the open office with triangular individual workstations ($F=3.05$, $p<0.05$). The subjects from the open office with triangular individual workstations had the distinctively higher scores, both under the background sound and under their ambient sound even though they and the subjects from the open office with rectangular individual workstations were software designers.

Another one way analysis of variance was conducted while excluding the two test results from the open office with triangular individual workstations. The results showed there was no significant difference between the test results from the open office with rectangular individual workstations and the combined office with open meeting places and closed individual offices. Three t-tests (paired two samples for means) were conducted to compare the test results between the three groups with the background sound and with the ambient sound. The results indicated no significant differences either.

4. SUMMARY

The results showed the test scores of the subjects from the open office with triangular individual workstations were significantly different from the scores of the other two groups. This is interesting because the open office with triangular individual workstations was initially intended to stimulate workers by increasing contact between them and their co-workers. As shown in the questionnaire results, the workers in the open office with triangular individual workstations complained more about the acoustic discomfort than the workers in the other two offices. From the results, one might assume that the real reason for the complaints might not be due to the acoustic problem, but rather due to increased stress from the stimulating environment.

There were no significant differences in the test scores between the sites with the background sound and with the ambient sound, although the mean scores with the ambient sound were slightly lower than the mean scores with the background sound. However, in office noise experiments of Banbury & Berry (1998), office noise with and without speech disrupted performance on a mental arithmetic task and the test scores with quiet sound were significantly higher than the test scores with office noise. According to logic and the results of Banbury & Berry, the experiment was expected to find significant differences between the test scores under the background sound and under the ambient sound. The difference between this experiment and Banbury & Berry’s was the cognitive load difference of the tasks. The mental arithmetic task consists of long sequences of additions and subtractions, which is not a simple task. On the other hand, the proof-reading task can be categorized as a simple task.

Consequently, the simple task test might not result in significant differences under the two different sound conditions, which are in the range of recommended office sound background level, below 40 to 45 dBA. Although it is below the recommended office sound level, noise might bring out significant differences when workers do complex tasks, where certain information needs to be carried out from beginning to the end in their cognitive processing.

A limitation of this paper is the small number of subjects who have participated in these experiments due to the limited amount of worker available in the workplaces where the ambient sounds were recorded. However, this study is valuable in that real workers participated as subjects with their ambient working sound. The participation of the real office workers under their own ambient sound has been extremely rare. In future research a series of performance tests need to be developed that convey actual tasks by office workers rather than the proofreading test used in this study.

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