The influence of crowd density on the evaluation of soundscape in typical Chinese restaurants

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ABSTRACT

The methodology of soundscape has been used in the evaluation of indoor spaces, whereas research on the soundscape of restaurants has been limited. Based on a questionnaire survey and acoustic measurements of typical restaurants in Harbin, China, the influence of crowd density on the evaluation of soundscape has been analyzed in this study, considering several dining styles, including centralized, separate and disperse ones. It has been found that the sound source types, which users heard, are significant different at varying crowd density. For instance, with the centralized style, the background music is mainly sound heard by users with the crowd density from 0 to 0.06 persons/m^2, while surrounding speech can be mainly heard with the crowd density from 0.06 to 0.30 persons/m^2. With the crowd density increased from 0.06 to 0.25 persons/m^2, the sound pressure level inside the restaurant can be increased by 5.6dBA with centralized style, 4.9dBA with separate style, and 3.5dBA with disperse style, respectively. The acoustic comfort becomes better when the crowd density is ranged from 0.10 to 0.15 persons/m^2 with centralized style and from 0.15 to 0.20 persons/m^2 with separate style.

Keywords: Soundscape, Crowd density, Dining style I-INCE Classification of Subjects Number(s): 03.1

1. INTRODUCTION

The acoustic environment in restaurants is very important since restaurants are not only used as spaces for public dining but also public entertainment and communication. A series of domestic and overseas studies of background noise and speech intelligibility (STI) in restaurants have made considerable progress. The studies on speech intelligibility have shown that increasing boundary absorption typically increases the speech transmission index (STI) by 0.2–0.4 (1). These studies of background noise have shown the ideal noise level in restaurants to be 50–60 dBA (2); The acoustic environment in restaurants can be deeply affected by equipment noise, including lampblack machines and fans (3). It is not favorable to use any type of stone material for sound absorption in restaurants (4). The concept of soundscape as put forward by Schafer is widely used for subjective evaluation of acoustic environment (5). More recently, soundscape has been defined by the International Organization for Standardization (ISO) as the acoustic environment as perceived, experienced, and understood by a person or people in context (6). Chinese restaurants cover many dining styles. However, the issue of whether these different dining styles may influence soundscape has not yet been addressed. The influence of crowd density on the perception of soundscape was here analyzed in three typical types of dining establishments in Harbin, China, here called centralized, separate, and dispersed, using a questionnaire and acoustic measurements.

2. METHODOLOGY

Chinese dietary culture is derived from the Zhou Jin Dynasty (7), which dates back more than three thousand years. The Chinese diet has since developed into eight cuisines, including Sichuan, Shandong, Guangdong, Fujian, Jiangsu, Zhejiang, Hunan, and Anhui cuisines (8). The Chinese eat rice as a staple food, and vegetables, meat, melons, and fruit as non-staple foods; they drink tea and liquor as beverages. Regarding seasonality, Chinese prefer to eat cold food such as cold noodles and cucumbers in sauce in summer and hot food such as hot pots and barbecue in winter. The Chinese are also skilled at adding medicinal ingredients to their food to prevent and treat disease. Aesthetic perception is also important, and

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turnips, cabbage, and wax gourds are often carved into flowers and containers (9). As part of its continual evolution, Chinese traditional dietary culture has incorporated aspects of Western dining. In modern China, there are various types of restaurants with both Chinese and Western elements. Chinese restaurants have expanded their significance beyond dining alone; they are also places of emotional communication, family gatherings, and commercial negotiations.

Based on the considerations of Chinese diet culture, three typical restaurants were selected as survey sites, Hongming Hot Pot (HHP), Alpine Buffet (AB), and LeA Pizza (LAP). The scale, layout, and ambiance of these restaurants are shown in Fig. 1. In terms of the plan, three restaurants were rectangular or nearly rectangular, and their dining areas and kitchens were separated by a partition. In terms of scale, these restaurants ranged in size from 910–1208 m^3, with a maximum capacity of 38–39 tables and 142–172 persons. For decorations, ceilings were often made of gypsum board, wall with brick and marble, and grounds were made of marble or wood. With respect to dining style, these restaurants can be divided into three categories, centralized, separate, and dispersed. In centralized restaurants, diners are seated around a brazier or hot pot so that they may cook their food at their table. In separate dining, such as buffet, many prepared foods are arranged around a central table. The diners walk past the table with their plates and take what they want. Then they sit down to eat, either together or alone. In dispersed dining, diners are offered a menu and select the dishes that they want, and then the dishes are brought to the table, and they serve themselves. (Fig. 1).

In order to evaluate the acoustic comfort level of the auditory environment in restaurants, intensive questionnaire surveys, and objective measurements of the soundscape were performed during five periods covering the whole day: 10:00–12:00, 12:00–14:00, 16:00–18:00, 18:00–20:00, and 20:00–22:00. Diners from each of these periods were extracted for interviews. These interviewees were asked to describe up 3 sounds that they had heard and sort the strength of these sounds, then assess the general acoustic comfort of the restaurant. A five-point bipolar category scale was used in the questionnaire, and the words in the scale were chosen from previous studies: 1) very uncomfortable; 2) uncomfortable; 3) neither comfortable nor uncomfortable; 4) comfortable; 5) uncomfortable.

In order to assess the influence of crowd density on the level of sound pressure, the A-weight sound pressure level was measured immediately after each interview. The 801 sound pressure level meter was set in slow-mode and A-weight, and instantaneous data were read every 10 s at a location at least 1 m away from walls and other main reflectors, 1.2–1.5 m off the ground (10). A total of 5 min of data were collected at each survey position, and then the corresponding A-weight equivalent sound pressure level (LAeq) was derived.

Software SPSS 15.0 was used to establish a database with all subjective and objective results (11).

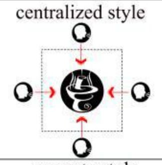
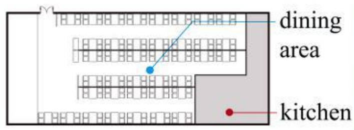
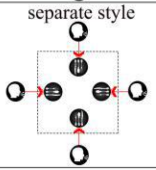
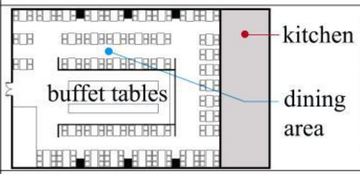
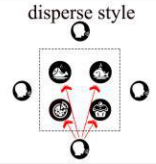
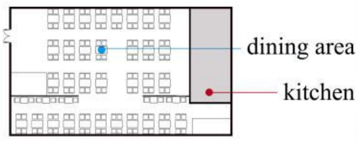
Restaurant Name	Dining Styles	Scale	Layout	Ambiance
HHP	centralized style 	910m^3 39tables 156persons		
AB	separate style 	1208m^3 39tables 172persons		
LAP	disperse style 	942m^3 38tables 142persons		

Figure 1 – Dining styles, scale, layout, and ambiance of three typical restaurants

3. RESULTS

3.1 Influence of sound sources

The relationships between the crowd density and sounds (cooking sounds, surrounding speech, background music, clinking of tableware, and footsteps) users heard in three typical dining styles are shown in Fig. 2. Based on statistics and analysis, this paper showed there to be three main sounds users heard in each restaurant. In centralized settings, for example, the sound of cooking, surrounding speech, and background music were the three types of sounds most noted by diners. Results showed that sounds from different sources can be heard by users at varying dining styles. Diners in centralized restaurants were the only ones who included the sound of cooking in their top three; diners in separate restaurants were the only ones who named footsteps; and those in dispersed restaurants were the only ones who named the sound of tableware. Unlike the other two types of restaurants, customers at centralized establishments prepare their food on-site during the meal. In separate type restaurants, users do not prepare their own food during the meal and communicate with other diners more frequently. In dispersed restaurants, there are many kinds of food, and the frequency of communication between users and use of tableware is even higher.

The sources of sound are also significantly different at different crowd densities. In centralized style dining, background music, cooking, and speech were the main sounds, in which the speech was reported by just 17% users when the crowd was 0 to 0.06 persons/m^2, on the other hand the speech was reported by 67% users at a crowd density of 0.18 to 0.30 persons/m^2. One possible reason for this may be that users share a cooking brazier, which may increase the frequency of communication between users. In separate style restaurants, background music was still the most reported sound, heard by 50% of diners at a crowd density from 0 to 0.06 persons/m^2, while footsteps were reported by 58% of diners at a crowd density of 0.06 to 0.12 persons/m^2. At this time, background music became masked by footsteps. One possible reason for this may be that diners frequently move between dining area and buffet tables, which increases the proportion of footsteps heard. The speech was reported by 60% of diners at a crowd density of 0.12 persons/m^2, and 70% at 0.30 persons/m^2. Footsteps were reported by 40% of diners at a crowd density of 0.12 persons/m^2, and 30% at 0.30 persons/m^2. One possible reason for this is that the footsteps may have been drowned out by surrounding speech. In dispersed style restaurants, background music was reported by 74% of diners at a density of 0 to 0.06 persons/m^2, while 58% of diners at 0.06 to 0.12 persons/m^2. Surrounding speech and tableware were both reported by fewer than 50% of diners. The influence of background music was greater in dispersed dining than in the other two types because there was almost no sound of cooking or footsteps. Surrounding speech was reported by 50% of diners at 0.12 persons/m^2 and 60% at 0.30 persons/m^2, and background music and tableware crashing were reported by fewer than 50% of diners, probably because of the masking effect of surrounding speech.

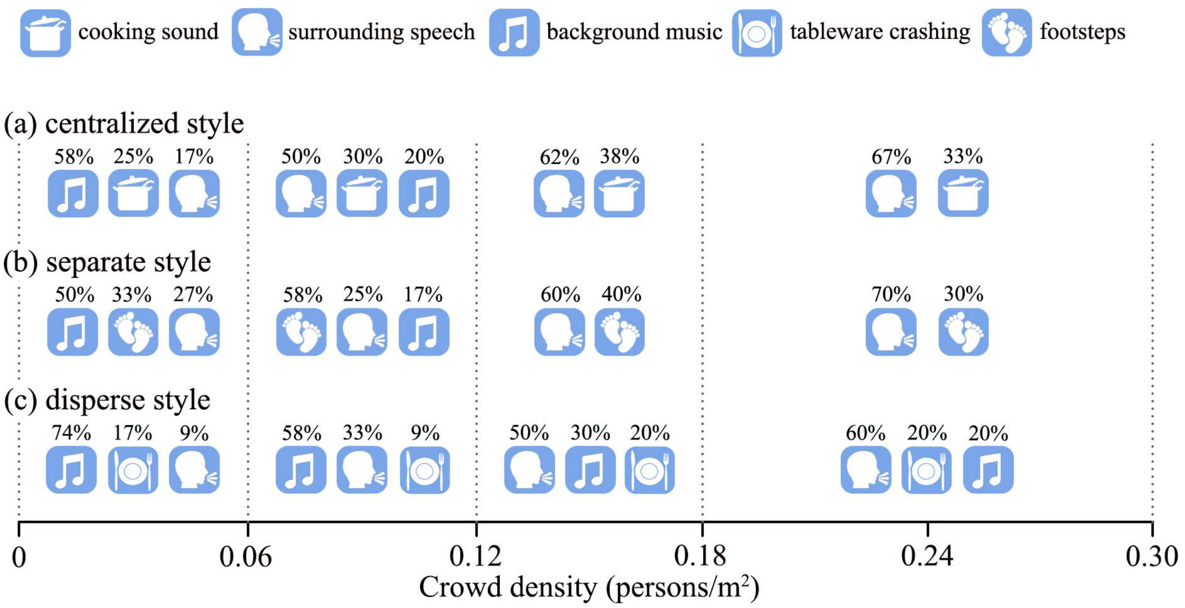


Figure 2 – Relationship between crowd density and the sounds heard by diners in three typical types of dining establishments: (a) centralized style, (b) separate style, (c) dispersed style

3.2 Influence to LAeq

Fig. 3 shows the relationships between crowd density and the measured LAeq for three typical dining styles, with a corresponding linear regression curve and the coefficient of determination R^2. Results demonstrated that there is a general correlation between crowd density and the measured LAeq ($P < 0.001$), with R^2 as 0.669 in centralized dining, 0.703 in separate dining, and 0.753 in dispersed dining, when the crowd density ranged from 0 to 0.30 persons/m^2. As crowd density increased, the number of different sounds and global sound emissions also often increased, so increasing the LAeq. When crowd density increased from 0.06 to 0.25 persons/m^2, the level of sound pressure inside the restaurant can increase by 5.6 dBA with centralized style, 4.9 dBA with separate dining and 3.5 dBA with dispersed dining. For the same crowd density, however, the LAeq of centralized dining was generally higher than that of separate or dispersed, with values of 1.9 dBA and 3.3 dBA. One possible reason for this is that diners in centralized restaurants communicate more frequently than in the two types because of the effects of the sound of cooking. As shown in section 3.1, surrounding speech was the principal sound reported by centralized diners at a crowd density of 0.06 to 0.30 persons/m^2. Unlike in the other two settings, surrounding speech had the greatest influence on the sound environment throughout the dining process. The hot pot provided for cooking in the middle of the table blocked diners' view, which may make talk more loudly to their companions, which is similar to the results reported by the previous study of the auditory environment in open-plan offices (12).

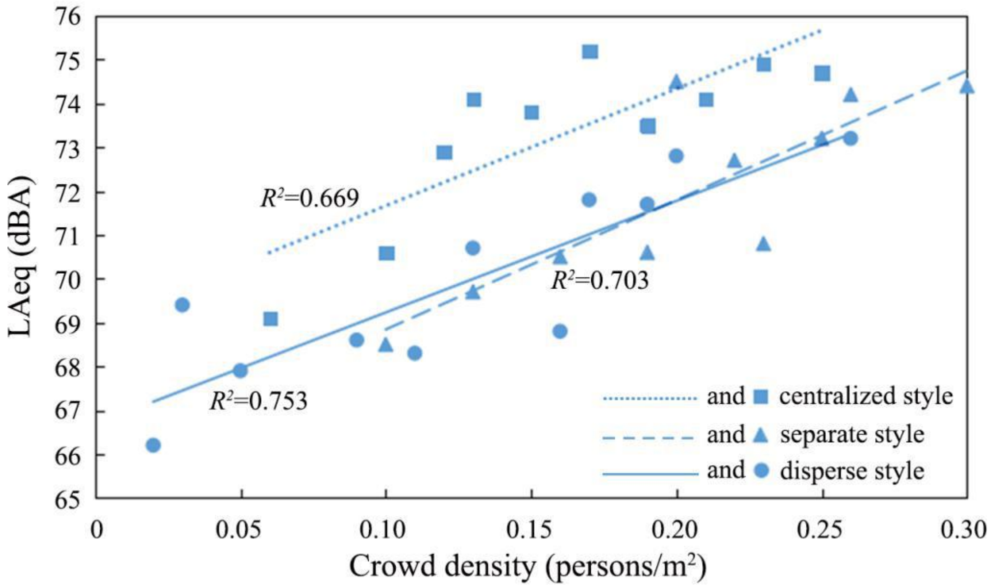


Figure 3 – Influence of crowd density on the measured sound pressure level in three typical dining establishments

3.3 Influence on acoustic comfort

Fig. 4 shows the relationships between the crowd density and the acoustic comfort of diners in three typical dining establishments, including corresponding linear regression curve and the coefficient of determination R^2. This demonstrates that there is a general correlation between the crowd density and the measured LAeq ($P < 0.05$), with R^2 as 0.469 in centralized style, 0.713 in separate style and 0.789 in dispersed style when the crowd density ranged from 0 to 0.30 persons/m^2. In centralized and separate dining, the value of acoustic comfort takes on a parabolic shape, first increasing and then decreasing with crowd density. In centralized dining, when the crowd density is within a certain range, such as 0.10-0.15 persons/m^2, the users usually have better acoustic comfort, with the value from 3.3 to 3.7. The acoustic comfort evaluation score becomes lower at either lower or higher crowd density, such as 0.10-0.15 persons/m^2. With separate dining, when the crowd density is within a certain range, such as 0.15-0.20 persons/m^2, the users usually have better acoustic comfort, with the value ranging from 3.7 to 4.3. The acoustic comfort score becomes lower at a lower or higher crowd density, when the crowd density is within this range, such as 0.15-0.20 persons/m^2. Further analysis showed that, when the crowd density ranged from 0.10 to 0.15 persons/m^2 in centralized restaurants, surrounding speech and sounds of cooking were mainly heard by users and the corresponding sound pressure level was 71.5-73 dBA, which makes users feel more comfortable. One reason for this may be that users prefer to have dinner in these busy establishments and sound environments with lower crowd density make users feel more deserted. However, when the crowd density exceeded this range, although surrounding speech and sounds of cooking were still the main sounds reported by diners, corresponding sound pressure levels increased to 73–75.5 dBA, which made users uncomfortable. The linear trend of acoustic comfort with varying crowd density in dispersed dining, however, was significantly different from the other two dining styles. As crowd density increased, decreasing the acoustic comfort of diners. The users usually reported better acoustic comfort, with the values ranging from 3.3 to 4.3, when the crowd density ranged from 0 to 0.12 persons/m². One possible reason for this is that background music was the main reported sound, so users had a better acoustic comfort evaluation with the crowd ranged from 0 to 0.12 persons/m². As the crowd density increased, however, increasing LAeq in restaurants and background music became more and more completely drowned out by unpleasant sounds, such as surrounding speech. Consequently, acoustic comfort showed a decreasing linear shape with increasing the crowd density at disperse style restaurant.

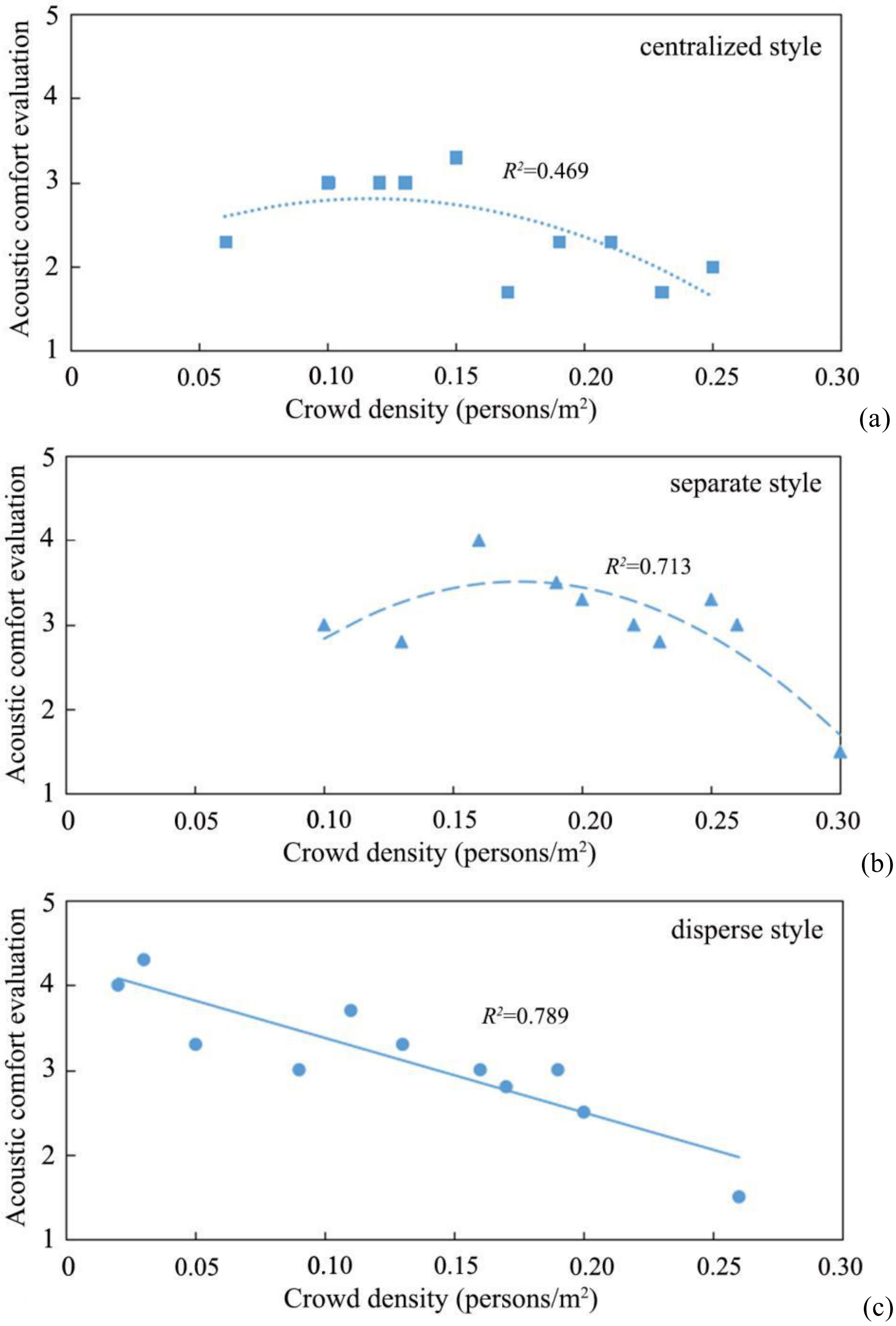


Figure 4 – Relationships between the crowd density and the acoustic comfort evaluation, with quadratic regressions and coefficients R^2, in (a) centralized, (b) separate, and (c) dispersed dining

4. CONCLUTIONS

Based on a questionnaire survey and acoustic measurement, the influence of crowd density on the evaluation of soundscape was analyzed, considering several dining styles, such as centralized, separate, and dispersed dining. It can be seen from this study:

(1) On the influence of crowd density on types of sound, results showed that the types of sound noted by diners differed significantly at different crowd densities. For example, in centralized dining, background music was the primary reported by diners at a crowd density of 0–0.06 persons/m^2, while surrounding speech was reported at a crowd density of 0.06–0.30 persons/m^2.

(2) On the influence of crowd density on sound pressure, as crowd density increased, LAeq also increased. As crowd density increased from 0.06 to 0.25 persons/m^2, the sound pressure level inside the restaurant increased by 5.6 dBA in centralized dining, 4.9 dBA with separate dining, and 3.5 dBA with dispersed dining.

(3) In terms of the influence of the crowd density on acoustic comfort, with centralized type and separate dining, the value of acoustic comfort showed a parabolic shape that first increased and then decreased with increasing crowd density. When the crowd density ranged from 0.10 to 0.15 persons/m^2, the acoustic comfort increased from 3.3 to 3.7 in centralized dining. When the crowd density ranged from 0.15 to 0.20 persons/m^2, the acoustic comfort increased from 3.7 to 4.3 in separate dining. In dispersed dining, acoustic comfort decreased as crowd density increased.

This study provides a reference for the improvement of the evaluation of soundscapes in typical Chinese restaurants and the design of such establishments using a predictive model of the dining sound environment of artificial neural networks.

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REFERENCES

1. Kang J. Numerical modeling of the speech intelligibility in dining spaces. APPL ACOUST. 2002;63(12):1315-1333.
2. Chen X. Research on acoustic environment of underground dining space. Harbin, China: Harbin Institute of Technology; 2012.
3. Shi JH, Qin G, Wu JG. Restaurant's lampblack machine and fan noise nuisance case study. Environment and Development. 2013;25(11):153-155.
4. Wang MY. Study on Chinese restaurant indoor acoustic environment. Xi'an, China: Chang'an University; 2012.
5. Schafer R M. The tuning of the world. New York, USA: Knopf; 1977. (Reprinted as Our sonic environment and the soundscape: The tuning of the world. Destiny Books, 1994.)
6. ISO. ISO 12913-1 Acoustic-soundscape-Part1: Definition and Conceptual Framework. International Organization for Standardization. 2014.
7. Si MQ. Records of the historian. Beijing, China: Zhonghua Book Company; 2006.
8. Lv XM, Ding X, Dai YY. The forming process and background of eight Chinese cuisines. Food and Nutrition in China. 2009;(10):62-64.
9. Yao WJ. History of Chinese diet books. Shanghai, China: Shanghai Guji Press; 2011.
10. Meng Q, Kang J, Jin H. Field study on the influence of spatial and environmental characteristics on the evaluation of subjective loudness and acoustic comfort in underground shopping streets. Applied Acoustics. 2013;74(8):1001-1009.
11. Li XS, Chen ZZ. Correctly using SPSS software for principal components analysis. Statistical Research. 2010;27(8):106-108.
12. Wang DY. Study on acoustical environment in open-plan offices. Nanjing, China: Southeast University; 2004.