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Technical note

An investigation of acoustical environments in the elderly care facilities

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ABSTRACT

62 rooms including living rooms, common rooms and dining rooms in 11 elderly care facilities had been measured, and some objective acoustical parameters in these rooms were measured such as background noise level (BNL) and reverberation time (RT). The range of BNL in 62 rooms was from 26.8 dBA to 67.2 dBA, and the mean BNL was 41.3 dBA and the standard deviation (SD) was 10.1 dBA. In these rooms, the averaged BNL in the living rooms was lower than those in the common rooms and the dining rooms, while the dining rooms had the highest averaged BNL. The RT in 500–4000 Hz octave bands, early-to-late sound ratio (C_{50}) in 500–4000 Hz octave bands and speech transmission index (STI) in these rooms were 0.36–1.86 s, −4.48 to 9.67 dB and 0.47–0.81, respectively. Their mean values were 0.94 s, 1.73 dB and 0.64, and the SD were 0.40 s, 3.09 dB and 0.09, respectively. For all these measured rooms, the living room had a relatively short RT with a good speech intelligibility, while the dining room had a long RT with a fair speech intelligibility. To provide the elderly people with a good speech communication environment, some sound absorption and insulation treatment measures should be taken for the long RT and high BNL in the rooms of the elderly care facilities to reduce the BNL and RT and improve the speech intelligibility in these rooms.

1. Introduction

Compared with the acoustical characteristics of performance space, such as concert hall, opera house, the acoustical characteristics of the elderly care facilities has usually been ignored. Studies have shown that the elderly people are more difficult to understand speech in the environment with high background noise level (BNL) and long reverberation time (RT) than young adults people because of elderly's hearing loss [1]. According to the data released by the National Bureau of Statistics of the People's Republic of China, the number of elderly people over 60 years old accounts for 16.14% of the total population by the end of 2015 in China, which was an increase of 3.94% from the end of 2010 [2]. With the increasing of the elderly people, more and more old-age care institutions emerged. There were 167 elderly care institutions (nursing home, homes for elderly) in Guangzhou in 2015 [2]. Poor room acoustical environment will not only lead the barriers in speech communication for elderly people, but also cause many psychological problems for the elderly, such as loneliness, self-esteem and autism. These problems greatly prejudiced the quality of life of the elderly people and their family relationships.

Kameda and Sakamoto [3] conducted the objective acoustical measurement and subjective questionnaire survey to evaluate the influence of the station concourses' acoustical environment on the elderly's verbal communication. Their results showed that the elderly people would be much easier to understand people's voice when the signal to noise ratio was above 10 dB. Reinten [4] performed acoustical measurements in 8 common rooms in three different elderly care facilities and conducted a survey on the perception of speech intelligibility in common rooms by elderly people using a questionnaire. The results showed that there were poor correlation between the subjective survey results and the objective acoustical parameters, and no reliable conclusions were drawn. He found that five of the eight rooms were high BNLs and long RTs which can be prevented with the introduction of guidelines. Hout et al. [5] measured BNLs in five common rooms and five sleeping rooms of care facilities for older adults, respectively. The results show that the mean levels of BNL during the daytime were 55.3 dBA and 42.7 dBA in common rooms and sleeping rooms, and the mean BNL in the night period were 32.2 dBA and 32.1 dBA, respectively. They found that the peak sound levels were mostly caused by the slamming of doors (e.g. closets) and activities of residents and professional caregivers. Davies et al. [6] conducted a survey of 207 elderly people with hearing loss. They found that the speech communication of elderly people was significantly affected by the presence of background talkers in a reverberant environment. Their results showed that the elderly respondents tended to focus on their own hearing loss rather than on how particular acoustic conditions exacerbate a

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communication difficulty. Their responses demonstrated that background speech, reverberant conditions and background noise were the main causes.

So far, most acoustical researchers mainly investigated the acoustical characteristics of performance space, conference room, and so on. In recent years, they also investigated the acoustical environment in classrooms, especially elementary school classrooms. However, there are few studies on the acoustical environment in the elderly care facilities. In present study, 62 rooms including the living rooms, common rooms and ding rooms in 11 elderly care facilities were investigated. The objective acoustical parameters such as the BNL, early decay time (EDT), RT, early-to-late sound ratio (C_{50}) and Speech Transmission Index (STI) in these rooms were measured and analyzed.

2. Method

62 functional rooms in the 11 elderly care facilities were selected. They were 23 living rooms, 27 common rooms and 12 dining rooms. The living rooms includes single room, double room and multi-room according to the number of elderly people lived in the room. Each living room was equipped with a separate toilet. The common rooms includes painting room, calligraphy room, reading room, entertainment chess room, multi-media room, rehabilitation room, etc. Most of these rooms were in shape of rectangular, while other rooms were in irregular shape. All living rooms and dining rooms, and most of common rooms had no acoustical treatment with the plastered and painted walls and ceilings, and wooden or ceramic tile floors. A few common rooms (such as reading room, multi-media room) had acoustical treatment, some walls and ceiling had sound absorption panels with the wooden floors. The number and the volume of the measured rooms were shown in Table 1. The data shown in the brackets were the volume of the rooms. The data with a superscript represented the average volume of the same type of functional rooms.

The room impulse responses were measured by using a sine sweep signal generated from Cool Edit Pro with Aurora acoustical plug-in and reproduced by an omni-loudspeaker. During the test, the tables, chairs, furniture and other facilities in the rooms were not removed out, and the doors, windows were closed and electrical equipment was turn off. The omni-loudspeaker was set at a corner, and 1.5 m from the ground in the room. The microphone at the receiver point was 1.2 m from the ground. Three receivers (Fig. 1a) were set in the small rooms (such as the living room) and 4–8 receivers (Fig. 1b) in the large rooms such as dining rooms and some common rooms. The objective acoustical parameters, such as EDT, RT, C_{50} and STI without noise, were calculated from the measured room impulse response by using the DIRAC room acoustics software.

Noise in living rooms and common rooms was measured in unoccupied state, but the noise in dining rooms was measured in the normal service condition with less people during the test. There are a few common rooms connected with other rooms. During the test, all rooms of doors and windows were closed and electrical equipment were turned off. The BNL in each receiver was measured by a B&K2250 portable acoustical analyzer. The microphone was about 1.5 m from the ground. The arrangement of receivers was the same as those for the measurement of room impulse response. The average value of the BNLs across all receivers in a room was taken as BNL in the room.

Table 1
The statistics of the number and volume (m^3) of the rooms in 11 elderly care facilities.

Elderly Care facilities	Living rooms	Common rooms	Dining rooms
A	1 (67.8)	2 (794.8[a])	1 (493.5)
B	3 (57.2[a])	3 (288.5[a])	1 (680.3)
C	2 (47.8[a])	2 (364.6[a])	1v (795.5)
D	1 (41.9)	1 ((234.9)	1 (450.6)
E	2 (65.0)	1 (311.9)	1 (128.0)
F	3 (71.5[a])	3 (444.1[a])	1 (499.7)
G	2 (54.5[a])	4 (244.0[a])	1 (443.3)
H	2 (61.4[a])	3 (650.6[a])	1 (431.6)
I	3 (63.1[a])	3 (526.7[a])	2 (183.8[a])
J	2 (71.5[a])	3 (207.2[a]))	1 (236.1)
K	2 (71.4[a])	2 (366.2[a])	1 (278.2(

[a] The average volume of the rooms in the same type.

3. Results and analysis

The factors that affected the verbal communication of the elderly mainly are the high BNL and long RT in the elderly care facilities. The C_{50} and STI which calculated from the room impulse response were used to evaluate the objective speech intelligibility. In present study, the effect of the noise was not taken into account for the STI. Table 2 showed the statistics results of the BNL, EDT, RT, C_{50} and STI in the 62 rooms. The EDT and RT were the mean in 500–1000 Hz octave band, and the C_{50} is the mean in 500–4000 Hz octave band

3.1. BNLs

Low BNL is necessary for elderly care facilities. It provides a quiet living environment for the elderly. It can be seen from Table 2 that the average BNL of 62 rooms was 41.3 dBA, and standard deviation (SD) was 10.1 dBA, and the range of BNL of 62 rooms was from 25.7 dBA to 67.2 dBA. Specifically, the mean values of BNL of living rooms, common rooms and dining rooms were 36.8 dBA, 40.7 dBA and 55.1 dBA, respectively. The BNLs in living rooms were from 25.7 dBA to 46.4 dBA, and in the common rooms from 26.2 dBA to 54.0 dBA and in dining rooms from 34.5 dBA to 67.2 dBA. Fig. 2 showed the detailed BNLs in the living rooms, common rooms and dining rooms for each elderly care facility. In Fig. 2, some results with the error bars represented the mean BNL of all same type functional rooms in the elderly care facility and corresponding SD. It can be seen from Fig. 2, there were no significant difference in BNLs between living rooms and common rooms in unoccupied state except in care facilities A, D and E. Due to connecting with another room, the common rooms in facilities A, D and E were affected by noise from other rooms, so BNLs in common rooms were higher than those in the living rooms in these elderly care facilities. However, BNLs in the dining rooms were higher than those in the living rooms and common rooms except for the care facility F. The dining room's BNL was measured under the normal service condition. Moreover, most of the dining rooms were adjacent to the kitchen. Fig. 3 showed a distribution of BNLs in 1/3 octave band for three different type rooms in elderly care facility G. As shown Fig. 3, the noise in the living room and the common room was mainly concentrated in 100–3200 Hz, while the noise in the dining room was in 250–5000 Hz with the noise level over 20 dB higher than that in the living room and common room. Because the dining room was connected to the kitchen and a small shop where noise was transmitted to the dining room to result in a high BNL in the dining room.

3.2. RTs

The EDT, RT, C_{50}, STI were obtained by averaged across all receivers in each room. The mean values EDTs and RTs in 62 rooms in 11 elderly care facilities were given in Table 2. The EDTs in living rooms, common rooms and dining rooms were 0.33–0.89 s, 0.33–1.80 s and 0.57–1.88 s, and RTs were 0.36–0.96 s, 0.37–1.79 s and 0.64–1.86 s, respectively. In some common rooms and dining rooms, the volume of these rooms was relatively larger and no acoustical treatment was employed, the tables, chairs and other furniture were the only sound absorbing materials in these rooms. This resulted longer EDTs and RTs in these common rooms and dining rooms. It can be seen from Table 2, the mean of EDTs and RTs in these rooms were 0.89 s and 0.93 s. They were higher than the values of 0.68 s and 0.61 s from 8 common rooms measured by Reinten [4]. Fig. 4 showed the mean of EDTs and RTs