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An investigation of speech intelligibility for second language students in classrooms

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ABSTRACT

In this paper, speech intelligibility in 9 classrooms of a middle school and 11 classrooms of a university in Hong Kong was investigated. The subjective speech intelligibility tests were conducted with students aged from 12 to 21 in these classrooms. Besides, objective acoustical measurements were performed in each listening position and testing conditions in each classroom. The relationship between subjective speech intelligibility scores and speech transmission index (STI) was discussed based on regression models. The effects of different age groups on the speech intelligibility were compared. The results show that speech intelligibility scores increase with STI value for all age groups. The speech intelligibility scores increase as the age increases under the same STI condition. The differences between age groups are decreased with the increase of STI values. English speech intelligibility scores in Hong Kong are always lower compared with native language researches under the same values of STI. Better STI values and better acoustical environment are needed because English is not the native language for students in Hong Kong but the official educational language.

1. Introduction

The indoor acoustical environment is not only related to productivity, health anxiety and comfort, but also is related to acoustical quality in a space [1–4]. The education of every citizen is essential to modern societies. Most formal education takes place in the classrooms, where a high level of acoustical quality is required [5]. Evidence shows that poor room acoustics, such as excessive noise and reverberation, reduce speech intelligibility in a classroom and interrupt verbal communication between teachers and students [6]. The room acoustical factors that affect speech intelligibility include reverberation time (RT or T_{30}), early decay time (EDT), early-to-late sound energy ratio (C_{80}), signal-to-noise ratios (SNRs) and speech transmission index (STI) [7]. Bradley [8] first indicated that SNR was an essential factor compared with RT. Moreover, STI method was based on the assumption that the degradation of speech intelligibility in rooms was related to the reductions in the amplitude modulations of speech signals by both room acoustics and ambient noise [9,10]. The STI method is a combination of both room acoustics and signal-to-noise component into objective measure of speech intelligibility in rooms. The STI method was shown to be successful by Peng in evaluating in Chinese speech intelligibility of an elementary school [11,12].

Several studies were devoted to the study of the speech intelligibility in classrooms. Some researchers conducted a series of speech intelligibility tests in classrooms for teachers and children aged 8–15 years old under a variety of road traffic noise condition with RT from 0.7 s to 1.5 s [13]. Bradley and his co-workers [8,14,15] investigated speech intelligibility using the English Fairbank rhyme test in occupied classrooms with RT from 0.39 s to 1.20 s for children aged 12 to 13 years old through a small loudspeaker with its directivity similar to human's mouth. Peng and his co-workers [16,17] have investigated acoustical parameters (e.g. RT, SPL, STI, etc.) in the elementary classrooms and discussed the relationship between Chinese speech intelligibility and the acoustical parameters. The results indicated a high correlation between Chinese speech intelligibility and these acoustical parameters.

However, in a modern and globalized world, the interaction between multilingual and multicultural people in public, commercial and social spaces is gaining importance, and oral communication is at the center of this interaction [18]. The differences in intelligibility among languages have been noticed. Houtgast and Steeneken [9] indicated that language specification effects could be a factor causing disparity among 10 Western language tests. Different linguistic environments and different educational modes may lead to different relationships between speech intelligibility and acoustical parameters. Kang [19] compared the differences in intelligibility between English and Mandarin under reverberation conditions and noisy conditions. Other researchers reported the impact of room acoustical conditions on the

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speech intelligibility of different languages [18,20]. As for classrooms in Hong Kong, it is special with other classrooms that English as the second language among local citizens is widely used in education. The relationship between speech intelligibility scores and STI in second-language classrooms through in situ measurement for young listeners has not been reported so far.

In the current study, speech intelligibility in classrooms was assessed by students in a middle school and a university. The speech intelligibility test signals recorded in the anechoic chamber were reproduced through a loudspeaker with its directivity similar to human's mouth. The aim is to investigate the speech intelligibility scores among students in Hong Kong and compare the relationship between subjective speech intelligibility scores and acoustical parameters to the native language speaking country.

2. Experimental method

2.1. Classrooms for investigation

In this study, 9 classrooms in a middle school and 11 classrooms in a university in Hong Kong were investigated. Classrooms in the middle school were not decorated with acoustical treatment (lime walls, cement floors, etc.). Classrooms in the university were well decorated with acoustical treatment (sound absorptive panels, sound absorptive ceilings, floor isolation mat, etc.). All the classrooms were rectangular in shape and the temperature in Hong Kong during the investigation was around 27 °C, and the humidity was around 90%. The dimensions of the classrooms are shown in Table 1. Classrooms 3A, 3B, 3C and 3D refer to Grade C (aged from 14 to 16). Classrooms 2A, 2C, and 2D refer to Grade B (aged from 12 to 14). Classrooms 1C and 1D refer to Grade A (aged from 12 to 13) in the middle school.

Four listening positions were arranged in each classroom, a schematic drawing of classroom 3A was shown as an example in Fig. 1. Other desks and chairs were not shown in the classroom. Speech intelligibility tests were accomplished with junior students in middle school and undergraduates in university. The junior students aged from 13 to 15 years old and undergraduates aged from 19 to 21 years old (adults). Referring to the previous studies, the ages of participants had a significant influence on the performance of the speech intelligibility tests [21–23]. Elliott [21] reported the performance of children aged under 15 years old performed significantly poorer than adults. In the current study, the speech intelligibility test results of junior students and undergraduates were used for discussing the differences between age groups.

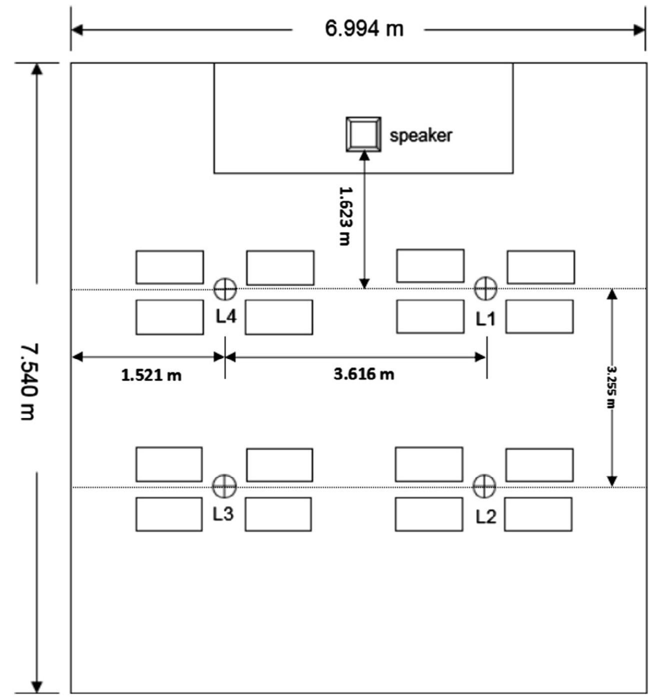

Fig. 1. Schematic drawing of classroom 3A and showing of listening positions.

Table 1
The dimensions of all the classrooms.

School	Classroom	Length * width/m^2	Height/m	Volume/m^3
Middle school	3C	6.981 * 7.535	2.983	156.91
	3B	6.965 * 7.549	2.962	155.73
	3A	6.994 * 7.540	2.993	157.84
	3D	6.968 * 7.513	2.963	155.11
	2A	6.796 * 7.496	2.980	151.81
	2C	6.953 * 7.523	2.975	155.61
	2D	6.966 * 7.529	2.944	154.40
	1C	6.968 * 7.567	2.944	155.23
	1D	6.959 * 7.529	2.991	156.71
University	A	10.988 * 8.224	2.534	228.99
	B	8.906 * 5.846	3.087	160.72
	C	8.836 * 8.335	2.458	181.03
	D	8.168 * 5.541	2.409	109.03
	E	8.259 * 6.022	2.524	125.53
	F	8.868 * 5.245	2.502	116.37
	G	9.845 * 7.202	2.991	212.07
	H	8.156 * 5.625	2.423	111.16
	I	8.298 * 5.864	2.465	119.95
	J	8.956 * 8.265	2.564	198.06
	K	8.532 * 6.658	2.523	143.32

2.2. Speech intelligibility test materials

In the current study, the speech intelligibility test word list was based on ANSI S3.2-1989 [24]. Test materials were selected directly to compare the phonetically balanced (PB) word scores. The test signal material which contained 50 six-word rows of similar-sounding English words were used. The test words in the carrier phrase are "The x row reads y," where x and y are replaced by the number of row and the pronunciation of the corresponding word. Readers were told to read the materials at a constant speed (4 words per second) and 65 dB sound pressure. One male and one female local residents who are English teachers in middle schools were chosen as readers in the experiment. The whole recording procedure was completed in the anechoic chamber of the Hong Kong Polytechnic University. As shown in Fig. 2, a random-field microphone (B&K 4935) was placed at a distance of 0.5 m from the speaker and 1.0 m above the ground in the anechoic chamber, meanwhile, the speaker sat on the chair and the microphone was placed on the tripod in front of the speaker. The signal was collected from pulse hardware (B&K 3160-B-042) into the computer. All of the children were native Cantonese speakers, and no medical reports of their hearing impairment were reported from them and their parents. They represented the typical general listening audiences.

2.3. Speech intelligibility tests in the classrooms

The speech intelligibility test signals recorded in the anechoic chamber were reproduced by a loudspeaker which is similar to human mouth. The loudspeaker was located at the center of the platform where a teacher frequently stands and orients toward the students (location of the loudspeaker see Fig. 1). It was set 1.5 m above the floor and 0.5 m from the blackboard on the front wall. The speech level at 1 m directly in front of the loudspeaker was set at 65 dBA by adjusting the volume of the loudspeaker when the subjects seated around the listening positions. Two testing conditions were investigated in the experiment. The first condition was carried out with the mechanical ventilation system