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Technical note

Measurement and analysis of teaching and background noise level in classrooms of Chinese elementary schools

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ABSTRACT

The background noise and teacher's teaching speech levels were measured in classrooms of Chinese elementary schools during class time in two conditions of using or without using sound reinforcement system (SRS). The ranges, mean values and standard deviations of the measurement data are reported and analyzed. It is found that in the condition of without using SRS, the relationship between the background and teaching levels satisfies the lambert effect quite well, while in the other condition of using SRS, this effect does not hold. Differences of background noise level and thus teaching level seem to be found between different courses but not be found between genders of the teachers. Finally, the background noise level is observed generally higher in classrooms of junior grades than the senior, and so is the teaching level.

1. Introduction

Favorable acoustical environment in the classroom helps improve the quality and efficiency of teaching, and secure the mental and physical health of teachers and students. Noise in the classroom not only hampers the students to hear the teacher clearly, but also increases the burden of the teacher who has to speak louder. There are many national standards of different countries concerning on the background noise in classrooms with different level of strictness. While, for example, American standard ANSI-S12.60 suggests that the background noise in classrooms should be lower than 35 dBA [1], Chinese standard GB 50118–2010 "Code for Design of Sound Insulation of Civil Buildings" requires that the permitted maximum background noise in classrooms is 45 dBA [2]. Knecht [3] carried out measurements in 32 empty classrooms of elementary schools in Oho state of America. The background noise level ranges from 32 to 67 dBA in the classrooms, and is below 35 dBA in only 4 of them. Kiri [4] made statistical analysis on 25 published research reports, and summarized that the background noise ranges from 22 to 70.5 dBA in empty classrooms and from 48 to 85 dBA during teaching time. Some researchers also found that the noise in classrooms decreases with the increase of age of students [5]. Bradley [6] pointed out that compared with reverberation time, signal noise ratio is an acoustical index that deserves even more concern. Song [7] suggested that in order to achieve favorable speech intelligibility, the ideal signal noise ratio should be more than 15 dBA.

The teaching level in the area of students were measured in many researches [4,5,8–11]. Picard and Bradley [5] made statistics of measured data in related researches before 2001 involving from elementary schools to universities, and found the mean value of teaching level is about 60.1 dBA. Hodgson et al. [8] pointed out the teaching level in classrooms of universities is normally within the range of 40–80 dBA. In classrooms of elementary schools, Airey [9] reported the mean value of teaching level is 69.6 dBA with the minimum and maximum values being 41.8 dBA and 83.6 dBA respectively. Bottalicoa and Astolfi [10] measured the teaching level at a distance 1 m away from each of 73 teachers in elementary schools, which is 62.1 dBA for the female teachers and 57.7 dB for the male teachers averagely. Sato and Bradley [11] measured the teaching level at 108 seats in 27 classrooms of elementary schools. The average value of overall data is 60.1 dBA with the standard deviation of 4.4 dBA, while the average values for the grades 1, 3 and 6 are 59.9, 61.7 and 58.8 dBA respectively.

However, the teaching and background noise levels in the classrooms of Chinese schools were seldom reported. In this paper, the teaching and background noise levels in classrooms of elementary schools are measured.

2. Methods

Totally 46 classrooms of 6 grades in 3 elementary schools of Guangzhou city, China, were chosen for the measurement, involving 3 courses of Chinese, mathematics and English. The middle frequency reverberation times in these unoccupied classrooms are between 0.4 s

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and 1.3 s. The classrooms all have a rectangular plane and a volume between 172.5 and 268.3 m^3. There are 30–45 students in each classroom. Most classrooms of younger grades have installed wireless sound reinforce system (SRS). Totally 64 teachers, 12 males and 52 females, participated the measurements, and 26 of them used SRS. The SRS system is mainly composed of a built in and portable one-channel amplified speaker. The size of the speaker is small, for example, a typical one is 82 mm × 108 mm × 37 mm. The teacher can conveniently wear the system on his or her body, normally at the waist. As found in measurements, in classrooms of lower grades, students tend to make higher level noise and lose their attention to the class more easily, and the teacher is more likely to use SRS to protect his or her voice and make the students more concentrated on the study by higher teaching level. In general, the lowest teaching level will be enhanced by SRS about 10–15 dBA, while the highest teaching level is close to the condition without using SRS because with the help of SRS the teacher needs not to raise the voice to achieve a high teaching level.

One or two transducers were set in the classroom under every measurement. The transducers set at the middle of the front rows of students or (and) the middle of the rear rows. They were placed 1.1 m high over floor to approximate the height of ears of seated children.

The signals, which contain teaching sound and background noise in the classroom, were recorded with sampling rate of 44.1 kHz. Every signal is longer than 15 min. On Basis of statistical significance, Hodgson [8] pointed out that the Gaussian Mixture Model (GMM) is useful to separate and calculate the teaching level and background noise level. In GMM, the A-weighted overall sound level and background noise level are calculated with time intervals of 200 ms at first, and the teaching level and background noise levels are then obtained by using two normal distributions to fit them respectively.

3. Results and discussions

The data of 98 cases were obtained, including 59 ones without using SRS (condition 1) and 39 ones using SRS (condition 2). For the cases without using SRS, the range of the background noise level is 51.1–69.7 dBA, and the range of the teaching level is 58.0–82.4 dBA, while for the cases using SRS, the ranges are 61.1–73.6 dBA and 71.4–82.9 dBA respectively. Those data fall in the statistic range of 48–85 dBA reported by Kiri [4]. However, the range of teaching level measured in condition 1 is much wider than condition 2, with the lowest level reaching 58.0 dBA. This is due to the influence of teacher position, namely being far or near to the audience at different times. But the influence becomes less obvious when SRS is used. The means and standard deviations (SD), as well as the level ranges, are listed in Table 1. In the table, BNL represents the background noise level and TL the teaching level, and the numbers in brackets are the sample sizes.

Among the three investigated schools, one directly faces a nearby road of heavy traffic, and another is separated from the road by buildings but traffic noise is still heard. However, the measurements show that the main contributor of the classroom background noise is the activity of students inside. The neighboring classrooms and nearby sports ground of the school are the contributors of second importance. The minimum, maximum and mean values of teaching and background noise levels in condition 2 are all higher than condition 1. The tests of homogeneity of variance suggest that, at the significance level of $\alpha = 0.01$, the measured background noise level of two conditions are samples from two populations of different variances (namely the variances or standard deviations are significantly different), and so are the measured teaching level. And then, the tests of means support that, at the significance level of $\alpha = 0.001$, the means of background noise level of the two populations (using or without using SRS) are different, and so are the means of teaching level. The fact that the mean value of the background noise level in condition 2 is higher than in condition 1 while the standard deviation is lower, implies that there might be a stable component, perhaps the quite stead traffic noise for example, added into the background noise in condition 2, compared with condition 1. When the teacher feels the environment is noisy, he or she will tend to use SRS, and reversely when the teaching level is enhanced by SRS, the background noise level might be enhanced.

Table 1
Ranges, means and standard deviations of measured levels/dBA.

Condition	SPL	Min	Max	Mean	SD
Without using SRS (59)	BNL	51.1	69.7	62.8	4.7
	TL	58.0	82.4	72.0	5.5
Using SRS (39)	BNL	61.1	73.6	66.2	2.9
	TL	71.4	82.9	77.8	3.2

Based on analysis of known researches, Picard and Bradley [5] found that if background noise level arises by 1 dB, the teacher generally arises the teaching level accordingly by 1 dB as well, which is named as “lambert effect” [12] and more obvious in conditions without using SRS. This effect implies a trend that teaching level has a same rate of increase as the background noise level, and the signal noise ratio (SNR), which is the result of teaching level subtracting its corresponding background noise level, distributes around a constant mean value with a small standard deviation. In other words, the lambert effect means that there is a strong linear relationship, $y = x + \mu_{SNR}$, between the teaching and background noise level, where y represents teaching level, x the corresponding background noise level and μ_{SNR} the mean value of SNRs.

Fig. 1. plots the data of teaching vs background noise level of the 59 cases without using SRS. For checking whether the lambert effect is satisfied for the data in this study, we first make least squares linear regression on these data by forcing the slope of the regression line to be unit. The solid line in Fig. 1 represents the following regression equation:

$$y = x + 9.24 \tag{1}$$

where the standard error of the regression is 2.29 dB. The intercept 9.24 in Eq. (1) represents the mean value of SNRs, and the standard error of the regression is just the standard deviation of SNR values.

The dashed line in Fig. 1 is the result of an ordinary least squares linear regression directly made on the data, which shows trivial difference from the thick line; the corresponding regression equation is

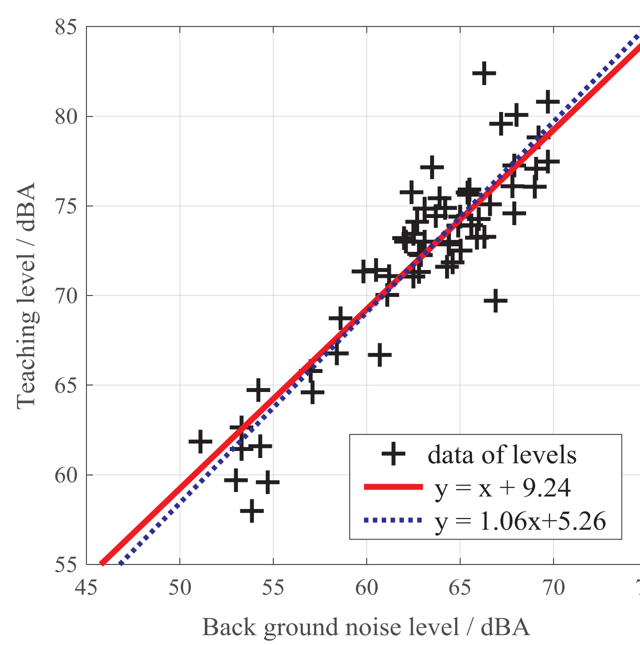

Fig. 1. The teaching and background noise levels of cases without using SRS.