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Investigation of Chinese word recognition scores of children in primary school classroom with different speech sound pressure levels

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ABSTRACT

Chinese word recognition (CWR) test was conducted by grades 3 and 5 children under the different conditions of reverberation time (RT), background noise level (BNL) and speech sound pressure level (SSPL) in three primary-school classrooms. The CWR scores and signal to noise ratios (SNRs) have been obtained at listening positions. Results show that the CWR score for grades 3 and 5 children increases with increase of SSPL, decrease of RT or increase of age, but it decreases with increase of BNL under the same conditions. For a mixed noise of 56 dBA (speech-spectrum-like noise and ambient noise), the CWR scores in the classroom for grades 3 and 5 children reach a peak at SNR of 15–20 dBA under the same RT and age of children condition. For the natural ambient noise, the CWR score for grades 3 and 5 children gradually increases with increase of the SNR. The high SSPL could not guarantee good CWR for children in classroom, which also depends on RT and BNL in classroom. When the classroom has long RT or high BNL, the increase of SSPL would not be necessarily to achieve better CWR. The novelty of the present study is to further evaluate and confirm the results under environments of real classrooms (not simulated room in laboratory).

1. Introduction

Speaking and listening are the primary communication in a classroom. An effective learning space depends on some basic acoustical factors including (1) appropriate reverberation time (RT), (2) low background noise level (BNL) and (3) preferred speech sound pressure level (SSPL) [1]. These acoustical factors play a critical role in establishing a preferred learning environment. An environment with poor speech intelligibility affects concentration and academic achievement of children [2]. Many existing studies have investigated the acoustical environments in classrooms and most of them related to RT and BNL [or signal-to-noise ratio (SNR)] [2–7]. Bradley, Hodgson and their colleagues [3–6] have investigated the relationship between these factors and speech intelligibility by carrying out a series of experimental measurement and theoretical studies in classrooms. Some of their studies suggest that noise is the most critical factor, and the design criteria for acoustical environments in classrooms should be based upon speech intelligibility [3–5]. Shield [2] has investigated the effects of BNL on the children's achievement. Negative correlation between the BNL and children' achievement has been found.

Kryter [8] has explored the influence of different SSPL and BNL on speech intelligibility in a reverberation environment. Knudsen and Harris [9] have investigated the percentage of syllable articulation as a function of SSPL with noise free and noise of 43 dB under a condition of no reverberation. They found that the articulation rapidly increases with increase of SSPL. Song [10] has discussed the influence of SSPL and SNR on speech articulation using a mono room impulse response with 0.5 s RT in a virtual classroom. Peng [11] has investigated Chinese Mandarin speech intelligibility using phoneme balance words test for adults under different SSPL conditions in a simulated classroom and discussed the effect of different SNRs on Chinese Mandarin speech intelligibility with different BNLs. However, the results from Peng and Song are obtained from adults and from the virtual classroom where the acoustical environment may be different from real classrooms.

On the other hand, even though speech intelligibility in a classroom is satisfactory for adults, it is not necessarily satisfactory for children under the same SSPL and BNL condition in real classroom conditions. This is because children's phoneme identification abilities may not be well developed until 13–15 years old and children's auditory perception has not reached the adult level [12–14].

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Although Peng et al. [15,16] has investigated the effects of the reverberation and noise on the speech intelligibility of children in the primary school classroom, the test of speech intelligibility has been performed in a given SSPL. In their study, the SSPL at 1 m directly in front of the loudspeaker was set at 65 dBA by adjusting the volume of the loudspeaker [16]. No research was reported on the effect of SSPL on the subjective speech recognition of children in the primary school classroom.

In the present study, three classrooms with different RTs times have been selected under different BNL and SSPL conditions. Subjective Chinese word recognition (CWR) for grade 3 and grade 5 children has been conducted. CWR scores in different BNL and SSPL conditions have been obtained and analyzed. The effects of BNL and SSPL on CWR of children in these classrooms have been explored.

2. Experimental methods

2.1. Classrooms

In this paper, three rectangular classrooms have been selected. Their dimensions are $9.35 \times 7.90 \times 3.70\ m^3$ (Classroom A), $8.60 \times 6.15 \times 3.25\ m^3$ (Classroom B), $9.35 \times 7.90 \times 3.15\ m^3$ (Classroom C). There is no sound absorption treatment for classrooms A and B. Both sides of the walls besides the windows are plastered in classrooms A and B. There are two blackboards on the front and back walls respectively in the classrooms. The ceiling is plastered and the floor is covered with ceramic tile. There are 45 desks in each classroom. For classroom C, mineral-fiber acoustic ceiling tiles with 1.5 cm thickness is installed on the ceiling (Brand: Armstrong; Model: School Zone Smart; Specification: Noise reduction coefficient (NRC) > 0.60, Ceiling attenuation class (CAC) = 33 and Light reflectance (LR) = 0.85). The other interior surfaces of the classrooms A and B are the same, besides all window curtains of classroom B were closed to achieve a desirable RT during the tests. Such condition of closing all curtains in classroom B is unusual for general teaching activities in China and is generally not used as a design situation in national standards. For each classroom, a source (JBL-6325P loudspeaker) has been set at 1.5 m above the floor in front of the room where the teacher would generally stand. A listening position is located at the mid-back of the classroom. The averaged RTs in 500–2000 Hz octave bands at the listening position of the three classrooms are shown in Table 1. The RT at the listening position in classroom C complied with the requirements of the ANSI S12.60-2002 (R2010), while that in classroom B is complied with the requirements of China civil building acoustic design specification GB 50118-2010. However, RT in classroom A exceeds the value specified the above mentioned standards.

2.2. Word recognition test

Subject testing is conducted for each listening position using Mandarin Chinese test word lists as specified by GB 4959 [17]. The test uses 25 five-word rows of similar-sounding Chinese monosyllabic words and is similar to modified rhyme test of English. The five words in each row are randomly arranged and differ only in the initial consonant sound (for example in Chinese Pingyin: hao, sao, gao, zao, kao). Thirteen word lists are derived from five basic word lists. One list is used for students to practice, the rest twelve word lists are used for the test. The test word in carrier phrase is "The × row reads -", where the "×" stands for row number and "-" stands for a test word. All word lists have been recorded at the rate of 4.0 words per second in an anechoic chamber of $8.2 \times 6.1 \times 6.1\ m^3$ by using an omni-directional precision microphone at a distance of 0.5 m from the speaker. The recordings have been edited by CoolEdit Pro. A ten-second interval of silence between two adjacent carrier sentences allowing listeners to answer the test words (i.e. mark the answer on the test paper) has been inserted.

Table 1
The RTs and noise levels in three classrooms.

Classroom	RT/s	Noise level (AN)/dBA
A	1.30	45.9
B	0.81	48.9
C	0.46	45.5

Based on the average speech spectrum from a male speaker, a speech-spectrum-like noise is applied in these experiments. The CWR test signals recorded in an anechoic chamber and noise have been reproduced by a JBL-LSR6325P loudspeaker with its directivity similar to human mouth. Numerous studies [3,7,18–23] on BNLs and SSPLs in typical classrooms have been found in existing publications. From these studies, A-weighted SSPLs in the range of 40–80 dB(A) have been found, and BNLs vary from 32 to 77 dBA [3,18–23]. Elizabeth et al. [23] have found that the BNL in the classroom is in the range of 52–62 dBA. Shield and Dockrell [18] have indicated an average BNL in the classroom is 56.3 dBA. In the present study, two types of noise are selected. One is natural ambient noise (AN) condition of the classrooms (i.e. no other artificial noise is added) in the listening position, while another is about 56 dBA mixed noise (MN) which was the mixture of a 55 dBA speech-spectrum-like noise and the ambient noise in the classroom. The SSPL at the receiver position has been set at 50, 55, 60, 65, 70 and 75 dBA for AN in classrooms and at 55, 60, 65, 70, 75 and 80 dBA for MN. It notes that when SSPL is 80 dBA under the AN condition, the SNR at the listening position would be more than 30 dB. Therefore, those cases are not considered in the present study. A total 12 testing conditions have been tested at each classroom. The level of AN at the listening position during the test is shown in Table 1.

2.3. Subjects

Five children at grades 3 (age from 8 to 9 years old) and 5 (age from 10 to 11 years old) in each classroom have participated in the tests, respectively. All children were randomly selected from primary school and no hearing tests have been performed. They are representative of general listening audiences. All subjects can speak and understand standard Mandarin Chinese. They reported that they have no known hearing problems. They have received a few minutes of instruction prior to the tests. For each testing condition, two test word lists have been used and the subjects evenly sat around the receiver position in each classroom. Presented by playback system in closed-response format, the subject's task is to identify the correct answer from five choices. Averages of the subjective CWR scores across all ten lists are obtained for each testing condition.

3. Results

The subjective CWR at the listening position for grades 3 and 5 children have conducted in three classrooms with the different RTs. The CWR scores and its standard deviation under the different RT and BNL conditions are shown in Fig. 1. It can be seen that the CWR score increases with decrease of RT or increase of age, but it decreases with increase of BNL under the same SSPL condition.

Under the 56 dBA MN condition, Fig. 1(a) shows a peak at SSPL being 70–75 dBA under the same RT and age of children condition.