Comprehension of dysphonic speech by primary students

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Abstract

Children need clear auditory signals and low background noise to learn. When classroom acoustics are poor, teachers often compensate by raising their voices. Long-term vocal overuse is the primary cause (60%) of the high prevalence of voice problems. Speech intelligibility tests were performed in primary schools with normal hearing students using words produced with a normal voice and simulating a dysphonic voice. Artificial noise and classrooms with different reverberation times were used to obtain a range of Speech Transmission Index from 0.2 to 0.7 (from bad to good). Results showed a statistically significant decrease in intelligibility for dysphonic voices with a maximum of 15% intelligibility loss. This study provides important insights into the enormous variability in speech intelligibility in classrooms by characterizing intelligibility when students receive degraded auditory input which results from the intersection of classroom acoustics and poor teacher voice quality.

Keywords: speech intelligibility, classroom acoustics, dysphonia, primary schools.

1 Introduction

Classroom settings require a very high level of acoustical quality to optimize learning outcomes. Generally, when the teacher is speaking, the students should be able to hear everything the teacher says, but noise and poor acoustic conditions may interfere with the communication. Among the noise sources present in a classroom, the noise generated by the students themselves is the dominant one [1,2]. Several studies have analyzed the effect of noise and poor classroom acoustics on the learning process and academic achievement of students, such as reduced student long-term attention, auditory discrimination and speech perception, and reading ability [3-6]. The teachers are often forced to increase their vocal effort in order to compensate for the acoustic complexity of a classroom [7-8]. This compensation, in addition to other occupational pressures (e.g., high speaking load), are contributors to the high prevalence of voice problems among teachers (about 60% of school teachers)[9].

Voice problems among teachers directly affect speech transmission in the classroom by decreasing the teacher's voice quality, which is the primary source of instruction. Voice quality plays an important role in determining the reactions of listeners to talkers [10]. Several studies have shown that students are less able to pay attention to teachers with poor voice quality, making students more susceptible to other acoustic disruptions in the classroom and influencing the degree of information acquired [11-15]

Although a high level of acoustical quality is extremely important to optimize learning outcomes, classrooms are often characterized by less than ideal acoustic conditions (e.g., noisy rooms, echo, poor sound insulation). The main goal of research in classroom acoustics is to find the acoustical features that increase speech intelligibility. To pursue this goal several studies have analyzed the relationship between subjective indices of intelligibility and objective acoustics indices that quantify the quality of a communication path. The principal

way to subjectively quantify the quality of speech communication is the Intelligibility Score, defined as the percentage of a message understood correctly [16].
Because this index may fail to capture the perceptual effort of listening (such as listening to a hoarse voice or unfamiliar accent), the Listening Difficulty rating was introduced to quantify this perceptual component [17,18]. Among the objective acoustic indices, the Speech Transmission Index (STI) [19,20] is the most complex. It quantifies the quality of the communication transmission in a room, considering the decrease in amplitude modulation of the speech due to noise and reverberation. A second, simpler way to objectively quantify the speech transmission quality of a communication path is the Speech- to-Noise Ratio (SNR), which is the ratio between the speech and the noise levels. Most classroom-based studies have focused on classroom acoustics (reverberation time and clarity) and noise present in the classroom. In 1981, Houtgast [21] administered intelligibility tests in Canadian classrooms with a variety of road traffic noise conditions and with a reverberation time (RT) in the 0.7–1.5 s range. In 1986, Bradley [22] determined the combined effects of SNR and RT (varying from 0.4 s to 1.2 s) on speech intelligibility for 12- to 13-year-old students in their classrooms, using the Word Intelligibility by Picture Identification (WIPI) test. In a study by Bradley and Sato [23], the mean intelligibility scores were significantly related to SNR and the grade of the students. They tested students in grades 1, 3, and 6 in classrooms with RT equal to 0.4 s, which is the current RT value suggested by the American standard on classroom design.
Such studies have been the basis for current national and international standards for classroom design. However, none of them considered the possibility of teachers with voice problems and the complications that dysphonic voices would introduce in the communication.
This research is significant because it extends an important pairing of problems related to student learning: classroom acoustics and teachers with voice disorders. It will provide important insights into the enormous variability in speech intelligibility in classrooms by characterizing students' abilities in terms of spoken word recognition when students receive degraded auditory input. The degraded auditory input results from the intersection of classroom acoustics and poor teacher voice quality. This research contributed to gain a better understanding of the communication conditions needed by students, particularly young children in the early grades, to understand their teacher even with degraded voice quality.

2 Methods

2.1 Stimuli

The stimuli used consisted of the words from The Word Intelligibility by Picture Identification (WIPI) test. The words were recorded in a single-wall soundproof room. A female actress pronounced the words with normal voice quality and repeated the recording simulating a dysphonic voice.

2.2 Case study

Tests were conducted in four classrooms at two schools across the United States. The first school is located in the university campus area. Both classrooms selected for measurements are located on the ground floor. The first classroom has an area of 39 m^2, an average height of 2.7 m, and a volume of 106 m^3. Sound absorbing panels are present in the ceiling and windows are located in the upper part of the back wall. The second classroom has an area of 61 m^2, an average height of 3.15 m, and a volume of 191 m^3. Again, the windows are located in the upper part of the back wall of the classroom. The reverberation times in the occupied condition are 0.34 s and 0.71 s for the first and second classrooms respectively.
The second school is located in a residential area. The first classroom, located on the second floor, has an area of 58 m^2, an average height of 2.7 m, and a volume of 156 m^3. Sound absorbing panels are located in the ceiling and two windows in the sidewall. The second classroom, located on the ground floor of the building, has an area of 72.4 m^2, an average height of 3.0 m, and a volume of about 216 m^3. The ceiling is made of sound-

absorbing panels and there are two windows in one of the side walls. The reverberation times for the first and second classrooms, in the occupied condition, are 0.29 s and 0.39 s, respectively. The four classrooms accommodated 55 students, equally distributed between males and females, with normal hearing and ages ranging from 7 to 11 years old.

2.3 Intelligibility test

The questionnaire administered to the children consisted of 8 tests that evaluated the following conditions: 2 voice qualities (normal speech and dysphonic speech) and 4 noise conditions (no noise with SNR from 5.6 to 22.6 dB, low noise from 1.4 to 11.3 SNR, medium noise from -5.8 to -8.8 dB SNR, and high noise from -12.9 to -7.4 dB SNR). In each test consisted of 8 words. Upon hearing the cue word, the children had to choose among 6 pictures the one they heard and assess the difficulty in hearing the word.
The speech stimuli were played in the classroom using the Head and Torso Simulator (HATS, 45BC KEMAR, GRAS, Holte, Denmark) with a signal level of 66 dBA at one meter of distance, measured under anechoic conditions. Children's babble noise was played to simulate a real school environment. The noise was reproduced through 4 JBL Flip 5 Bluetooth speakers placed in different spots in the classroom. During the test, 6 Tascam DR 40 X recorders, each with a Behringer ECM 8000 microphone, were located around the classroom to record noise levels and STI. The intelligibility scores obtained by the children were correlated with the objective acoustic parameters measured by the nearest microphone.

3 Results

3.1 Acoustic measurements

A generalized linear mixed model (GLMM) fitted by maximum likelihood with a binomial distribution (Laplace approximation) was used to analyze speech intelligibility and listening difficulty. The results of the relationship between speech intelligibility and STI, are shown in Figure 1. The graph shows a statistically significant difference between dysphonic and normal speech. This difference is present for STI values greater than 0.37.

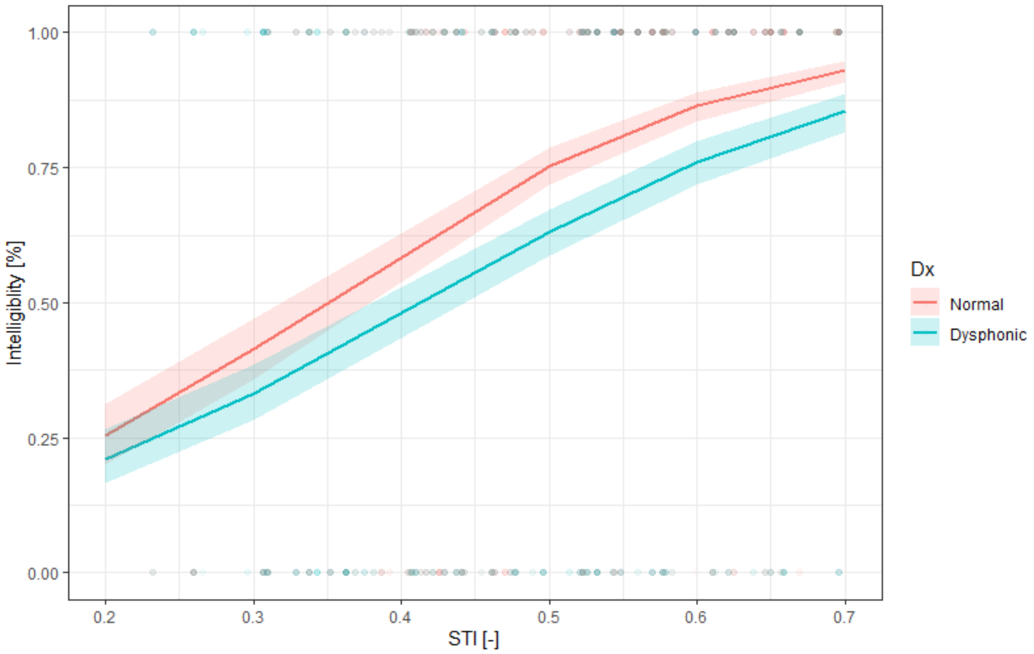

Figure 1 - Regression lines of speech intelligibility (%) for normal and dysphonic voices in relation to STI

The relationship between listening difficulty and STI is shown in Figure 2. The results showed a statistically significant difference for STI values greater than 0.36 between the two regression lines.

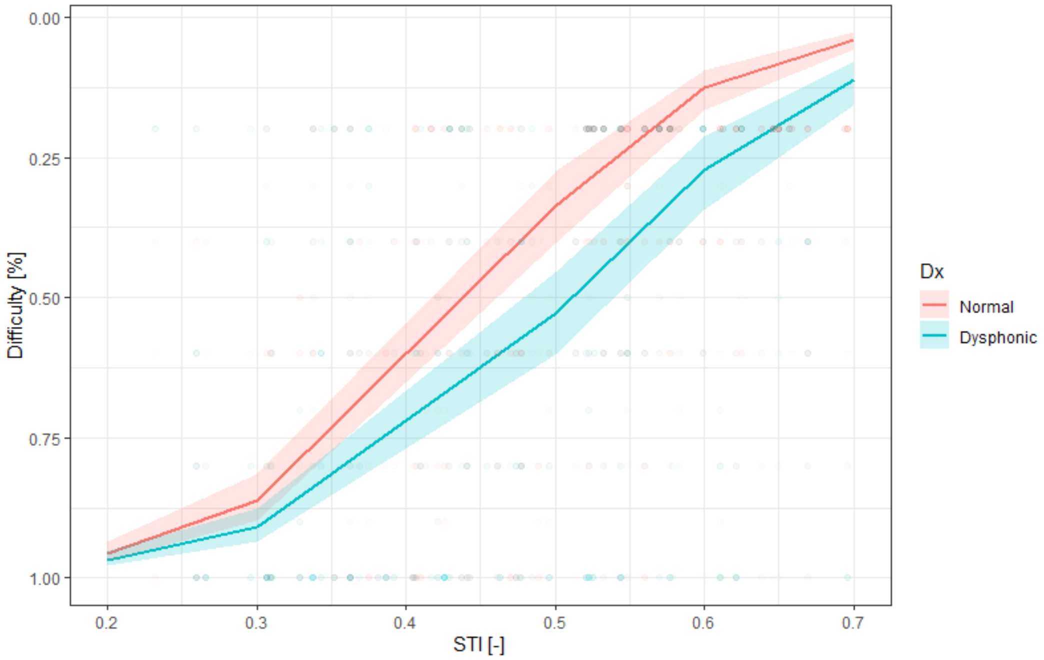

Figure 2 - Regression lines of listening difficulty (%) for normal and dysphonic voices, on a scale of 1(highest difficulty) to 0 (no difficulty)

Figure 3 shows the relationship between speech intelligibility e SNR. The graphs highlight a statistically significant difference between the two voice conditions for values greater than 4 dB.

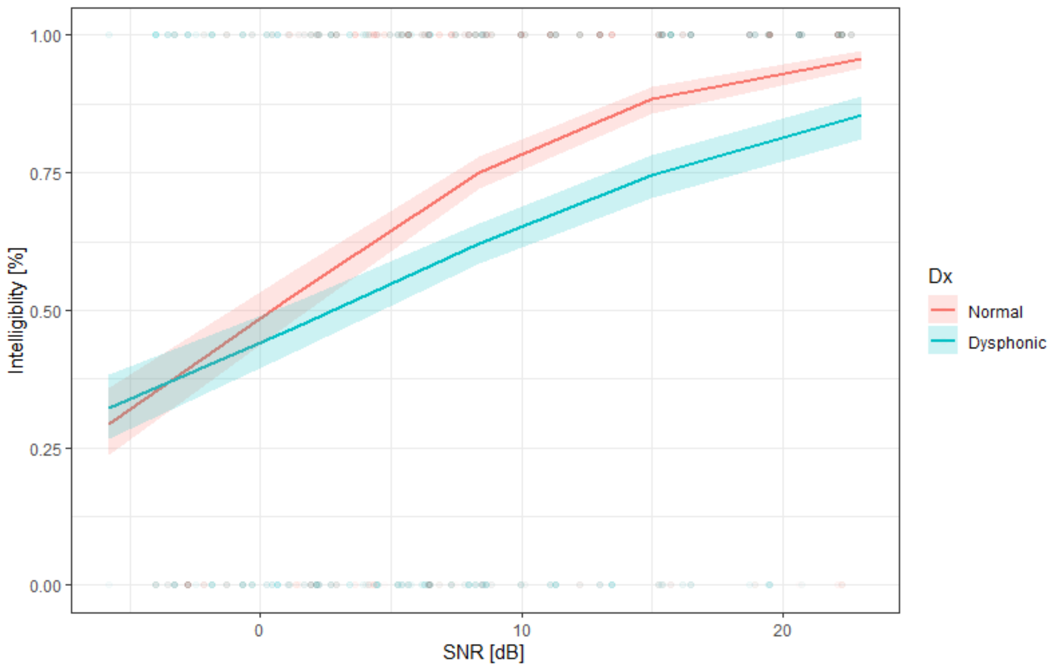

Figure 3 - Regression lines of the relationship between speech intelligibility (%) and SNR for normal and dysphonic voices.

The relationship between listening difficulty and SNR is shown in Figure 4. The difference between normal and dysphonic voices is statistically significant for values between 2 dB and 22 dB.

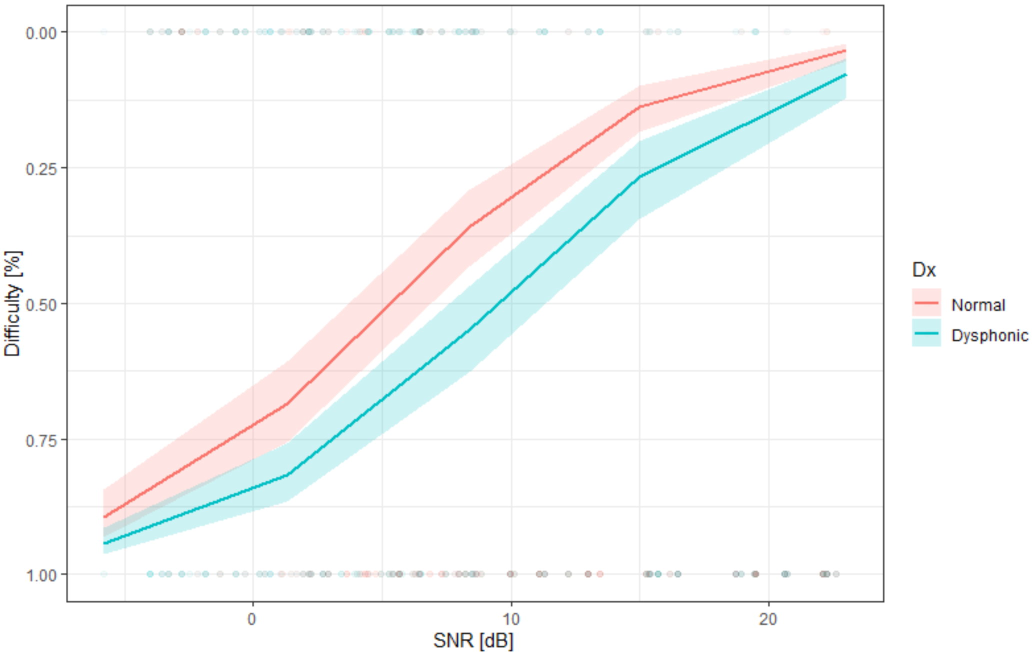

Figure 4 - Regression lines of the relationship between listening difficulty (%) and SNR for normal and dysphonic voices.

4 Conclusions

The objective of this project is to evaluate the acoustic conditions that allow optimal intelligibility, in primary school classrooms, even when the teacher suffers from voice disorders and in the presence of typical classroom noise. The main conclusions are: (1) dysphonic speakers are less intelligible than speakers with normal voice quality and more difficult to listen to for STI values greater than 0.4, (2) Under conditions of poor acoustics, the two voice types were not statistically different, (3) the SNR showed that in conditions of optimal classroom acoustics, (e.g. greater than 22 dB), students do not perceive difficulty in discriminating normal and dysphonic voices. However, intelligibility scores show a significant difference between the two conditions, demonstrating that dysphonic voices are less intelligible despite good acoustics. The information obtained in this research can be used to outline pragmatic guidelines for giving children the best chance for academic success, even when their teachers suffer from voice impairment.

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