Speech and noise measurements in active university classrooms

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Summary
One can measure speech and noise levels separately but then the noise is not the same as experienced during the speech in active classrooms. Acoustical measurements and recordings were made during 15 lectures in 11 university classrooms. A statistical method modified by Sato and Bradley (2008, JASA) was used for obtaining octave band speech and noise levels in active classrooms. In the 11 active university classrooms the students experienced: speech levels of 51.5 dBA (s.d.=2.7 dBA), noise levels of 44.3 dBA (s.d.=2.1 dBA), and a speech-to-noise ratio of 7.2 dBA (s.d.=2.7 dBA).

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1. Introduction

Previous studies [1, 2] have reported that the effect of SNR is often more important for both older adults and younger children listeners. For example, the results of speech intelligibility tests in elementary school classrooms [3] showed that a SNR of +15 dB is not adequate for the grade 1 and 3 students. The results of speech and noise measurements in elementary school classrooms [4] showed that the measured noise levels in unoccupied rooms were greater than the recommended maximum noise level of 35 dBA in ANSI S12.60 [5]. The mean noise level measured in working classrooms was 49.1 dBA. For achieving a minimum SNR of +15 dBA in these classrooms, the speech level would have to be greater than 64 dBA. For the grade 1 and 3 students, the speech levels would have to be greater than 67.5 dBA and 69.5 dBA, respectively. The results of the 30 UBC classroom acoustical survey [6] showed that the background noise level exceeded 35 dBA in 29 unoccupied classrooms and exceeded 45 dBA in 12 classrooms. The results also showed a significant effect of the presence of students on the acoustical conditions in classrooms, emphasizing the need for the design criteria for occupied classrooms. Classroom quality was strongly correlated with the background noise level and the related signal-to-noise ratios [7]. A more recent study in 12 university classrooms [8] showed that adding occupants led to larger changes in SNR values of up to 2.8 dB for the more absorptive classrooms.
In the present study, acoustical measurements and recordings were made during 15 lectures in 11 university classrooms. To process the recordings a practical approach [4] was used to identify separate speech and noise levels in octave bands. A histogram of distributions of the combined speech and noise levels was plotted. Two normal distributions were fitted to each histogram of the combined speech and noise levels. The measured speech and noise levels were compared with the values reported in two previous studies [4, 9].

2. Measuring speech and noise levels

Acoustical measurements and recordings were made during 15 lectures in 11 university classrooms at Kangwon National University in Korea. Of the 11 classrooms, 10 were used for university lectures, and 1 was used for computers. All classrooms had rectangular shapes with windows on one side. The mean number of occupants was 41 (65% occupancy) for the measurements of the occupied classrooms. Speech-reinforcement systems were installed in classrooms, but they were not in operation during the measurements. Table 1 presents the data describing the 12 university classrooms used for the measurements. The mean mid-frequency T_{30} (500-1000) values, for both occupied and unoccupied classrooms are also included in Table I.

Table I. Data for 11 university classrooms used for the measurements including mean mid-frequency T_{30} (500-1000 Hz) values.

	Width, m	*Depth, m*	*Height, m*	*Volume, m^3*	*Number of occupants*	*Mean 500-1000 Hz T_{30} unoccupied, s*	*Mean 500-1000 Hz T_{30} occupied, s*
Mean	8.5	10.8	2.8	257	41	1.12	0.64
s.d.	0.7	2.0	0.2	38	12	0.41	0.15
Max	9.1	16.5	3.0	343	67	1.80	0.90
Min	6.7	7.2	2.5	190	19	0.61	0.37

The volume of 11 classrooms varied from 190 m^3 to 343 m^3. They were mostly used for small to medium size classes with less than 100 occupants. These classrooms had plastic tablet-arm chairs or wood desks and chairs. The mean mid-frequency T_{30} (500-1000) values for the occupied and unoccupied classrooms were 0.64 s and 1.12, respectively.

Recordings of speech and noise levels in active classrooms were made during 15 lectures in 11 classrooms listed in Table I. Recordings were made at four receiver positions using 1/2" free-field microphones (G.R.A.S, Type 46AF) and sound measurement software (Dewesoft, Dewesoft Ver.7.0) evenly distributed among the seated occupants in each classroom, at a height of 1.2 m. Speech and noise levels were recorded for 10 min of lectures with the instructor being the main source of speech in active classrooms. The noise in active classrooms was mostly from air conditioners, beam projectors, other adjacent rooms, and outdoors. In the active classroom measurements, no significant noise from student activity occurred.

The calculations require calibrated recordings of combined speech and noise sounds. To process the recordings one must be able to cut them up into 200 ms blocks. Then the average A-weighted levels of each 200 ms block can be plotted as a histogram of the distribution of the recorded combined speech and noise levels. This usually produces a histogram with 2 peaks, the higher peak usually indicates the peak of the speech level distribution and the lesser peak the ambient noise levels. By fitting the combination of two separate normal distributions to the distribution of measured speech and noise levels, one can separately identify the distributions of speech and noise levels as proposed by Hodgson et al. [9].

Sato and Bradley [4] developed a practical approach for making it possible to identify separate speech and noise levels in octave bands so that one could calculate STI values or other measures expressing results in octave band values. The first step of this process was to separate the 200 ms samples into either speech or noise samples based on the distribution of their A-weighted levels. Then all of the 200 ms noise samples and all of the 200 ms speech samples were separately assembled. As they pointed out listening to each of these assembled sample groups one can hear whether one has speech or noise. One can also octave band filter each group and use the octave band levels to represent either the speech or noise in an active classroom. Figure 1 describes the fitting of two normal distributions to the recorded combined speech and noise levels.

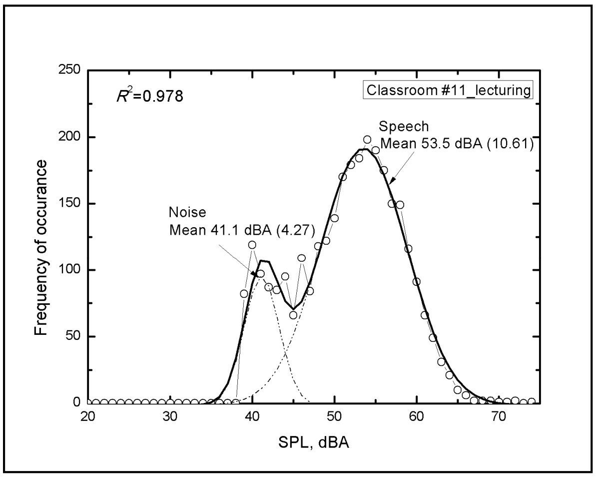

Figure 1. Example frequency distributions of A-weighted speech and noise levels of the recorded 200 ms segments and the fitting of two normal distributions.

3. Noise levels and speech levels in active university classrooms

Table II presents mean octave band noise levels, speech levels, and speech-to-noise ratios along with their overall A-weighted levels averaged over the measured results for 15 lectures in 11 active university classrooms. The mean overall noise level was 44.3 dBA (s.d.=2.1 dBA) and the mean speech level was 51.5 dBA (s.d.=2.7 dBA). The mean speech-to-noise ratio was 7.2 dBA (s.d.=2.7 dBA). The mean speech and noise levels measured in the 11 active university classrooms were compared with values measured during 18 lectures in 11 UBC classrooms [9]. The UBC classrooms varied from small lecture rooms with volumes around 110 m^3 to large lecture rooms with volumes around 957 m^3. In the UBC classrooms, the mean speech and noise levels were 50.8 dBA (s.d.=2.7 dBA), and 44.4 dBA (s.d.=3.5 dBA), respectively. The mean speech-to-noise ratio was 7.9 dBA (s.d.=3.1 dBA). The results showed that the speech and noise levels were 0.7 dBA higher and 0.1 dBA lower than in the 11 UBC classrooms.

In the active 27 elementary school classrooms [4] the students experienced: speech levels of 60.1 dBA (s.d.= 4.4 dBA), noise levels of 49.1 dBA (s.d.= 4.3 dBA), and a speech-to-noise ratio of 11 dBA. The present results and 11 UBC classrooms survey [9] show that the measured speech and noise levels are about 8.6 and 4.8 dBA lower than in the 27 elementary school classrooms. The noise generated by children increased the noise levels by typically 5 dBA and the increases varied up to a maximum of 10 dBA relative to the same classrooms without student activity [4].

Figure 2 plots the mean speech and noise levels measured at 4 positions in active classroom #10. Among 15 lectures in 11 active classrooms, this classroom has the lowest speech-to-noise levels, which is 2.4 dBA. While the results for classroom #11 in Fig.1 show the highest speech-to-noise levels, which is 12.4 dBA. Figures 1 and 2 indicate that frequency distributions of the measured speech and noise levels vary in each classroom.

As shown in Table II, the mean noise levels reaches a maximum at 125 and 250 Hz octave bands and decreases with frequency. The mean speech levels are highest in the 125, 250, 500 Hz octave bands than in the other octave bands and decreases with frequency. The mean speech levels are greatest at 500 Hz and resulted in highest speech-to-noise ratios than in the other octave bands.

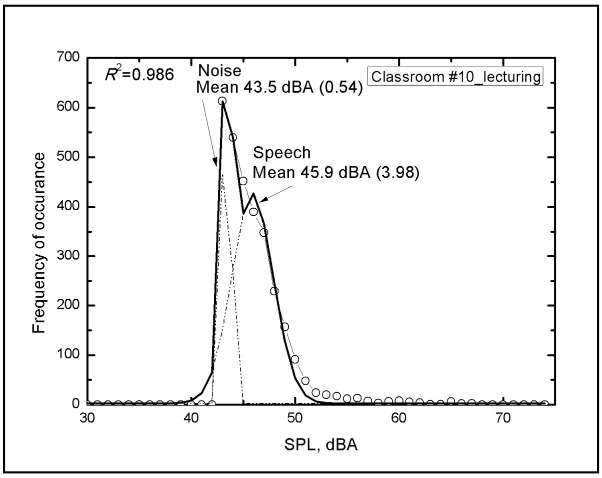

Figure 2. Frequency distributions of the speech and noise levels in active classroom #10.

The six parts of Fig. 3 plot the mean A-weighted octave band level frequency-distributions curves measured at 4 positions in active classroom #11. The results in Figs. 3(a) ~ (f) show that the higher peak usually indicates the peak of the speech level distribution and the lesser peak the ambient noise levels.

4. Conclusions

Acoustical measurements and recordings were made during 15 lectures in 11 university classrooms. A statistical method [4] was used for obtaining octave band speech and noise levels in active classrooms. The mean overall noise level was 44.3 dBA (s.d.=2.1 dBA) and the mean speech level was 51.5 dBA (s.d.=2.7 dBA). The mean speech-to-noise ratio was 7.2 dBA (s.d.=2.7 dBA).

Table II. Mean octave band noise levels, speech levels, and speech-to-noise ratios along with their overall A-weighted levels for measured in active university classrooms.

Parameters	*Frequency, Hz*						
	125	*250*	*500*	*1000*	*2000*	*4000*	*Overall levels, dBA*
Noise levels, dB	45.2	42.7	40.0	37.5	34.8	36.3	44.3
s.d.	5.2	4.5	3.2	2.6	2.0	0.7	2.1
Speech levels, dB	49.6	50.1	51.0	44.6	41.0	38.9	51.5
s.d.	3.1	3.6	3.6	3.0	2.8	1.8	2.7
Speech-to-noise ratio, dB	4.3	7.4	11.1	7.0	6.2	2.6	7.2
s.d.	2.7	3.4	3.5	2.5	1.7	2.2	2.5

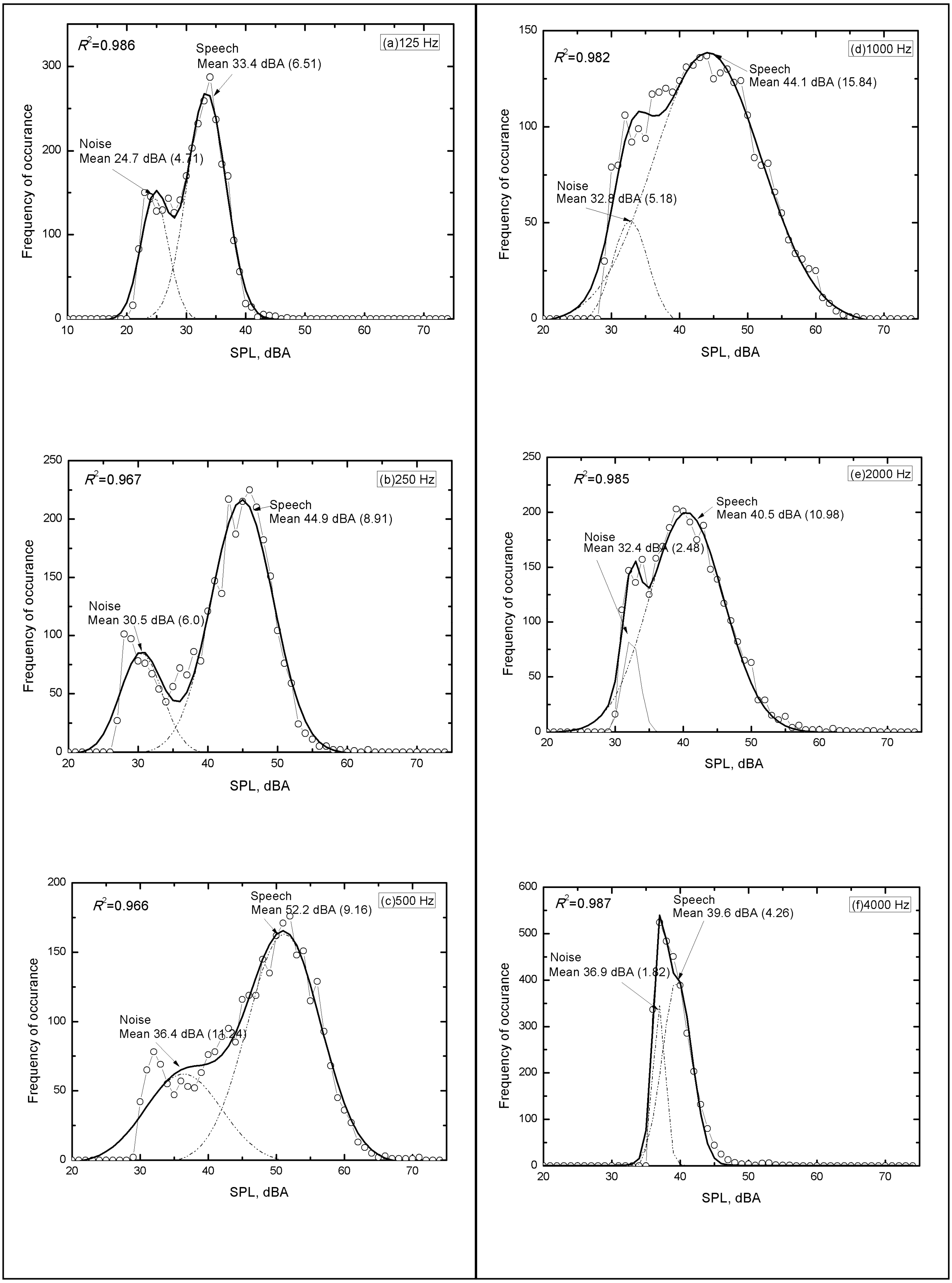

Figure 3. Mean A-weighted octave band level frequency-distributions curves measured at 4 positions in active classroom #11

The results showed that the speech and noise levels were 0.7 dBA higher and 0.1 dBA lower than in the 11 UBC classrooms [9].

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