MEASUREMENT OF TYPICAL SPEECH AND BACKGROUND-NOISE LEVELS IN UNIVERSITY CLASSROOMS DURING LECTURES

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Introduction

As part of a study on classroom acoustics [1], an experimental procedure has been developed for determining typical long-term speech and background-noise levels in university classrooms during lectures. A particular objective was to determine typical levels of student-activity noise as separate from ventilation noise; previous work had suggested that it can be surprisingly high [1]. The procedure involved recording lectures, digitizing and filtering the recordings, and determining long-term sound-pressure-level distributions. The procedure has been applied to lectures in UBC classrooms.

Classroom Recordings

A total of 18 lectures were recorded at up to four positions in 14 classrooms. The classrooms were seminar and lecture rooms which contained 10-291 seats and 7-290 students, and with unoccupied mid-frequency reverberation times that varied from 0.5-1.8 s. Both male and female instructors - teaching a wide variety of subjects at various academic levels - were involved. Recordings were made using calibrated Bruel & Kjaer 4145 microphones and a TASCAM DA30 Mk II digital tape recorder. Data were collected for 10-15 min - in three blocks at the beginning, middle and end of the class - at each position. As a cross check, ventilation-noise levels were measured at each test position in each classroom on a separate occasion using a sound-level meter.

Analysis Procedure

Recordings at each position in each class were digitized and filtered using digital 63-8000 Hz octave-band and A-weighting filters. Software processed the resulting pressure time histories as follows: the signals were squared; short-term (using intervals which decreased over the test frequency range from about 160 to about 1 ms) mean-square pressures were calculated; interval sound-pressure levels were calculated; sound-pressure-level frequency distributions were determined and plotted; the resulting distributions were best-fit by one, two or three normal-distribution curves in an attempt to identify peaks. Only the A-weighted results have been analyzed to date, and will be discussed here.

Results

Attempts to best-fit one or two normal-distribution curves to the results generally gave a poor fit; however, three curves usually gave a very good fit. These were identified with three components of classroom sound - speech signal, ventilation noise and student-activity noise. However, in most cases it was not immediately obvious which, if any, of the three best-fit levels corresponded to which sound component - nor what was the correct level order.

In order to cast some light on this, levels were compared with ventilation-noise levels measured independently, and with typical long-term speech levels published in the literature [2]. Regarding ventilation noise, the agreement was generally poor - suggesting that such levels vary significantly with time - but indicated that the lowest of the three levels was likely that due the ventilation. The highest of the three noise levels generally corresponded fairly well to expected speech levels. The middle level was, therefore, usually associated with student-activity noise.

Fig. 1 shows a typical A-weighted level-distribution curve. It apparently has two main peaks - at 41 and 52 dBA according to the best-fit results - apparently corresponding to long-term ventilation and speech levels, respectively, as discussed above. The best-fit procedure identified a third peak - which is not obvious in Fig. 1 - at 43 dB. In a few cases the frequency distribution appeared to have only a single peak, indicating low signal-to-noise ratio, and making identification of component levels difficult. Following is a summary of the results:

Background noise - Ventilation-system noise levels varied from 33-46 dBA. Student-activity noise levels varied from 38-49 dBA. Total background-noise levels varied from 39-50 dBA.

Speech level - Speech levels at individual positions varied from 41-60 dBA. Room-averaged levels varied from 47-57 dBA with an average value of 53 dBA. Differences between male/female speakers and front/back seat positions altered levels by ±1.2 and ±1.5 dBA, respectively. Speech levels did not vary significantly with room acoustical conditions. It can be hypothesized that instructors adjust their voice levels to compensate for the acoustical conditions and maintain a constant speech level. To test this, speech levels and diffuse-field theory were used to estimate long-term instructor sound-power levels. These varied from 56-68 dBA with male/female differences varying this value by ±1.2 dBA, respectively. There was a strong correlation with room size - average speech power levels of 61 dBA (<30 seats), 62.5 dBA (30-80 seats), 64 dBA (>80 seats) - supporting the hypothesis.

Signal-to-noise ratio - It is speech-signal to total-background-noise ratio which determines speech intelligibility. Thus, for each position in each classroom ventilation- and student-activity-noise levels were added energetically and the results subtracted from the speech level. The resulting individual-position signal-to-noise ratios varied from 2-13 dBA. This was in all cases lower than the signal-to-noise ratio of about 15 dBA considered necessary for excellent speech intelligibility for normal-hearing adults [3].

[1] M. R. Hodgson, "UBC-classroom acoustical survey", *Canadian Acoustics* **22**(4) 3-12 (1994).
[2] K. S. Pearsons, R. L. Bennett and S. Fidell, "Speech levels in various noise environments", Bolt, Beranek and Newman report to USEPA, Canoga Park, CA (May 1977).
[3] J. S. Bradley, "Uniform derivation of optimum conditions for speech in rooms", Report BRN 239, National Research Council Canada, Ottawa (1985).

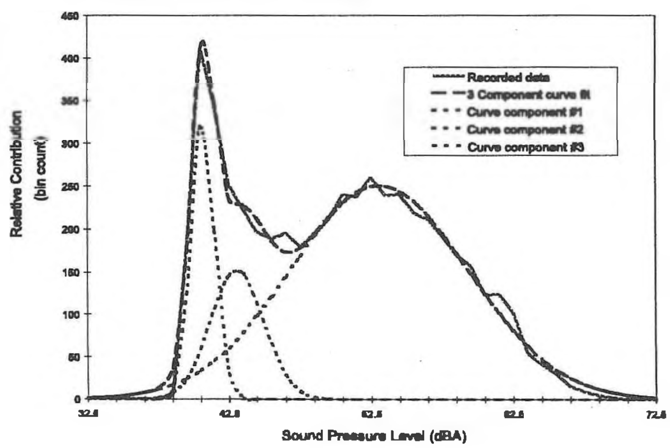

Fig. 1. A-weighted long-term sound-pressure-level distribution curve at a front seat in a 84-seat classroom with a male instructor.