Using Speech Intelligibility Scores to Rate Sound Insulation

Hyeon Ku Park, John S. Bradley and Bradford. N. Gover

Institute for Research in Construction, National Research Council, Montreal Rd., Ottawa, K1A 0R6

Introduction

Airborne sound insulation ratings can be evaluated in terms of their correlation with various subjective ratings of sound insulation. This paper considers sound insulation ratings in terms of the intelligibility of transmitted speech because speech is a common type of disturbing sound and because speech intelligibility tests can provide accurate subjective ratings.

Airborne sound insulation is usually rated in terms of the ISO *Weighted Sound Reduction Index* (R_w) or the ASTM *Sound Transmission Class* (STC). Previously, Vian et al. [1] related subjective ratings of sound insulation to frequency limited (125 Hz – 4k Hz) A-weighted level differences. Tachibana et al. [2] found judgements of the loudness of transmitted sounds to be predicted by a simple arithmetic average transmission loss over frequency. Recent research has shown the intelligibility of speech from meeting rooms to be well related to frequency-weighted signal-to-noise ratios [3], suggesting possible new wall transmission loss ratings.

Experimental Procedures

Listening tests were carried out in a sound isolated and acoustically dead test space. Subjects heard speech sounds, modified to include the transmission characteristics of 20 different walls, presented from loudspeakers in front of them. At the same time, noise with a –5 dB/octave spectrum shape and an overall level of 35 dBA was played from loudspeakers above the subject.

The characteristics of the 20 simulated walls were chosen to represent a range of STC values evenly distributed from STC 34 to 58 (R_w 33 to 56). They included a variety of construction types and transmission characteristics including wood stud, steel stud and concrete block walls.

The speech tests used the Harvard sentences [4]. These are phonetically balanced English sentences with content that is of low predictability, which is important to minimize the effects of guessing. The sentences were all recorded by the same clear-speaking male talker. The speech source level and the ambient noise levels were held constant throughout the tests. Only the sound transmission characteristics of the simulated walls were varied.

Fifteen subjects heard 5 different sentences for each of the 20 different simulated walls. The speech intelligibility scores of the 75 combinations of 5 sentences and 15 subjects per wall were averaged and plotted versus various sound insulation ratings.

Results were analyzed by fitting Boltzmann equations to plots of mean speech intelligibility scores versus various airborne sound insulation measures [5]. Various insulation ratings were compared in terms of the R^2 value of each relationship since there were always 20 average intelligibility scores.

Standard Sound Insulation Measures

Figure 1 compares the variation of STC values and mean speech intelligibility scores and their standard errors versus wall number with the walls ordered in terms of increasing STC value. Although the even distribution of STC values is evident, the mean intelligibility scores do not closely follow the same trend.

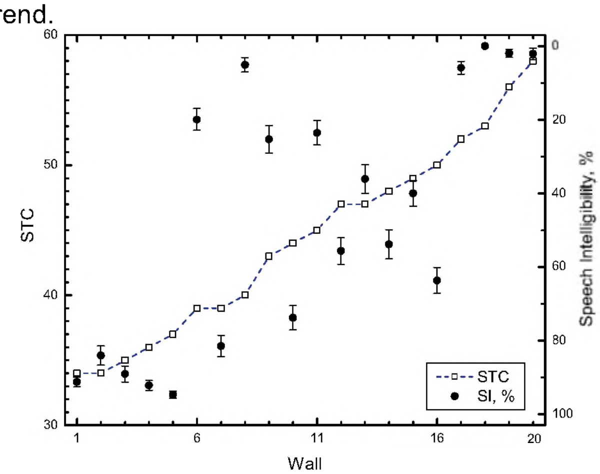

Figure 1. Mean speech intelligibility scores (right hand axis) with error bars indicating the related standard errors and Sound Transmission Class (STC) values on left hand axis versus wall number.

Boltzmann equation fits to intelligibility scores for STC values and R_w values led to significant ($p<0.05$) but low R^2 values (0.510 and 0.542 respectively).

Varying the 8 dB rule in the STC measure led to modest increases in R^2 values and with the 8 dB rule completely removed an R^2 of 0.661 was obtained.

Speech Intelligibility Type Measures

A number of measures were evaluated that are derived from or related to measures of speech intelligibility. The *Articulation Class* (AC) is a single number attenuation rating derived from the *Articulation Index* (AI) and includes the same frequency weightings. Table 1 lists the R^2 values for relationships with the various speech intelligibility related measures and shows a value of 0.856 for AC values. The *Articulation Index* (AI) and the *Speech Intelligibility Index* (SII) are similarly better predictors of the intelligibility of the transmitted speech.

Recent work [3] on the speech security of meeting rooms showed that frequency-weighted signal-to-noise ratios of the transmitted speech and ambient noise were good predictors of speech security. Several of these measures, SNRai, SNRsii22, and SNRuni32 again led to higher R^2 values. However the simple A-weighted speech – noise level difference (SNR(A)) was not a good predictor of intelligibility scores

Measure	R^2
AC	0.856
AI	0.864
SII	0.899
SNRai	0.896
SNRsii22	0.913
SNRuni32	0.853
SNR(A)	0.259

Table 1. R^2 values for predictions of intelligibility scores by speech intelligibility type measures.

Some Better Predictors of Intelligibility

Previous work on the speech security of meeting rooms indicated that a simple arithmetic average of *transmission loss* (TL) values over frequencies important for speech was a successful predictor of the intelligibility of transmitted speech. AA(200-2.5k), an arithmetic average of TL values from 200 to 2.5k Hz, was strongly related to intelligibility scores (R^2 = 0.959).

Alternatively a new spectrum weighting term ($C_{400\text{-}2.5k}$) added to R_w values led to an R^2 value of 0.951. The $C_{400\text{-}2.5k}$ term equally weighted frequencies from 400 to 2.5k Hz with zero attenuation and strongly attenuated other frequencies. Further details of this and other results can be found in reference [5].

Conclusions

The standard sound insulation ratings STC and R_w were not strongly related to intelligibility scores. However, removing the 8 dB rule from the STC rating or limiting the included frequency range led to improved R^2 values.

Measures in which decibel values are arithmetically averaged over a range of frequencies, were all generally quite successful. These included: AA(160-5k), AA(200-2.5k), AI, SII, SNR_{ai}, SNR_{sii22}, SNR_{uni32}, and AC values. However, when measures included energy averaging of values at various frequencies, results tended to be less successful.

The arithmetic average transmission loss measure AA(200-2.5k) and the R_w measure with the new spectrum weighting term $C_{400\text{-}2.5k}$ provided very good relationships with mean speech intelligibility scores and are considerable improvements over existing standard measures. The new spectrum weighting is also appealing because it adds to an existing standardized approach. However, these new ratings must now be tested in terms of responses to other types of sounds with different acoustical characteristics than speech.

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