ASTM METRICS FOR RATING SPEECH PRIVACY OF CLOSED ROOMS AND OPEN PLAN SPACES

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1. INTRODUCTION

ASTM International currently publishes two measurement standards for assessing speech privacy in building spaces. ASTM E2638 "Standard Test Method for Objective Measurement of the Speech Privacy Provided by a Closed Room" [1] is applicable only to enclosed spaces, and includes the definition of a measure called Speech Privacy Class (SPC). ASTM E1130 "Standard Test Method for Objective Measurement of Speech Privacy in Open Plan Spaces Using Articulation Index" [2] is applicable only to open plan spaces, and uses the Articulation Index (AI) as a privacy measure. This paper discusses the relationship between the two metrics, and their suitability for use in any type of space, including spaces not fitting the definition of either open or closed.

2. ASTM E2638

The E2638 method provides a rating of the average performance of a closed room – without any assumptions as to talker location – to each of a number of listener positions outside the room, close to the room boundaries. The level of a spatially uniform, broadband noise sound field is taken as the "source" level, and the corresponding levels at listener positions are taken as the "receive" levels. The level difference between the two is the measure of sound insulation that is part of the method.

For each receiving point, the level difference *LD(avg)* is added to the background noise $L_b(avg)$ to yield the Speech Privacy Class SPC = *LD(avg)* + $L_b(avg)$. Here "*(avg)*" means the 1/3-octave band values are arithmetically averaged from 160 to 5000 Hz.

3. ASTM E1130

The E1130 method provides a rating of the speech privacy between a specific source position and orientation and receiver position, in an open plan space. A calibrated loudspeaker with a specified directionality is required, and the reference "source" level is determined in a free field. The receive level is determined in the open plan space under consideration, and the difference between the two is the relevant measure of sound insulation. From this so-called "level reduction", and the measured background noise level, the AI is calculated, for a specified speech spectrum. AI by definition ranges from 0 (no intelligibility) to 1 (total intelligibility). E1130 also includes the definition of a metric called Privacy Index, which is simply a re-normalization: PI = (1 – AI) x 100%.

4. SPC AND PI

Regardless of how 1/3-octave band values of sound insulation and background noise are measured, both metrics (SPC and PI) can subsequently be calculated. Figure 1 shows the relationship for 100 simulated cases involving a wide range (in terms of spectral shape) of "level difference" or "level reduction", and of background noise.

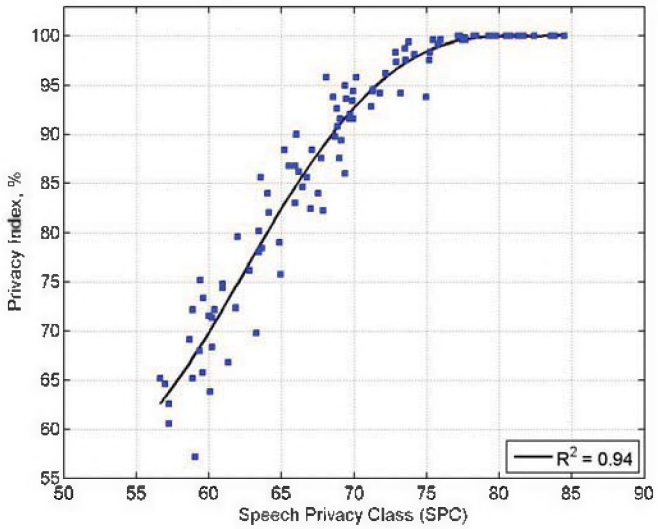

Figure 1. Relationship between Privacy Index, PI (per ASTM E1130) and Speech Privacy Class, SPC (per ASTM E2638). The R^2 of the 4th-order polynomial fit is 0.94.

Notice first that the correlation between SPC and PI is high (R^2 = 0.94). Also notice that, because PI is by definition limited to a maximum value of 100%, but SPC is not limited, a wide range of physical conditions are represented in the region PI > 95%. The sound insulation or noise can vary by ~12 dB, and yet PI varies by only a few percent.

E2638 includes a table of categories that identifies the frequency with which speech sounds would be audible or intelligible for various SPC values. These categories are given in Table 1 along with the corresponding SPC value, and, from the curve fit in Fig. 1, the corresponding equivalent PI value. E1130 includes definitions of "normal" and "confidential" speech privacy; the corresponding PI values are given in Table 2, along with the equivalent SPC values (from Fig. 1).

Based on the relationship of Fig. 1, the "Minimal Speech Privacy" category (SPC 70) is very nearly equivalent to "Confidential Speech Privacy" (PI = 95%). These results agree with those in Fig.5 of Ref. [3], using the specified voice spectrum to determine SPC.

Table 1: Categories of speech privacy defined in ASTM E2638 with corresponding SPC and equivalent PI values.

E2638 Categories	SPC	Equivalent PI, %
Minimal speech privacy	70	93
Standard speech privacy	75	98
Standard speech security	80	100
High speech security	85	100
Very high speech security	90	100

Table 2: Categories of speech privacy defined in ASTM E1130 with corresponding PI and equivalent SPC values.

E1130 Categories	PI,%	Equivalent SPC
Normal speech privacy	80	64
Confidential speech privacy	95	71

5. SPEECH INTELLIGIBILITY AND PRIVACY THRESHOLDS

Figure 2 shows the relationship between speech intelligibility scores and SPC (top) and PI (bottom), for a listening test described in Ref. [4]. The high correlation for both metrics implies both are useful for rating intelligibility over a wide range (from 100% to 0%).

Figure 3 shows the relationship between the percentage of listeners correctly identifying: at least one word from test sentences (labeled "Intelligibility"); and, the presence of speech sounds (labeled "Audibility"), also from experiments described in Ref. [4]. The correlations are high in all cases, but are somewhat higher for SPC (top) than for PI (bottom).

Notice that due to the truncation of PI (to a maximum value of 100%), the ability to distinguish among cases of moderate to high privacy is poor. All conditions higher than SPC 75 correspond to conditions for which PI > 98%. In this range, the audibility ranged from 100% (all listeners heard speech sounds) to 0% (no listeners heard speech sounds), and intelligibility ranged from about 15% to 0%.

Note that the relationships in Figs. 2 and 3 between intelligibility and thresholds and the two metrics should not be considered unique: varying the speech level, for a given SPC or PI, would result in different subjective scores. Only because the same source speech level was used for all tests in Figs. 2 and 3, are comparisons possible.

6. DISCUSSION

The two current ASTM metrics for rating speech privacy of building spaces are highly correlated, and both seem well suited for use in conditions where speech is intelligible, such as in open plan spaces. Of the two, SPC is best suited for use in conditions of high privacy, where speech is not intelligible. SPC also offers practicality in that a difference in, for example, 5 dB of sound insulation will correspond to a difference of 5 in SPC, whereas the corresponding difference in PI depends on the absolute value, and could be 0–2% for conditions of high privacy.

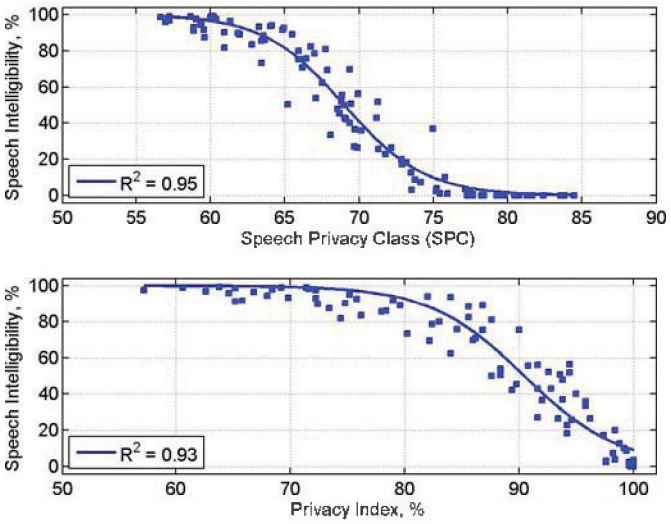

Figure 2. Speech intelligibility (% words understood) vs SPC (top) and PI (bottom). The R^2 of the Boltzmann curve fit is shown on each.

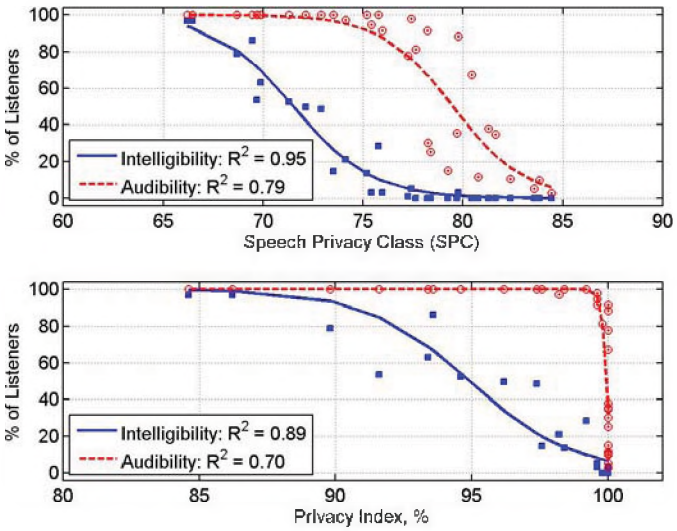

Figure 3. Fraction of listening test participants (in %) correctly identifying at least one word (Intelligibility – squares) and identifying the presence of speech sounds (Audibility – circles) vs SPC (top) and PI (bottom). The R^2 of the Boltzmann curve fits are shown on each plot.

REFERENCES

[1] ASTM E2638-10 ASTM Intl., West Conshohocken, PA.

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[3] J.S. Bradley, "Comparisons of Speech Privacy Measures," Proceedings of INTER-NOISE 2009 (Ottawa).

[4] B.N. Gover and J.S. Bradley, "Measures for assessing architectural speech security (privacy) of closed offices and meeting rooms," *J. Acoust. Soc. Am.* **116**, 3480–3490 (2004).

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