Speech privacy in healthcare buildings:review of early studies and current procedures for analysis

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Since the mid-1950s studies on speech privacy problems in buildings, including healthcare facilities, have convincingly shown that a typical person's sense of acoustical privacy is directly related to the intelligibility of the intruding speech in adjacent spaces. Both in experimental and in real-world settings most people feel they have adequate "confidential" privacy when the articulation index (AI) of the intruding speech is 0.05 or less. Higher values of AI, up to about 0.10, are acceptable for less demanding tasks, i.e. for "normal" or "everyday" privacy. The analysis procedure quantifies each of the significant variables involved and compares summations of these metrics with response data from prior case histories both to predict and, in the case of existing situations, to evaluate speech privacy conditions. In the mid 1960s independent review of the analysis method showed that sufficient accuracy is preserved if commonly used metrics such as A-scale and STC values are used in place of more cumbersome frequency based metrics. Later in the 1960s the method was successfully applied to open plan spaces although achieving "confidential" levels of speech privacy in such spaces proved difficult. Lessons learned in applying this relatively simple analysis method over the years are discussed.

1 Introduction

This paper traces the development of a relatively simple method for assessing speech privacy problems in a wide variety of building types including healthcare facilities. The worldwide post WWII building boom exposed the inadequacies of then existing criteria and standards for acoustical sound isolation between fully enclosed spaces as well as between work spaces with only partial height or no separating partitions generally referred to as "open plan". The development and increased use of lighter weight and readily moveable partition systems, particularly for high-rise commercial office buildings, further aggravated acoustical privacy problems. To address these problems research was initiated to examine case histories where there was complete data on the acoustical variables involved as well as adequate understanding of the subjective responses of building occupants. Simultaneously a series of controlled experiments were conducted to judge subjective reactions of subjects to variations of the several variables involved in speech transmission between rooms.

This work through the late 1950s and conclusions are reported in Cavanaugh et al, "Speech privacy in buildings" [1]. A fundamental conclusion from these studies was the strong relationship between a person's sense of acoustical privacy and the intelligibility of the intruding speech over the existing background sound in a receiving space. Although the level of speech intelligibility for a typical building occupant to feel a sense of "confidential" acoustical privacy is quite low, the plethora of work on speech intelligibility by researchers at Bell Labs, at Harvard's Psychoacoustic Lab, and at other research centers permitted development of meaningful metrics for each of the key speech related variables in a building's space-to-space sound transmission paths. Key references for this earlier work on speech intelligibility are also cited in [1].

Another significant conclusion from this early work on enclosed adjacent spaces was that many building occupants, perhaps the greater majority in any given working environment, are satisfied with slightly less than "confidential" privacy i.e. AI values up to about 0.10. Their concern is more with annoying or distracting intrusive speech than it is with intelligibility. This less demanding condition has been called "normal" or "everyday" speech privacy. In addition, there is a condition even more demanding than "confidential" speech privacy wherein extraordinary listening means (i.e. ear-to-wall listening, electronic detection etc.) may determine content and meaning of speech. The latter are beyond the scope of this simplified analysis method and require unique analysis methodologies for applications in highly classified spaces found in military and embassy buildings. Research by Bradley, Gover and others at the National Research Council, Ottawa on speech privacy and speech security over the past decade shows promise in developing methodologies to more effectively deal with higher order speech privacy concerns.

In the mid-1960s after publication of [1], Robert Young reviewed the initial enclosed plan analysis method and raw data for the case studies to determine whether the more generally used metrics for room-to-room sound isolation and background sound (STC and A-scale sound levels) might be adopted without sacrificing accuracy in the basic analysis procedure. Young convincingly demonstrated that little accuracy would be lost with replacement of the more complex ratings which he reported in his paper, "Re-vision of the Speech Privacy Calculation" [2].

With successful application of this early methodology to fully enclosed room adjacencies, a growing number of case histories of open plan acoustical privacy were addressed in the early 1960s. As anticipated, the enclosed plan analysis method (with appropriate modifications) predicted occupant response equally well although "confidential" levels of acoustical privacy are generally difficult to achieve in typical buildings. This initial work on open plan acoustical privacy is reported in an unpublished paper delivered in April, 1969 at the 77th ASA Meeting [3].

2 1950s Studies On Speech Privacy Between Enclosed Spaces

Figure 1 demonstrates that speech privacy between enclosed spaces in a wide variety of building types is not a "one dimensional" problem. Plotting observed subjective response against frequency averaged sound isolation performance alone for 37 case histories shows no correlation. That is, one is equally likely to find satisfaction or strong dissatisfaction with minimal sound isolation between rooms of 25 dB or higher.

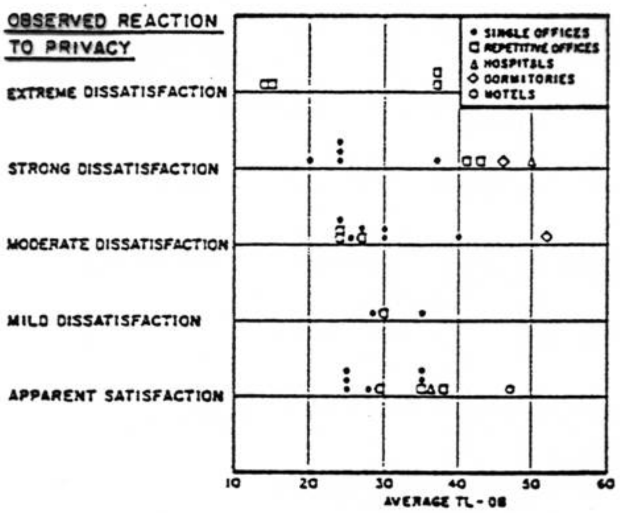
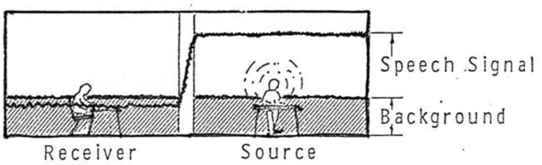


Figure 1. Plot of subjective reactions observed in 37 case histories of speech privacy versus the average TL rating of the sound isolating wall. Published laboratory TL values were used; where the wall was flanked by other sound transmission paths, measured values were used.

The essential elements in speech privacy analysis between enclosed rooms, as well as the approximate range (in dB) of each of five significant variables, is shown in Figure 2. Clearly overall speech privacy can be affected by performance of each of the variables in equal measure.



Variable	Approximate range (dB)
Speech effort	12 ("Conversational", "Raised", "Loud")
Source room absorption	10-15
Partition NR	20-50
Background ambient	30
Privacy requirement	6 ("Normal", "Confidential")

Figure 2. Variables in speech privacy between adjacent rooms.

Figure 3 shows the worksheet used to compile data for the 37 speech privacy case histories which incorporates rating factors for each of the five variables in the typical room-to-room speech transmission path:

1. Source Room Absorption Factor: Experience indicates that the average room absorption factor (in dB) for typically finished and furnished rooms is proportional to the room floor area.
2. Source Room Speech Effort: Prior research had indicated that there is typically a 6 dB differential with each incremental change in vocal effort from "conversational" to "raised" to "loud" voice.
3. Measured or Calculated Adjacent Room Background Noise Rating: NC rating curves are utilized to rate the room background noise spectrum. When the spectral shape generally matches the NC curve the prefix "N" is assigned to the NC rating value. Similar prefixes are assigned when the spectral shape generally matches NC shape at low frequencies below 1kHz ("L"), at high frequencies above 1kHz ("H") and at only the mid frequencies around 1kHz ("M").
4. Measured or Calculated Room-to-Room Noise Reduction: A rating is assigned to the noise reduction frequency response curve with a "N", "L", "H" or "M" prefix taking into account the spectral shape of the measured or calculated receiving room background noise rating.
5. Speech Privacy Requirement or Expectation: A rating "0" is assigned if the receiving room's occupant needs or expects "confidential" privacy (AI 0.05 or less of the intruding speech) or "6" for "normal" privacy (up to AI 0.10 of the intruding speech).

A summation of the five rating factors from the worksheet is compared with the case history data in Figure 4. Note that the example case history total summation "N81" indicates an expected response of "Extreme Dissatisfaction". Figure 4 represents a comparison of the observed reaction of building occupants to speech privacy conditions for all 37 case histories and indicates excellent correlation with the proposed rating scheme. Also indicated is the approximate condition for an AI 0.05 ("confidential" speech privacy.

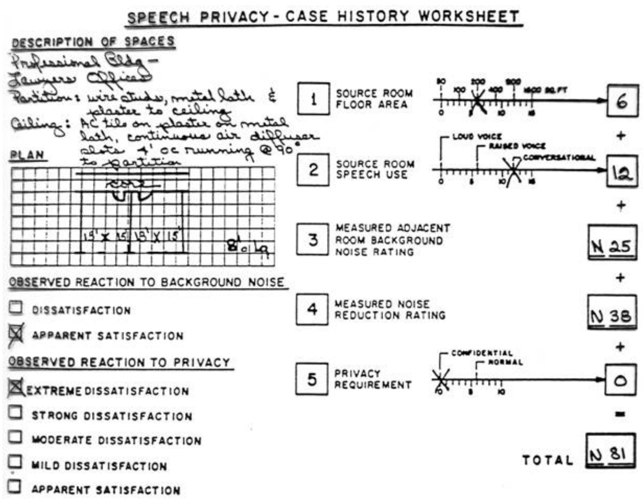


Figure 3. Worksheet for compiling case history data.

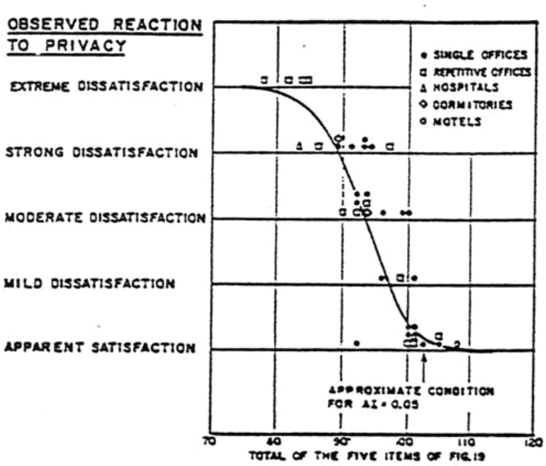


Figure 4. Plot of subjective reactions observed in 37 case histories versus the total rating from proposed speech privacy rating scheme.

3 1960s Refinement Of Speech Privacy Evaluation Methodology And Extension To Include Open Plan

Following the 1962 publication of [1], Robert Young began a dialogue with the study's authors toward re-evaluation of the original case history data and the resultant speech privacy analysis methodology. Young postulated that the more cumbersome methods for rating the receiver room background sound and the room-to-room noise reduction could be replaced with the then more commonly used A-scale ratings and STC or NIC ratings without sacrificing accuracy in the overall analysis method. His study convincingly demonstrated this to be the case and is reported in his 1965 paper "Re-Vision of the Speech Privacy Calculation" [2].

Figure 5 represents a key finding in Young's study and his suggested rearrangement of the five variables into two segments:

- Group A: Source Room Absorption, Source Room Vocal Effort and Privacy Requirement.
- Group B: Room Background Noise Rating and Room-to-room STC or NIC.

The sum of the Group B ratings subtracted from the sum of the Group A ratings yields the "Sound excess X, dB", and thus the expected occupant reaction. From Figure 5 an Excess of "0" would indicate occupant satisfaction.

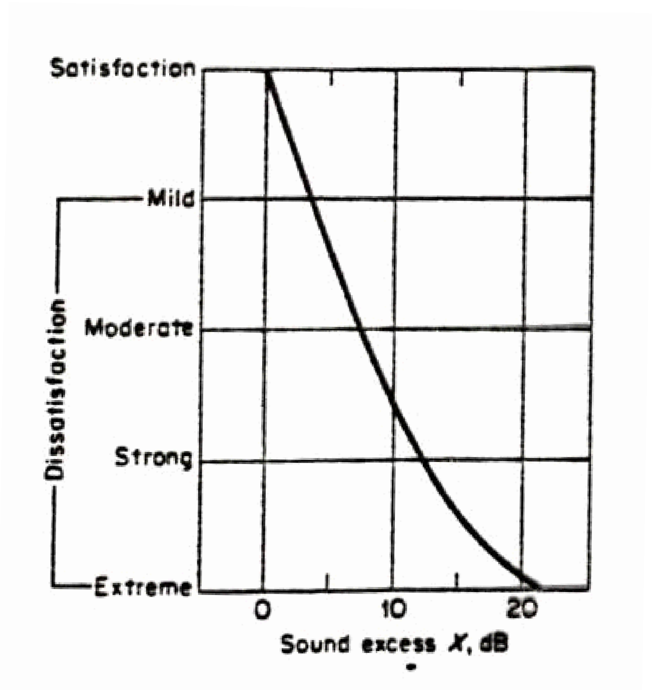


Figure 5. Simplified rating procedure using A-scale weighted room background sound levels and STC or NIC room-to-room sound isolation weightings [2].

The 1960s saw a significant increase in open plan configurations in buildings of nearly all types, commercial and governmental offices, healthcare facilities, educational facilities and others. Figure 6 is a schematic comparison of the similarities and dissimilarities in the speech sound transmission paths for conventional fully enclosed adjacencies and for open plan arrangements. Figure 7 is a worksheet adapting the enclosed plan analysis methods to open plan configurations. The sum of the open plan speech privacy ratings (or the Excess values if the Young calculation method is used) may be compared with case history data to evaluate the extent of the speech privacy problem and to determine corrective measures if needed.

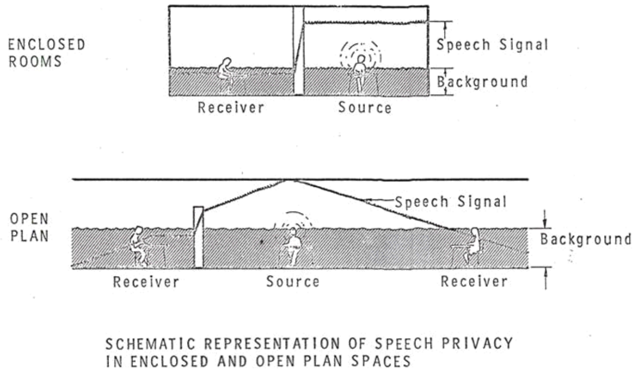


Figure 6. Schematic representation of speech privacy conditions in enclosed and open plan configurations [3].

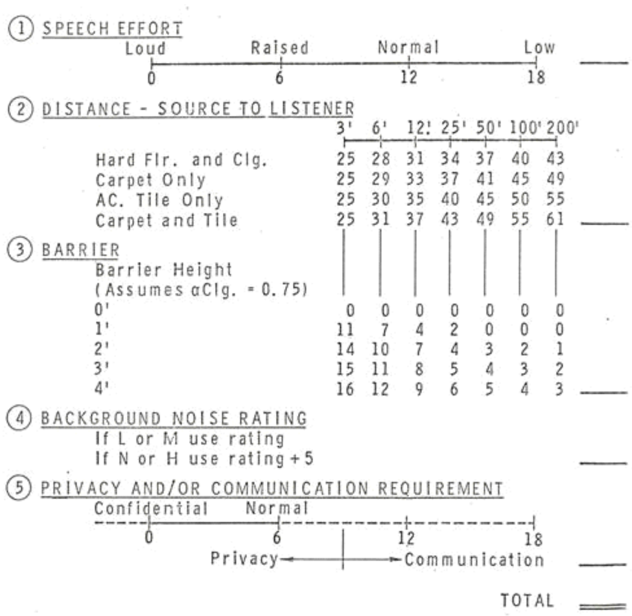


Figure 7. Worksheet for open plan speech privacy analysis [3].

4 Conclusions And Suggestions For Further Research

The simplified analysis and evaluation methods outlined in this paper have worked exceedingly well in dealing with speech privacy problems in enclosed and open plan configurations for over 50 years. As with all simplified methods there are limitation that must be understood to effectively and successfully use these methods. Some of these are listed below, and many represent opportunities for further research:

- Insensitivity of simplified ratings to large dips in sound isolation performance or background sound spectra
- Speech source spectral and intensity variations from idealized values.

- Low frequency component performance abnormalities
- Component field versus lab performance, flanking, etc.
- Variations in occupant privacy expectations
- Need for criteria to deal with speech privacy in highly classified, secure environments
- Cultural and language variations in speech privacy concerns

Acknowledgments

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References

[1] W. J. Cavanaugh, W. R. Farrell, P. W. Hirtle and B.G. Waters, "Speech privacy in buildings", J. Acoust. Soc. Am., 34, 475-493 (1962)

[2] R. W. Young, "Re-Vision of the speech privacy calculation", J. Acoust. Soc. Am., 38, 524-533 (1965)

[3] P. W. Hirtle, B. G. Waters and W. J. Cavanaugh , "Acoustics of open plan spaces: some case histories", J. Acoust. Soc. Am., 46, 91, (A) (1969)