Case Studies of a Method for Predicting Speech Privacy in the Contemporary Workplace

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An abbreviated version of a Summary Report dated January 2003 under the title "Designing Acoustically Successful Workplaces: Case Studies of a Method for Predicting Speech Privacy in the Contmporary Workplace". A full copy of the report is availbable from www.cbe.berkeley.edu.

Editor's note: Numbering from the original paper has been retained to enable readers to make sense of the complete version. Because the paper has been abbreviated, some numbers will not be consecutive. Additional background information given in footnotes has also been omitted .

1.0 Introduction

In surveys of office environments that measure occupants' satisfaction with their workspace, the intrusion of unwanted sound—noise—vies with temperature as the leading source of dissatisfaction (Harris, 1978, 1991, Sundstrom, 1994, Brill, 2001). Recent research by the Center for the Built Environment supports this finding, with more than 40% of employees responding to CBE's occupant satisfaction survey reporting that workplace acoustics make it harder for them to do their job (CBE, 2001). Moreover, an elevated level of workplace noise has been shown to increase stress, decrease motivation and is associated with risk factors for musculoskeletal disorder (Evans, 2000) .

To improve this situation, architects, interior designers, and facilities management professionals need to be able to translate a proposed design into a specific prediction of acoustical satisfaction with the resulting workspace. Over the past 40 years, acoustical consultants have in fact developed such a method. In the late 1950's, engineers at Bolt, Beranek & Newman recognized that a majority of acoustical complaints in offices were related to speech privacy—overhearing unwanted conversations or feeling that one is overheard. Building on research at Bell Labs that correlated a listener's ability to understand words with the ratio between the loudness of a person's voice and the loudness of the background noise, these engineers demonstrated that a listener's inability to understand words in a workplace setting is part of this same continuum of signal to noise. They then showed that that a series of objective measurements can establish this ratio and accurately predict an occupant's satisfaction with their speech privacy (Cavanaugh 1962). Over the past forty years, this method for predicting speech privacy satisfaction with has been simplified (Young, 1965), adapted for use in open plan environments (Pirn, 1971) and consolidated into worksheet formats for both open and closed office environments (Egan, 1972). Versions of this calculation procedure have been published in leading texts on acoustical design, including ones by Cavanaugh (1999), Egan (1988), and Salter (1998) .

Acoustical consultants have found these speech privacy calculations useful for analyzing design documents, evaluating full-scale prototypes and identifying problems in fully occupied and functioning buildings. These calculation procedures have not, however, been disseminated widely in the architectural and interior design community. Reasons may include unfamiliar measurement units and concepts, the specialized testing equipment required for prototype and in situ evaluations, a lack of formal testing validated and illustrated in the context of today's offices, and cost and aesthetics-driven decision making which does not identify the risks of unacceptable acoustics .

This paper presents an updated, simple, easy-to-use version of a predictive methodology, the Speech Privacy Predictor (SPP). SPP is intended to help those designing, furnishing or retrofitting open plan and private offices. To illustrate the application of the SPP method, nine case studies are described below. These case studies document acoustical conditions in an office building where the Center for the Built Environment had previously conducted an occupant survey. In layout and utilization, this building is representative of a typical modern office—large open plan areas, ubiquitous telephones with built-in speakerphones, distributed common areas, and widespread use of computers. It is also typical of the acoustical shortcomings of modern offices: CBE's occupant satisfaction survey had detected significant occupant dissatisfaction with speech privacy .

Each case study is designed to demonstrate how the SPP calculation is performed. The case studies evaluate the reliability of the SPP method, by comparing predicted results with measurements of actual acoustic conditions as well as the subjective level of acoustic dissatisfaction reported by those who had taken the CBE Survey.

Results of these comparisons show broad agreement between the predictive tool, measured acoustic conditions, and surveyed employee dissatisfaction. The SPP method therefore appears to be a viable tool for designing to achieve good acoustical environments. This finding is especially noteworthy because while poor speech privacy has been shown to reduce worker motivation, interfere with concentration and compromise the security of meetings and confidential discussions, retrofitting office spaces with poor acoustic performance is often an expensive and disruptive solution.

2.0 Method

2.1 Building Selection

To illustrate the application of the SPP method, and evaluate its effectiveness as a design tool, a series of case studies were conducted in a building where the Center for the Built Environment had conducted a Post Occupancy Evaluation Survey.1 This Class-A office building was constructed in 1980 for its current owner, and contains 650,000 gross square feet of office space. The building's layout is typical of the modern office: 15% of gross space is used for enclosed private offices and conference rooms, with the remainder used for open plan workstations, common areas, lobbies, circulation, and a variety of other operations. Office equipment is also characteristic of the modern workplace: ubiquitous telephones with built-in speakerphones, computers on nearly every desktop, broad distribution of laser printers, and centrally located areas for photocopying.

While nearly two-thirds of the 687 respondents reported overall satisfaction with their workspace, and nearly three-quarters of respondents expressed overall satisfaction with the building, CBE's survey had detected significant dissatisfaction with acoustical conditions. In contrast to pluralities reporting that lighting, air quality, temperature, office equipment, and furniture made it easier to get their jobs done, 46% of building occupants reported that the overall noise level in their workspace made it harder for them to get their job done.

This level of acoustic dissatisfaction relative to other building attributes is consistent with nearly two-dozen similar occupant satisfaction surveys CBE has administered over the past three years. It is nonetheless puzzling, because the surveyed building is owner-occupied, constructed less than twenty five years ago as a headquarters building with premium finishes and materials, and has a responsive and involved facility management staff. Moreover, dissatisfaction is not limited to occupants working in open-plan areas: more than a third of respondents in the enclosed private offices also expressed dissatisfaction with their speech privacy. Nor can acoustical dissatisfaction be attributed to unusual or specialized work processes, overcrowded conditions, rapid growth or management turbulence: the majority of the building's occupants are managerial and professional workers engaged in the types of 'knowledge work' characteristic of many modern business enterprises, and the building's owner/occupant has not engaged in expansion, acquisition or layoffs in the five

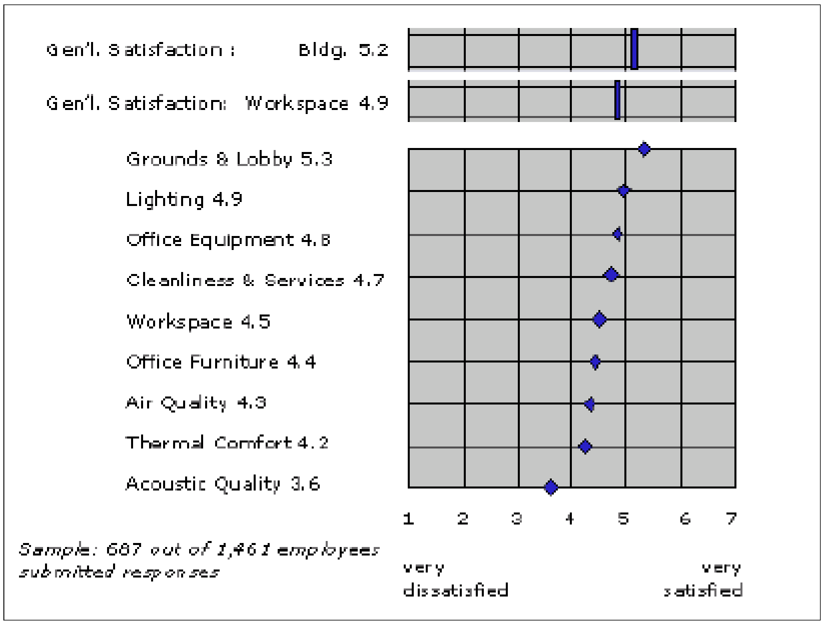


Table 1: Summary of Post occupancy Evaluation Results by Category

years before the survey. Would the SPP method have predicted this level of acoustic dissatisfaction?

2.2 Selection of Case Study Locations

CBE's research protocol allowed us to filter data by floor and office type (enclosed/open plan). We then worked with the building's facility manager to identify floors that had a representative range of acoustic and work conditions, and responses that tracked with the overall building.

Open Plan Case Studies.

The physical layout of workstations in the case study floor were representative of those distributed throughout the facility, consisting of standard 8 foot by 10-foot cubicles, enclosed by 62-inch high acoustical partitions. The ceiling finishes were also representative of those found throughout the building, consisting of 2-x 2-foot mineral-fiber ceiling tiles with a noise reduction coefficient (NRC) of 0.55 and a ceiling attenuation class (CAC) of approximately 35. Floors were finished with standard carpet tiles.

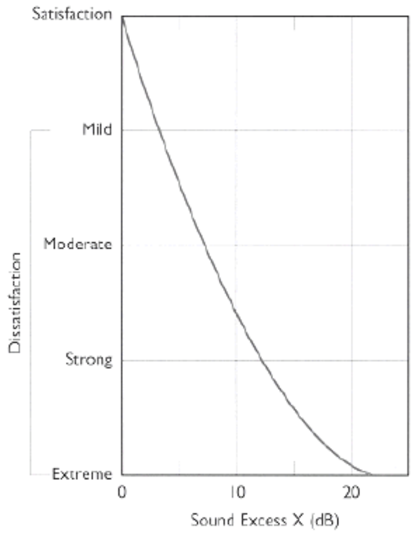
Private (Enclosed) Office Case Studies.

Although private offices varied more in size than did open-plan workstations, the private offices we studied were standardized at 10 feet wide by 15 feet deep, and were located in the building core. These offices were constructed of uninsulated steel stud partitions faced with one layer of gypsum board on each side.

A solid core wood door and a five-foot expanse of floor to ceiling glazing were part of the corridor-facing wall. Partitions terminated at the underside of the suspended acoustic tile ceiling. Ceiling and floor finishes were identical to open plan areas.

Conference Room Case Studies.

Narrative comments revealed frequent complaints of sound transfer between private offices and conference rooms, and between the conference rooms themselves. We conducted case studies in three representative conditions: between a large conference room and a private office, between a small conference room and a private office and between a small conference room and a large conference room. Like private offices, conference rooms were located in the building core, and shared the same modular geometry (large conference rooms were 15 feet by 20 feet, small conference rooms 10 feet by 15 feet). Construction assemblies and finishes for conference rooms were nearly identical to those found in private offices, including the same acoustic tile ceilings, carpeted floors and walls of gypsum board on steel studs, with the corridor



SOUND EXCESS	LEVEL OF DISSATISFACTION
+3	Mild
+7	Moderate
+12	Strong
>+20	Extreme

Figure 2: Levels of Speech Privacy Acceptability, per Cavanaugh

facing wall including a solid core door, and an expanse of floor to ceiling glass. No sound absorbing panels were installed on any walls.

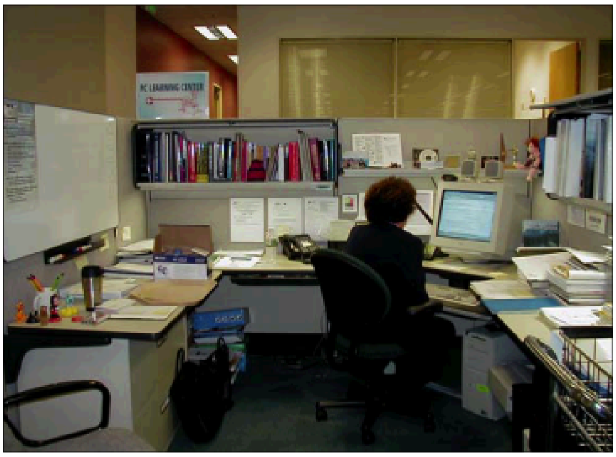
2.3 Application of the SPP Method

To establish the ratio of intruding speech to the ambient background noise the SPP method considers a pair of adjacent spaces, the source space, where conversation is occurring, and the receive space, where speech privacy is being measured. The calculation procedure simply involves subtracting isolation factors from source factors, in order to produce a single number rating called sound excess for the receive space. Speech-privacy satisfaction can then be plotted as a function of the single number sound excess rating, as illustrated in Figure 2.

To illustrate the SPP method's application and evaluate whether it would have predicted the unsatisfactory conditions detected by the CBE survey in both open and enclosed office settings, a SPP predictive calculation procedure was performed for each case study location. These calculations drew on the following information: workstation layout, room surface treatments and materials, partition heights and construction, voice levels, room sizes, and background noise. To test the reliability of the assumed values for the variables involved in these calculations, a series of acoustical measurements and field observations of occupant behavior were also made in each case study location. Predicted and measured results were described in terms of the level of satisfaction predicted by the SPP method, and congruence of these ratings with the CBE survey's overall finding of occupant satisfaction with speech privacy was evaluated. The worksheets and detailed description of the SPP method's variables and calculation method are summarized in Appendix 1.

3.0 Open Plan Case Study Results

Three open plan case studies are described below. Overall, the level of dissatisfaction predicted by the SPP method correlated with the dissatisfaction with speech privacy expressed in the CBE survey and with measurements of actual acoustical conditions. There was, however, more spread between predicted and measured SPP values than in case studies of private



offices and conference rooms. We attribute this spread largely to the greater range of conditions that the SPP procedure must account for in an open plan environment. In this case, better than predicted noise reduction between workstations was achieved by a combination of a partition product that performs better than expected, a greater than usual number of absorptive surfaces, and a noisy HVAC system in one of the three measured locations.

Although it may seem counter-intuitive, the most effective way to improve speech privacy in open plan offices is to introduce background noise in a controlled manner. This is commonly referred to as sound masking, and is typically achieved by placing loudspeakers in the ceiling plenum.

Two additional design issues contribute to speech privacy problems in these offices. First, a lack of appropriate meeting and conference spaces leads occupants to hold impromptu meetings in their cubicles, even though occupants are aware that this will disturb their neighbors. Secondly, grid-like layouts of cubicles create an extensive network of circulation 'streets' where casual conversation is likely to occur and disturb other occupants.

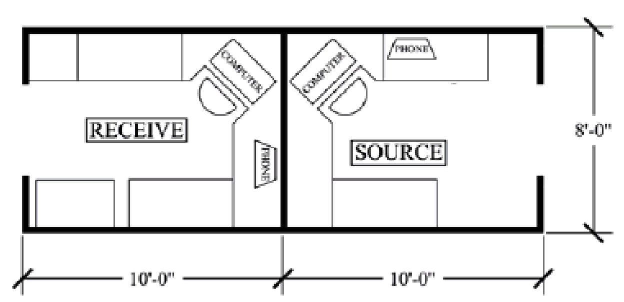
Finding 1: In open plan settings with underfloor air distribution or traditional variable air volume overhead ventilation systems (HVAC), the background sound level will be too low to achieve "normal" speech privacy. In these environments the background sound can be augmented with sound masking system. Adequate absorptive surfaces such as acoustical ceiling and partitions and a carpeted floor will also be required.

Finding 2: In open plan offices, there should be a distribution of enclosed 'teaming' and conference spaces, located proximate to the work area, with good visual access to and effective acoustical separation from the open plan work area to accommodate both formal and informal group conversation.

Finding 3: In open plan settings a 'boulevard' and 'cul-de-sac' layout should be used to ensure that impromptu casual conversation occurs away from workstations.

3.1 Case Study 1: Open Plan Workstation to Workstation

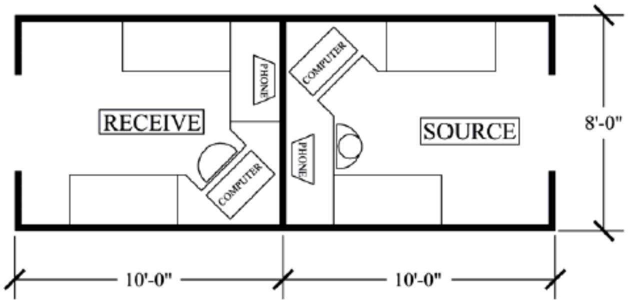
In this case study, we observed work-related conversation occurring between two co-workers in a cubicle adjacent to the evaluation space. Even though a nearby HVAC supply air diffuser was mis-adjusted, creating additional background noise and improving the signal-to-noise ratio in this workspace, the occupant commented, "I am disturbed by conversations in adjacent cubes, it makes it difficult to concentrate". Although the employees in the adjacent cubicle were maintaining a respectfully quiet conversational voice, it is difficult to accommodate any meeting activity in an open plan workstation. Even if there were a sound masking system, this level of conversational activity given this cubicle spacing would produce "moderate dissatisfaction."



SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Low Voice	54	Conversational	60
B. Speech Privacy Criterion	Normal	9	Normal	9
Sum Source Factors		**63**		**69**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
C. Distance: Source to receiver (from table)	6 feet	5	N/A	
D. Barrier Noise Reduction (from table)	Source to barrier: 3' Receiver to barrier: 3' Break in line-of-sight: 1'	8	N/A	
C+D Noise Reduction (measured in situ)		13	Measured	17
E. Background Noise (dBA, receiving cubicle)	Typical: Open Plan (without	40	Measured (Under	42
Sum Isolation Factors		**53**		**59**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+10		+10
Predicted level of acceptability	Strong dissatisfaction		Strong Dissatisfaction	

3.2 Case Study 2: Workstation to Workstation

In this case study, we observed no unusual activities. The occupant of this cubicle and others nearby spoke in low speech levels into their telephones. This voice level is characteristic of the type of speech behavior that is most successfully accommodated in an open plan environment. The very low level of background noise created unsatisfactory speech privacy conditions. The occupant commented, “I can hear others talking but I tune it out. No one can use a speakerphone because it would bother other people”. SPP calculations suggest that the introduction of 8 dBA of additional background noise through a well-tuned sound-masking system would create acceptable acoustical conditions for this partition system and cubicle layout, assuming the workgroup would consistently maintain the low voice level we observed.



SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Low Voice	54	Low Voice	54
B. Speech Privacy Criterion	Normal	9	Normal	9
Sum Source Factors		**63**		**63**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
C. Distance:Source to receiver (from table)	6 feet	5	N/A	
D. Barrier Noise Reduction (from table)	Source to barrier: 3’ Receiver to barrier: 3’ Break in line-of-sight: 1’	8	N/A	
C+D Noise Reduction (measured in situ)		13	Measured	17
E. Background Noise (dBA, receiving cubicle)	Typical: Open Plan (without sound masking system)	40	Measured	37
Sum Isolation Factors		**53**		**54**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+10		+9
Predicted level of acceptability	Moderate-strong dissatisfaction		Moderate-strong Dissatisfaction	

4.0 Private Office Case Study Results

Case studies of private offices are described below. Here, too, we found that occupant dissatisfaction predicted by the SPP method correlated broadly with the overall speech privacy dissatisfaction detected in the CBE survey. Moreover, predicted values calculated from design document data corresponded well with values derived from measurement.

Had the design originally been evaluated with the SPP method, a series of options could have been iteratively explored. This process would have begun by identifying employees requiring “confidential” speech privacy and those requiring “normal” speech privacy. Construction assemblies that could achieve the required levels of speech privacy would have then have been recommended. These assemblies would likely have included acoustically upgraded wall construction, and details minimizing the sound transfer between offices where the wall terminates at the underside of a continuous, suspended ceiling. Additional acoustic details to minimize sound leaks at wall penetrations and floor/ceiling connections, as well as methods to minimize the ‘cross talk’ that occurs from unlined ducts running between offices would also have been recommended.

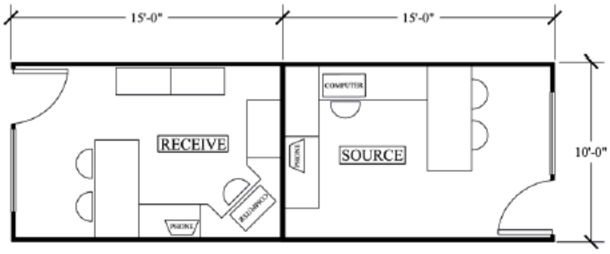
Finding 1: In standard private offices (100-200 square feet) where 'normal' speech privacy is desired and speakerphone use limited, an ordinary steel stud ceiling-height wall can be used if the A-weighted background noise level is at least 40 dB. In a contemporary office building with carpeted floors, a suspended acoustical ceiling, and VAV or underfloor HVAC systems, this level of background noise is likely to be achieved with the installation of a sound masking system. Alternatively, "normal" speech privacy can be achieved in standard private offices with an acoustically upgraded wall assembly.

Finding 2: In a similar office setting where a where a speakerphone is frequently used, a "confidential" level of speech privacy is required, and a more typical background noise level of 35 dB is desired, an acoustically rated, slab-to-slab partition wall is required.

Finding 3: Speakerphone use should be specifically considered and accommodated in either the acoustical design of private offices or in nearby spaces such as specially designed 'phone booths' and conference rooms.

4.1 Case Study 4: Private Office to Private Office

In this case study, we observed speakerphone use in the office adjacent to the evaluation space. The occupant using the speakerphone later told us, "walls are thin. I know my voice carries, and I am concerned that my neighbors can hear me".



A well-known psycho-acoustic feedback mechanism describes the tendency of people to raise their voice when they experience difficulty comprehending the person(s) they are speaking to. In an office setting, this frequently occurs when people use speakerphones.

In the past, private offices have typically been designed to provide normal to confidential speech privacy for informal conversation between two or three people. This voice level is lower than that typically used by speakerphone users. Because speakerphones have become increasingly widespread in office settings in recent years, an organizational decision should be made regarding their appropriate use.

One possibility is to restrict speakerphone use to conference rooms and/or specially designed rooms, sometimes referred to as 'phone booths'. Alternatively, speakerphone use within an office can be accommodated by using an acoustically rated construction that will provide the required level of speech privacy for this voice level.

(Continued on page 22)

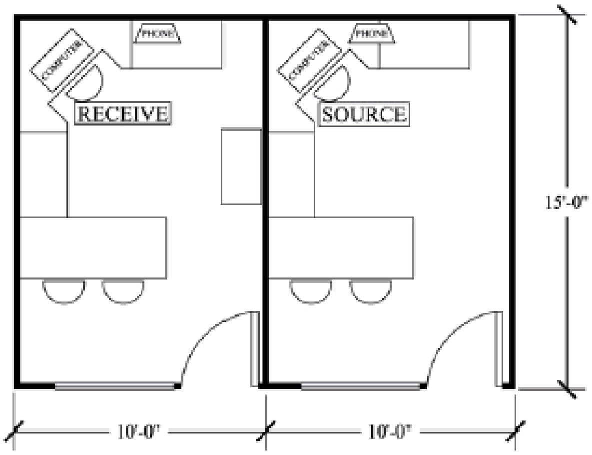
(Continued from page 21)

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Raised	66	Raised	66
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq.ft	6	150 sq.ft	6
Sum Source Factors		**87**		**87**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling.	39	Measured	39
E. Effect of Receive Room (from table)		2		N/A
F. Background Noise (dBA, receiving room)	Typical: Private Office	35	Measured	33
Sum Isolation Factors		**76**		**72**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+11		+15
Predicted level of acceptability	Strong dissatisfaction		Strong Dissatisfaction	

4.2 Case Study 5: Private Office to Private Office

In this case-study, we observed no unusual activity in the adjacent office or open plan area. The occupant of the evaluation space complained, "I have quiet neighbors, but I can hear talking from the offices on both sides of me. It's not that I can hear what they are saying, but that I can hear that people are talking, and it's distracting".

The level of speech privacy desired by this occupant, inaudibility, is not ordinarily provided in private offices.



SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Conversational	60	Conversational	60
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq.ft	6	150 sq.ft	6
Sum Source Factors		**81**		**81**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling.	39	Measured	37
E. Effect of Receive Room (from table)		0		N/A
F. Background Noise (dBA, receiving room)	Typical: Private Office	35	Measured	38
Sum Isolation Factors		**74**		**75**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+7		+6
Predicted level of acceptability	Moderate dissatisfaction		Moderate Dissatisfaction	

5.0 Conference Room Case Study Results

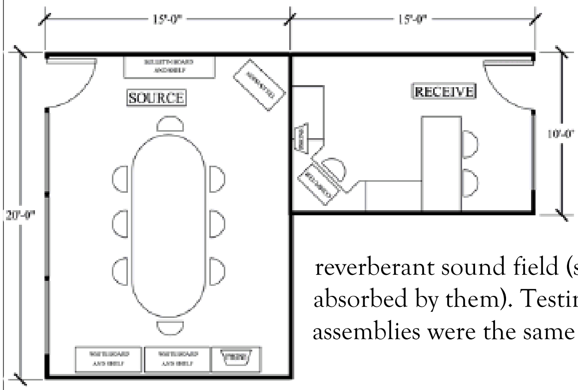
In the CBE survey, respondents identified the intrusion of conference room noise into adjacent meeting spaces and private offices as a significant problem. In the three conference room case studies described below, the source of this problem is clear: as part of the office space's modular design, conference rooms are fashioned from the same wall assemblies and floor and ceiling finishes as private offices. Conference rooms, of course, typically accommodate activities where a louder voice level is used than occurs in a private office. Therefore, a wall assembly that is adequate for a private office is not likely to work well for a conference space.

Had these conference room designs been evaluated with the SPP method at the design stage, acoustically improved wall constructions would have been recommended. An adequate acoustical design would also include details for minimizing sound leaks and the 'cross talk' between conference rooms and adjacent spaces connected by unlined ducts and shared ceiling plenums. Sound absorbing wall treatments and upgraded ceilings would likely have also been recommended to minimize reverberation and the build-up of sound within these rooms.

Finding 1: Contemporary office design emphasizes flexibility. Wall and ceiling constructions that will provide normal speech privacy in private offices are not likely, however, to produce acceptable results given elevated voice levels and increased privacy requirements of a conference/meeting space.

Finding 2: Some conference rooms are specifically designed to accommodate teleconferencing and audio-visual presentations. These spaces must also be designed to provide an appropriate level of acoustical privacy that allows these rooms to operate without disturbing occupants in adjacent spaces.

5.1 Case Study 7: Large Conference Room to Private Office

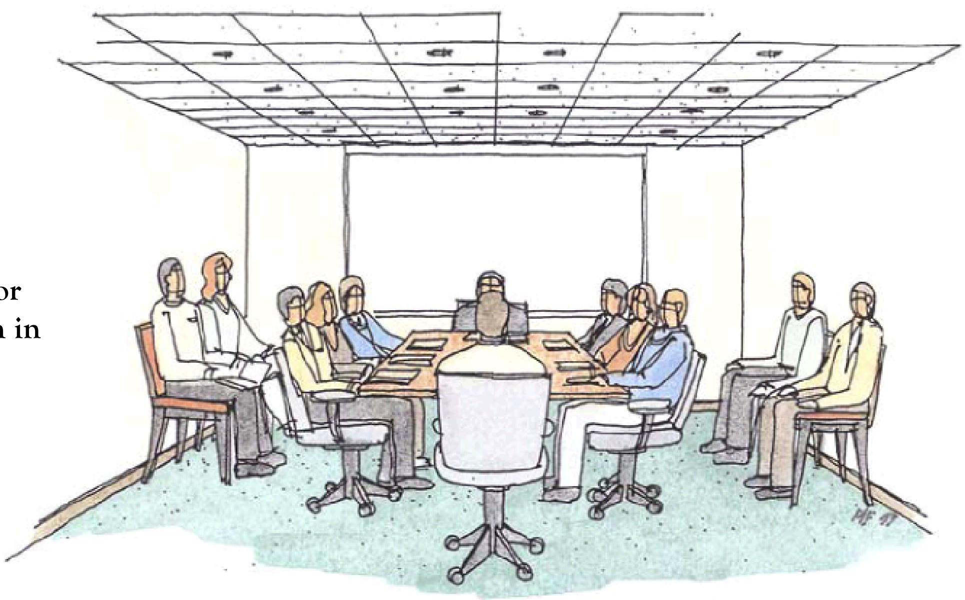


In this case study, we investigated the level of privacy between a large conference room and the occupant in an adjacent office. Although we did not observe the conference room in use, the presence of audio-visual equipment in this room suggests that the room supports presentations to an assembled group. When speaking to a group, a presenter typically uses a "raised" to "loud" voice level. The room itself lacked absorptive materials on its walls, contributing to a reverberant sound field (sound reflected by the room's surfaces rather than being absorbed by them). Testing showed that the acoustical performance of the wall assemblies were the same as for private offices.

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Loud (Presentations)	72	Loud (Presentations)[1]	72
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	300 sq.ft	2	300 sq.ft	2
Sum Source Factors		**89**		**89**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling.	39	Measured	39
E. Effect of Receive Room (from table)		5		N/A
F. Background Noise (dBA, receiving room)	Typical: Private Office	35	Measured	38
Sum Isolation Factors		**79**		**77**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+10		+12
Predicted level of acceptability	Strong dissatisfaction		Strong Dissatisfaction	

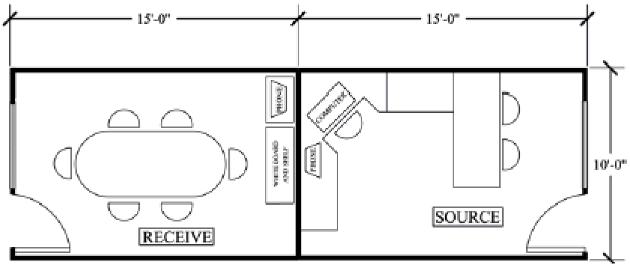
Note 1. No conference was taking place, this value was predicted

Ceilings and partitions need to provide adequate sound insulation for group conversation in conference rooms



5.2 Case Study 8: Small Conference Room to Private Office

In this case study, we investigated the level of privacy between a small conference room and the occupant in an adjacent office. Although we did not observe the conference room in use, we would predict that the room's smaller size would encourage the use of a lower voice level than in the larger conference room. Voice levels are still greater than those typically used in a private office, however. Moreover, the room's lack of absorptive materials and use of standard ceiling height wall construction contribute to a level of acoustical impact even greater than in the larger conference room, where a louder voice would typically be in use. An occupant in an adjacent office confirmed this behavior: "[I] can hear conversations from adjacent offices and from the conference room behind me. The conference room is worse."



SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Raised	66	Raised[1]	66
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq.ft	6	150 sq.ft	6
Sum Source Factors		**87**		**87**
ISOLATION FACTORS	**PREDICTED**		**OBSERVED**	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling.	39	Measured 3 1/2" steel stud 5/8" drywall each side	39
E. Effect of Receive Room (from table)		0		N/A
F. Background Noise (dBA, receiving room)	Typical: Private Office	35	Measured	37
Sum Isolation Factors		**76**		**76**
SOUND EXCESS	**PREDICTED**		**OBSERVED**	
Source factors minus isolation factors		+11		+11
Predicted level of acceptability	Strong dissatisfaction		Strong Dissatisfaction	

Note 1. No conference was taking place, this value was predicted

6.0 Conclusions

Believing in the benefit of an open and collaborative work environment, an ever-greater number of managers, professionals and executives are abandoning private offices and adopting open plan areas with specialized office spaces to accommodate the casual conversations, informal meetings and even speakerphone use that once occurred in private offices.

The poor performance of these open plan environments in occupant satisfaction surveys appears to primarily result from their inability to provide the level of speech privacy employees feel necessary for them to concentrate and be productive. The high level of acoustical dissatisfaction identified in these surveys may also be working to negate some of the presumed good will and free exchange of ideas associated with open-plan spaces.

At the same time, a litigious environment and emphasis on the protection of intellectual property mean that speech privacy is more important than ever before.

Clearly, there is a need for a reliable tool enabling building design and management professionals to evaluate whether a given office design will provide a satisfactory level of acoustical satisfaction.

Based on the nine case studies described above, the SPP method appears to offer an effective framework for anticipating speech privacy problems and crafting solutions for proposed spaces.

In each case study, the level of acceptability for speech privacy predicted by the method was broadly congruent with the level of acoustic dissatisfaction reported by occupants of these spaces during our in-person interviews and with the aggregated response of occupants in case studies recorded by the CBE's post-occupancy evaluation survey.

Use of the SPP method during the design process also promises significant cost benefits, because acoustical upgrades are inexpensive when incorporated into the original design, but are substantially more expensive when performed as part of an acoustical retrofit.

At the design stage, for example, the wall separating the private offices we studied could have been upgraded to provide an acceptable level of speech privacy simply by adding a 3-inch glass fiber blanket ($0.60 per square foot), a layer of gypsum board ($1.20 per square foot), and selecting a ceiling with a higher transmission loss rating ($1.00 per square foot).

Retrofitting these offices now, however, would involve completely rebuilding the wall ($15 per square foot), as well as replacing the ceiling ($3.50 per square foot), nearly ten-times the cost of the original upgrade. (See appendix 2.)

When used in open plan areas, the SPP method showed greater variability in its predicted results. Research is underway to establish the range of this variability, and to compare results obtained with the SPP method to those obtained with ASTM's widely accepted standard method for evaluating (but not predicting) speech privacy in open plan offices.

An important next step in disseminating the SPP method will be to develop a companion design guide of best practices in acoustically successful office design, which will augment the SPP method's application among

Appendix 1 Detailed Method For Using The Speech Privacy Predictor (Spp)

Introduction

The Speech Privacy Predictor (SPP) is based on research by Cavanaugh, Farrell, Hirtle, and Watters (Cavanaugh 1962). Cavanaugh found that the ratio of intruding speech to the ambient background noise in the office was the best predictor of satisfaction with speech privacy. Cavanaugh's rating scheme considers five variables needed to determine the signal-to-noise ratio for a pair of adjacent office spaces. These variables are (1) how loud the voices of people using a space typically are, (2) the level of privacy required, (3) the background noise in the adjacent room (4) the effect of size, furnishings and finishes of the adjoining room, and (5) the ability of the intervening partition to block sound. Cavanaugh's procedure combines these variables into a single number rating for sound excess. Over the past 40 years, Cavanaugh's method of predicting an occupant's acoustic satisfaction based on the ratio of intruding speech to the ambient background noise has proved exceptionally durable. The Cavanaugh method underlies all leading approaches to quantifying office acoustics in North America, including those established by the American Society for Testing and Materials (ASTM, 1994) and the U.S. General Services Administration (GSA, 1975). Robert W. Young (1965) simplified the measurement protocol, and Rein Pirn (1971) adapted the method for use in open plan offices. SPP draws upon the procedure published in Egan (1988), Salter et.al. (1998) and Cavanaugh (1999).

Calculation Procedure

The SPP method calculates sound excess to predict the level of speech privacy acceptability of an office space. Drawing on simple design and space programming data, values representing 'source' and 'isolation' factors are each summed. Isolation factors are then subtracted from the source factors. Each of these variables are described in detail below. Note that the source space is the location where the occupant is speaking, and where the confidentiality of conversation will be evaluated. The receive space conversely is the location where the speech in the source space is intruding and can potentially be overheard or will be distracting. Note also that the calculation procedure is somewhat different for open plan and enclosed office spaces.

Calculation of Source Factors

Source factors include two variables that are shaped by occupant behavior and expectations: speech privacy criteria and source voice level. In certain cases, overheard conversations may aid team processes. In others, the ability to understand even partial sentences may inhibit the ability to discuss sensitive work and personnel issues.

1. Voice Source Level

Based on programming data, estimate the typical voice level associated with the loudest likely behavior of employees in the workgroup occupying the space.

Voice Source Level	Typical Activity	Criteria (dBA)
Low	Telephone conversation using a low voice level	54
Conversational	Casual conversation between two people in an office setting	60
Raised	Conversation of three or more people in a meeting	66
Loud	Talking into a speakerphone, delivering a presentation	72

2. Speech Privacy Criteria

Acoustical engineers refer to three standard levels of speech privacy. Based on programming data, determine which level of privacy is appropriate for the workgroup occupying the space.

Level of Speech Privacy	Description	Criteria (dBA)
Confidential	Speech from adjacent space is audible but not intelligible—the listener is aware that a conversation is occurring, but is not able to understand individual words	15
Normal	Speech from adjacent space is audible and partially intelligible—the listener has the ability to comprehend an occasional word but never full sentences	9
Marginal	Speech from adjacent space is largely understandable	3

3. Effect Of Source Room

In private offices and conference spaces, voice levels in the source room are adjusted to account for the amount of absorption provided by the furnishings and room volume.

Floor Area (Square Feet)	Criteria Room with 50% Absorptive Surfaces (dBA)	Criteria Room with less than 20% Absorptive Surfaces (dBA)
60	+9	+15
125	+6	+12
250	+3	+9
500	0	+6
1000	-3	+3

Calculation of Isolation Factors

4. Distance From Source (Open Plan Areas)

Sound from the source workstation will attenuate as the distance between workstations increases. Note that these values assume absorptive ceiling and workstation partitions, and carpeted floors.

Distance from Source Workstation to Receiver Workstation (feet)	**Criteria** (dBA)
3	0
6	5
12	10
24	15

5. Barrier Noise Reduction (Open Plan Areas)

This criterion accounts for the effectiveness of the partitions between workstations as a function of STC of the partition itself, the layout of the workstations and the amount of absorptive finishes in the space. This calculation assumes an absorptive ceiling (minimum NRC of .65), partitions with a minimum STC of 18, and 50% of panels/ wall surfaces above 3 feet having sound absorbing materials, such as bookcases with books or acoustical panels.

Distance Receiver to Barrier	**Criteria: Barrier height/Distance Source to Barrier**											
	Slight Break in Line of Sight for Source to Barrier Distance			1 foot Break in Line of Sight for Source to Barrier Distance			2 foot Break in Line of Sight for Source to Barrier Distance			3 foot Break in Line of Sight for Source to Barrier Distance		
	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.
3-feet	5	5	5	8	7	7	11	10	9	13	12	12
6-feet	5	5	5	7	7	6	10	9	8	12	11	10
12-feet	5	5	5	7	6	6	9	8	8	12	10	9

6. Partition Construction (Private Offices And Conference Rooms)

This criterion accounts for the acoustic performance of the walls separating the source and receive spaces. This value is measured in terms of the Sound Transmission Class (STC) rating of the partition. The table lists STC values for standard partition types. These values assume full height (slab to slab) construction, and the use of acoustical sealant at all penetrations and wall connections.

Wall performance will be less if there are even small gaps at floor/ceiling connections, corners, doors frames, outlet boxes, or if the wall terminates at the underside of an un-insulated suspended ceiling.

Wall Type	Criteria (STC)
3 5/8” metal studs, 24” o.c., 1 layer 5/8” gypsum board each side	39
Same as above, with 3” glass fiber in cavity	44
Same as above, with 3” glass fiber in cavity and 2 layers 5/8” gypsum board one side	50
Double row of 3 5/8” metal studs on separate plates, 24” o.c., 1 inch between plates, 1 layer 5/8” gypsum board each side, 3 ½” glass fiber both sides	59
Same as above, 2 layers 5/8” gypsum board each side	63

7. Effect Of Receive Room (Private Offices And Conference Rooms)

The receive room will absorb some of the intruding sound radiating from the common wall.

Ratio Floor Area Receive Room to Common Partition Area	Criteria Room with 50% Absorptive Surfaces (dBA)	Criteria Room with less than 20% Absorptive Surfaces (dBA)
1	+0	-5
1.5	+0	-3
2	+3	-2
3	+5	0
4	+6	+1
5	+7	+2
6	+8	+3
10	+10	+5

8. Background Noise Level

The level of background noise in the receive space is critical in masking speech from the adjoining source space. Based on research summarized by Egan (1998), if intruding speech is on average 10 dB below the background noise, satisfaction with speech privacy approaches 100%. Conversely, if intruding speech is on average 5 dB above background noise, dissatisfaction approaches 100%. Although it may seem counter-intuitive, many contemporary open plan office spaces are too quiet, and require the insertion of additional noise. This noise is called ‘sound masking’ and represents a ‘controlled quiet’ that sounds somewhat like ventilation noise. Sound masking differs from ‘pink’ noise (unpleasant, unnatural) and ‘white’ noise (hissy, annoying). Sound masking needs to be specified and installed by a trained professional, because it is specifically tuned in a given space to offer an optimum sound spectrum.

Condition	Criteria (Background Sound, dBA)
Quiet ventilation system, no nearby office equipment, no traffic noise intrusion through building façade, sound absorbing ceiling	30
Recommended limit for steady state background noise in private offices and conference rooms	35
Constant air volume mechanical system, nearby office equipment and/or moderate traffic intrusion, standard acoustical tile ceiling	40
Sound masking system	45
Recommended limit for steady state background noise in open plan areas	50

Editor’s note: See full paper for sample worksheets, testing protocol, and detailed survey results. ❑