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Applying Occupant and Building Performance Measurement and Design to Improve Office Acoustics

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A Professional Paper from
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Foreword

The first professional paper that the American Society of Interior Designers (ASID) produced was *Sound Solutions* in 1996. A lot has changed in the practice of interior design and in the design of office spaces since that time. Nevertheless, *Sound Solutions* continues to be one of the most frequently requested ASID publications. Perhaps that is because the issues it addresses – reducing office noise, ensuring audio privacy and increasing productivity – continue to rank foremost among the concerns that clients and their employees raise during the design process.

Indeed, these issues have become more exacerbated as businesses have sought to economize and reduce the square foot cost of their facilities. As the authors of this new professional paper on acoustic office design point out, as a result of this trend, work spaces have been getting even smaller, workers are being brought into even closer proximity to one another, and sensitivity around privacy and noise has greatly increased since the mid-90s. It was decided, therefore, that the time had come to revisit *Sound Solutions* and determine whether it still met the needs of office designers in today's work environment.

Sound Solutions represented some of the best thinking at the time by interior designers and industry as to how various products in the office environment could work together to address the problem of noise. And many of the findings and tips provided in *Sound Solutions* are as valid today as they were then. But as the authors of this paper explain, today's office environment is much more acoustically complex, and the solutions needed to address issues of noise and privacy require a more holistic approach than focusing on product alone. Continued research into acoustics and the behavior of occupants has revealed that other factors, such as organizational culture, employees' expectations and the presence or absence of other environmental stimuli (to name just a few), can greatly impact occupants' perceptions of sound and personal privacy. Thus it is that this paper takes a different approach than that in *Sound Solutions*. I believe you will find it a helpful companion to *Sound Solutions* and a number of industry papers on this topic.

On behalf of ASID, I especially want to thank the authors of this new paper, Steven J. Orfield of Orfield Laboratories, Inc., and Jay L. Brand, Ph.D., of Haworth, Inc. Their experience and insights have contributed greatly to a more thorough understanding and appreciation of acoustical office design. I also want to thank Elizabeth Ebihara and the management at Haworth for their support of this project and their generous assistance with the design of the publication.

ASID is very pleased to have worked with such a talented team on this project. Collaboration is the key to all of our success. This manual is evidence of how professionals working together can achieve greater results. In the end, not only we, but our clients and the occupants, all benefit.

Linda Elliott Smith, FASID
President
American Society of Interior Designers

Table of Contents

Preface

About eight years ago, ASID published its first office acoustics paper entitled *Sound Solutions*. Much of the emphasis in that effort was to help designers understand the importance of acoustics in the office in terms of acoustical privacy, focusing primarily on product acoustics. One intention of this update is to move from the product-based approach discussed in that original publication to a more process-based approach framed by the broad context of occupant experience in the office. This effort is also intended to place acoustics in the framework of the complex stimulus set of the office, and to evaluate the concept of privacy in the acoustical, visual and psychological contexts in which it actually exists.

Having been involved with the landscaped and open office for 33 years, Orfield Laboratories is quite familiar with the relevant physical acoustics issues. Six years ago, Orfield Laboratories founded the Open Plan Working Group (OPWG) to develop an international research and design focus on building performance and occupancy research. The work within this group and with these colleagues has helped to expand our thinking about the perceptual dimensions of the open plan office.

In the design field, we have been laboring under the impression that we need to provide acoustical privacy, and that if we employ the most highly rated acoustical products, we will have a sufficient acoustical solution (privacy). This is simply not the case. In the control of physical acoustics, distance (between occupants) is the single most important variable, and we have been reducing that distance significantly over the history of the open office.

We now face three important questions which research can resolve in the next few years:

- When people say they need privacy, what do they mean and how much do they need?
- How do we evaluate the benefits of providing privacy?
- How can the level of privacy a particular person needs be provided in high-density work environments?

Good occupancy research can answer the first two of these questions. The third asks more fundamentally whether we should reconsider our current views of office density – particularly as this issue relates to open vs. closed office planning – once we better understand the benefits of privacy. The operational cost of the office is at least 85% reflected in the cost of people. Once we demonstrate acoustical benefits, will we have the courage to make the decision that occupants, rather than buildings, should be our profit centers?

The authors would like to thank Tom Smith, Ph.D., Dave Berg, Mike Role, Sherry Role, and Derrick Knight for their assistance and reviews of this publication. We would also like to thank Michael Berens, Director of Communications and Knowledge Resources for ASID, for his insightful critique and suggestions.

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Acoustics, Privacy and Productivity: A Process Approach

Acoustics and privacy are of great concern to the design and the client communities. Acoustic consultants developed a relatively clear understanding of the physical acoustics issues (how sound works in open offices) many years ago. Since that time, the design landscape has changed dramatically, and it has become more obvious that acoustics is part of a broad perceptual context of the privacy problem definition and solution in the open office.

There are a number of areas of specialized study underlying an advanced program for acoustics in the office of today:

- Occupancy Studies
- Perceptual Programming
- Office Simulation and Prototyping
- Building Performance Studies and Standards
- Human Resource Management

Thus, acoustics must be studied formally with the client population; it must be understood in terms of acoustical and visual privacy needs, as well as in relation to other occupant needs, such as territoriality. Privacy is not only an acoustical phenomenon; it is also a visual and psychological construct. Many aspects of design other than physical acoustics can influence privacy.

We have the sciences of occupancy research and building performance as well as the sciences of simulation and prototyping at our disposal. We now need to understand, in the early phases of a project, those aspects that contribute to this concept of privacy in ways that are positively reinforcing to the occupant and are profitable for the client in terms of human resources management (occupant outcomes such as retention, ease of hiring, absenteeism, satisfaction, etc.).

The greatest change in the future of acoustical office design is the new movement toward a better, more scientific understanding of what the occupant needs in order to feel better, perform better and enjoy better job satisfaction. As we begin to gather this information, we must understand that the occupant cannot tell us many of these details, because occupants are largely unaware of what motivates them. Thus, we can only find these important answers by using appropriate evaluation tools to define them, applying acoustical solutions to implement them that include other important privacy domains, and evaluating their benefit to the organization.

Overview

This manual addresses acoustic issues in building environments, with a primary focus on office environments. In this regard, the acoustics community developed a relatively clear understanding of physical acoustics issues (for example, how sound travels in open offices) many years ago. However, subsequent to the initial applications of this knowledge, perspectives on interior design changed dramatically. It now seems obvious that acoustics can and should be addressed in a broader design context that considers not only the physical attributes of sound, but also how noise and sound quality in work environments influence occupant perceptions of their work in relation to other interior design factors (such as privacy).

This manual therefore takes an occupancy-systems approach to the analysis of office acoustics issues. This conceptual model assumes an interaction among exposure to sound (quantified by physical acoustic measures), perception of sound quality (which influences employee attitudes, motivation, morale, satisfaction, and emotional state regarding their work – and thereby their functional capacity for work performance), and work performance outcomes (such as productivity or standard human resource [HR] metrics). Various methods outlined in this manual will describe how to measure and quantify employee perceptions.

The rationale for the multi dimensional approach to office acoustics analysis adopted in this manual rests on the premise that acoustic design embraces all of the systems components specified in the previous paragraph, and that acoustic design analysis therefore must consider system interactions among all of these components in order to arrive at an understanding of the nature and determinants of acoustic design quality.

This perspective assumes a multi disciplinary framework for understanding office acoustics that encompasses not only acoustic physics and engineering, but also interior design, building performance analysis and standards, perceptual psychology, occupancy research, facilities management, organizational behavior and human factors/ergonomics.

To address these themes, this manual has been organized into four sections. The first three move from a general to a specific treatment of office acoustics, dealing respectively with the general design context of the office (Part I), conceptual issues in office acoustics (Part II), and the technical practice of office acoustics (Part III). Part IV explores future trends in office acoustics.

The broad message of this manual is that the greatest change in the future of acoustical office design will be a movement toward a better understanding of what the occupant needs in order to feel better, perform better and enjoy better job satisfaction. In attempting to gather this information, we must understand that occupants cannot directly articulate either the nature of or the solution to many of these needs, because typically they are not cognitively aware of what motivates them. Thus, the only way to find these important answers is to use occupancy research to characterize them, and then to apply demonstrated solutions in the acoustical and other interior design domains.

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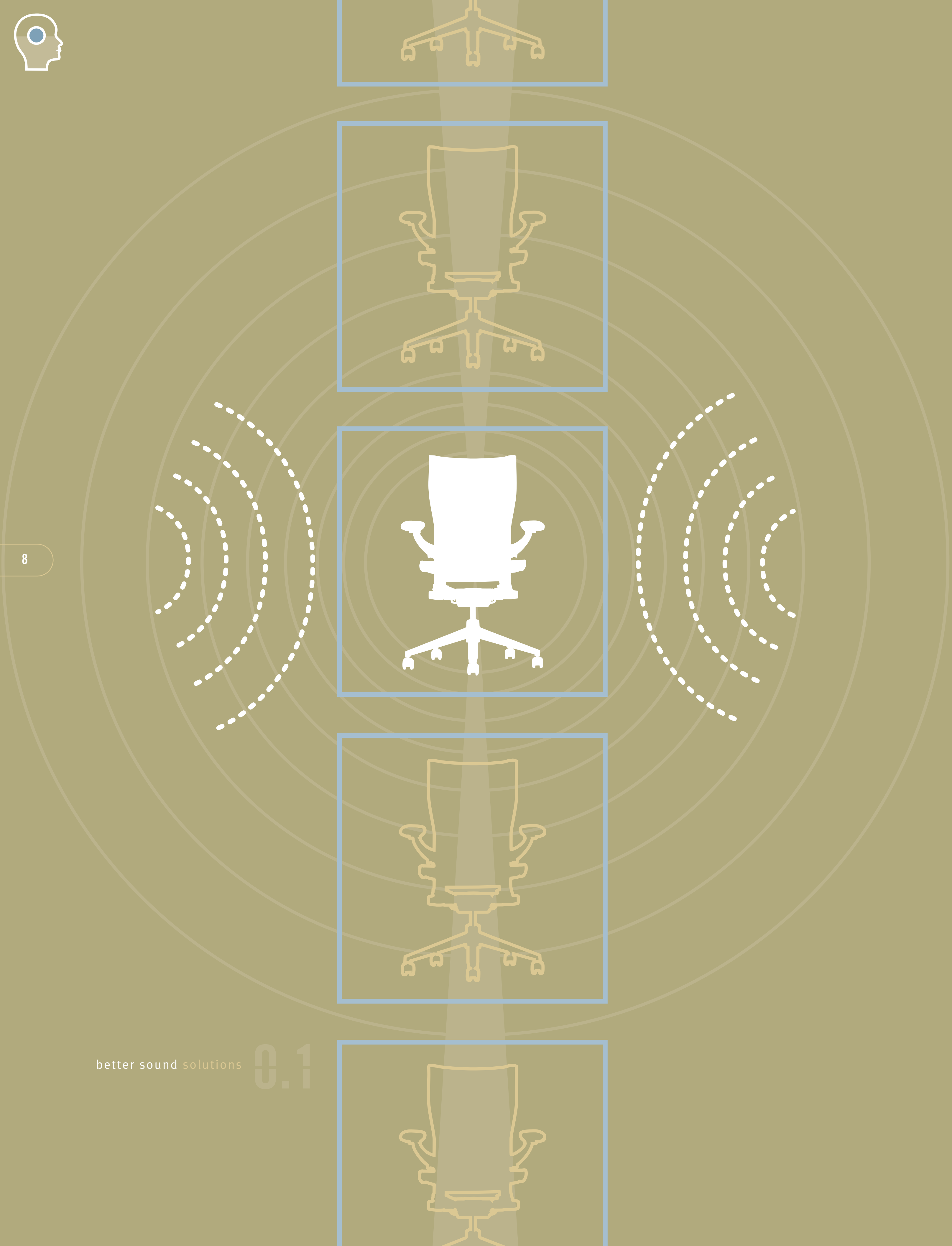
PART I



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PART I The General Design Context of the Office

Introduction

Since its inception in the 1970s, the open plan office has engendered much discussion, many publications and many studies with regard to its acoustical performance. Much of this discussion has focused on speech privacy and the need for privacy in the open office. Concurrent with this focus on acoustical privacy has been a focus on visual privacy, generally referenced to the ability to see or be seen by other occupants when working. The metaphor in both cases is a physical one, although privacy relates more to occupants' perceptions and may be influenced by many other variables. This manual, in focusing on acoustics, will also discuss other modalities for this reason.

In the 1970s, most acousticians understood how the open plan office functioned acoustically, and early open-plan or landscaped office projects generally included an acoustical consultant on the design team. Since that time, through the 80s, 90s and early 2000s, an interesting trend has emerged in office planning. As cubicle size has steadily decreased, the claims for the need for privacy have become more and more pronounced. Indeed, the cubicle office has become smaller and smaller, moving from the 12' x 12' workspaces of the early 70s to the 6' x 8' or 6' x 6' workstations of the present day. (The 144 square-foot dimension was originally chosen because it allowed 12' between occupants, providing confidential speech privacy.) By comparison, four of the current 6' x 6' workstations could fit into one of the older style workstations. The work areas of call centers, an interesting subset of the open office, are generally significantly smaller than even those of a typical open plan office.This trend toward smaller workspaces and closer proximity between occupants presents us with a set of fundamental questions that essentially remain unresolved:

- When is acoustical privacy from adjacent occupants really important?
- When it is important, what are the results of the fact that most open plan occupants don't have this privacy, and that density will limit their ability to obtain it?
- Why is it that occupants seem to prefer physically non-private enclosed offices to physically non-private open plan offices?
- Why is it that many enclosed office occupants leave their doors open?
- Why is it that enclosed office occupants rank the enclosed office as more "acoustically private" than the cubicle, even when there is no measurable difference?
- What part does "visual privacy" play in this process?
- Why is the trend in open plan design to use smaller and smaller spaces; fewer and fewer acoustical panels; lower, non-absorptive panels; or panels with low venting "holes" in them?
- How can the reported preference of most employees for acoustical privacy be reconciled with the emerging trend favoring "den" or "club" types of collaborative space arrangements in open plan design?

We have long been on a collision course between privacy and space utilization, and the economics of space have won the battle so far. Since no one has yet established the economic argument for privacy, the simpler economic argument based on real estate costs has triumphed.

We are thus on the horns of a dilemma, in that we believe we need privacy – we don't get it – yet we seem to manage just the same. How do we resolve this impasse: either accept a significantly lowered value of acoustical performance or prove that such performance is, in fact, important?

The remainder of this section considers various strategies that may be deployed for dealing with this dilemma. The next section first places the acoustic design environment in the broader context of environmental perception. The two subsequent sections deal, respectively, with the role of building performance analysis in delineating physical design conditions in the office environment and the role of occupancy research in documenting perceptual effects of exposure to these conditions among occupants of such environments. Methodological tools for occupancy research are outlined in the next section, followed by a consideration of the implications of acoustic design for occupant productivity as an outcome measure.

Environmental Perception

It is important to understand that acoustics does not stand alone as a variable in an open plan office; it forms part of a broader stimulus context. Neither is its meaning only about sound and privacy. The following thought experiment about offices explores many of the relevant issues from a much wider vantage point than is typically employed. An office occupant lives and works in a multi-modal environment, and that environment may be rich with stimuli, or it may be very limited in stimulus content. This stimulus content may be in flux and highly detectable, or static – thus possibly leaving the occupant in perceptual stasis.

It is typical that the office environment moves from complex to simple as we move from the large company level to the departmental level and on to the workstation level. At the company level, as for example in a large floor plate office, one walks through high levels of visual, acoustical, thermal, olfactory and tactile stimuli. These environments generally feature highly complex stimuli that can be difficult to process, potentially prompting disorientation on many levels. Moving to the departmental level, one often arrives at a moderately complex environment, where visual and typically acoustical complexity can be significantly reduced; thermal and olfactory stimuli are often moderately reduced.

Upon entering the workstation or "cubicle," the environment often changes radically. As one sits in the typical workstation configuration, facing an office panel and looking at a corner-mounted computer screen, the most radical change occurs. Visual stimulation – including views, daylighting, exposure to activity and complexity – reduces dramatically, and distant views generally are not available. Thermal perception is much reduced, as the workstation significantly affects airflow and other thermal comfort criteria. Olfactory and tactile stimuli are also usually much reduced; the occupant may habituate to this perceptually limited environment and move toward perceptual stasis. Interestingly, in this scenario acoustics moves from being a secondary consideration at the larger scales to being the primary dynamic stimulus at the workstation scale.

Thus, in the typical workstation design, we have taken away most visual, air movement, tactile and olfactory stimuli. Having moved the occupant into an approximation of a sensory deprivation environment, we now notice that the occupant may respond in a very sensitive way to the only sensation that is still significant – the aural stimulus, or speech and noise. While we know from perceptual research that reducing the input to one sensation often increases the sensitivity of those remaining, we don't seem to understand that this may be precisely the reason we encounter many acoustical complaints in the open plan office. In the complex office environment, there is cognitive dissonance between the visual appearance of privacy and the absence of actual privacy. This is not intended to dismiss the need for acoustical privacy but rather to place it in the context of the broader, complex perceptual environment.

Building Performance Background

We have long been on the march to improve the performance of the office environment, and the science of improving this performance has come to be known as building performance. The study of building performance generally includes evaluation of the quality of daylighting, lighting, acoustics (and vibration) and thermal comfort. More recently, we have begun to evaluate the office environment in terms of levels of scale. From this view, the larger scale of open plan offices corresponds to a macro-ergonomic environment, while the smaller scaled workstation environment is often referred to as a micro-ergonomic environment. Since the inception of building performance in architectural planning, human factors and ergonomics evaluations have increasingly informed the micro-level issues to insure that building performance relates to the personal environment.

Building performance science will add benefit to the open office project via the evaluation of pre-occupancy performance, determination of deficits in this performance, comparison to "state of the art" performance and specification of a set of building performance standards which can be used in the design process, verified by engineering and simulation and confirmed in the commissioning of the project. Employing this process adds performance responsibility to the other responsibilities of the design team and assures the client that there are clear expectations and minimum performance levels. This helps the design team understand which of their decisions will affect building performance and which will not.

Currently, building performance is in competition with space utilization and energy use, as well as with the construction and operating costs of the office facility. The design and facilities communities have put forth much effort with regard to the cost side of constructing and operating offices. However, the current facilities cost approach is limited in that facilities costs represent from five percent to eight percent of the costs of an operating office. The other 92 percent to 95 percent is reflected in the costs of people along with information technology and information systems. While we know much about how to control the facility cost structure, we know very little about influencing the cost of people with design – regardless of whether those costs are human resources costs (hiring, retention, absenteeism, illness) or direct/indirect productivity costs.

Occupancy Research

The most recent addition to the equation of office design is the application of occupancy research to the design process. Occupancy research is, in general, the testing of office occupants and of offices to determine:

- How the occupant ranks his/her quality of work
- How the occupant is affected by the principal variables that influence and are influenced by the office design:
  - Perceived organizational quality
  - Perceived work task quality
  - Perceived compensation quality
  - Perceived environmental quality
  - Perceived workstation quality
- How the occupant responds due to his/her perceptions of facilities quality
- How employee perceptions of office quality relate to measures of prevailing environmental conditions

From a small but growing body of research, it seems clear that the occupant responds to the environment in measurable ways, and these responses influence the occupant's perception of the quality of other work related benchmarks.

Based on pre- and post-occupancy comparison of specific facilities, it has been demonstrated that increasing the occupants' ranking of the environment and the workstation can increase their ranking of the organization, the work task and their compensation. Decreasing the quality of the environment can cause concomitant reductions in rankings of these variables. Early research has also suggested that responses to negative changes in the environment can be partially measured by negative changes in relevant human resource measures, including ease of hiring, worker retention, absenteeism, tardiness, etc.

In repetitive task environments, and in those "knowledge worker" environments where group performance metrics have been established, it also seems clear that productivity can be affected by environmental quality. In keeping with our occupant-centered focus, environmental quality must be defined in terms of the phenomenology (the personal, subjective experience) of the people occupying that environment. As just one example, a recent study of lighting found that reducing the discrepancy between objective lighting conditions and subjective lighting preferences improved mood and satisfaction.

Thus, we have an approach for resolving questions of acoustical performance via the use of occupancy research to determine:

- How occupants currently rank their environment and other job quality issues
- How these rankings are affected by changes in the acoustical performance of the office
- How this ranking relates to human resource values within a given organization

Occupancy Research / Case Studies

The preceding section introduces occupancy research as both a scientific and practical strategy for investigating the psychology of acoustics. This approach accepts the premise that occupant perceptions of the acoustic environment do not necessarily correspond to the physical characteristics of that environment. Yet employee perceptions and emotions, influenced by acoustic and other work design factors, can affect job satisfaction and job performance. Occupancy research can be used to unravel and delineate the rich relationships among acoustic conditions, employee perceptions of these conditions, and work performance and productivity outcomes. The summaries of the two projects below illustrate how organizations can benefit from such information.

Recently, a client of Orfield Laboratories (OL) began a project for the consolidation of staff from a number of different sites into a renovated building at the company's headquarters. The client has been very interested in the concept of occupancy research to determine if it can provide better baseline information in the design of new projects. As a result, their director of facilities decided that he would use this project as a test case to begin to determine the value of occupancy research.

The building in question was an old, saw-tooth roofed, brick warehouse that was being converted into an open plan office. The client was interested in the potential for a high-quality space through the application of building performance standards to this project. So, prior to the commencement of design, a pre-occupancy study (an Open Plan Working Group Certified Building Performance Measurement study) was undertaken to determine the current feelings of the occupants for five categories of information:

- Organizational quality
- Work task quality
- Compensation quality
- Environment quality
- Workstation quality

The project then commenced, with design tasks occupying the next few months. After move-in, a second, or post-occupancy study was completed to commission the project and to measure early results of the process. Graphs of some of the findings are on the following pages.

Major findings of the pre-occupancy study included these results:

- Employees gave quite high rankings to the first three variables, but lower rankings to the last two. This confirmed that they were highly satisfied employees with regard to their organization, job and compensation, but were not so satisfied with their environment. The rankings for the first three values were as high as very satisfactory post-occupancy values for most companies.

- This raised the inevitable question of whether such a highly rated company could actually increment its value to its employees by improving facilities design and performance.

The post-occupancy study confirmed the value of facilities design, even in highly rated organizations. The major findings included:

- The employees gave even higher rankings to the first three variables, and they raised their rankings considerably on the last two. This demonstrated the value of facilities changes in organizations whose employees are otherwise highly satisfied.

- In a few areas of the facilities where the inevitable problem existed of still unmet commissioned performance standards, rankings in all five categories went down until appropriate remedies were implemented.

Conducted with Olmsted County (OC) in southern Minnesota, another OL client, the second project evaluated the occupancy design features of an older building (formerly a hospital) housing their community service workers. Prompted by a need for better baseline information about interior design quality and performance as perceived by their employees, OC also viewed the project as a test case to determine the value of occupancy research for reducing or eliminating design weaknesses.

For this study, office workers were categorized by their office type (private, two-person and multi-person). This study used the same CBPM 227-item occupancy quality survey questionnaire and building performance measurement techniques as the prior study described above.

As in all occupancy research, this study addressed several hypotheses relevant to the interaction between actual acoustical performance and occupants' perceptions of their environment.

Hypothesis 1. The number of occupants in an office will influence perceptions of occupancy quality.

Figure 1 presents results related to this hypothesis. The graph depicts the percent of high quality rankings on different occupancy quality indicators given by occupants in different office types. Except for organizational quality, private office occupants gave higher quality ratings than did occupants of two-person and multi-person offices. Some of these differences no doubt related to the status of the private office occupants (many were administrators and managers) in terms of compensation and perhaps work station quality. However, physical measurements indicated similar noise, lighting and thermal comfort conditions in the three types of offices, yet private office occupants still rated their work environment quality higher than did the other office occupants. This result lends support to Hypothesis 1 at least for these work environments.

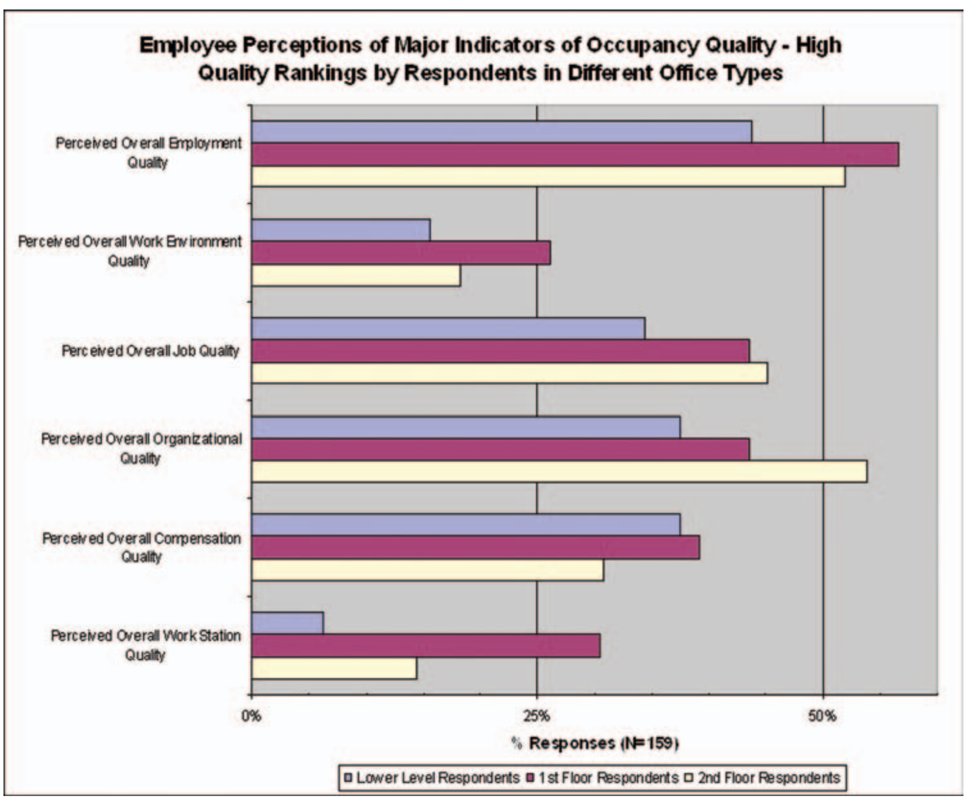

Figure 1 – Rankings of major indicators of occupancy quality

Hypothesis 2. The number of occupants in an office will influence occupant perceptions of noise and privacy quality.

Figure 2 presents results addressing this hypothesis; figures 3 and 4 are additonal examples. Again, percent of high quality ratings are shown. As the number of office occupants increased from private to two-person to multi-person offices, ratings of privacy and noise quality decreased, providing support for Hypothesis 2. The pattern of privacy rankings is perhaps understandable. However, average measured noise levels in the three office types differed by only 1 dB, suggesting that factors other than physical acoustics influenced these ratings of noise and privacy quality.

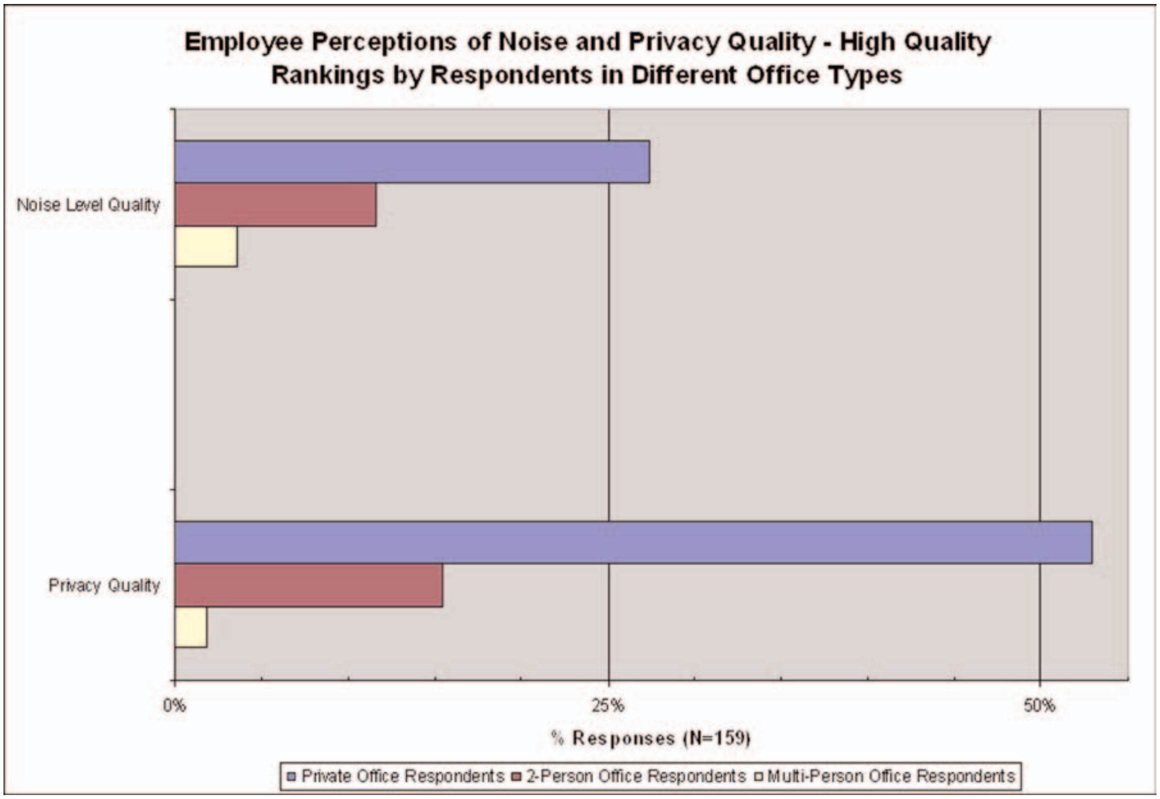

Figure 2 – Quality ratings of noise and privacy by occupants in different types of offices

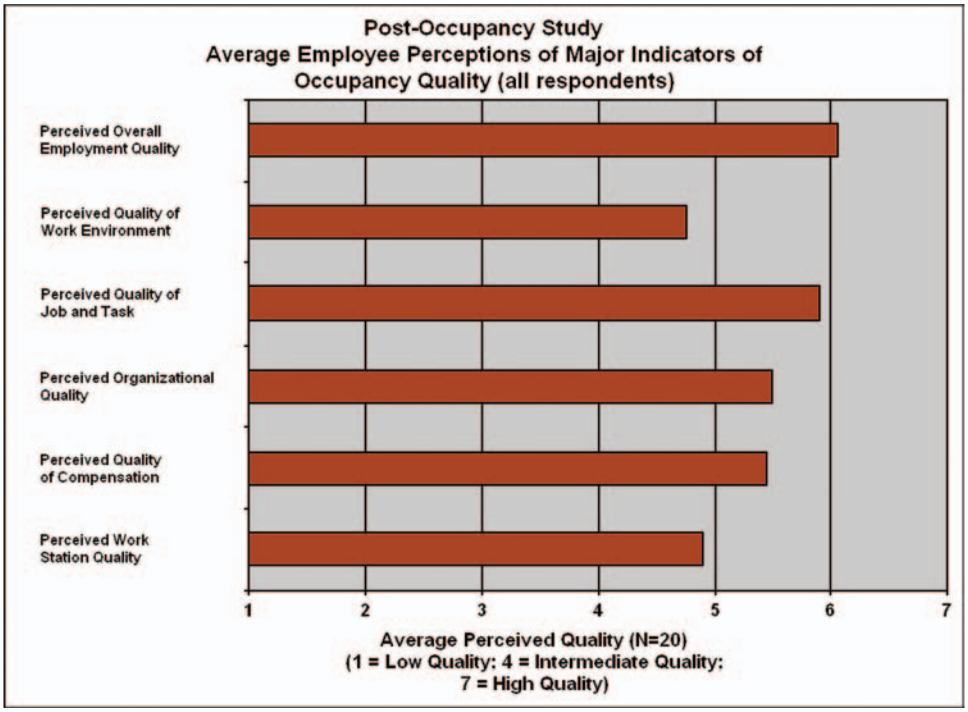

Figure 3 – Average employee perceptions of major indicators of occupancy quality

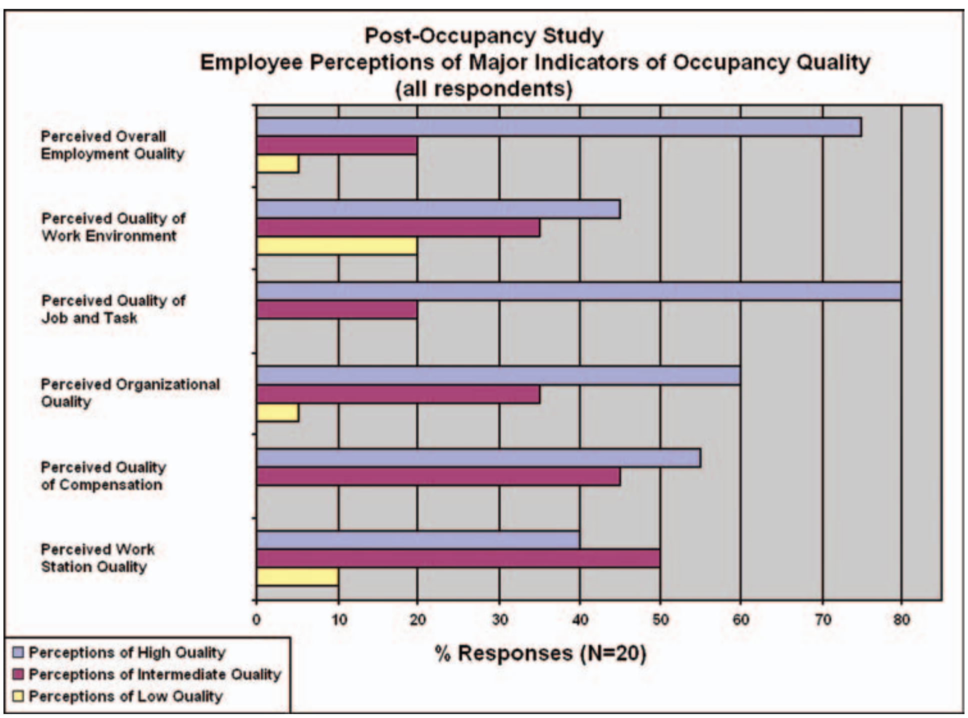

Figure 4 – Distribution of employee perceptions of major indicators of occupancy quality

Hypothesis 3. Perceptions of noise level quality and privacy quality are correlated.

Figure 5 presents results bearing on this hypothesis. This graph plots ratings of noise level quality on the Y-axis and ratings of privacy quality on the X-axis (1 = low quality; 7 = high quality). This regression line indicates a positive correlation (linear association) between ratings of noise level quality and ratings of privacy quality, a statistically significant relationship. These results provide support for Hypothesis 3.

These results support an occupancy systems interpretation of the acoustic environment. In this regard, there are two key conclusions. First, occupant perceptions (i.e., acoustic psychology) are as important as physical measurements in determining the quality of the acoustic environment. Second, acoustic conditions interact in various ways with other work design factors to influence employee perceptions of their work quality, job satisfaction and job performance. The benefits of this set of studies include the knowledge that even in very highly rated organizations, facilities benefits can be measured. Additionally, early post-occupancy studies can quickly demonstrate problem areas indicated by both the subjective rankings and the broader organizational rankings from the occupants.

Via the addition of human resource values to these pre- and post-occupancy studies, an economic benefit model can be created that characterizes the financial value of such projects. Such a process can be employed iteratively over numerous projects to understand the critical value of exact design and performance strategies.

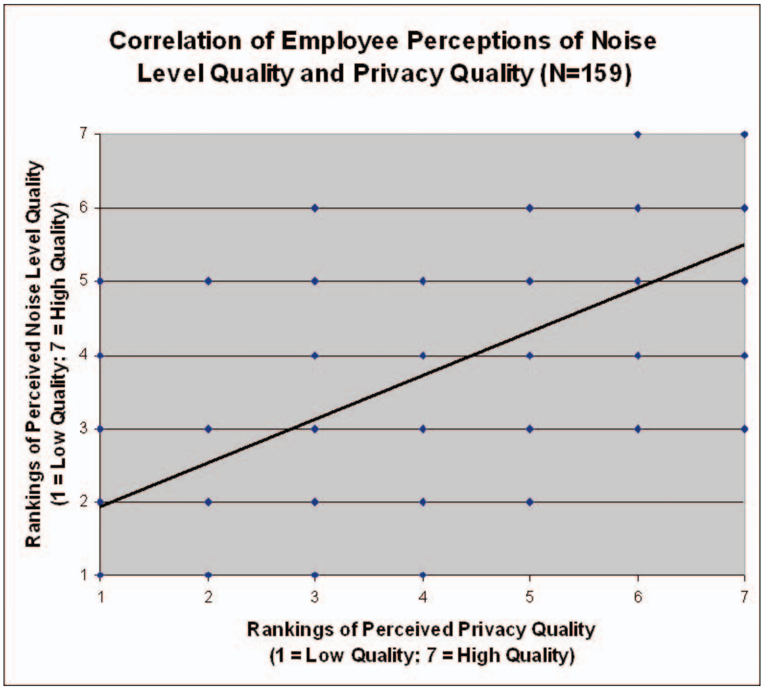

Figure 5 – Correlation between perceptions of noise level quality and privacy quality

Design Tools / Prototyping, Simulation and Testing

Figure 6 – Orfield Laboratories 1981 Open Plan Lab

Figure 7 – OPWG Open Plan Laboratory of 2001

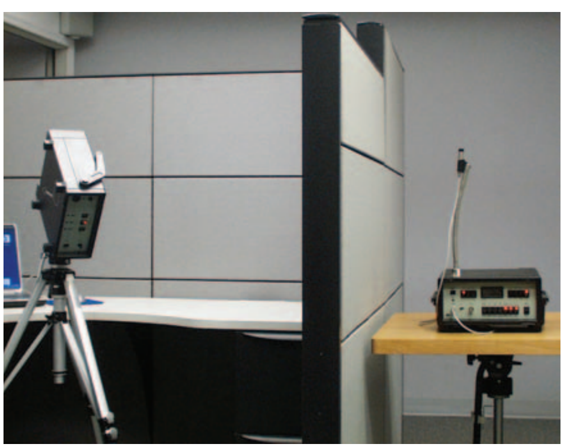

Figure 8 – RASTI Testing of speech intelligibility

Since the inception of the open plan office, design prototyping has been considered an extremely useful tool for understanding both the performance of a space and people's response to it. Acoustically, it can allow members of the design team as well as occupants to experience the future space, thus providing definitive design guidance.

A recent addition to the set of tools that can be used for building performance and occupancy research include the acoustical and visual simulation of environments. Thus, it is now possible to simulate the acoustical or visual performance of spaces – and to measure aspects of the occupants' response to these un-built environments – with a high probability that these tests will indicate future success or failure for specific design approaches. These simulations include computer (CAD) visualizations, acoustical simulations and "auralizations." Thus, occupants can listen to the possible acoustical outcomes of various space designs prior to ranking design quality or indicating their preferences.

Design Tools / Perceptual Response Programming

Various tools have been developed for obtaining occupant input to inform workspace design. Most often they consist of surveys, interviews, focus groups (often called “design charettes”), observation or some combination of these basic techniques. Although different design firms tend to employ distinct labels for implementing these tools, in general this process is termed programming. Programming presumably ensures that the environmental solution resulting from the design process will meet the expectations of its occupants – particularly their functional needs and preferences.

While programming no doubt serves a useful function, its role most likely relates to achieving “buy-in” for particular design goals. By engaging those people most affected by the space design, programming may assist in the organizational behavior aspects of change management and perhaps with other issues relevant to corporate transition. Certainly details such as the number of chairs, phones, workstations and offices must be determined, and thus some sort of data gathering is necessary.

However, it is unlikely that occupants can provide reliable, predictive information about how their work environment influences them. That is, most of us are not aware of how objective light levels, air movement and temperature gradients, or ambient noise levels affect us – at least not within the ranges typically encountered in office environments. Thus, to seek occupants’ opinions about design characteristics – particularly from groups requiring consensus – will rarely provide useful information – information that can predict future behaviors and attitudes relative to the design. Other more indirect, yet consistent methods based on measuring individuals are needed for this purpose.

One such method is called Perceptual Response Programming, or PRP. Similar to Perceptual Market Research (PMR is a process developed in 1991 and used in the OPWG and in product research), this technique quantifies immediate, individual responses to images of spaces that differ in terms of features relevant to design alternatives for a project. This method thus captures perceptual preferences that lie outside of awareness but are nonetheless important to understand in order to represent occupants’ expectations.

One particularly effective method of researching the visual side of privacy is via visual PMR juries, which present images of offices for semantic ranking by occupants. “Semantic ranking” simply involves participants selecting a number along a scale defined by extreme descriptions of some environmental characteristic, such as “tense” to “calm.” The occupants, upon viewing the images, often infer conditional performance via the visual image, and can consistently rank perceived privacy among the attributes that are included in the testing. (Each of the images shown to the occupants is often ”content mapped” so that correlations can be calculated between aspects of the image and semantic rankings; for example, degree of enclosure might relate to perceived privacy levels.)

Figure 9 – GSA IWL jury study image 1

Figure 10 – GSA IWL jury study image 2

Two interesting examples of this type of jury in OL recent history are the GSA Integrated Workplace Lab (IWL) project in Pittsburgh and the OPWG experimental psychology color juries which have been performed around the U.S. and Canada over the past four years (see *ASID ICON* magazine, November 2001).

The first jury – part of a project collaboration with KSBA Architects – was conducted with the future occupants of the GSA IWL as an indirect test of visual privacy, defined by the experience of observing and being observed in one's workstation. Two illustrative images are shown at left. This jury ranked a strong negative response to both experiences, which resulted in a design intended to avoid these phenomena.

The second jury was developed to assess the sensitivity of jury testing regarding indirect inferences related to color (for example, could different colors influence the "comfort" ratings of workstations?). In this jury, 11 images of the same four cubicles were presented in 11 different color combinations in an attempt to measure the inferential response of the audience (architects, facility managers, clients) to color changes.

The semantics used in this jury included:

Semantic Scales
Comfortable – Uncomfortable; Tense – Relaxed; Confining – Free; Private – Not Private; Productive – Unproductive; Exciting – Boring; Distracting – Not Distracting; Efficient – Inefficient; Quiet – Noisy; Orienting – Disorienting; Pleasant – Unpleasant; Dull – Stimulating

This jury was performed six times, and statistical analysis of these combined jury data yielded generally consistent results across all six samples, with the following being the principle findings:

- Workstations with yellow-colored chairs and brown-colored panels were ranked as less private and noisier. It seemed that visual "loudness" may have suggested acoustical noise and lack of privacy.
- These same workstations were rated as more tense (and thus less relaxing) and more disorienting.
- Different disciplines gave consistently different ratings on some of the semantic rating scales across all 11 images.

The results from these juries demonstrated the consistent ability of viewers to rank aspects of images that could not have been gleaned from a design charette or "focus group," because such settings cannot elicit individual response measures to unknown design features along a quantitative, comparative scale. However, it is precisely this kind of indirect, inferential information that can make the difference between a positive or negative design from the perspective of occupants.

Figure 11 – Color psychology jury image 1

Figure 12 – Color psychology jury image 2

Figure 13 – Color psychology jury image 3

Productivity

The final consideration for understanding an approach to acoustics is to view it in the context of direct and indirect productivity measures. Direct productivity is measured principally in repetitive work environments, such as call centers or production areas. In these types of offices, it is easy to track the speed and output of work. Productivity is simply the change in output per worker, and it can often be assessed individually. This can then be converted into economic values, and the profit per worker can be calculated.

Indirect measures of productivity are useful in the case of non-repetitive employees, or the group commonly referred to as “knowledge workers.” These measures include such human resource issues as ease of hiring, retention, absenteeism, illness and tardiness, and sometimes include business metrics developed by an individual company or department to measure the ability of a worker population to meet specific long- and short-term goals.

Productivity plays an interesting role in the discussion of office acoustics, because it has often been claimed that speech privacy increases productivity – although there are limited high quality studies in this regard. We can survey an employee group to see if they believe there is an association between privacy and productivity, and they will generally indicate that there is. But gathering opinions about the perception of productivity and its causes is similar to all opinion-based research; it often proves unreliable as a method for predicting or understanding outcomes. Therefore, we must establish any causal relationships between various aspects of privacy and productivity via high-quality occupancy research that does not simply rely on shared opinions.

Once we have established that causal relationship – based on either direct or indirect productivity measures – it can be converted into an economic-benefit argument for privacy. And the costs of providing privacy can be balanced against the economic base of occupant (and organizational) benefit.

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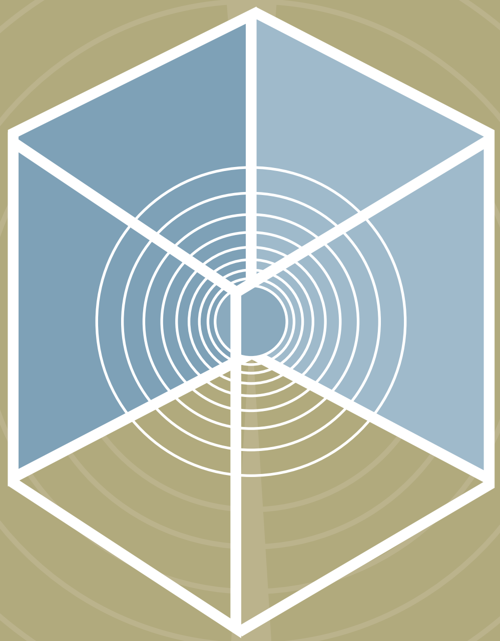
PART II



better sound solutions 0.2

PART II Conceptual Issues in Office Acoustics

Introduction

As we move from the broader sensory domain back to the acoustics domain, we must begin to understand the physical acoustical issues of the office. What are the important problems to solve? It is first important to understand that office acoustics is not only about noise and speech privacy; it can also be about preferred environments. Noise and privacy have their place in the discussion, but it is simplistic to view office acoustics via only these dimensions. It may also be important to understand that while the occupant can converse about privacy, he generally cannot discuss his complex acoustical preferences.

Environmental Acoustics of Building Types

Architectural building types, as well as outdoor environments, often have quite predictable acoustic characteristics. Some encourage quietness (churches, libraries), some encourage loudness (day care centers, shopping centers, athletic facilities), some encourage communication (offices, conference centers), some encourage calmness (homes), some encourage excitement. Many of these environments are preferred environments, because they are also voluntary environments. We go to such places to experience the complex stimulus set and the higher order behaviors for which those spaces were designed. The office environment clearly affects occupants along many dimensions – in both preferred and non-preferred ways. Occupancy research can ultimately clarify these influences.

The Sound Quality Movement

One of the most profound changes in acoustical engineering in the last 25 years has been the movement toward sound quality as a method of evaluating products and environments. The sound quality movement – or the movement toward the psychological assessment of the feelings and associations engendered by sound – entered the United States broadly with the founding of the Sound Quality Working Group by Orfield Labs, sponsored by a group of consulting and test system manufacturers who wanted to be in the forefront of the next generation of product acoustics.

This sound quality emphasis argues that the "silencing" of products (and environments) is not necessarily what consumers (occupants) want. Rather, they want products to acoustically reinforce their feelings about quality, value, appropriateness and performance, etc. Sound quality studies began early in the 90s for firms such as Harley Davidson, Whirlpool, Maytag, GE, Black & Decker and many others. These studies, which employed quantitative subjective research as well as measurement research, demonstrated that the result of simply quieting a product was often negative, but creating an acoustically reinforcing product was generally positive. This view of product noise as a potentially positive stimulus was an entirely new approach for Fortune 500 engineers and marketing staff, who had previously viewed acoustics as a way to quiet noisy (and annoying) products. With the sound quality movement, these firms began to accept acoustics as a positive part of the consumer environment – as long as this advantage could be demonstrated with good quantitative consumer research. And the outcome of this movement has been dramatically more consumer-reinforcing product acoustics.

Office Acoustical Sound Quality

As these modern acoustical approaches have begun to be applied to architecture, many of the same sound quality issues are being confronted. The office environment, if typical of other preferred environments, must have acoustics that are reinforcing to the occupant, that make the occupant feel peaceful, secure, private (or public), valuable, etc. Such environments should also allow the occupant to have some choice over the selection of these acoustical qualities, either by control (masking level, etc.), by behavior (moving toward or away from the acoustical stimulus) or by changing environments (moving into a conference room). It might be ideal if the building, at different scales, could supply a known acoustical-stimulus set which was either selectable or automatic (through sensing occupant behavior), and perhaps controllable at the workstation. Such "architectural dynamics" systems could provide both preferred and reinforcing acoustical stimuli in both static and dynamic forms. Automated acoustic environments may represent one long-term solution to many acoustical problems within the office.

It is currently possible, by control of density, workstation design, and other materials selection (ceiling, carpet, wall materials, office systems, raised floors, etc.) to move the acoustical environment increasingly toward a preferred environment – but this can only be done experientially. We can start with optimization of these environments at their current density, or we can begin by working with idealized solutions that are outside the range of densities currently in use. In either case, perceptual response programming can be used to simulate and measure the occupant benefit of the range of options considered.

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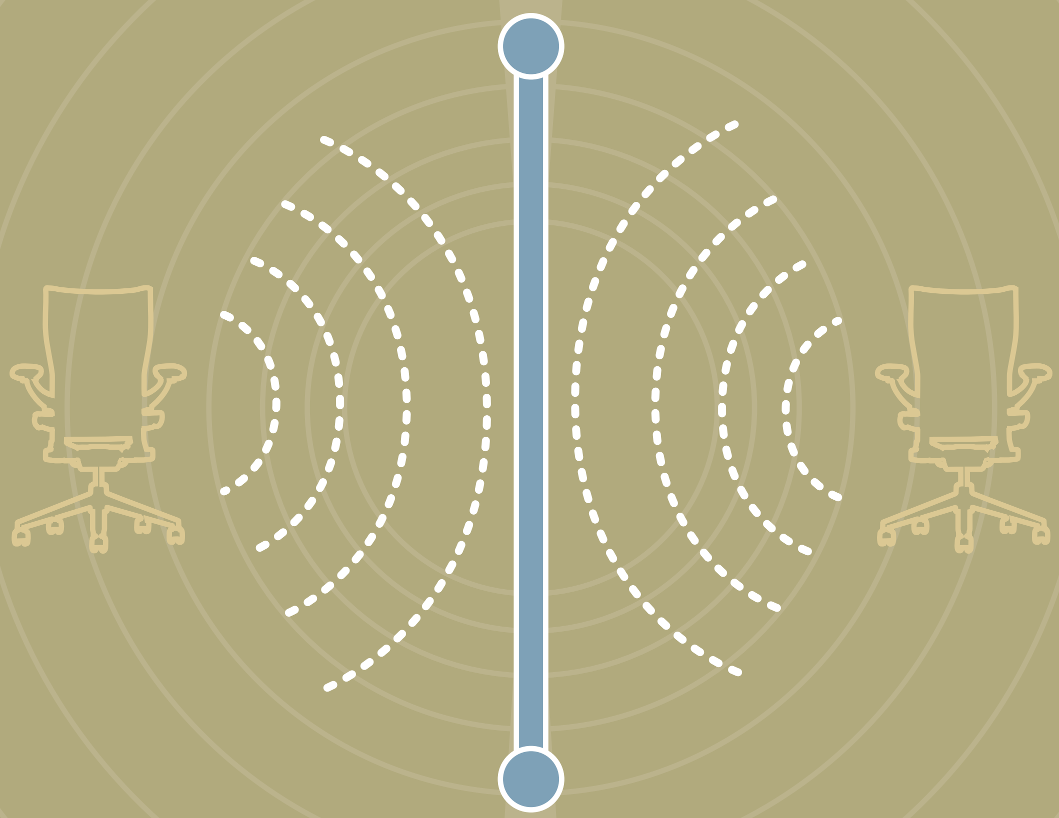
PART III



PART III The Practice of Office Acoustics

Introduction

Office acoustics, a reasonably well-known practice that developed between 1960 and 1980, is broadly based on the physical model of acoustical noise reduction. Its intention is to control noise (unwanted sound) by various techniques, so that the occupant will find the office environment acoustically positive. It has the tools and metrics of room acoustics, including

- Reverberation time
- Background noise
- Speech intelligibility
- Distance attenuation
- Barrier attenuation
- Flanking attenuation

It also has the tools of audiology and psychology at its disposal, including

- Hearing loss and visual loss
- Forward masking
- Signal complexity
- Talker and listener orientation
- Message complexity
- Noise/message annoyance

The process of noise reduction and control is illustrated by the source-path-receiver model. This model suggests that sound can be controlled via three strategies:

- Source Control
  (at the talker, the printer, the office machine, etc.)
- Path Control
  (between the source and the listener)
- Receiver Control
  (at the listener)

Each of these strategies has a series of methods and products that can be employed to solve defined problems, and the development of new acoustical solutions should fall into these same domains.

These methods are:

- Source Control
  - Voice level
  - Talker orientation
  - Telephone side-tone level and headset use
  - Distance between talkers within same workstation
- Path Control
  - Distance between workstations
  - Absorption of reflections at ceiling, floor, walls, furniture components
  - Attenuation of direct sound via barriers
- Receiver Control
  - Listener orientation
  - Headset use
  - Masking of sound via HVAC and sound masking

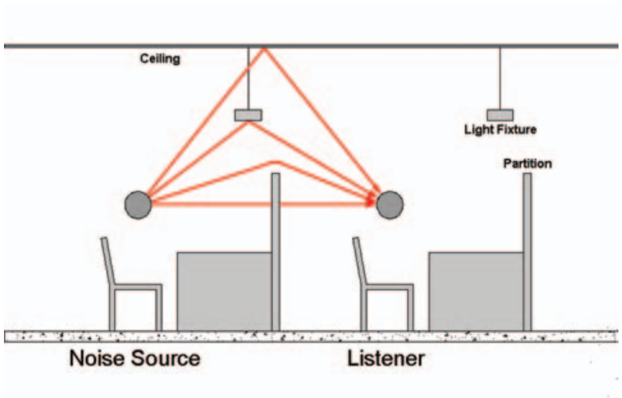


Figure 14 – Open office sound paths – elevation

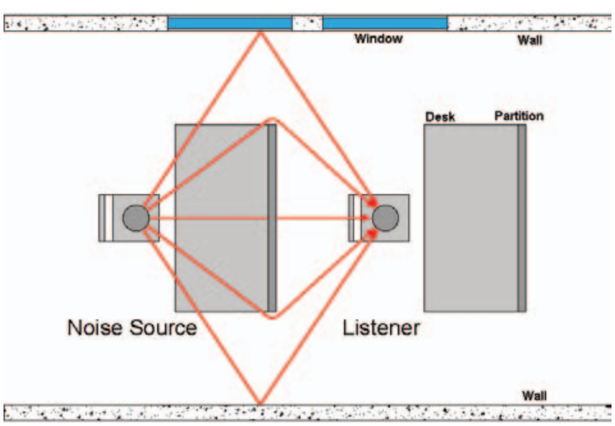


Figure 15 – Open office sound paths – plan

Perception of Occupant Voices

The perception of voices is possible when the source sound travels to the listener at residual levels above the background noise in the listener's workstation. The process looks something like this:

- The talker (who is a potential noise source) talks at a normal level between about 42 dBA and 70+ dBA, according to traditional research and some more recent research efforts.
- The voice is dispersed in a pattern that is related to the localized frontal distribution of speech.
- This sound moves toward the adjacent listener along a series of paths:
  - Sound travels through the office partition and joints
  - Sound reflects from the ceiling and lighting fixtures
  - Sound reflects from adjacent walls and furniture components
  - Sound reflects from the floor
  - Sound diffracts (bends) over the office partition
  - Sound diffracts around the office partition
- The sound arrives from all these paths, with its losses on each path, and it recombines to form the total sound at the listener's ear.
- If this sound is above the background noise level of the listener's work area, it is audible. If enough speech (words/sentences) can be understood, it is intelligible. Each of these paths offers an opportunity to reduce the sound, but this total reduction is limited due to the fact that sound diffracts over and around barriers, and the maximum insertion loss of barriers is limited by their size.
- Each of the products in this process is rated with a performance value that provides a partial measure of its benefit. The remainder of its benefit is derived from its use.

Of course, if either of a pair of office occupants is standing, or if another occupant is standing in the corridor, this entire chain of performance breaks down, since in these cases the panel height above the mouth position is often effectively zero. Finally, if the listener can see the talker, the level of privacy is reduced substantially due to the additional value of semantic interpretation provided by visual cues (i.e., lip reading).

Process and Product Ratings

Acoustical products used in offices are rated on a number of standardized tests that provide information about their performance under certain exact test configurations. Additionally, there are ratings of "system performance" which do not rate the products but rather rate total performance of the products and the environment. Some of these ratings are informally defined as follows:

Process Ratings

- **Articulation Index (AI)** – the percentage of speech intelligibility at the listener (the most commonly used intelligibility metric)
- **Articulation Loss of Consonants (ALcons)** – the percentage loss of consonant articulation across a speech channel
- **Speech Transmission Index (STI)** – the percentage of speech intelligibility at the listener
- **Rapid Speech Transmission Index (RASTI)** – the percentage of speech intelligibility at the listener

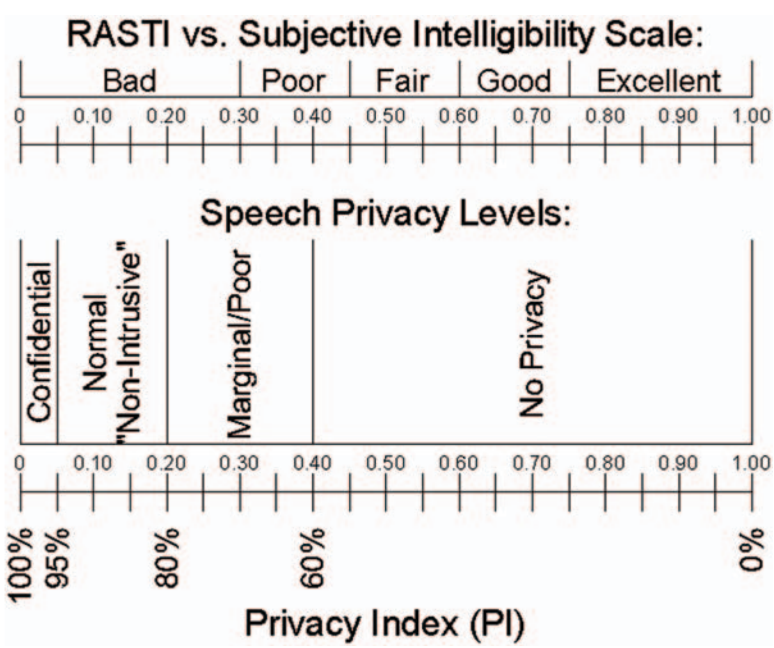


Figure 16 – RASTI vs. Subjective Intelligibility Scale

Product Ratings

- **Noise Reduction Coefficient (NRC)** – the percentage of sound absorbed by a product under a specific American Society for Testing and Materials (ASTM) laboratory test procedure. This test is a measure of the decay time of a sample in a reverberation chamber. It is not similar to the use of the product in an open plan office.
- **Sound Transmission Class (STC)** – the amount of sound attenuation (reduction) of sound passing through a product sample under a specific ASTM laboratory test procedure. This test is a measure of the noise reduction of a sample mounted between two reverberation chambers. It is not similar to the use of the product in an open plan office.
- **Articulation Class (AC)** – the amount of speech intelligibility/privacy provided by a product under a specific ASTM laboratory test procedure. This test is a measure of the speech intelligibility levels provided by reflection from or diffraction over and around the sample. It is a model of one aspect of Noise Reduction via use of the product sample. Products commonly used in open plan offices have these ratings available

- Partitions may have an AC, STC and NRC rating
- Ceiling tiles may have an AC, STC and NRC rating
- Acoustic wall panels generally have an NRC rating

Electronic sound masking systems generally are process-rated for intelligibility and are specified for suitable spectral response and level. They can be tested under ASTM standards as well, specifically, E-1573-02:

"Standard Test Method for Evaluating Masking Sound in Open Offices Using A-Weighted and One-Third Octave Band Sound Pressure Levels"

Figure 17 – Noise Reduction Coefficient (NRC) testing of acoustical wall panel

Privacy Levels and Their Application

Privacy levels were defined in the early 60s and 70s as were privacy-need classifications. Typically, there were office occupants with confidential privacy needs, those needing a lack of distraction and those without specifically definable needs. The commonly accepted levels for each of these categories was referenced to Articulation Index values as follows:

– **Class 1** - Confidential Privacy - .05 or <
– **Class 2** - Low Distraction - .2 or <
– **Class 3** - No Requirement - > .2

This is similar to the newer ASTM standards (ASTM 1374-02) recently developed to deal with acoustics in offices. The principal difference is that due to different densities of work areas, occupants previously had better levels of privacy in most cases.

Additionally, the Class 2 level – Low Distraction – was not generally referred to as privacy in the early history of office acoustics. However, the newer ASTM guide refers to the older Class 2 category as "normal privacy" or "non-intrusive," with the caveat that "normal speech privacy may be described as the absence of distraction." Thus, there has been a movement, even in the standards bodies, to reduce significantly the definition of privacy, being fully aware that Class 1, or ASTM's "confidential privacy," is hardly ever attained in current open plan offices.

It is interesting that the new Health Information Portability Accounting Act (HIPAA) regulations focus on speech privacy as one of their concerns. Many vendors of products and services attempt to identify Class 2 or ASTM's "normal privacy" level as their goal, even though this clearly does not protect confidential communication and is not identified as a target under the law. This is important to keep in mind as one considers the real needs of the occupant, both from the standpoint of preference as well as legal considerations.

ASTM Approach to Open Office Acoustics

The American Society for Testing and Materials (ASTM) has established many of the acoustical test procedures that are used by American acoustical laboratories. The ASTM guide (ASTM Standard: E 1374-02 Standard guide for Open Office Acoustics and Applicable ASTM Standards) to acoustics is helpful because it frames acoustics and privacy issues in terms of its own test standards and a reasonable approach to defining many of the variables involved – with an emphasis on product variables. It also provides some recommendations with regard to applications. This guide, along with a definition of acoustical privacy, provides the following statement:

"The attenuation of sound between neighboring workstations in an open plan office is typically much less than that potentially available between closed plan offices. Nevertheless, a degree of acoustical privacy can be achieved if component selection and interaction are understood."

The ASTM guide is also very careful to recognize that product ratings are not the answer:

"While this guide attempts to clarify the many interacting variables that influence office privacy, it is not intended to supplant the experience and judgment of experts in the field of acoustics. Competent technical advice should be sought for success in the design of open offices, including comparisons of test results carried out according to ASTM standards."

After its introduction, the guide proceeds to cover these topics:

- General Open Office Acoustical Considerations
- Components of the Open Plan Acoustical Environment
- Evaluation of Mock-up or Completed Space

Finally, there are some recommendations with regard to applications:

- Ceilings – Higher absorption values, no exact recommendations
- Ceilings – Continuous acoustical performance for sound masking
- Lighting – Must not be a flanking reflector
- Barrier Heights – Minimum 60", little additional value above 80"
- Raceways – Often reduce the acoustic performance of barriers
- Hang-on Components – Will generally degrade the acoustical value of the partition
- Masking Sound – Most effective means of controlling ambient sound

Specific Acoustical Recommendations

Once a determination is made that acoustical privacy or low distraction privacy is needed, there is a set of specifications that may help in achieving this privacy.

In order to determine if performance is achieved by these specifications, it is necessary either to model the office design or to prototype the design, so that verification can be completed. There are many reasons why, even with the best of systems, the actual layout of the space will not achieve a Class I or Class II privacy level. These include:

- High density (too little distance between occupants)
- Louder than average speech
- Talker orientation
- Standing talkers or listeners
- No properly tuned masking system
- Extremely quiet HVAC system (this will often cause masking to sound too intrusive at effective levels).

Definitions and Work Styles

It is important to remember that the definitions of privacy will drive the process of acoustical analysis and the specification of solutions. If the project is defined as a collaborative environment where groups of people work together, then privacy needs may be focused on inter-departmental privacy, with little focus on privacy within the group. On the other hand, the needs may be defined as individual confidential privacy for other, more information-sensitive organizations.

Prototyping and Testing

To anticipate how a complex open plan office design may impact privacy, the acoustics can be calculated with reasonable accuracy by the acoustical consultant. But why should space designers prototype and test acoustical performance? The reasons for testing and prototyping are multiple and complex:

- Occupants must experience the environment in order to begin to understand their complex responses to both acoustics and other variables that might affect perceptions of speech privacy and acoustical quality.
- Interactions between variables cannot be intuitively understood without experiencing the designs.
- The actual technical performance may not achieve what the ratings suggest, due to either design failures or to product performance failures. (Many partitions have leaks between panel joints and through raceways that dramatically reduce the ASTM-tested value, which is normally determined without raceways or joints.)

- Design questions that might never have arisen will begin to become clear experientially once prototypes are in place. Often the questions that were never discussed become issues at the point of prototyping.

There are many design issues in the approach to office planning that will aid in acoustical performance as well as in other building performance modalities.

- Talker orientation in workstations
- Distance between talkers
- Height and rating of partitions
- Workstation entry orientations
- Selection and placement of glazing in workstations
- Selection and placement of components in workstations
- Type and placement of VDT screen

One general guideline with regard to layout is that if the occupant is not facing into a panel, improvements in performance will often occur in acoustics, daylighting, lighting and thermal comfort.

Measurements that Orfield Labs and many others have made over the past three decades suggest that when one faces into a partition in a typical cubicle:

- Acoustical voice levels increase due to talker orientation.
- Ambient light levels at the front of the work surface are approximately one quarter of their empty room value. When occupants work on surfaces at right angles to the partition (normal desk style), this value doubles.
- Daylighting, if available, decreases dramatically, as the occupant's body shadow and the partitions reduce daylighting from all four directions.
- The occupant often confronts stagnant air conditions, lowering thermal comfort and increasing local pollution due to decreased air movement.

Additionally, visual supervision by the occupant of the entry to the workstation will often be strongly preferred, due to its providing the ability to see who may be standing at or near the workstation entry and listening to conversations. This will also tend to prevent persons in the corridor from overhearing workstation conversations, since the occupant can now see such potential eavesdroppers.

Figure 18 – Typical workstation layout

Figure 19 – Advantageous workstation layout

Offices and Conference Rooms

While private offices are assumed to provide better acoustical performance, they often perform similarly to open plan spaces for several reasons. Many times the doors are open, most office corridors are not sound masked, and many offices have opaque corridor walls, allowing others to stand outside an office with an open or a poorly isolated door and listen to entire conversations in the office.

For this reason, as well as for daylighting applications, it is often better to consider a glazed interior corridor, as few employees are inclined to stand outside of glazed offices listening to conversations.

Specific differences between open plan and closed office and conference spaces, along with their differing needs, include:

- The need for either full height walls or highly rated ceiling systems (full height walls are generally superior).
- The need – if walls are just to the ceiling – to have the air-return plenum isolated as a flanking path for sound.
- The need in both cases to assess the HVAC systems for sound transmission to adjacent offices and to the corridor.
- The need to have highly rated isolated doors to insure that the door will not compromise the wall (acoustic) values.
- The need – if offices are adjacent to the outside wall – to design very effective joints between the curtain wall and the common office wall.

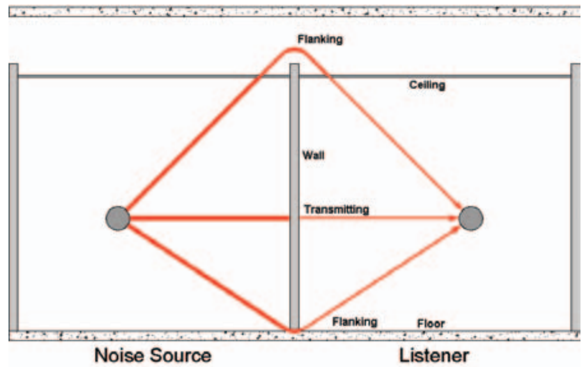


Figure 20 – Private office sound paths – elevation

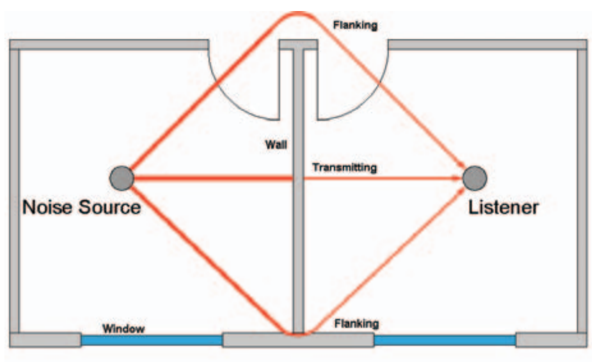


Figure 21 – Private office sound paths – plan

Outline for an Open Office Project

The process and methods discussed in this manual can be easily and directly employed on any project to ensure that acoustics (or other perceptual stimuli) will be positively perceived by the occupant and will provide a measurable economic benefit to the client.

These methods can be incorporated into the standard design phases in most projects, and they do not change the normal activities included in the design process but simply add substantial definition and performance to the project.

Schematic Design

- Assemble full design team, including the acoustical consultant.
- Perform occupancy studies of each relevant department or work group to draw baselines on current building performance and job quality rankings. These studies should include human resource statistics and productivity statistics, if available.
- Based on the occupancy studies and other programming results, develop a building performance hypothesis and an occupancy performance hypothesis.
- Employ visual juries, simulation, prototyping and acoustical engineering to test schematic designs for building performance and occupancy satisfaction.
- Take iterative steps based on the results of tests.
- Finalize schematic design approach.

Design Development

- Employ ongoing acoustical consulting to insure that the standards adapted in Schematic Design are followed and to suggest and test acoustical engineering solutions for the project.
- Develop final acoustical applications that meet the performance standards of Schematic Design. Develop plans, specifications and performance standards for acoustical solutions.

Contract Documents

- Review inclusion of plans, specifications and performance standards in the final contract documents.

Contract Administration

- Assist design team and vendors to understand the specifications and to respond to the bids for the project. Review and accept/reject alternatives.

Commissioning

- Perform early post-occupancy studies to determine issues which are problematic and in need of resolution.
- Develop a list of compliance issues for contractors.
- Retest to confirm compliance.
- Perform late post-occupancy studies to determine outcomes of the project in terms of building performance, occupancy satisfaction and financial outcomes from changes in human resource values or productivity.

Considerations When Selecting Acoustical Consultants (Acousticians)

An acoustical consultant is a professional, usually with an engineering degree or equivalent credentials, whose primary role is to provide advice on acoustical requirements and noise control in a variety of situations. These professionals come from a wide variety of areas and are generally not certified under any standardized certification process. Thus, experience, capabilities and client references are very important to consider when engaging an acoustical consultant. For more information, contact the Acoustical Society of America at (516) 576-2360, asa@aip.org, or on the Web at www.asa.aip.org.

Design firms must investigate the knowledge, abilities, experience, and testing and modeling capabilities of an acoustical consultant, as well as his or her general orientation to the holistic design process. Although acoustics can often be the missing link in office projects, sometimes the opposite occurs, and acoustics becomes the most important part of the project – an equally bad mistake. Projects that over-emphasize one building performance area over others frequently suffer from failures in daylighting, lighting and thermal comfort.

In design-build projects, the acoustical and audio engineering are often the responsibility of electrical and mechanical contractors, who seldom have a depth of expertise in these areas. On other projects, the electrical and mechanical engineering staffs may be tasked to determine acoustical and audio-visual solutions. While these engineers generally have a higher degree of training and expertise than do some other contractors, they are rarely trained in the nuances of acoustical and audio-visual consulting and thus often rely on outside contractors and vendors for the development of acoustical solutions. In either case, the results are usually less than satisfactory.

PART IV


2005
2010
2015
2020
2025

PART IV The Potential for Future Office Acoustics Research

Very little has been done to change the nature of office acoustics over the past 30 years. In the 1970s the products available were

- Highly rated partitions
- Highly rated ceilings
- Highly rated wall panels
- Highly rated carpet/flooring
- Effective sound masking systems
- Effective HVAC systems at controlled levels

In the meantime, many things have happened to reduce product performance:

- Office panels are now more often low-absorption Noise Reduction Coefficient (NRC) panels at lower heights with "vent" holes in the bottom and raceways at many heights. Their joints are often very poor.
- New systems are often not comprehensively tested with the various panel and construction types for realistic (*in situ*) performance data.
- Open plan ceiling specification no longer assumes highly rated ceilings in many cases.
- Use of acoustical wall panels has been dramatically reduced.
- Sound masking systems are now often vendor-designed and tuned-systems with evenness ratios of +/- 8-10 dBA, rather than the +/- 2 dBA of older systems.
- Many HVAC systems are no longer analyzed for Noise Criteria (NC) performance.

Part of the reason for these reductions is the misperception that product specification alone will resolve acoustical issues, without either understanding the specification or knowing whether the ratings are correct. Part of the reason is the infrequent use of acoustical consulting and testing on open plan offices.

As we look toward the future of the open plan office, we must look for a more complex and meaningful future. This means that

- We need to better understand the needs for and benefits of privacy for each project, and we must measure (pre and post) the occupants and the office to determine the outcomes and value of the design process.
- We need to bring acoustical expertise back into the design process, where it has been set aside. The probability that a design team, working with an acoustical vendor team alone, will produce an optimized acoustical environment has been very low in practice. This relates to both definition and results.
- We need to be able to put a dollar value on acoustical benefits for each client, which means that projects must use occupancy studies both before and after project implementation, using commissioning on the project and employing remediation at the early post-occupancy phase.

With regard to products, there remain many interesting applications from acoustics, psychological perception, audiology and behavioral science that could be employed in the development of a whole new range of products and practices for the open-plan office. These products have the potential to:

- Reduce speech-related noise at the source
- Reduce speech-related path noise
- Reduce speech-related noise at the receiver
- Reduce the perception that privacy is necessary in some cases
- Increase the perceptual value of each level of privacy

We have done much to argue for privacy and little to prove its need or value. We now need to begin to understand who needs privacy, when they need it, how we can provide it and what is the cost-benefit equation. We have to understand implicitly that this is not about acoustics but about occupants and their perception of the quality of their acoustical environments. In other words, with the help of the design and facilities communities, we must put the evaluation and measurement of people back into the design equation.

Postscript / Preferred Architectural Environments

One promising metaphor for research on the future of the office is "preferred environments." These are generally "voluntary" environments, which simply means that they are places occupants have chosen to be. Two likely candidates for the top preferred environments are outdoor spaces and the home.

Before considering these environments, it is important to note two clear distinctions between such environments and the open plan office: First, these other environments are indeed "voluntary"– we don't need to be there; we choose to be there. Secondly, we can be dynamic with respect to these environments. We can move through them to create a dynamic – a dynamic involving both occupants and their perceived environment.

Certainly we might choose to be at home or outdoors for social or other reasons unrelated to the physical environment per se; and no doubt one source of the lack of choice regarding work environments involves employment requirements themselves. Other pertinent considerations might include the degree to which people feel free within a particular organization to alter their work environment or choose a location other than their office based on shifting needs, such as privacy or team-based activities. Indeed there is some evidence that a greater sense of personal control defined in this way may improve evaluations of the work environment.

However, since notable differences between the features of one's home and/or favorite park (or garden) and those of a typical open plan office exist, this suggests that these different characteristics play a role in determining our preferences. In this regard, the outdoor environment is generally a complex sensory environment. Favored outdoor environments are selected at least partly because their stimuli have positive emotional and associative impact. The stimuli will generally include all the senses, some in static and some in dynamic mode. For example, it may be hot (static) but the wind may be blowing (dynamic). It may be bright (static), but clouds may be moving overhead (dynamic). It may smell of flowers (static), but the wind may change that experience (dynamic). In any case, we seem to have strong emotional and associative responses to our preferred outdoor environments.

The home presents an interesting case, since it represents enclosure, as does the office. Yet again, we have a choice of spaces to occupy. We can change them at will, and they vary dramatically on the stimulus level. The typical home ranges from loud to soft, from bright to dark, from complex to simple, from warm to cool – and is tactilely complex. It is an environment designed to let the occupant exhibit certain kinds of behavior in several specialized settings (i.e., eating, sleeping, talking, playing). In addition, the home is generally an indoor and an outdoor environment. The choice of a home thus includes the choice of indoor, outdoor and community environments.

One of the central problems in office design, as we seek to augment currently popular approaches, is to begin to understand how to make offices into preferred environments. Like the home, the office calls for certain kinds of behavior, and it provides a local space (the workstation) and some general spaces for this behavior. As we explore office design, it is useful to ask if expected "office behaviors" are appropriate to the tasks at hand and if office environments support those behaviors in ways that are similar to other preferred environments.

About the Authors / Glossary of Acoustical Terms / Bibliography

About the Authors

Steven J. Orfield

Steven Orfield founded Orfield Laboratories 33 years ago after majoring in Philosophy at the University of Minnesota. In 1969, Steve began researching and consulting on acoustics and lighting in the open plan office for two of the first manufacturers of office systems in North America.

Orfield Labs worked principally in the architectural building performance field (daylighting, lighting, acoustics, A-V) until 1980, when Steve entered the corporate research field. From an early interest in perception and measurement, Steve has developed the firm into the only multi-disciplinary subjective-objective research lab in the United States, serving clients here and abroad. Steve holds patents in both the acoustics and lighting fields.

He has also been instrumental in introducing new approaches to his fields with the founding in 1991 of the Sound Quality Working Group, in 1998 of the Open Plan Working Group, and in 2003 with the founding of the Medical Facilities Working Group. These three organizations are intent upon changing their fields in fundamental ways and moving them toward perceptual and occupant-based approaches. Steve has published over 100 articles in the firm's disciplines in the national press and has presented many seminars locally and nationally. In 2001 Steve was invited to serve as an Adjunct Professor of Acoustics at the Architecture School at the University of Minnesota while teaching a graduate course in Acoustics with the staff of Orfield Labs. Orfield Laboratories is a federally certified (NIST/ NVLAP) acoustical laboratory.

Jay L. Brand, Ph.D.

Prior to joining Haworth, Inc., six and a half years ago, Dr. Brand, was chair of the department of psychology at La Sierra University in Riverside, Calif., and later associate professor of psychology at Loma Linda University, where he helped develop Ph.D. and Psy.D. programs in psychology – both accredited by the American Psychological Association. He has held various positions at Haworth, including human factors/cognitive engineer, organizational behavior specialist and corporate ergonomist. His current title is cognitive psychologist.

As a member of a number of professional societies, Dr. Brand conducts and applies research on a number of areas, from sensation and perception, cognition and industrial/organizational psychology, to the design and evaluation of work environments. The results of this work provide implications for specific product designs, space configurations and layouts, and individual and organizational outcomes. Currently an associate editor of *Ergonomics in Design*, he believes that the strategic blending of both artistic and scientific understanding of emotion, intuition and cognition within their cultural and spiritual contexts will guide the design of effective work environments that delight their occupants.

Glossary of Acoustical Terms

Absorption
The properties of a material composition that convert sound energy into heat, thereby reducing the amount of energy that can be reflected.

Acoustics
The science of sound: its production, transmission and effects.

Acoustical Properties
The properties of a material that absorb or reflect sound.

Acoustical Analysis
A review of a space to determine the level of reverberation, or reflected sound (see **Reverberation**, also **Reverberation Time**), in the space (in seconds) as influenced by the building materials used to construct the space. Also, a study of the amount of acoustical absorption required to reduce reverberation and noise.

Acoustical Consultant
A professional, usually with an engineering degree or equivalent credentials, whose primary role is to provide advice on acoustical requirements and noise control in a variety of situations. These professionals come from a wide variety of areas and are generally not certified under any standardized certification process. Thus, experience, capabilities and client references are very important to consider when engaging an acoustical consultant. For more information, contact the Acoustical Society of America at (516) 576-2360, asa@aip.org, or on the Web at www.asa.aip.org.

Acoustical Environment
The acoustical characteristics of a space or room influenced by the amount of acoustical absorption, or lack of it, in the space.

Architectural Acoustics
The control of noise in a building space to adequately support the communication functions within the space and their effect on the occupants. The qualities of the building materials used to determine their character with respect to hearing clarity.

Articulation Class (AC)
A method for predicting speech intelligibility under specified conditions – most commonly, the one-third-octave-band method. This method calculates a weighted sum based on the differences in sound energy between speech and ambient noise within each one-third-octave band containing speech frequencies.

Attenuation
A reduction in a sound's energy or sound pressure level (SPL) (see **Sound Pressure Level**).

A-Weighted Sound Level (Noise level)
A measure of sound pressure designed to reflect the response of the human ear, which does not respond equally to all frequencies. Since the ear is less efficient at low and high frequencies than at medium or speech-range frequencies, it is necessary to reduce the effects of the low and high frequencies with respect to the medium frequencies to describe sound in a manner that reflects these response biases. Also called the "noise level," the resultant sound level is said to be "A-weighted," measured in dBA units (see also **Decibel**). Sound level meters have an A-weighting setting for measuring sound levels. Most occupational, industrial and environmental noise levels are measured using A-weighting.

Audiogram
A chart or table relating hearing level to frequency for pure tones.

Audiometer
An instrument for measuring hearing acuity.

Background Noise
With respect to some reference sound, all ambient noise remaining after considering one sound as a signal (e.g., speech). Typically measured as the average sound pressure level (SPL) within different frequency bands or across various lengths of time. Used in calculations of signal-to-noise ratios.

Backward Masking
The ability of sounds to alter the sensory or perceptual threshold of other sounds occurring before them.

Glossary of Acoustical Terms

Baffle
A free-hanging acoustical sound-absorbing unit. Normally suspended vertically in a variety of patterns to absorb and therefore reduce reverberation and noise levels. Also an arrangement within a silencer or muffler.

Barrier
A material that when placed around a source of noise inhibits the transmission of that noise beyond the barrier. Also, an environment or any physical object that interferes with communication or listening.

Barrier Attenuation
Reduction in the sound pressure level (SPL) of a sound as a function of a barrier placed between the sound's source and a receiver (e.g., a listener), orthogonal to the source-receiver path.

Bel
A measurement of sound intensity named in honor of Alexander Graham Bell, initially used to relate intensity to a level corresponding to hearing sensation.

Boominess
Low frequency reflections. In small rooms, acoustical panels with air space behind can better help control low frequency reflectivity.

Cochlea
A snail-shaped mechanism in the inner ear containing hair cells along the basilar membrane that respond to sound frequencies to aid in sound recognition.

Cycle
In acoustics, the cycle is the complete oscillation of pressure above and below the atmospheric static pressure.

Cycles Per Second
The number of oscillations that occur in the time frame of one second (see **Frequency**). Low frequency sounds have fewer and longer oscillations.

Damping
The dissipation of energy with time or distance. The term is generally applied to the attenuation of sound in a structure owing to the internal sound dissipative properties of the structure or to the addition of sound dissipative materials.

Decibel (dB)
Sound level in Bels as a logarithmic ratio. Sound intensity described in decibels. Examples: breathing=5 dB; office activity=50 dB; jet aircraft during takeoff at a distance of 300 feet=130 dB.

Diffusion
The scattering or random reflection of a sound wave from a surface. The direction of reflected sound is changed such that listeners can have the sensation of sound coming from all directions at equal levels.

Distance Attenuation
Reduction in the sound pressure level (SPL) of a sound as a function of the distance from its source to a receiver (e.g., a listener).

Echo
Reflected sound producing a distinct repetition of the original sound. In mountains, echo is distinct by reason of sound wave travel after the original signal has ceased.

Equal Loudness Contours
Curves represented in graph form as a function of sound level and frequency that listeners perceive as being equally loud. High frequency sounds above 2000 Hz (see **Hertz**, also **Frequency**) are more annoying. Human hearing is less sensitive to low frequency sound (see also **Phon**).

Flanking Attenuation
Reduction in the sound pressure level (SPL) of a sound as a function of a barrier placed along and parallel to the path between the sound's source and a receiver (e. g., a listener).

Forward Masking
The ability of sounds to alter the sensory or perceptual threshold of other sounds occurring after them.

Free Field
Pertaining to a situation where sound waves propagate from an outdoor source with no obstructions.

Frequency
The number of oscillations or cycles per unit of time. Acoustical frequency is usually expressed in Hertz (Hz) units, where one Hz equals one cycle per second.

Frequency Analysis
An analysis to determine the character of a sound (i.e., high vs. low frequency) by measuring the amount of resonance (see **Resonance**) at various frequencies that compose the overall sound spectrum.

Hearing Impairment
A degree of hearing loss due to numerous causes, including illness, disease or exposure to excessively high noise levels. Between 25 and 50 million people of all ages in the U.S. have some degree of hearing impairment. In general, hearing impairment means a mild to severe hearing loss, in contradistinction to deafness which is generally described as little or no residual hearing with or without the aid of a listening device. Hearing-impaired persons are particularly adversely affected by long reverberation times.

Hearing Ranges
16 - 20000 Hz (Absolute frequency thresholds for humans)
600 - 4800 Hz (Speech privacy issues)
250 - 2500 Hz (Typical small table radio)

Hearing Loss
In auditory perception, a condition characterized by either a temporary or permanent sensory or perceptual threshold shift.

Hertz (Hz)
Frequency of sound expressed by cycles per second (see **Cycle**).

Intensity
See **Loudness**.

Interstimulus Interval (ISI)
In audition (hearing) experiments, the time between the offset of one sound and the onset of another (e. g., used in studies of forward and backward masking).

Inverse Square Law
Newton's mathematical equation, proving that for every given distance traveled from the source, sound level drops 6 dB.

Loudness
A listener's subjective impression of the strength of a sound. The average deviation above and below the static value due to a sound wave is called "sound pressure." The energy expended during the sound wave vibration is called "intensity" and is measured in intensity units. Loudness is the physical resonance to sound pressure and intensity.

Masking
The process by which the threshold for hearing one sound is raised due to the presence of another sound.

Message Complexity
Those aspects of sound that relate to its being deciphered, understood or interpreted. Can relate to either subjective (e.g., semantic meaning) or objective (e.g., predictable or uncertain) criteria. Measured with verbal scales or using formal information theory.

Mounting
Standards established by the American Society for Testing and Materials (ASTM) to test the acoustics of materials by representing a typical installation. For example, a mounting test specimen is attached directly to the test room surface or furred out to produce an air space behind.

Noise
Unwanted sound that is obtrusive or interferes with listening. Noise does not have to be excessively loud to qualify as interference.

Noise Criteria (NC)
Noise criteria curves evaluate existing listening conditions by measuring sound levels (preferably at ear level) at the loudest locations in a room. Noise criteria may also be referred to in dBA levels.

Glossary of Acoustical Terms

Noise Isolation Class (NIC)
A single number rating of the degree of speech privacy achieved through the use of an acoustical ceiling and sound absorbing screens in an open office. NIC has been replaced by the Articulation Class (AC) – also known as the Articulation Index (AI) – rating method (see Articulation Class).

Noise Reduction (NR)
The amount of noise that is decreased through the introduction of sound absorbing materials. The level (in decibels) of sound reduction on a logarithmic scale.

Noise Reduction Coefficient (NRC)
The NRC of an acoustical material is the mathematical average, to the nearest multiple of 0.05, of its absorption coefficients at center frequencies of 250, 500, 1000 and 2000 Hz.

Noise/Message Annoyance
Although noise can be defined as any unwanted (or annoying) sound, the **noy** measures a sound's noisiness. One noy is defined as a sound subjectively equal in noisiness to an octave band of random noise centered at 1000 Hz at an SPL of 40 dB. In general, annoyance is measured using verbal scales, such as noticeable – intrusive – annoying – very annoying – unbearable. There are a number of factors – both acoustic and non-acoustic – that can influence the annoyance quality of noise.

Octave
A pitch interval of 2 to 1. A tone whose frequency is twice that of the given tone. (Referring to a musical scale, from "do" to "do.")

Octave Bands
Sounds that contain energy over a wide range of frequencies are divided into sections called "bands." A common standard division is in 10 octave bands identified by their center frequencies: 31.5, 63, 125, 250, 500, 1000, 2000 and 4000 Hz.

Perceived Noise Level and Perceived Level of Noise
We might hope these were synonymous, but alas, they are not. PNL relates to phons and is measured in PLdB, whereas PLN relates to sones and is measured in PLdB. The primary distinctions between these two approaches have to do with the reference sounds and different acoustical tables used for their derivation.

Phon
A unit of loudness related to equal loudness contours – subjective impressions of equal loudness by listeners as a function of frequency and sound level (dB). An increase in low frequency sound will be perceived as being much louder than an equivalent high frequency increase.

Pitch
That aspect of auditory perception with respect to sound that changes as the sound frequency changes (as from high to low), although this can also be influenced by sound intensity – particularly at very low or very high frequencies.

Reflection
The amount of sound wave energy (sound) that is rebounded from a surface. Hard, non-porous surfaces reflect more sound than soft, porous surfaces. Some sound reflection can enhance the quality of the signal of speech and music.

Resonance
Reinforcement and prolongation of a sound by reflection or by vibration of other bodies, as in sympathetic vibration.

Reverberation
The continued reflection of sound from surfaces (e.g., within a room) after its source has ended. Reverberation continues until the sound waves lose energy through absorption and eventually die out.

Reverberation Time
The time taken for sound to decay 60 dB after the sound source has stopped. Reverberation time, a basic acoustical property of a room, depends only on room volume and the absorptive properties of its surfaces and contents. This property has an important influence on speech intelligibility.

Sabine
A unit of sound absorption based on one square foot of material. Baffles are frequently described as providing *x* number of sabins of absorption, based on the size of the panel tested, through the standard range of 125 - 4000 Hz. The number of sabins for other acoustical materials is determined by the amount of material used and its absorption coefficients.

Sabine Formula
A formula developed by Wallace Clement Sabine that allows designers to plan reverberation time in a room in advance of construction and occupancy. Defined and improved empirically, the Sabine Formula is T=0.049(V/A), where T = Reverberation Time (time required for sound to decay 60 dB after source has stopped) in seconds; V = Volume of room in cubic feet; A = total square footage of absorption in sabines.

Septum
A thin layer of material such as foil, lead, steel, etc., between two layers of absorptive material that prevents sound waves from passing through the absorptive material.

Signal Complexity
Those aspects of sound relating to its spectral and temporal richness (e.g., musical instruments whose sounds integrate multiple frequencies have a characteristic timbre); sounds can also exhibit various complexities with respect to time, such as repetition and duration.

Signal to Noise Ratio (S/N)
The sound level of a speaker above background noise at the listener's ear level. The inverse square law impacts the S/N ratio.

Sone
A unit of loudness related to the relative subjective loudness of different sounds. (Forty phons equals one sone, and every ten additional phons doubles the number of sones).

Sound
Sound is an oscillation of pressure, stress particle displacement and particle velocity in a medium. Sound produces an auditory sensation caused by its oscillation.

Sound Absorption
The property possessed by materials, objects and air to convert sound energy into heat. Sound waves reflected by a surface create a loss of energy. The energy not reflected is referred to as the absorption coefficient.

Sound Absorption Coefficient (SAC)
The fraction of energy striking a material or object that is not reflected. For example, if a material reflects 70 percent of the sound energy incident upon its surface, then its Sound Absorption Coefficient would be 0.30. SAC = Absorption/Area in sabins/ft.2

Sound Level
A subjective measure of sound expressed in decibels as a comparison corresponding to familiar sounds experienced in a variety of situations.

Sound Pressure Level (SPL)
An important measure of sound loudness; the level is calculated in decibels by 20 times the logarithm to the base 10 of the ratio of the measured sound pressure level and the reference point.

Sound Level Meter
A device that converts sound pressure variations in air into corresponding electronic signals. Typically, the signals are filtered to exclude sound waves outside the desired frequencies.

Sound Transmission Class (STC)
A single-number system used to rate the sound transmission performance of a wall, panel, ceiling, etc. The higher the ranking, the better the ability to obstruct sound transmission.

Glossary of Acoustical Terms

Speech Intelligibility
The ability of a listener to hear and correctly interpret verbal messages. In classrooms with high ceilings and hard parallel surfaces, such as glass and tile, speech intelligibility is a particular problem. Sound bounces off walls, ceilings and floors, distorting the teacher's instructions and interfering with students' ability to comprehend.

Spectrum
The description of a sound wave's components of frequency and amplitude.

Stimulus Onset Asynchrony (SOA)
In audition (hearing) experiments, the time between the onset of one sound and the onset of another (e.g., used in studies of forward and backward masking).

Talker and Listener Orientation
The facing directions of a talker and listener relative to each other, for example, azimuth angle (in the horizontal plane).

Time Weighted Average (TWA)
The measure used by the U.S. Occupational Safety and Health Administration (OSHA) to measure noise levels in the workplace. It is equal to a constant sound level of eight hours' duration that would cause equivalent hearing loss as the variable noises to which a worker is actually exposed. (This hearing loss, of course, occurs over long-term exposures.)

Ultrasounds
Sounds with frequencies higher than 20,000 Hz. The frequency region containing these frequencies is called the ultrasonic region.

Visual Loss
In vision, a condition characterized by a temporary or permanent sensory or perceptual threshold shift or by various other reductions in one or more perceptual quality criteria.

Volume
The cubic space of a room bounded by walls, floors, and ceilings determined by the mathematical equation Volume=Length x Width x Height of space. Volume influences reverberation time.

Wavelength
Sound that passes through air produces a wavelike motion of compression and refraction. Wavelength is the distance between two identical positions in the cycle or sound wave. Similar to ripples (waves) produced by dropping a stone in water. Length of sound waves varies with frequency: low frequencies are characterized by longer wavelengths, whereas high frequencies are associated with shorter wavelengths.

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About ASID

The American Society of Interior Designers (ASID) is a nonprofit professional society representing the interests of interior designers and the interior design community. The Society is led by a volunteer board of directors that includes the Society's president, president-elect and immediate past president. Daily operations are carried out by a small staff housed in the Society's headquarters in Washington, D.C.

ASID is the leading professional organization for interior designers with the largest residential and commercial leadership. With more than 35,000 members, ASID establishes a common identity for professionals and businesses in the field of interior design.

Of the Society's 20,000 practicing interior designers, 6,500 practice primarily in the commercial field and 4,000 primarily in the residential field. The remaining 9,500 work in both commercial and residential design.

ASID Industry Partners include more than 1,900 member firms with more than 5,000 individual representatives, uniting the professional designer with manufacturers of design-related products and services. The Society's membership also includes more than 10,000 students of interior design.

The association has 48 chapters throughout the United States and more than 450 international members. ASID was founded in 1975 with the consolidation of the American Institute of Decorators (AID) and the National Society of Interior Designers (NSID).

Professional members of ASID must pass rigorous acceptance standards: They must have a combination of accredited design education and/or full-time work experience and pass a two-day accreditation examination administered by the National Council for Interior Design Qualification (NCIDQ).

ASID promotes professionalism in interior design services and products for the workplace and home. To keep up with the unique needs of its members, ASID conducts independent research on topics related to the practice and business of the profession.

ASID designers receive the most current information about appropriate materials, technology, building codes, government regulations, flammability standards, design psychology and product performance.

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