RSG INC.
RESOURCE SYSTEMS GROUP, INC.

SOUND DESIGN FOR EDUCATIONAL FACILITIES

Architectural Acoustics White Paper

By Eddie Duncan, ASA

THE LEARNING ENVIRONMENT

Imagine sitting in a room in a hard chair, the back of which offers the kind of support where you cannot help but have good posture. As you look slightly down toward the small workspace in front of you, you hear the rumble of an airplane overhead. You think about the good breakfast you had this morning. Bam! You hear the slamming of what sounds like a metal door. With it being so warm out today, your attention is drawn to the hum of the air conditioner. Then you begin to think about all the things you can do this afternoon, but those thoughts are interrupted by the murmur of speech from the adjacent room. You think about how you're not a big fan of the fluorescent lights overhead, especially the buzzing sound they sometimes make. Luckily the hum of the highway, which is just a few hundred feet outside the building, doesn't bother you much because living right next to an interstate has made you immune to it, or at least immediately unaware of it. All at once, you notice the whistle from the train down town, feet shuffling from other people around you, and then the clangor of the loud bell on the wall startles you. You take a deep breath and prepare to concentrate. You are back in school.

This is actually the atmosphere that a majority of students attempt to learn in everyday and it is really just a start. It doesn't include the banging from the shop class next door, the music from the adjacent band and chorus rooms, the chatter from various students in class, chairs scraping on the floor, computer fans, and so much more.

SPEECH INTELLIGIBILITY AND LEARNING

As an adult, it is easy to imagine how difficult it would be to learn in an environment such as the one described above. For a child learning in such an environment would be even more difficult. The reason is related to vocabulary. In most cases of conversation and speech, people do not usually understand 100% of the words spoken. Since adults have a fairly broad vocabulary, they are able to fill in the words that they miss by using the context of the sentence or conversation, especially when they are familiar with the topic being discussed. On the other hand, most children have a more difficult time filling in the words they miss because they are still learning new topics and new vocabulary.

55 Railroad Row, White River Junction, Vermont 05001
TEL 802.295.4999 ▪ FAX 802.295.1006 ▪ www.rsginc.com

One way to evaluate this issue is to measure the speech intelligibility of a room. This can be done by having a speaker read a simple word list aloud while many listeners write down the words they hear. The total percentage of correct words written down is a measure of speech intelligibility.

Reading and understanding a word list is much different from reading a paragraph from a text book, though. For example, imagine that you use a word list to test the speech intelligibility of a room and find it to be 75%. This means that one out of every four words is misunderstood or unintelligible. This would not be too much of a problem for adults in a real world situation because they would be able to understand the speech in context. Children, however, are not as adept at understanding from context, particularly when the context is a subject they are still learning about. As Figure 1 illustrates, people of varying ages with average hearing abilities can all hear equally well when individual words are read, but as vocabulary increases with age, people can understand more words in the same environment when the words are read in context with one another. Students with hearing impairments, ear aches, and social and learning disabilities are at a further disadvantage when trying to understand speech.

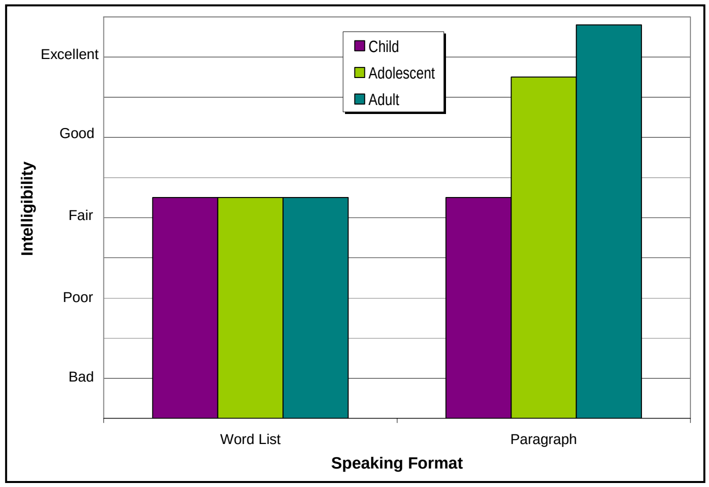

Figure 1: Speech Intelligibility Comparison between Different Age Groups and Reading Scenarios

Noise and improper acoustic design in the classroom can also take a toll on teachers . It is stressful to work in a noisy environment, especially when your job function relies on continual communication. No one enjoys speaking with a raised voice all day long.

STANDARDS

In 2002, the need for quality classroom acoustics was recognized by the American National Standards Institute (ANSI), with the assistance of the Acoustical Society of America (ASA), when they released S12.60-2002, "Acoustical Performance Criteria, Design Requirements and Guidelines for Schools." The standard addresses the three main acoustical characteristics that make speech intelligibility poor in most of our schools today. Those characteristics are background noise, noise isolation, and reverberation; they are described in the following sections. The standard provides limits for various acoustical performance parameters, but still leaves much flexibility for the design. Its appendices also provides practical design guidelines to help meet the standard.

Background Noise

It is important that background noise be kept at low levels in a learning environment. The ANSI standard addresses this issue by setting maximum steady background noise levels. The best way to understand the effect of background noise is to compare it with the source you want to hear. This is described by the signal-to-noise ratio.

The signal-to-noise ratio is simply the difference in sound levels between the sound you want to hear (the signal) and the background sound (the noise). In a classroom setting, the teacher's voice is the signal and the rest of the backgrounds sounds are the noise. In general adults require a minimum signal-to-noise ratio of 6 to 8 dB for speech to be understood. For children the signal-to-noise ratio must be 10 dB or more. For hearing impaired listeners, the ratio is even higher, around 15 dB or more.

Speech from a teacher is typically between 50 and 65 dBA, depending on where a student is seated in the classroom. Background noise can often intrude on these speech levels. To illustrate this, let's go back to the classroom described at the beginning of this paper. For the sake of focusing on the background noise within the room, we can ignore the outside sound sources like trains, planes, and automobiles. We can also ignore the noise coming from adjacent rooms. What is left is a room with a noisy air conditioner, buzzing florescent lights, and feet and chairs shuffling on the hard tile floor. If all these sources produce a background noise level above 45 dBA, that noise starts to intrude on the speech. This gives us a signal-to-noise ratio of 5 to 20 dB. This means that a student may or may not understand the teacher depending on where he or she is sitting in the room.

Background noise in a room can be addressed through the use of acoustically absorptive materials in the room, and careful attention to the design of HVAC systems, wall partitions, doors, and windows.

Noise Isolation

Another source of background noise is sound that invades the space from another area. This includes noise from classes in other rooms, corridors, and outdoor sources. Sound from outside sources can be minimized with proper design of partitions and placement of rooms.

The ANSI standard addresses noise isolation by setting minimum Sound Transmission Class (STC) and Impact Insulation Class (IIC) ratings for walls and floor/ceiling assemblies. STC is the rating a partition is given based on how well it attenuates airborne noise and IIC is the rating a partition is given based on how well it attenuates structure-borne noise.

Reverberation Time

A different characteristic of sound that affects speech intelligibility has to do with how sound acts within a room. Depending on the size of the room, the materials within it, and the materials that compose the spatial envelope, speech can be either clear or unintelligible. These factors influence what is called reverberation, which is the sound you hear in a room after the source of the sound is terminated (this is similar to, but not the same as, an echo). A large room with hard surfaces will typically be very reverberant, while a small room with mostly soft surfaces will typically have little reverberation. If a room has a lot of reverberation, then sound will, in essence, bounce around the room making sound from one spoken word run into the words that follow it. If a room has little reverberation, then sound will be emitted from the source and then be absorbed. Designing a room where sound is absorbed quickly helps makes speech clear in a classroom setting.

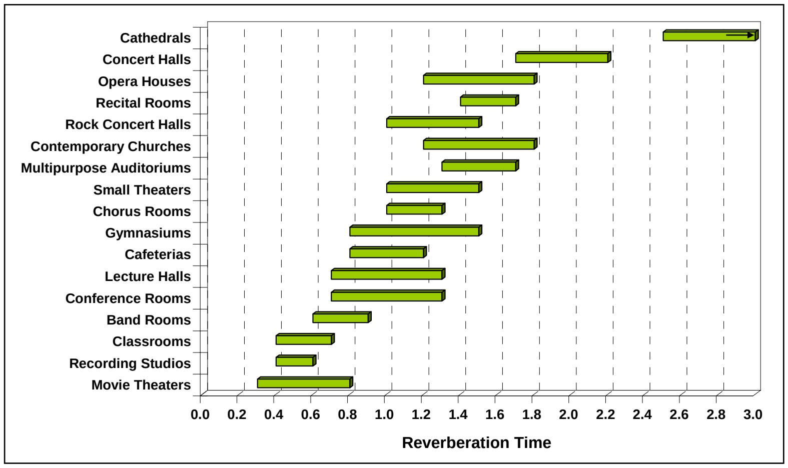

Figure 2: Optimum Reverberation Times at 500 Hz for Various Spaces

The ANSI standard sets maximum values for reverberation time for different sized rooms. Proper reverberation times vary, depending on the size and use of the room. The reverberation time of a classroom, for example, is not the proper reverberation time for an auditorium. This can be seen in Figure 2, which shows generally accepted optimum reverberation times for different spaces.

RESPONSIBILITY

So who is responsible for assuring the ANSI standard is implemented? While school boards and officials may be aware of the problem of learning in a noisy environment, they are probably unsure of how to solve the problem. That often leaves the responsibility to the designer or architect. For buildings that are already in use, designs need to be updated and spaces retrofitted, which often has significant costs associated with it. The best time to approach acoustic problems, therefore is in the design phase of a new building. The designer can begin this process by following the design guidelines in the appendices of the ANSI standard, but while these guidelines are very helpful, it is best to have a professional acoustical consultant provide advice for design details and check conformance with the ANSI standard.

BEYOND THE CLASSROOM

While the core learning area is the classroom, it is not the only place in a school where learning takes place. Our educational facilities are filled with all sorts of spaces for special classes and programs. Gymnasiums, auditoriums, cafeterias, laboratories, band and chorus rooms, wood shops, offices, and other rooms,, all have different acoustical demands in order for their design to adequately meet educational and occupational needs. The design goals can become even more complex with the recent trend towards multipurpose spaces. Some common design issues are listed below:

- Gymnasiums are often too loud and reverberant, which not only hinders learning, but could potentially impact the hearing of instructors and students.
- Speech intelligibility in auditoriums is often weak without amplification. In addition, when the space is used for music, it is important that the room isn't too "dry" (having little reverberation) or too "live" (having too much reverberation).
- Band and chorus rooms require a special mixing of sound so that performers can not only hear themselves well, but can also hear how they blend with the rest of the group.
- Shop rooms are usually too loud, making it difficult for students to hear instructions and safety information..
- Cafeterias are often loud and reverberant. This can lead to an unpleasant social atmosphere and, if these rooms double as study halls, a poor learning environment.

CONCLUSIONS

Educational facilities are composed of many diverse acoustic environments. By, following the ANSI standard S12.60-2002 and using some of the information provided in this paper, architects and school officials can begin to plan sound designs for educational facilities that better meet the needs of students and teachers.

About RSG, Inc. – RSG specializes in the planning, analysis, and management of business, infrastructure and natural resources. We believe that high-quality, objective analysis is a prerequisite to resolving complex problems. More than just analysts, scientists, and technicians, we're communicators – our study results are clear, concise, and directly applicable to a client's particular questions and challenges. Our solutions are creative and grounded by 20 years of experience with clients as large as federal government agencies and Fortune 500 companies and as small as local interest groups and townships. RSG is a member of the National Council of Acoustical Consultants.

About the author – Eddie Duncan is an Associate at RSG, Inc. working in the field of architectural acoustics. He graduated from the Rensselaer Polytechnic Institute, where he studied engineering and acoustics. He is also a member of the Acoustical Society of America.