# Part 4: Better Hearing:
# Creating a Hearing-Friendly Environment

Section 1: Basic acoustics
How sound travels in a room, and where the problems arise.

Section 2: First Aid for Noisy Classrooms (as well as home and office)
Practical things you can do today to reduce the noise and raise the understanding.

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## 1. Basics of Acoustics

Acoustics has to do with the transmission, reception, and clarity of sound within a given space. While we are mainly concerned here with improving the acoustics within the classroom environment, these principles and guidelines would apply to other environments as well.

We first need to ask who can benefit most from good acoustics. The answer is that good acoustics means good speech intelligibility and that helps *everyone's* comprehension. But for the following groups of students, good acoustics can mean the difference between success and failure:

- hard-of-hearing (HOH) students
- very young children whose language skills are still developing
- children learning to read, because they need to clearly hear the letter sounds (especially the softly-spoken consonant sounds).
- students learning English as a second language
- students with learning disabilities and attention deficit problems

How clearly we understand someone depends upon the:

1. level of background noise
2. distance from the speaker
3. loudness of the speech (signal strength)
4. signal-to-noise ratio (SNR)
5. amount of reverberation (echoes)

We will look closely at how these five factors impact speech intelligibility. In “First Aid for Noisy Classrooms” (below) we will provide dozens of tips for improving the acoustics in the classroom. Many of these tips are also applicable to the home and office environment.

**1) Background Noise** is sound we do not want to hear that covers or masks the sound we *do* want to hear. It may include people talking, chairs scraping, traffic sounds, or the hum of a refrigerator. In a classroom, noise may arise from outdoors, from adjoining classrooms and hallways, and from within the classroom itself: heating and air conditioning noise, student talking and movement, computers and other electrical equipment.

**Tip** To reduce the noise within a classroom you should:

a) prevent it from arising *within* the room in the first place, and
b) keep it from entering from outside the room.

**2) Distance from the speaker** also affects speech comprehension. The further we move from the sound source, the weaker the sound gets and the greater the probability that noise and reverberation will interfere with it.

To understand how distance affects the volume of the speaker's voice, we need to know that as the distance doubles, the sound intensity drops by six decibels. So if a student four feet away hears the teacher at a volume of 60 dB, a student eight feet away would receive the sound at 54 dB, at 16 feet it would be 48 dB and at 32 feet the sound would drop to 42 dB.

4' = 60 dB
8' = 54 dB
16' = 48 dB
32' = 42 dB

How does this relate to our perception of loudness? Well, every 10 dB drop in decibels is perceived as a 50% drop in loudness. Since we have almost a 20 dB drop, the student sitting in the back of the room would be receiving the words at about 1/4 the volume of the student in the first row.

**3) Loudness of the Speech (signal strength)** obviously has an affect on our ability to understand the speaker. But if you ratchet up the volume, is it always enough? Even a speaker with a powerful voice will get drowned out if the competing noise is louder. In order to determine speech intelligibility, we need to know both the volume of the speech *and* the volume of the noise. And that's where the signal-to-noise ratio comes in.

**4)** The **Signal-to-noise ratio (SNR)** compares the volume of the speech to the volume of the noise. It tell us whether a teacher in a noisy classroom, for instance, will likely be heard by all the students, including those sitting in the back.

> **Tip** The **signal-to-noise ratio** (SNR) compares the loudness of the speech to the loudness of the background noise (in decibels).

> **Tip** The SNR will vary from point to point within the room. To find the SNR simply subtract the noise from the signal. If the teacher is speaking at 60 dB (as measured in the first row) and the noise level is 50 dB, the SNR in the front of the room is 10 dB.

If the speaker speaks louder or if we move closer, the effect is the same. The signal strength has increased and we can hear him better. The more we can raise the signal above the noise, the easier it will be to understand the speaker.

A student with normal hearing needs an SNR of about 10 to 15 dB for reasonable comprehension. But consider the person with hearing loss. He's starting off at a real disadvantage. Even under ideal conditions he still has trouble hearing many sounds *clearly*. His grasp is tenuous at best so any masking or distortion of speech sounds results in his losing them. For reasonable comprehension, he needs an SNR of 20 to 25 dB. So the student with hearing loss, even if he were in the first row, would be missing a lot if the SNR were only 10 dB. (Also keep in mind that the SNR shrinks significantly as we move towards the back of the room.)

In the previous example, where the sound drops from 60 dB to 42 dB as you move to the back of the room, the SNR is -8 dB (42 dB - 50 dB). This is a *negative* SNR with very poor comprehension.

To repeat, students with normal hearing need an SNR of 10 dB for good comprehension while students with hearing loss need an SNR of 20-25 dB or more.

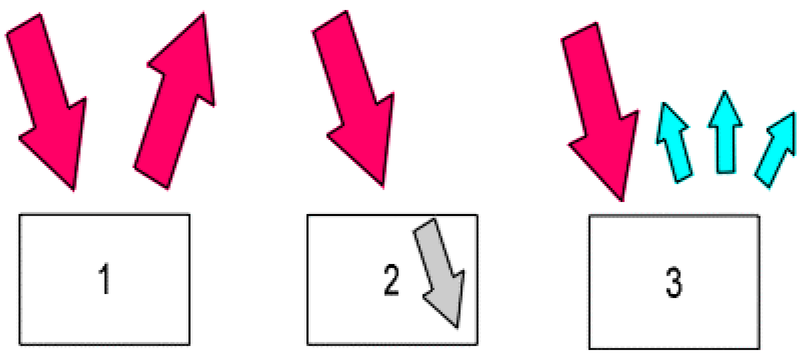
> **Tip** To improve the signal-to-noise ratio:
>
> 1) raise the signal
> 2) lower the noise
> 3) decrease the distance to the speaker
> 4) do a combination of all three

The easiest way to raise (improve) the SNR is to get closer to the sound source or bring the sound source closer to you.

**5) Reverberations** are echoes. If you've ever tried carrying on a conversation in a stairwell, you know that severe reverberation can make it almost impossible to understand what someone is saying. Here's what's happening. Stairwells have lots of hard, flat surfaces that reflect, rather than absorb sound. Sound waves ricochet wildly in all directions like a steel ball flying around a pinball machine. Since the surfaces are not absorbing the sounds, the sounds take much longer to decay and die out. These reflected sounds arrive at our ears at multiple times after we hear the direct sound.

What happens when sound waves hit a wall or an object in a room?

The illustrations below show sound being 1) r**eflected**, like a rubber ball hitting a wall 2) **absorbed** and 3) **diffused**, with much weaker reflections scattered in all directions. (In reality, all three occur at the same time but one predominates.)




Reverberations are the arch enemy of speech clarity for two reasons:

1) Reverberations **raise the noise level;** they cause a buildup of sound in the room consisting of the sum of the original sound and its reflected sounds.
2) Since reflected sounds arrive at our ears after the original sound**,** they **distort and smear everything in their wake.** Our brain can filter out a lot of noise, but it has much more difficulty with distorted words since they more closely resemble the original sounds.

To make matters worse, excessive reverberation doesn't distort the words equally; it does more damage to the consonants than it does to the vowels. We have seen that consonants are more important to speech intelligibility than vowels ("Hearing loss, audiograms, and speech intelligibility"), yet are much weaker. The vowels, having more energy, bounce around the room longer, smearing and covering up the hapless consonants.

How can we tell if the reverberations are excessive? We measure the reverberation time, the RT. **Reverberation Time (RT)** is basically the time it takes for a sound to die down. (Technically, it's the time required for a sound to drop by 60 dB.)

How much reverberation can we tolerate before we lose speech comprehension? Careful testing has shown that most people with normal hearing can tolerate an RT of up to one second without serious loss of comprehension. But for a person with hearing loss, anything more than one-half second RT can cause comprehension problems.

How can you determine if reverberation in your classroom is excessive?

**Four ways to determine if your classroom has excessive reverberation:**

1. **Clapping test**. When the room is empty and relatively noise-free, clap your hands loudly (one time) at different points in the room. If you hear a ringing sound or if the clap takes more than 1/2 second to die down, you may have excessive reverberation.

2. **Speech intelligibility test**. Lists of words and nonsense syllables are read aloud by a speaker or played on a tape recorder while listeners record what they hear. The percentage of correctly-heard words is an indication of speech intelligibility in a given room. Your school audiologist can provide more information on cost and exactly how to conduct such tests.

3. **Computer software evaluations.** Programs in which you enter the dimensions of the room and the surface nature of furniture and objects contained

within, can tell you whether reverberation is a problem.

4. **Acoustical engineers** can measure the reverberations using sophisticated (and expensive) equipment.

Reverberation time depends upon the **volume** of the room and the **surface material** of the room and the objects within.

**Tip** To reduce the reverberation time of the room:
a) Decrease the volume (hang a suspended ceiling, for example).
b) Increase the absorption by "softening up" the room. Reduce and break up the hard, flat surfaces in the room and add soft objects.

By breaking up the surfaces that reflect sound, with objects that absorb and diffuse the sound, the clarity will increase. The next section will provide more detail.

# 2. First Aid for Noisy Classrooms

## To Improve the acoustics within a classroom:

1. Pinpoint the sources of the noise.
2. Keep noise out of the room.
3. Prevent noise from arising *within* the room.
4. Decrease reverberations (Reverberation Time) and noise levels
5. Increase signal strength (increase speech volume and/or decrease distance to speaker).

## 1) Pinpoint the sources of the noise.

Noise can enter the classroom from the outdoors, from adjoining classrooms, from hallways, and from within the room. To pinpoint the major noise offenders, you'll want to start with an unoccupied classroom with all equipment off (including heating and air conditioning). Listen for any noises, pinpoint the exact sources, and one-by-one start turning on the a/c, heating, and the various pieces of equipment in the room, while listening at each stage. If the adjoining spaces are unoccupied, turn on a radio to simulate the noise coming from those areas.

This process is described fully in an excellent recent article by Mike Nixon, an acoustical engineer, "Assessing the acoustics in your child's classroom: A guide for parents".

## 2) Keep noise out of the room.

Noise can enter the room from outdoors, from adjoining classrooms, and from hallways.

- Relocate class away from noisy areas such as shop and cafeteria.

- Many rooms have suspended ceilings where the interior walls do not meet the true ceiling. Noise in one room can go up and over the wall to the adjoining classroom. Acoustical tiling will absorb some sound and lower reverberation, but does not really act as a *barrie*r to sound waves.

- This is a tough problem to fix. Two possibilities exist:
    1. If possible, raise the wall to meet the true, structural

2. ceiling. (This may not be practical due to vents and electrical cables in the airspace.)

3. Install a barrier on top of the acoustical ceiling using R-11 fiberglass insulation, vinyl barrier, or noise barrier tiles. To get the most "bang for the buck," you may need to extend only 5' or 6' out from the wall instead of covering the entire ceiling. Seek the advice of manufacturers of acoustical materials or an acoustical engineer.

- If walls are sheetrock (gypsum board) with an air space between them, fill the space with sound absorbing foam.

- Look for air ducts between classrooms. If they are not being used, close them off or fill them with sound absorbing material. If they are being used, perhaps they can be lined with absorbent material.

- Fix cracks in walls. More noise can enter through a crack 1/16th of an inch wide than through the entire wall.

- Check to see if sound is entering from the bottom of the wall. The wall may not sit firmly on the floor, leaving a very thin gap between the wall and the floor. If so, remove the baseboard and caulk the gap to seal off the sound.

- Doors
  - Get a solid-core door. It keeps a lot more sound out than a hollow-core door. (A hollow-core door is basically hollow --you can tell by tapping-- and sound can pass right through it.
  - Check that the door closes snugly in the frame. If it doesn't, sound can get through. Replace/install weatherstripping.
  - Noise can also enter through the gap *under* the door. Install weatherstripping or a drop seal.

- Consider carpeting in the hallways and "softening up" hard, flat surfaces.

- Repair windows. Make sure windows are tight-fitting when closed and that rubber gaskets are in good condition and not missing from any areas.

- Use double-pane windows to keep out noises from the outside.
- Hang heavy curtains to cut down on outside noise.

## 3) Prevent noise from arising *within* the room.

It is most important to keep noise from arising in the first place. Prevention is easier and less costly than control.

- Thin carpeting on floor subdues scraping sound of chairs and desks and shuffling of feet.
- Rubber tips on chair and desk legs also cut down on the scraping sound. You can also use tennis balls (with slits cut in them) in lieu of rubber tips. Use weatherstripping to prevent surfaces from banging against each other (lowering desktops, for instance).
- Regular maintenance of HVAC (heating, ventilation, and air conditioning), fluorescent lights, computers, printers and other electrical devices.
- Keep machines turned off when not in use, especially overhead projectors. The cumulative effect can be significant.
- Place machines on sound absorbent pads.
- Minimize the time students are retrieving materials through careful planning and clear directions.
- Lower the reverberations within the room. (Please see next section.) Excessive reverberation increases the general noise level.

## 4) Decrease reverberations (reverberation time) and noise levels

Excessive reverberations (longer reverberation time) distort words and add to the general noise level.

- Place acoustical paneling on the side walls and particularly

- the back wall. This will prevent the teacher's voice from reflecting off the back wall and up towards the front.

- **Tips on installing paneling:**
  - Place panels on at least 20% to 25% of the wall.
  - Place panels mainly in the middle of the wall. Do not place them in the lower two feet of the wall because few sound waves strike that area.
  - Leave some space between each panel. Keep edges exposed. One panel should not touch another because that reduces its efficiency. Use a checkerboard or "shotgun" pattern.
  - Stagger the panels. Do not have one panel directly facing the panel on the opposite wall. This can produce "flutter" echoes, a pinball effect that occurs between parallel walls.
  - Use panels with a noise reduction coefficient (NRC) of .75 or higher.

- If you have high ceilings, install suspended ceilings with sound absorbent tiles. This is one of the best things you can do, for two reasons: it decreases the volume of the room, resulting in shorter reverberation time, and the tiles will absorb rather than reflect the sound. Look for tiles with a Noise Reduction Coefficient (NRC) of .75 or better. (The higher the number, the better.)

- Heavy curtains can absorb sound and keep them from reflecting off the hard-surfaced windows.

- Flat, hard-surfaced objects (bare walls, metal filing cabinets) raise the noise level and the reverberation time.
  - Place large, sound-absorbing objects around the room: bookcases and/or shelving containing objects of different size and textures, corkboards, fabric partitions, and paper pad easels. (Note: large objects should be placed at a slight angle from the wall --10% to 15%-- to break up the pinball effect of sounds ricocheting between parallel walls.)
  - Put up art projects: textured sculptures, macrame, mobiles, and fabric wall-hangings (Check fire codes)

- Mount acoustical panels (see above).
- Remember -- bare walls are a "no-no."

## 5) Increase speech volume and/or decrease distance to teacher.

To hear more clearly, we can also move the students closer to the teacher or make the teacher's voice louder. In either case, this would have the effect of raising the signal strength.

- Think of rearranging the furniture so no one is more than 15' or 20' from the teacher. When someone is speaking, make sure they don't turn their backs to the students. This cuts the volume in half.

- Consider using a sound field system. This is actually a sound *equalization* system. The teacher wears a lapel microphone and a portable, beltclip transmitter. Her voice is broadcast to wall or ceiling-mounted speakers so everyone can hear her equally well. (NOTE: If excessive reverberation is a problem, you should *not* use this technique as it may make the reverberations *worse*. First, get the reverberations under control. Then consider this type of system.)

- For students with hearing loss, the teacher can use a personal FM system in conjunction with a sound field system or by itself. Wearing a lapel mike and a small, beltclip transmitter, her voice is transmitted to a portable receiver worn by the student and pumped directly into his ear.