Hearing and listening in a typical classroom
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From Language, Speech & Hearing Services in Schools, July 1997

ABSTRACT: In the past, many educational audiologists dedicated the majority of their time to assessing the hearing status of students and providing listening solutions to those students with hearing loss. More recently, educational audiologists are positioning themselves (rightfully) as experts not only in hearing loss, but also in the acoustical environment for all students. In this role, audiologists are being called on to provide solutions for improving the listening environment in average classrooms that are full of students with normal hearing and with mild hearing impairment.

Although Flexer, Wray, and Ireland (1989) and Crandell, Smaldino, and Flexer (1995) have recently provided excellent reviews of classroom listening for the hearing professional, there is a need for a simple description of classroom listening for the educator, administrator, and parent. To assist local educational audiologists and classroom teachers in obtaining technology to enhance the classroom listening environment, the following article has been developed for use with administrators, school board members, and parents. The style is purposefully "chatty," and some terminology is simplified for the target audience.

KEY WORDS: sound field, classrooms, hearing, signal-to-noise ratio, classroom acoustics

Classrooms are auditory-verbal environments with listening serving as the cornerstone of the educational system (Flexer, 1993). When we take a minute to think about it, the majority of learning takes place through speaking and listening in the classroom. Actually, children spend 45% of the school day engaged in listening activities (Berg, 1987). The teacher does most of his or her teaching by talking, students ask questions, and students listen to both the teacher and other students. Multimedia materials also depend on students listening to a message.

It is easy to conclude that in order to do well in school, a child must be able to receive all auditory signals. In the case of students with known hearing loss, we are quick to provide special devices to make the sound audible or to provide special assistance to transform the audible signal into a visual signal. However, we do not usually think about the ability of the average student in the typical classroom to hear the spoken messages. We assume that all the normally hearing students can hear. Unfortunately, we are wrong.

The purpose of this article is twofold:

1. to provide a written document that can be used by educational audiologists to inform policymakers about problems with classroom acoustics, and

2. to provide a potential solution.
It is my hope that you will distribute this article to interested parties and then follow up with a demonstration of soundfield equalization. The most effective demonstration consists of placing the interested parties (e.g., school board members) in a real classroom with soundfield equalization set up. Fill the classroom with enough people to create a realistic noise environment. Then, teach a novel lesson to this group without soundfield equalization and with soundfield equalization and obtain a score in each condition. One effective lesson is to teach vocabulary in a foreign language and then have a spelling or grammar test. This eliminates the use of context and creates the classroom environment that is experienced by students on a daily basis. When the two conditions of the lesson are completed, encourage discussion of the two listening environments.

CLASSROOM ACOUSTICS

There are six issues to think about when determining if every student in a classroom can hear the necessary information: (1) the teacher's delivery, (2) the noise in the room, (3) the reverberation in the room, (4) the distance from the teacher, (5) the hearing ability of the student, and (6) the linguistic experience of the student.

Teacher's Delivery

Teachers need to talk approximately 15 dB louder than the background noise in the classroom (ASHA, 1995). However,

this is rarely achieved throughout the day in a typical classroom (Crandell & Smaldino, 1994).

There is every reason to believe that teachers generally attempt to deliver the spoken signal well. Many, however, are not able to produce a signal that is loud enough to overcome the noise background even when they speak loudly all day long. This may result in teachers with laryngitis, hoarse voices, and sore throats. Teachers who find themselves with extremely hoarse or weak voices often have to take a few days off because they know that their voice is their primary teaching and managing tool in the classroom.

Noise in the Classroom

Classroom noise levels should not exceed 35 dBA (Crandell, 1991: finitzo, 1988).

However,

typical classroom noise levels range from 41 to 51 dBA (Bess, Sinclair, & Riggs, 1984; Crandell & Smaldino, 1994).

The speech delivered in any classroom is accompanied by interference in the form of noise and reverberation. Background noise disturbs speech recognition by covering up part of the message. Crandell and Smaldino (1994) indicated that noise levels have shown
little change over the past several decades. It appears that regardless of what schools have done by way of construction, noise levels have not been reduced enough to ensure effective communication.

Regardless of the absolute noise or speech level in the classroom, it is the signal-to-noise ratio (SNR) that is most relevant to effective communication. The SNR is the relationship between the signal (in this instance, the teacher's spoken words) and noise. Favorable SNRs mean that the signal is louder than the noise. A positive (favorable) SNR makes it easier to hear the signal and therefore listeners expend less energy. For some listeners with mild hearing problems, this improved SNR may make it possible to hear a signal that would otherwise be inaudible.

Reports of SNRs for a variety of classrooms have ranged from +5 dB to -7 dB (Crandell & Smaldino, 1994; Webster & Snell, 1983). For maximum performance, adult listeners require SNRs that exceed +6 dB (Crum, 1974; Houtgast, 1981). Several investigators have reported that young listeners (with normal hearing) require higher SNRs than adults to achieve equivalent recognition scores (Crandell & Bess, 1987; Elliott, 1979, 1982; Nabelek & Robinson, 1982). The American Speech-Language-Hearing Association (ASHA, 1995) recently recommended SNRs of +15 dB in typical classrooms.

Reverberation Classroom reverberation times should not exceed 0.4 s (ASHA, 1995; Finitzo-Hieber & Tillman, 1978).

However, the majority of classrooms have reverberation times between .4 and 1.25 s (Crandell, 1991; Crandell & Smaldino, 1994).

Reverberation is dependent on the physical properties of the classroom and its contents. Reverberation is the persistence of sound within an enclosure that is created by sound waves reflecting off hard surfaces in the room (Nabelek & Pickett, 1974a, 1974b). The reflected energy masks (blurs) the direct sound energy. Reverberation time refers to the time it takes for a signal to decrease 60 dB in intensity. The higher numbers mean greater reverberation (more blurring) and poorer understanding. Once again, young listeners are more affected than adults by increases in reverberation (Crandell & Bess, 1987; Nabelek & Robinson, 1982).

Distance

Children should be within approximately 6 ft of the teacher in order to receive maximum intelligibility (Crandell & Smaldino, 1994).

However, achieving this distance for all children is impossible due to typical class sizes.
Distance from a teacher to a student greatly impacts the effect of noise and reverberation. The interaction of noise and reverberation is less detrimental when the listener is seated in the direct sound field (close to the teacher). Crandell and Smaldino (1994) reported a systematic decrease in speech recognition as the speaker-listener distance increased for a group of children (5-14 years) in an acoustically good classroom. Word recognition scores of 95%, 71%, and 60% were reported at 6, 12, and 24 feet, respectively. Considering these distances, children with normal hearing sitting in the middle or back of the classroom have much greater difficulty receiving and using the speech signal as compared with their front-row counterparts.

The Student's Hearing

Ideally, students would experience consistently normal hearing.

However,

on any given day about 43% of primary level children fail a pure-tone screening at 15 dB and/or an immittance screening (Flexer, Wray, & Ireland, 1989).

Many children suffer from transient episodes of middle ear infections that create a conductive hearing loss during the infection. It would be incredibly costly and impractical to monitor each child's hearing every day of the school year and/or provide special amplification during a time of decreased hearing for children who suffer from multiple middle-ear infections. Therefore, this population (almost half of all elementary school children) may go unserved. A good listening environment creates an audible signal for most of these children during times of mild hearing loss. They are at greatest risk in noisy classrooms, seated far from the speaker. Because this can impact so many children in one classroom, it is not possible to move everybody close enough to the teacher.

Children with unilateral hearing loss (very poor hearing in one ear and good hearing in the other) fail at least one grade at a rate of 36%, and 13% of these students use special resource assistance (Bess, 1986). Unfortunately, many students with unilateral hearing loss are not good candidates for personal amplification because the ear with hearing loss is too poor to amplify. Bess (1986) reported that students with unilateral hearing loss had greater difficulty understanding speech in background noise even in preferential seating arrangements. These students, in particular, need all the sound that is going to the good ear to be audible.

The Student's Experience

Adults can miss parts of a message and fill them in using their life and language experience.

However,
the young student is learning from the messages spoken in the classroom and has limited life experience to use to fill in the blanks.

Children with normal hearing and children with mild or unilateral hearing loss may not hear the entire spoken message when listening in noisy, reverberant rooms. Consider the child who hears "We use -les to make cider. Draw a picture of this fruit." A young student may not have the language and experience background necessary to fill in the missing sounds. Adults know you are meant to have heard the name of a fruit and it is a fruit that is used to make cider. Adults know that the missing word is "apples." However, for a young student, this sentence may be teaching new information, not simply offering instruction. Imagine the challenge a child faces when trying to listen and integrate all the new information presented in the school day when only part of the information may be heard. The task may become overwhelming. For some students, it is so overwhelming that they simply "tune out." Once they have missed part of what is said, it is very difficult to catch up. Someone who has missed what is being said or who has to work extremely hard to follow what is said is much more likely to go off task, become distracted, or become distracting.

But, "most" students seem to do okay. How can this be explained? There are a variety of reasons why a student may perform adequately. Some students are lucky enough to sit close to the signal most of the time, some students don't suffer from repeated episodes of middle ear problems, and some students who do okay could probably have done even better if the listening environment had been adequate. Our schools continue to work on a failure model with intervention coming after failure. A child can perform well below his or her peers without actually failing. Some students may be bright enough to keep up, but may not be performing anywhere near their potential. The presence of poor listening conditions not only increases the effort of learning, but reduces the energy available for performing other cognitive functions (Crum, 1974; Flexer, 1995). For many students, an unnecessary amount of energy is expended to just hear the signal in the classroom. This energy might be better used for thinking about what has been heard, integrating the information, and seeing how the information fits into their lives.

Summary of the Problem

Research has shown that a typical classroom provides an inadequate listening environment. To summarize, even if you believe that you can produce construction that will achieve a noise-appropriate (THE SOUNDFIELD EQUALIZATION SOLUTION

Description

Soundfield equalization is a classroom listening solution that consists of creating an environment where each child is at a favorable speaker-listener distance by routing the teacher's voice to loudspeakers around the classroom. A soundfield equalization system picks up the teacher's voice via a wireless microphone located very close to the teacher's
mouth. At this location, the signal is stronger than any noise in the classroom. The signal is then sent to an amplifier that drives loudspeakers that are positioned around the room (usually three or four of them). The amplifier is set and the loudspeakers are positioned to create a positive SNR (approximately +15 dB) in all listening areas of the classroom. This means that the signal is always louder than the noise. In essence, the system puts every student in the front row (acoustically speaking). These systems are often referred to as "soundfield amplification" systems. In reality, the system is not so much an "amplifying" system as it is an "equalizing" system. The system serves to enhance and maintain a positive SNR throughout the classroom. Because "amplification" often implies exclusive use with individuals with hearing loss, and/or that the signal is somehow louder than "normal," the term "soundfield equalization" offers a more accurate description.

Figure 1 illustrates the general setup of the soundfield equalization system around the room. There are several commercially available systems, which differ regarding certain features (lack of wire between speakers, need for power outlets, individual volume controls, etc.). The educational audiologist and the building engineer will work together to identify and set up the best system for a particular school. Flexer (1995) provided an excellent summary of features and acoustic measurement techniques to consider.

Supporting Evidence

The possible benefits of enhancing the communication environment for any group of children through the use of soundfield equalization may be reduced student fatigue, which ultimately results in improved academic achievement, and reduced teacher fatigue, resulting in more positive, energetic teaching. In some cases, the soundfield equalization system may produce a signal that can be heard versus one that cannot be heard by some students in the room (depending on their hearing status or location).

A variety of investigators have reported positive findings related to the use of soundfield equalization (Allen & Patton, 1990; Crandell & Bess, 1987; Flexer, Millin, & Brown, 1990; Flexer, Richards, & Buie, 1994; Jones, Berg, & Viehweg, 1989; Sarff, 1981; Sarff, Ray, & Bagwell, 1981; Zabel & Tabor, 1993). Authors have studied various academic and pre-academic behaviors for both students with normal hearing and students with mild hearing losses. The various reports have indicated increases in positive behavior and/or achievement with the use of soundfield equalization systems.

In several reports, teachers have been asked to describe the impact on students and have indicated less distractibility, fewer direction repetitions needed, and more attentiveness.

Results from project MARRS (Mainstream Amplification Resource Room Study; Sarff, Ray, & Bagwell, 1981) indicated that students in classrooms with soundfield equalization showed significant improvements in Scholastic Reading Achievement scores. This improvement was greater than or at least equal to that experienced by students receiving resource room instruction. In addition, Zabel and Tabor (1993) found improved spelling test scores with the use of soundfield equalization.
A complete soundfield equalization system for one classroom costs approximately $600 to $1,000 (with rechargeable batteries). Setup of the system may be done by your educational audiologist. Setup and teacher instruction take no more than an hour. These systems are very low maintenance. Our experience since 1993 (13 classes of K-2) indicates that repair costs have been less than $10.00 per classroom per year, with most units requiring no repair.

For some of the children in typical classrooms, the introduction of soundfield equalization may actually save money. Several populations are at risk for learning in noisy environments. These populations include children with transient and/or chronic middle ear problems, children with auditory processing difficulties, children with attention deficit disorder, and children considered to have "learning disabilities." For some of these populations, the signal may be audible without soundfield equalization (so technically they can hear), but the amount of noise may be so distracting that they cannot listen in the typical classroom environment. Students who actually fail in these environments often are provided with special services that cost money. From 1985 to 1990, the Putnam County, Ohio school system phased in 60 soundfield systems to mainstream children with learning disabilities. The number of students placed in learning disabled programs declined nearly 40% (26) in this time period. In 1990, the cost per year of placing a child in special education in Ohio was $2,600. This move to soundfield equalization translated into a savings of approximately $67,600 for the 26 students for 1 school year.

SUMMARY

Classrooms are largely auditory learning environments. In the typical classroom, a number of environmental and student factors interfere with listening. Berg (1993) reported that the use of soundfield equalization systems is the most cost-effective and acceptable technology for facilitating classroom listening. The use of a wireless microphone by the teacher and loudspeakers placed appropriately in the room may result in reduced student fatigue, increased on-task student behavior, improved classroom management, and decreased teacher vocal fatigue. The educational audiologist who works with your school can provide you with more information regarding these systems.

REFERENCES


Received November 21, 1995

Accepted September 20, 1996

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