Sound-Field Amplification:

Preliminary Information Regarding Special Education Referrals

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In this clinical exchange, the authors discuss acoustic accessibility and sound-field amplification in general education classrooms. They bridge theory to practice by presenting preliminary information from two different school systems demonstrating how an improved signal-to-noise ratio can have a positive impact on special education referrals.

General education classrooms are auditory–verbal environments; listening is the primary modality for learning (Berg, 1993; Chermak & Musiek, 1997). Instruction is presented through the speech of the teacher, with the underlying assumption that pupils can hear clearly and attend to spoken communication. To the extent that students cannot consistently and clearly hear the teacher, the entire premise of the educational system is undermined. Ironically, the acoustic environment rarely is considered when designing a school (Boothroyd, 2002; Crandell, Smaldino, & Flexer, 1995).

Our purposes in this clinical exchange are threefold. First, we discuss acoustic accessibility. Second, we describe sound-field amplification systems. Finally, we present information from two different school systems where a reduction in special education referrals occurred in buildings that have sound-field amplification systems in their general education classrooms (kindergarten through fifth grade). These two school systems offer examples of how sound-field technology can be beneficial.

ACOUSTIC ACCESSIBILITY IN THE CLASSROOM

In order to learn, children require a quieter environment and a louder signal than do adults. The quieter the room and the more distinctive the auditory signal, the better opportunity the child will have to process the signal and accomplish the desired cognitive integration (Anderson, 2001; Leavitt & Flexer, 1991). Sadly, most classrooms are "acoustically hostile" (Boothroyd, 2002; Crandell & Smaldino, 1996).

Children require a more favorable acoustic environment than adults for two main reasons:

1. Children cannot listen like adults because the auditory neurological network is not fully developed until about 15 years of age (Berlin & Weyand, 2003; Boothroyd, 1997; Musiek & Berge, 1998).
2. Children do not bring 30-plus years of listening and life experience to a learning situation; hence, they cannot perform the automatic "auditory-cognitive closure" of missed information (Flexer, 1999). To fill in the blanks of missed information, that information already has to be in the brain's "data banks" for retrieval. Children thus need a sharper auditory signal than that required by adults (Anderson,

> 2001). A classroom that sounds acceptable to an adult could be woefully inadequate for typical children who (a) have not reached their full neurological capacity and (b) have not had decades of language and life experience.

Because hearing is a first-order event in a general education classroom, if children do not hear clearly and consistently, their academic potential is compromised.

The main difficulty with trying to learn in a poor acoustic environment is that the child cannot distinguish specific speech sounds. Consequently, speech might be very *audible* but not consistently *intelligible,* causing children to hear, for example, words such as *walked, walking, walker* all as "_-*ah.*" (Leavitt & Flexer, 1991; Ling, 2002; Robertson, 2000).

A great deal is involved in "hearing" the teacher. Erber (1982) was one of the first to identify the levels of auditory skill development associated with hearing and listening, and Ling (2002) expanded on levels:

- *Detection:* This is the lowest, least sophisticated level of auditory skill development. Detection refers to the presence and absence of sound. Obtaining pure tone thresholds is a detection task.
- *Discrimination:* This involves distinguishing between two speech sounds. An example of a discrimination task would be noting if "da" and "tha" are the same or different.
- *Recognition:* This closed-set task involves selecting a target from a known list of alternatives.
- *Identification:* This is an open-set task that involves distinguishing a target from an infinite set of alternatives.
- *Comprehension:* This is the highest level of auditory skill development. Comprehension is achieved when a person can answer questions, follow directions, and hold conversations.

Without basic *detection,* none of the higher levels of auditory processing are available. *Comprehension,* the goal of classroom instruction, therefore is completely dependent on the initial detection of individual phonemes that make up the spoken message. Challenging acoustic environments, hearing problems, and the immature listening skills of children all compromise detection. Sound-field systems facilitate detection of spoken instruction.

When working on facilitating detection and creating acoustic accessibility, the SLP or teacher needs to consider three basic factors: ambient (surrounding/background) noise level, reverberation, and speech-to-noise ratio (Berg, 1993; Boothroyd, 2002). *Ambient noises* may originate from sources inside or outside the classroom, or even outside the building, especially if doors and windows are open.

Reverberation refers to the echo caused by sound being reflected off of smooth surfaces such as walls, ceilings, tables, windows, and chalkboards. Large rooms with high ceilings, bare walls, and bare floors tend to be highly reverberant environments. The longer the reverberation time, the more difficult it is for children to hear clearly because the signal is "smeared" (Boothroyd, 2002).

The *speech-to-noise ratio* (S/N ratio) is the relationship between the desired auditory signal, typically the teacher's speech, and all unwanted background sounds. The more favorable the S/N ratio, the clearer will be the speech signal received by pupils in the classroom.

In 2002, the American National Standards Institute recommended the following acoustic guidelines for classrooms:

1. ambient noise level in an unoccupied classroom should not be louder than 35 dBA;
2. reverberation time should not exceed 0.6 to 0.7 s, depending on the size of the room; and
3. although not specified, it was implied that the S/N ratio should be no poorer than +15 dB.

Creating the quietest learning environments possible is critical. This can be accomplished in a variety of ways:

- using acoustical ceiling tile across the entire ceiling;
- having solid, not moveable, walls;
- carpeting floors or using some form of rubber tip or tennis balls on the legs of desks and chairs;
- keeping fluorescent lighting systems and ventilating systems in good repair;
- installing well-fitting doors and windows and keeping them closed;
- keeping children and instruction away from noise sources;
- maintaining a small class size;
- ensuring that only one activity occurs at a time, with no acoustic "spillage" from other activities;
- having one acoustic focus in a room; and
- avoiding all open-plan classrooms.

The larger the room, the more children in a room, and the more simultaneous activities in a room, the noisier the environment will be. In a noisy environment, acoustic access to new and distinctive words and concepts is diminished, which can detract from comprehension and overall learning (Leavitt & Flexer, 1991).

SPEECH REINFORCEMENT SYSTEMS

Sound-field technology is an educational tool that can help manage the listening environment in the classroom, thereby facilitating acoustic accessibility of teacher instruction for all children in the room (Flexer, 1998, 1999). Sound-field systems are similar to small, high-fidelity, wireless public address systems that are self-contained in a classroom (Crandell et al., 1995; see Figure 1). The teacher wears a small, wireless microphone so teacher mobility is not restricted. The teacher's speech is sent via radio (FM) or light waves (infrared) to a receiver/amplifier and then to loudspeakers that are mounted on the walls or in the ceiling (Flexer, 1999).

The purpose of this technology is to evenly distribute the teacher's voice throughout the classroom, thereby providing a clear and consistent signal to all students in the room, no matter where they or the teacher are located (Boothroyd, 2002; Flexer, 1999). The positioning of the remote microphone close to the mouth of the teacher or other desired sound source creates a favorable S/N ratio and produces a nearly uniform speech level throughout the room. Every child hears as if seated in a front-row center seat (Rosenberg et al., 1999).

It could be argued that virtually all children could benefit from sound-field systems because the improved S/N ratio creates a more favorable learning environment. If children could hear better, more clearly, and more consistently, they would have an opportunity to learn more efficiently (Rosenberg et al., 1999). However, the populations that seem to be especially in need of S/N ratio–enhancing technology include children with the following conditions:

- fluctuating conductive hearing impairments,
- unilateral hearing impairments,
- "minimal" permanent hearing impairments,
- auditory processing problems,
- cochlear implants,
- cognitive disorders,
- learning disabilities,
- attention problems,
- articulation disorders, and
- behavior problems (Crandell et al., 1995; Rosenberg et al., 1999).

Some school districts, such as Oakland County, Michigan, have hundreds of general education classrooms that are amplified (Knittel, Myott, & McClain, 2002). Some districts have dozens, some just a few, and some districts have not yet heard of this technology. As illustrated in the following examples, there appears to be a strong relationship between hearing and learning.

IMPACT ON SPECIAL EDUCATION REFERRALS

The following examples focus on bridging theory and practice by showing how sound-field technology functions in two different school districts.

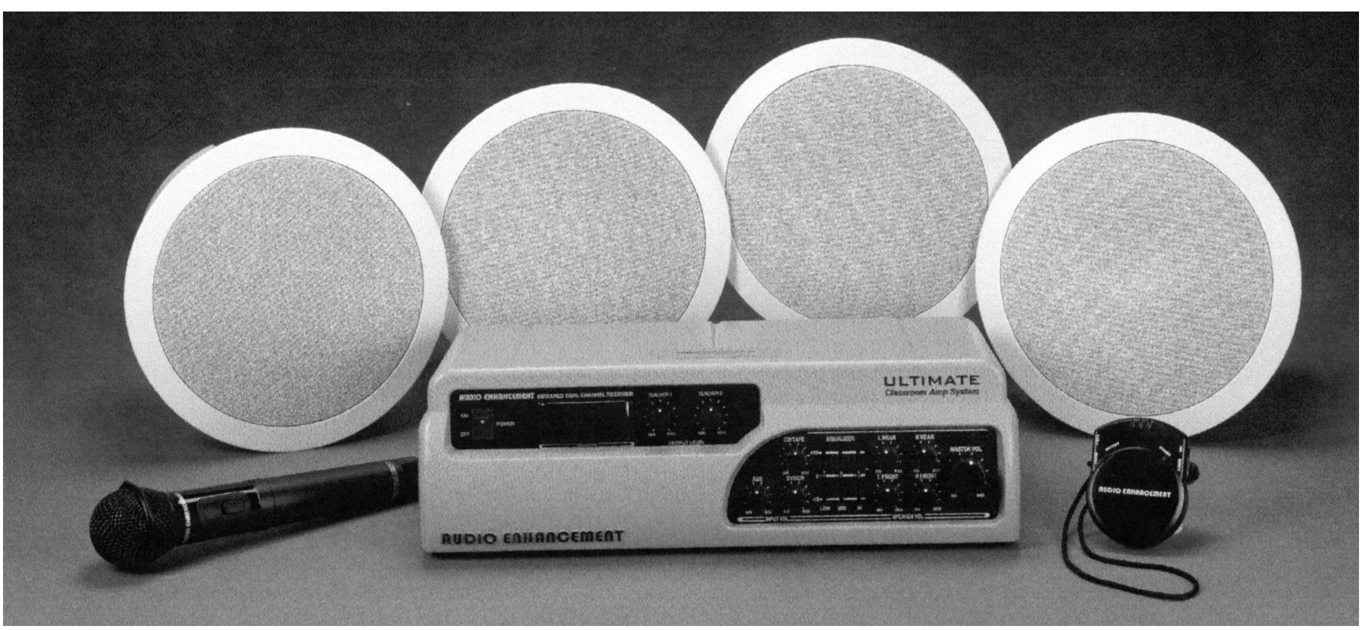

FIGURE 1. Photograph of an infrared sound-field amplification system; the teacher wears a wireless microphone transmitter, and the speech is sent via light waves to an amplifier and loudspeakers. The four circular loudspeakers are designed to be mounted, in a distributed fashion, in a drop ceiling. The handheld microphone is a pass-around microphone for the pupils to use (to facilitate auditory self-monitoring of their own speech as well as to enable the talker to be heard by all students in the room). The small, black, circular infrared transmitter is worn by the teacher. (Photo courtesy of Audio Enhancement)

Example 1: Oconto Falls, Wisconsin

The Oconto Falls School District purchased sound-field systems for all of its general elementary school classrooms and had the units installed in the fall of the 1998–1999 school year. The number of classrooms broke down as follows: Oconto Falls Elementary, 23 rooms; Abrums Elementary, 12 rooms; and Spruce Elementary, 2 rooms. Spruce is an old-fashioned, two-room schoolhouse, with four grades. The other classrooms are standard elementary classrooms with one grade and one teacher per classroom. At the beginning of the 1999 school year, the library and the art, music, and special education classrooms for students with learning disabilities and behavior problems also were amplified. No significant changes in curriculum, teachers, or class size occurred after implementation of the sound-field amplification system.

To help ensure effective implementation of the sound-field systems, all teachers were given an in-service session led by the educational audiologist and by the manufacturer's representative. The teachers learned about the rationale for the technology and practiced using their voices with the microphone.

Teachers must be given instruction regarding the system, its meaning, and its use prior to implementation. Improper use affects its effectiveness. In addition, someone must be available in the school to help troubleshoot equipment problems if any malfunction occurs.

Interviews with the teachers about the sound-field system's effectiveness revealed that students were having an easier time hearing the differences among words. For example, a first-grade teacher described how precisely students could distinguish the differences between the vowels in the words *will* and *well* when the system was used. Some teachers reported experiencing a significant decrease in vocal strain, less stress, and an easier time obtaining and keeping students' attention. Certainly, learning is enhanced when the child has clear and consistent access to the details of the teacher's spoken instruction.

Towards the end of the 1998–1999 school year, after 8 months of sound-field system use in all of the general education elementary school classrooms, the special education director reported a decrease in the referral caseload. This observation was confirmed when the referral rates were tabulated and compared to those from previous years.

As depicted in Figure 2, decreases in special education referrals were observed in both the 1998–1999 and 1999–2000 school years when compared to the previous 9 years. The average rate of referral for special education in the years from 1989 to 1998 was 7.72% of the total school enrollment. In

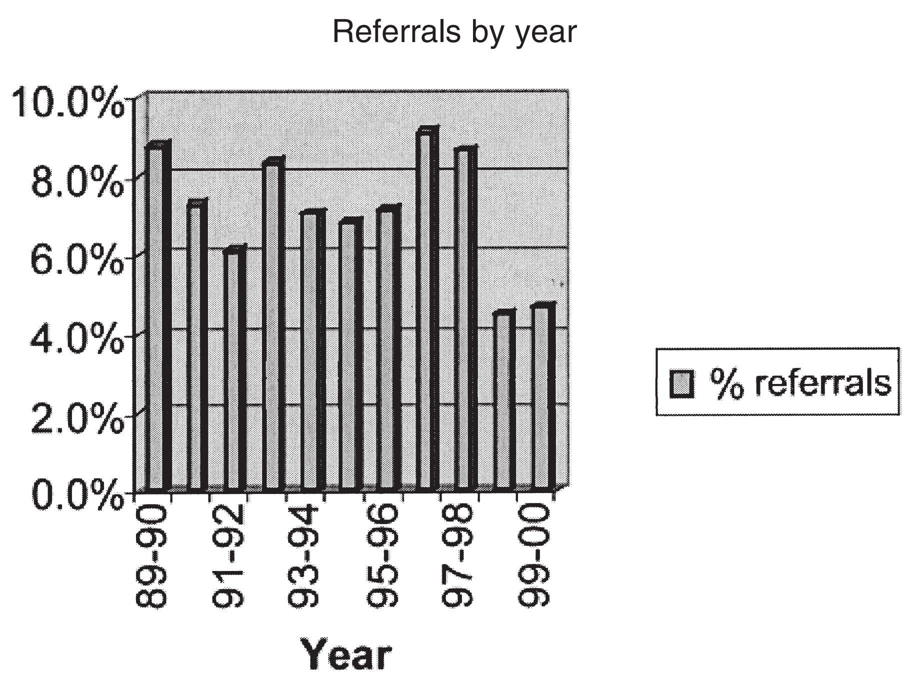

FIGURE 2. Following amplification of all kindergarten through fifth-grade classrooms at the beginning of the 1998–1999 school year in the Oconto Falls, Wisconsin, School District, significant decreases in special education referrals were noted in both the 1998–1999 and 1999–2000 school years (average of 4.6% of the student population) when compared to the 9 previous school years (average of 7.72% of the student population).

1998–2000, this rate dropped to 4.6%. Although it is alluring to attribute the observed deceases in referrals to the introduction of the sound-field system, these figures must be interpreted with caution because the numbers encompassed students referred into special education across all categories, including occupational therapy, physical therapy, vision services, and deaf/hard-of-hearing services. It is not possible to derive causal conclusions from observational data of this nature. The observed decrease in referrals is clinically relevant, however, and is the type of trend analysis that is used in making inferences about educational practices. As a result of these data, Oconto Falls has amplified all of its middle school classrooms and is in the process of amplifying new elementary classrooms that have been added to existing buildings.

Example 2: Northville, Michigan

A similar reduction in special education referrals was reported in the Northville Public Schools after the district instituted widespread use of sound-field amplification systems. In one K through fifth-grade building, all 22 classrooms were amplified. The students in that school came from a mixed socioeconomic environment. Prior to the introduction of sound-field amplification, the average pupil count was 250, with approximately 34 children placed in special education classrooms. After 5 years of sound-field use, in combination with other prevention activities—early reading training, motor development training, and visual memory training—the number of children placed in special education classes dropped to 6, even though the pupil count had increased to 500 (Sorenson, 2001). If the number of children in special education classrooms had kept pace with the doubling of the overall pupil count, as was the situation in the 5 years prior to sound-field implementation, the district would have expected to have placed more than 60 children. A cost-analysis indicated that Northville Schools would save about $3 million over the school life of this cohort of students. The value of improving learning for those children is substantial.

Again these figures must be interpreted with caution because prevention activities other than the sound-field system were also incorporated, and the impact of each individual activity was not identified. Furthermore, educational trends, such as mainstreaming, that were independent of the prevention activities would have probably resulted in more children with special education needs being placed in general education classrooms. The clinical relevance is that the creation of an acoustically accessible learning environment facilitated the inclusion of children with various learning challenges into general education classrooms and appeared to play a role in the decreasing need for special education services.

THE CONCEPT OF UNIVERSAL DESIGN

One of the stumbling blocks to having sound-field systems in general education classrooms is the perception that this technology is a "treatment" for hearing loss. Indeed, most amplification technologies, such as hearing aids and personal FM units, have been employed as treatments. Speech reinforcement systems, however, may be viewed as an acoustic accessibility issue that affects all children, much like lights in the classroom allow visual accessibility for all children. In terms of learning, the assistive technology is considered part of a universal design: It not specially designed for an individual student but rather for a wide range of students. In addition, universal design approaches are implemented by general education teachers rather than special education teachers ("Universal Design," 1999).

SUMMARY

The purpose of this clinical exchange has been to provide two examples of how to apply the theoretical tenet of acoustic accessibility to the practice of using sound-field technology in general education classrooms. Because children do not have the neurological maturity and decades of lifetime learning experience that adults have, they require a quieter environment and a louder signal in order to support their learning. Managing the auditory learning environment for children thus can have positive results.

In the two examples presented in this article, we found trends in terms of a reduction in referrals for special education from primary-level classrooms where the teacher's speech was amplified and evenly distributed around the room. This initial inquiry suggests that placing sound-field systems in general education classrooms using a universal design paradigm has merit.

More controlled studies clearly are needed. For example, the types of referrals for special education were not analyzed in this investigation, nor were the data regarding the number of children and specific categories of disabling conditions; this could be a focus of future research. In addition, the specific investigation of the use of sound-field amplification in inclusive classrooms should be studied. Finally, although these two examples present a compelling trend that is clinically relevant, it is not possible to derive causal conclusions from observational data of this nature.

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