Classroom Acoustics: A First Step Toward Education for All

In honor of Mike Nixon

By Karen Anderson, PhD, Audiologist

ASA Convention, Miami, November 14, 2008

Education is primarily provided through the medium of verbal instruction. With ever greater emphasis on test scores and teacher accountability it is important to recognize the effects of excessive background noise and reverberation on student learning. Michael Nixon was a leader in the movement to raise awareness of classroom acoustic effects and to achieve national written standards. He crossed professional lines to become an active member of the Educational Audiology Association, providing information and advice to the almost 1000 audiologists who work for US school districts. Mike was instrumental in not only raising awareness, but raised the bar for what educational audiologists should know about classroom acoustics. This paper will provide information on the listening challenges of learners with hearing loss (the most common birth defect), most of whom are educated in typically noisy classrooms. Acousticians are invited to learn more about the synergistic effects of excessive noise and reverberation on speech perception of this growing number of children, and what the hearing industry is doing to address these issues. Together, the voices of the acoustics and hearing industries are needed to champion the case for listening, learning, and a better future - footsteps left by Mike Nixon.

Slide 1:
Dr. Karen Anderson knew Mike Nixon and was pleased to submit this paper in his honor. Mike Nixon was a leader in the movement to raise awareness of classroom acoustic effects and to achieve national written standards. He crossed professional lines to become an active member of the Educational Audiology Association, providing information and advice to the almost 1000 audiologists who work for US school districts. Mike was instrumental not only in raising awareness, but he raised the bar for what educational audiologists should know about classroom acoustics. As a member of the Educational Audiology Association, Karen and Mike had conversations over the years about the need to bring the issue of classroom acoustics to the attention of educators and legislators to promote change, so that all children, including those with hearing loss, could achieve to a higher level of success.

Slide 2:
This paper will provide information on the listening challenges of learners with hearing loss, most of whom are educated in typically noisy classrooms. Acousticians are invited to learn more about the synergistic effects of excessive noise and reverberation on speech perception of this growing number of children, and what the hearing industry is doing to address these issues. But it is not possible to address all of the issues through technological advances. Together, the voices of the acoustics and hearing industries are needed to champion the case for listening, learning, and a better future - footsteps left by Mike Nixon.

Slide 3:
Education is primarily provided through the medium of verbal instruction. With ever greater emphasis on test scores and teacher accountability it is important to recognize the effects of excessive background noise and reverberation on student learning. Almost all Americans were educated in a classroom environment. We hold the common history of sitting in rows of desks with a teacher in the front of the classroom, a chalk board, and the rustle of energetic young learners and the whir of the ventilation system. Because of this shared experience most educators and the lay public have a mindset about the presence of noise in the school

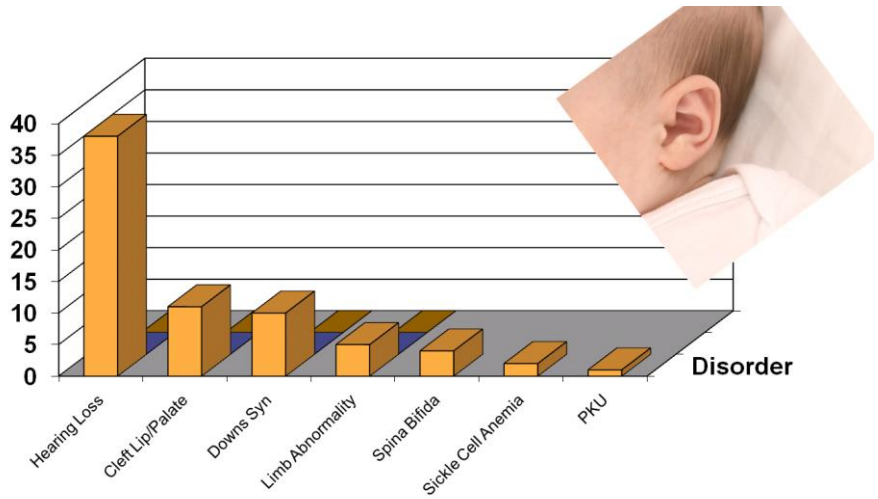
environment and how good, bad, important, or unimportant it really is. The value of personal experience in shaping beliefs is very strong. What this paper hopes to do is to open your eyes to a group of children that are often invisible, or their needs and abilities misunderstood. They are in every classroom of every school in America. Their personal experience is all too often fraught with confusion from only partially heard communications, and lack of success, from not experiencing equal access to verbal instruction.

Slide 4:
To set the stage it is important to recognize what populations research has indicated are experience greater speech perception difficulties in degraded listening environments. Many of these groups have normal hearing sensitivity. It is likely that other speakers will talk about these children and the link between better achievement and adequate classroom acoustics. In this paper we will hone in on the children with hearing loss.

Populations at greatest risk for effects from poor classroom acoustics

- Young (< 13-15 years old)
- Any amount of hearing loss
- Articulation disorders
- Language disorders
- Non-native language speakers
- Auditory processing disorders
- Minimal and unilateral hearing losses

Slide 5:
In 1998 Federal legislation was passed that funded state grants and federal research to support infant hearing initiatives because of two reasons: hearing loss is the most common birth defect and, if identified early and if families are provided appropriate intervention, the speech and language delays that accompany growing up with hearing loss can be prevented. Prevented. Throughout the United States there are increasing numbers of deaf and hard of hearing children who are starting school without substantial speech or language issues. This is one Federal program that through a decade of funding has made huge differences and improvements in every state. But the problem remains that children with hearing loss still have hearing issues when listening across distance and in the presence of excessive noise and reverberation. So children with hearing loss who are early identified can achieve a normal learning status but their struggles begin the minute they enter a typically noisy educational setting.



Slide 6: “Invisible” children with hearing loss – chronic ear problems

First will be presented information about children with hearing issues that are generally unidentified and their hearing problems are mostly unaddressed in a school setting.

Ear infection is the most diagnosed condition in children. Almost all children under the age of 3 have ear problems. This means that there is a buildup of fluid or infection behind one or both eardrums. The recommended treatment for ear problems by physicians is 'wait and see' if it gets worse. At any one time, 20% of 4-6 year olds can have a hearing loss in one or both ears due to ear problems. The degree of hearing loss can vary depending on the extent of the condition. Even if treated with antibiotics, 10% of children will continue to have fluid behind their eardrums and associated hearing loss 3 months after completing the medication. Children who have a history of chronic, recurrent ear infection tend to have greater degrees of hearing loss as this condition continues. Although 85% of children outgrow these problems by about age 5-8, 15% of the school population continues to experience fluctuating hearing that is typically unidentified. The bottom line – children with hearing loss due to ear problems are in every elementary classroom, are having problems learning to read, are not understanding directions completely, and are struggling. Excessive reverberation and classroom noise only exacerbate these difficulties.

Slide 7: "Invisible" children with hearing loss – loss due to noise

Another 'invisible' hearing loss is due to exposure to noise. For at least the last decade the Navy has had difficulty recruiting individuals who could perform sonor and other communications work because of the large number of young people with hearing loss due to over exposure to noise. Once thought to be mainly the 'farm kids' who were exposed to tractor noise or those who hunted frequently, the number of children with high frequency hearing loss due to noise is skyrocketing because of widespread use of ipods. Research done at Wichita indicated that typical loudness settings are 110-120 dB SPL. Permanent damage can occur after only 1 ¼ hours of listening to music at this loudness. Longer battery life, lighter and less obtrusive technology encourages use of these devices for longer periods of time than the Walkman headphones that were so popular, and also a concern, in the 1980s. A lawsuit was filed against Apple in 2006. At that time more than 42 million of the devices had been sold. The research you see on the slide is old by health statistics standards and even this is alarming. Where hearing loss due to chronic recurrent ear problems is a concern in the elementary years, hearing loss due to over exposure to noise is a concern in the middle and high school years.

- 5.2 million 6-19 year olds have hearing loss directly related to noise exposure. *(3rd National Health and Nutrition Examination Survey, Niskar et al. 2000)*
- "... over the last 10 years, the percentage of 2nd graders with hearing loss has increased 2.8 times; hearing loss in 8th graders has increased over 4 times." *(Montgomery and Fujukawa 1992)*

Slide 8: a children's story with hearing loss

What you see on this slide is a simple, well known children's story that has been altered as though you are listening with a 25 dB hearing loss. This amount of hearing loss is too often considered to be borderline normal and will not be addressed through hearing aids. It is a rough estimate of loss caused by fluid behind the eardrums and can be compared to listening with your fingers in your ears. Noise induced hearing loss occurs at the high frequencies of 4000 – 8000 Hz. Even a 25 dB hearing loss at 4000 Hz will cause difficulty discriminating between words like cat, cap, calf, cast.

Picture yourself as a young child who had not heard this story and did not have the advantage of a rich language base. Words run together and the very quiet consonant sounds that are so important to word intelligibility are often missed.

What is this story? (answer is at end of this paper) Think of the extra effort that it took for you to figure out what was said as this story was presented to you. Children who expend undue energy listening, have fewer mental faculties available for actual comprehension and storage into memory.

Identify a children's story: 25 dB loss

Won upon a time a itty mow when to vit a untry mow.
The untry mow live in a feel.
EEE wuz lad to shee hi zittyfren.
A too my ran abowda feel and lay unt noo.

Slide 9: minimal hearing loss and S/N

This graph brings us back to the topic at hand, the effects of even minimal hearing loss when a listener is exposed to different signal to noise ratios. As you can see, children with normal hearing can recognize sentence materials at 95% or greater even at 0 S/N. The children with minimal hearing loss, had 15-25 dB hearing loss from 500 – 2000 Hz. Even at +6 S/N these children were at a disadvantage. With so much of class instruction occurring between 0 S/N and + 6 S/N it is no wonder that these children will have difficulty attaining at the same rate, to the same level as their peers with normal hearing.

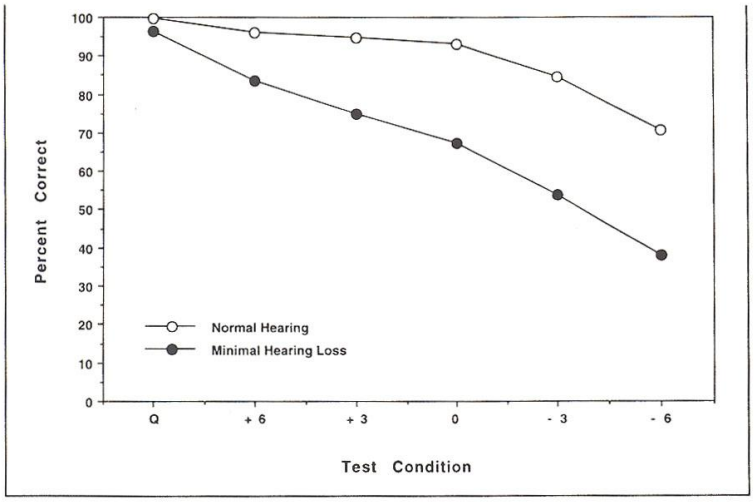


Figure 4–2. Mean sentential recognition scores, in percent correct, as a function of signal-to-noise ratio for children with normal hearing sensitivity (indicated by the open circles) and minimally hearing-impaired children (indicated by the closed circles). Figure adapted from Crandell, C. (1993). Speech recognition in noise by children with minimal hearing loss. *Ear & Hearing, 14*(3), 210–216.

Slide 10: missing pieces

Just think of the challenge of having to continually be held to understanding the full picture, when you are always missing a substantial number of the pieces. And unlike a picture, speech stimuli is constantly changing as is the vocal loudness of the teacher and background noise in the classroom.

Slide 11: minimal hearing loss and reverberation

This graph provides information about the performance of children with normal hearing and with minimal hearing loss in quiet and when listening at a 0.8 second reverberation time. Many classrooms have RT that exceeds 0.8s.

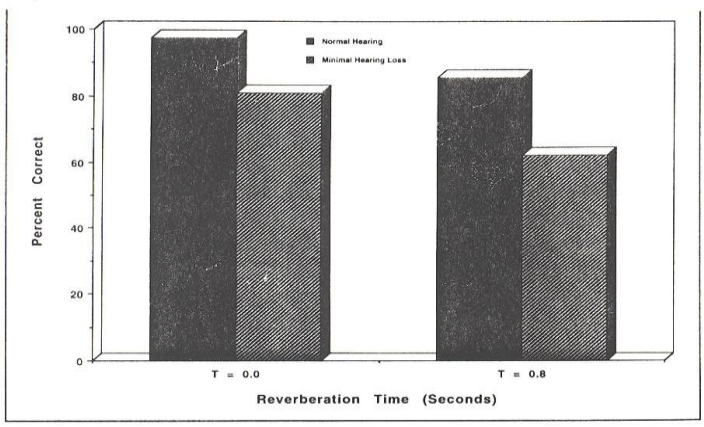
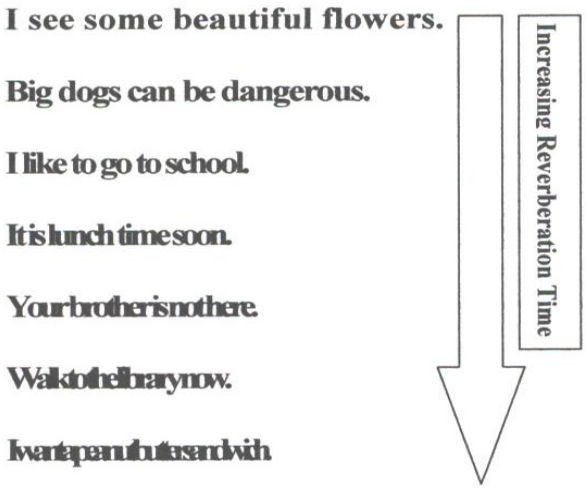


Figure 4–1. Speech perception of children with minimal degrees of sensorineural hearing loss (pure-tone thresholds from 15 to 30 dB from 500 to 2000 Hz) in a non-reverberant (T = 0.0 second) and reverberant (T = 0.8 second) listening condition. Adapted from Boney, S., & Bess, F. (1984). *Noise and reverberation effects in minimal bilateral sensorineural hearing loss.* Paper presented at The American Speech, Language, and Hearing Association Convention, San Francisco, CA.

Slide 12: Visual analogy of listening in reverberant conditions

This is a simplified visual analogy of listening when reverberation is smearing the speech recognition characteristics. With effort each of these sentences can be read. Again, the greater the effort that is put into receiving the message, the greater the restriction on the faculties available to process the message. One can clearly imagine the synergistic effects of both excessive S/N and reverberation time on the listening abilities of these 'invisible children.'

Visual analogy of speech sounds smearing together as RT increases



Slide 13: Children who are deaf or hard of hearing

For every 1000 children born, there will be approximately 3 children who have permanent hearing loss. This number increases by 20-25% by the time of school entry meaning that hearing screening of newborns does not inoculate them to progressive or acquired hearing loss due to genetic, disease or other conditions. For every child born without hearing there will be 6-7 who are hard of hearing, with mild to severe degrees of hearing loss. The number of deaf children who learn via sign language is diminishing because of the successes of cochlear implantation in one or both ears. This means that the large majority of children with permanent hearing loss are depending upon their ears as a primary avenue for learning.

Slide 14: S/N + RT for children with hearing loss

This table depicts the word recognition abilities for children with moderate degree of hearing loss wearing amplification. Even though this information is now 30 years old and amplification devices and the advantages of early identification on language have improved, there is still a pattern of difficulty as compared to children with normal hearing. In what would be considered a low classroom RT of 0.4s the children with hearing loss scored about 20% lower than those with normal hearing, regardless of the S/N. In the setting where S/N was only zero, the children with hearing loss scored over 25% lower than their peers with normal hearing.

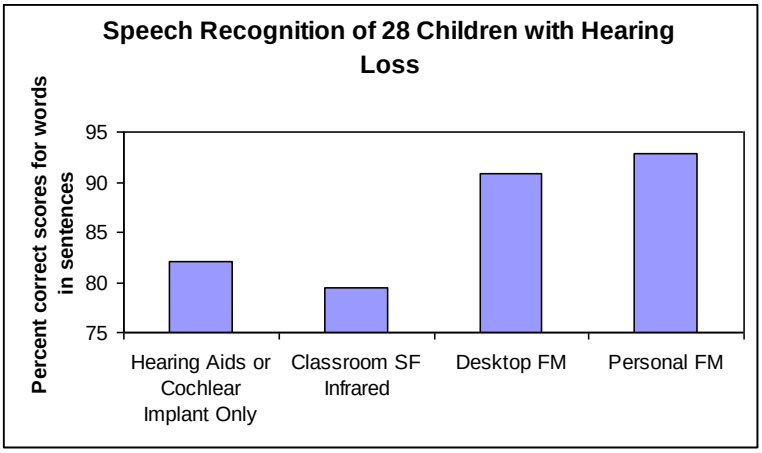
Test Condition	Normal Hearing	Hearing Impaired
RT = 0.0 Second		
Quiet	94.5	83.0
+12 dB	89.2	70.0
+6 dB	79.7	59.5
0 dB	60.2	39.0
RT = 0.4 Second		
Quiet	92.5	74.0
+12 dB	82.8	60.2
+6 dB	71.3	52.2
0 dB	47.7	27.8
RT = 1.2 Second		
Quiet	76.5	45.0
+12 dB	68.8	41.2
+6 dB	54.2	27.0
0 dB	29.7	11.2

Slide 15: RT for children with hearing loss
This table depicts word recognition under three RT conditions for children with and without hearing loss. The children with hearing loss were tested with and without their hearing aids. Again, this is 30 year old data but what I'd like to focus on is the lowest row of data. Although amplification was beneficial in quiet and low level RT, when the RT was high the children with hearing aids actually scored lower than when they were not amplified. This is a clear example of the classroom acoustic environment preventing access to verbal instruction

	GROUPS		
Reverberation Time (Seconds)	Normal	Hearing Impaired	Hearing Impaired (Aided)
0.0	94.5	87.5	83.0
0.4	82.8	69.0	74.0
1.2	76.5	61.8	45.0

Slide 16: Technology to address classroom listening needs
Whether you are young or old, the biggest complaint of persons with hearing loss is the difficulty of listening in background noise and reverberation. Various technologies are used to try to improve classroom listening, most notably personal FM systems that fit directly to personal hearing aids or implants, a personal FM that sits on the desktop, and sound field enhancement systems that place one or more loud speakers throughout the classroom. A study was conducted of 28 children; 22 of whom had high quality modern hearing aids and 6 had a cochlear implant. The children, age 8-14 were good language users and truly 'cream of the crop' participants that were chosen to minimize the influence of language skills on performance. The study was performed in actual classroom settings.

Slide 17: Summary slide
This summary chart says it all. Children listening with their personal devices scored no better, and many actually scored worse, when a sound field sound enhancement system was used. When the teacher's voice was delivered to the child within the critical listening distance via a desktop or personal FM system true benefit was observed. In a nutshell, sound field classroom amplification cannot be assumed to be of any benefit to the child with hearing loss using amplification devices and may indeed be detrimental.



Slide 18: Other technology

It is necessary for learners to access not only what the teacher says but also what is said by their peers – during class discussions, small group project work and for social exchanges. These too are part of learning. A personal FM system in which the primary signal is from the teacher does not address a child's total listening requirements. Even if FM technology provides substantial assistance to accessing verbal instruction it does nothing to help these other important activities that are all too vulnerable to poor classroom acoustic affects. Hearing aid manufacturers and cochlear implant companies are investing much into research and design of instruments that will provide more benefit. Specifically, directional microphones that allow a listener to focus in on the signal directly in front of them will be advantageous to a student who actually will take advantage of this point and listen approach. The very rapid speech of signal processing now has led to preliminary work on adjusting for signal smearing due to excessive reverberation time. There has also been renewal of research that has resulted in a new generation of devices that will shift acoustic information from the high frequency range into the range that an individual listener can hear. So as technology improves, some additional benefit to speech perception will result – at least for the children who have families that can afford this more expensive technology. Lastly, sound field technology, although it is largely ineffectual for the child with amplification, has indeed been shown to provide some benefit to children with minimal, fluctuating, and unilateral hearing loss at least in classrooms with appropriate reverberation characteristics.

Slide 19: Conclusion: Investing in Listening + Investing in Learning

As good as technology is, it does not remove the detriment caused to education by excessive reverberation and background noise. Every day children with hearing loss are required to learn in challenging acoustic environments that even the best technology cannot address. With all of the money now spent to develop 'smart classrooms' full of technology there remains little awareness or emphasis on the basic acoustic requirements of the learning environment. Acousticians, audiologists, parents, and educators working together can change this – and improve the learning and the futures of children with hearing loss. Classroom acoustics truly is a first step toward education for ALL children.

Thank you for listening

And thanks to Mike Nixon for his advocacy, leadership, and passion for an adequate learning environment America's children, and a better future for us all.

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Special session: "Classroom acoustics honoring Michael Nixon"

Jointly sponsored by TCAA, TCN and TC Speech.
Technical Areas: Architectural acoustics, Noise and Speech

Children's story on slide 8: The City Mouse and the Country Mouse.