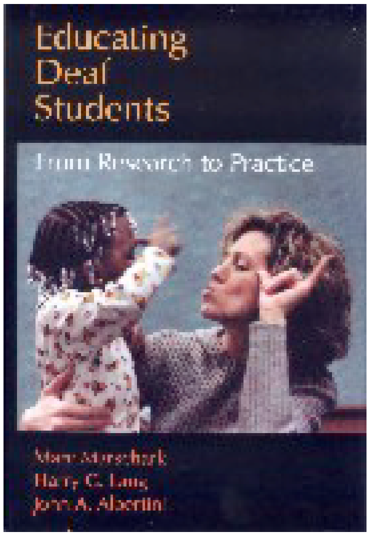

Marschark, Marc
Lang, Harry G.
Albertini, John A.

Educating Deaf Students: From Research to Practice, New York: Oxford University Press, 2002.

Chapter 3: Hearing and Hearing Aids

To help understand how hearing aids work, first consider how hearing works. Sounds are normally heard when some force (including air being forced across the human vocal cords) sets up vibrations in a medium like air or water, which conducts the vibrations to a receiver that decodes the acoustic vibrations into an auditory event. The magnitude of the vibrations ("sound waves"] determines the perceived loudness of the sound (in decibels). For example, the loudness of normal speech, without background noise, is about 60-65 dB. A live rock band begins at about 85-90 dB and may be as loud as 115 dB, about 10 percent louder than a jackhammer.

Loudness is not the only factor affecting whether we can hear speech, because the human ear (really the brain) can only perceive certain frequencies, corresponding to the number of sound waves reaching the ear per second. Normal hearing for humans is in the range of 20-20,000 Hz. Dogs can hear sounds greater than 30,000 Hz, so that "silent" dog whistles are simply designed to produce high-pitched (i.e., high-frequency) sounds between 20,000 and 30,000 Hz. When it comes to human speech, losses that affect hearing in the range of 500-2000 Hz are most troublesome, because, as we have noted, those are the frequencies at which the important features of spoken language are expressed. Vowels tend to fall in the lower frequency range: fricative consonants like /th/, /s/, and /f/ are in the higher frequency range. Vowels also tend to be louder than consonants, but they are not as important for distinguishing one word from another.

To give some idea of how hearing is visualized, we have provided copies of the audiograms for the three authors, one of whom has very acute hearing, one of whom has a mild hearing loss in one ear, and one of whom is profoundly deaf (fig. 3.1). Although the audiograms do not provide complete information concerning the qualitative or quantitative aspects of hearing/hearing loss, they are sufficient in this case to distinguish among the three of us and to suggest in which cases some kind of accommodation might be necessary. The situation is not necessarily obvious, however, and none of us wears hearing aids.

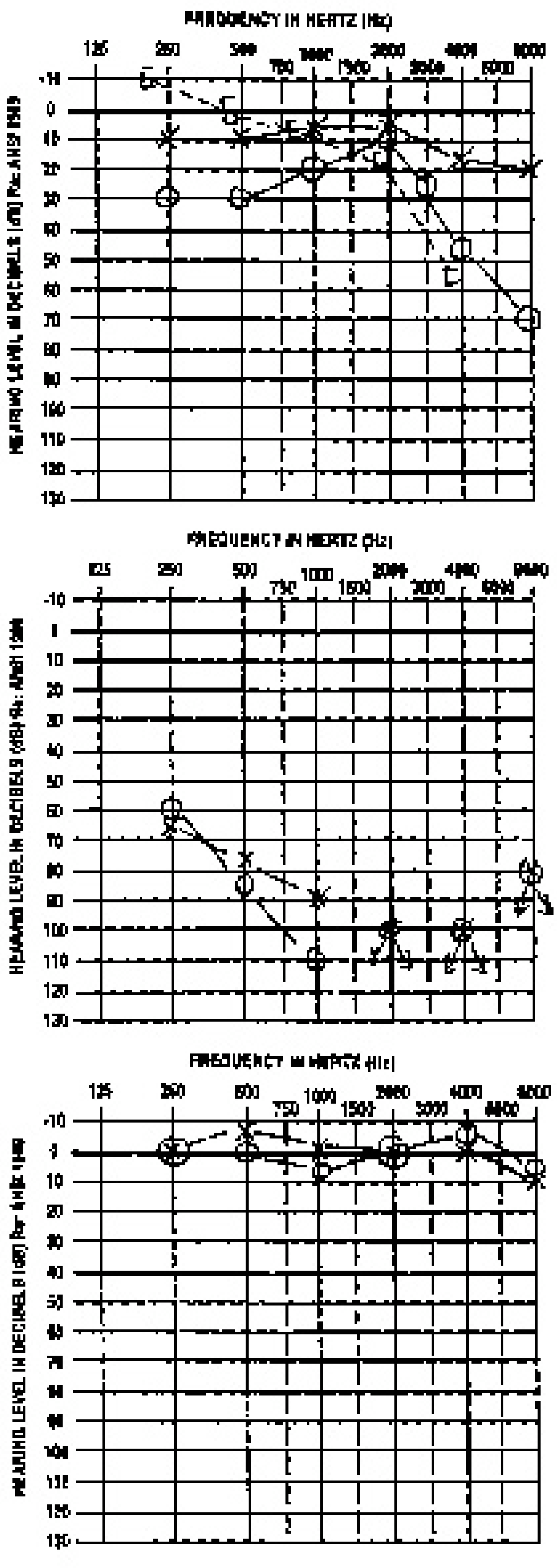

Figure 3.1. Audiograms of the three authors.

When sounds reach the outer ear, the vibrations in the air are funneled into the ear canal to the eardrum, which vibrates in response to the changing pressure. These vibrations correspond to the frequency or pitch of the sound and cause small movements in the hammer, anvil, and stirrup, the three small bones of the middle ear (and the smallest bones in the human body). The linked movement of the three bones transmits the vibrations through its connection to the oval window, a soft piece of tissue on the cochlea. That vibration of the oval window causes vibrations in the fluids on its other side, in the cochlea proper. Higher frequencies have shorter distances between waves and therefore make for faster vibrations that are passed along this chain.

The spiral of the cochlea contains a soft tube that holds the hair cells that receive the sound. When the fluid in the inner ear moves, the hair cells wave like seaweed on the floor of the ocean, creating nerve impulses that normally are carried to the auditory centers of the brain by the auditory nerve. Hearing loss occurs when there is damage or blockage somewhere along this sequence, from the outer ear to the brain. Usually, problems in the middle ear are less severe or less difficult to correct, whereas problems in the cochlea or the auditory nerve tend to result in more severe hearing losses.

A common cause of hearing loss in children, although one that usually is only temporary, is otitis media - frequently referred to simply as "ear infections." Otitis media occurs when the eustachian tube leading from the throat to the ear becomes blocked and fluid builds up in the middle ear. The hammer, anvil, and stirrup are designed to work in air, not in fluid, so that when an infection fills the area, movement along the chain is reduced and sounds are muffled. Antibiotics usually clear up ear infections, although the insertion of drainage tubes may be necessary in chronic or more severe cases. In remote geographical areas where antibiotics are not readily available, chronic otitis media can lead to permanent hearing loss. Even in less severe cases, occurring commonly in the United States, recurring bouts of otitis media may result in delays in reading ability and lower performance on verbal intelligence tests (Kindig & Richards, 2000; see also Johnson et al., 2000). It should not be surprising, then, that more severe, permanent hearing losses in deaf children can influence such abilities.

When hearing losses result from causes that are not readily cured or corrected, some degree of artificial correction might be provided by assistive listening devices, most notably hearing aids. Hearing aids amplify sound across a broad spectrum. Regardless of whether they fit behind the ear, in the ear, or are carried in a pocket, hearing aids are all much the same inside (fig. 3.2). Sound is picked up by a microphone, amplified, and sent via a speaker into a small tube. The tube is connected to a custom-made, plastic earmold that ensures a snug fit. The high-pitched "eeeeee" sound sometimes heard from hearing aids usually means that they are not tightly in place, so that there is feedback from the speaker to the microphone, much as would occur if a hand-held microphone were passed in front of a public-address speaker.

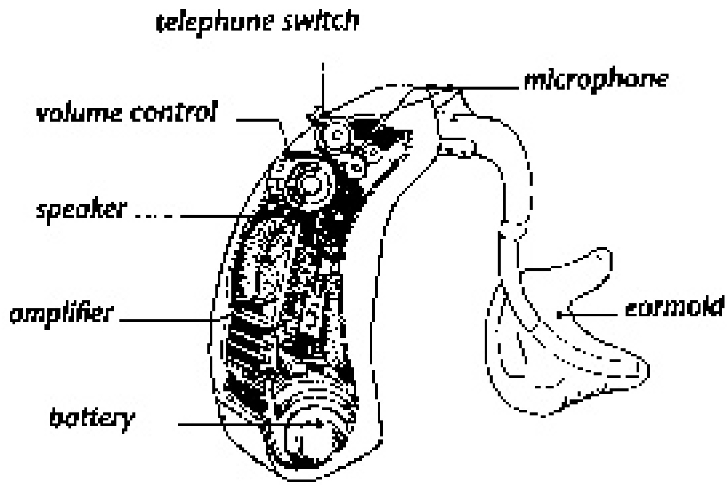

Figure 3.2. Schematic diagram of a hearing aid.

Most hearing aids are not specifically tuned to speech sounds the way that fully functioning human ears are. They amplify all sounds equally, so that background noise is increased just as much as the important sounds. These analog aids directly amplify sound picked up by the microphone. Sometimes background noise with such aids can become so loud that it impedes the perception of speech and desired environmental sounds. Newer hearing aids, both analog and digital, can be programmed to particular frequency patterns, matching the hearing losses of their users and blocking out other noise. Digital hearing aids, or digital signal processing instruments, are at the cutting-edge of this technology, as they can be matched precisely to the hearing losses of the user in terms of both decibels and frequency. Digital aids are now being produced by most hearing aid companies, but, like analog programmable aids, they are still quite expensive. Data for 1998 indicated that digital hearing aids represented only about 8 percent of total hearing aid sales, while programmable aids, overall, represented about 17 percent of sales in the United States. As development continues and prices decline, they should become increasingly popular, and user satisfaction should increase. This user satisfaction issue is not a trivial one. The hearing aid industry has a problem with consumers being disappointed with hearing aids, and approximately 20 percent of all aids sold, analog and digital, are returned to the manufacturer for credit (Kirkwood, 1999).

For children with some residual hearing, the use of hearing aids can be very important. Not only do hearing aids provide access to the spoken language of hearing parents and siblings, but in cases of progressive hearing loss, they can facilitate those children learning sign language and/or receiving speech therapy to maintain their spoken language skills. When there is more severe hearing loss, hearing aids, a cochlear implant, or the use of residual hearing may provide information to a deaf child in support of language development, even if they do not provide sufficient information for comprehension of language. Even a degraded auditory signal can indicate that a language event is happening, call attention to possible relations between prior events and language, and communicate social information such as turn-taking demands and emotional responses of others. Indeed, acquisition of sign language by most deaf children is assisted by spoken language received either by using residual hearing or speechreading, and hearing aids often provide an important support during the school years, even if they later are worn less frequently as an adult. Most audiologists recommend starting children with hearing aids immediately after diagnosis of hearing loss, or as early as possible, so that they become used to them and are exposed to auditory information as early as possible. Early use of hearing aids also typically is associated with better language development in children, although research is less clear on this issue when children have congenital hearing losses (see Marchark, 2001b, for a review).

Hearing aids also allow access to loop systems, which involve closed-circuit wiring that sends FM signals from an audio system directly to an electronic coil in the hearing aid. The receiver picks up the signals much like a remote control sends infrared signals to a television. There are also infrared loop systems that work exactly the same way. These systems are especially useful in large classrooms and lecture halls, situations where sound quality normally would suffer. Since 1988, federal law in the United States has required that all new telephones include loop-type circuitry that is consistent with hearing aid coils, making them more useful for many people with partial hearing losses.

Johnson, D. L., Swank, P. R., Owen, M. J., Baldwin, C. D., Howie, V. W., & McCormick, D. P. (2000). Effects of early middle ear effusion on child intelligence at three, five and seven years of age. *Journal of Pediatric Psychology*, *25*, 5-13.

Kindig, J. S., & Richards, H. C. (2000). Otitis media: Precursor of delayed reading. *Journal of Pediatric Psychology*, *25*, 15-18.

Kirkwood, D. H. (1999). In ‘98, hearing aid market hit new highs, but growth slowed. *The Hearing Journal*, *52*, 21-31.

Marschark, M. (2001b). *Language development in children who are deaf and hard of hearing: A research synthesis.* Washington DC: National Association of State Directors of Special Education.