

Understanding the Fundamentals of the Audiogram...So What?

By Larry Medwetsky

I have written this article based on my perspectives as being both a consumer with hearing loss since the age of three and as a practicing audiologist. Prior to becoming an audiologist, I was sometimes confused by the terminology used to explain my hearing loss.

What did it mean to have a moderately severe to severe sensorineural hearing loss? How did this relate to or explain the hearing difficulties I was encountering? I remember telling others I had a 50 percent hearing loss, even though I later realized I was confusing different test findings.

So What?

As an audiologist, I am motivated to ensure as much as possible that my clients not only understand the different terminologies but also how the test findings can help them to better understand the nature of their hearing difficulties.

One of my guiding principles was pursuant to a discussion I had a number of years ago at a directors' meeting at the Rochester Hearing and Speech Center, where I served as a vice-president of clinical services for many years. Dr. Peter Hixson, who was our president, led the discussion and was focusing on the needs of consumers of information. The focus of the conversation was the concept of "So what?"

Dr. Hixson felt strongly that if any information presented to consumers could be answered with So what?, then the information being shared was insufficient. For example, if an ad concerning hearing aid technology indicated that the hearing aid had dual microphone technology, multiple-band compression, and feedback suppression, a consumer naïve to such terminology could easily state "So what? What does that mean for me?"

It would be more helpful if one were to state the hearing aids had microphone

Anyone who has ever had their hearing tested should know how to read the audiogram, but that's easier said than done. Hopefully, after reading this article you will have a greater understanding of the principles discussed and use your knowledge going forward—be it in reviewing hearing test results you already have or when discussing your results at your next hearing test.

technology that could make it easier to adjust your hearing aids to your specific hearing loss, hear others more easily in noise, and do this without the annoying whistling common in older hearing aids, then that description would be more meaningful and actually answer the So what? question.

I believe the same principle holds true when explaining audiometric test procedures and the results obtained from that testing. My explanations should not lead consumers to feel *So what?* Rather, they should leave my office feeling that they possess a better understanding of:

- what they can and can't hear;
- why they might hear in certain settings but not in others; and,
- the rationale for the recommendations that were provided; and, in turn, have greater confidence in their subsequent decisions moving forward.

The Audiogram

With the assistance of Dr. Chizuko Tamaki, a colleague of mine, we have crafted a series of figures that build upon each other, the goal being for you to have a better understanding of audiometric findings and their implications.

An audiogram refers to the graph by which the results of a hearing test are recorded. However, before one can truly understand the implications of the hearing test results, one needs to be aware of certain basic principles underlying the audiogram.

Figure 1—Highlights Two Key Aspects, Frequency and Intensity

Each vertical line refers to a different frequency, while each horizontal line represents a different intensity level.

Let's start by focusing on the top, horizontal line. Pretend that you are sitting in front of a piano. The left side represents the bass-like, lower-pitched sounds. As you go up the scale the sounds become more and more treble-like (higher-pitched), with each vertical line representing a higher frequency (either one-half or one full octave higher than the previous vertical line).

Examples of low-pitched (125, 250 Hz) sounds include environmental sounds such as ocean waves or a truck, while high-frequency (4000, 8000 Hz) sounds are exemplified by sounds such as a bird (sparrow/robin, not ducks or geese) or a piccolo. [Hz is hertz, cycles per second].

The horizontal lines represent the different intensity (loudness) of sounds. The unit of intensity is a "decibel," often abbreviated as dB. There are two units of decibel. One is referred to as Sound Pressure Level, (SPL) which refers to the actual intensity of a sound.

For example, in the past you might have seen graphic representations of intensities of different sounds, some exhibiting very low intensity levels (such as whispers), while others being very loud and harmful to human hearing (e.g., jackhammer).

A second use of the decibel pertains

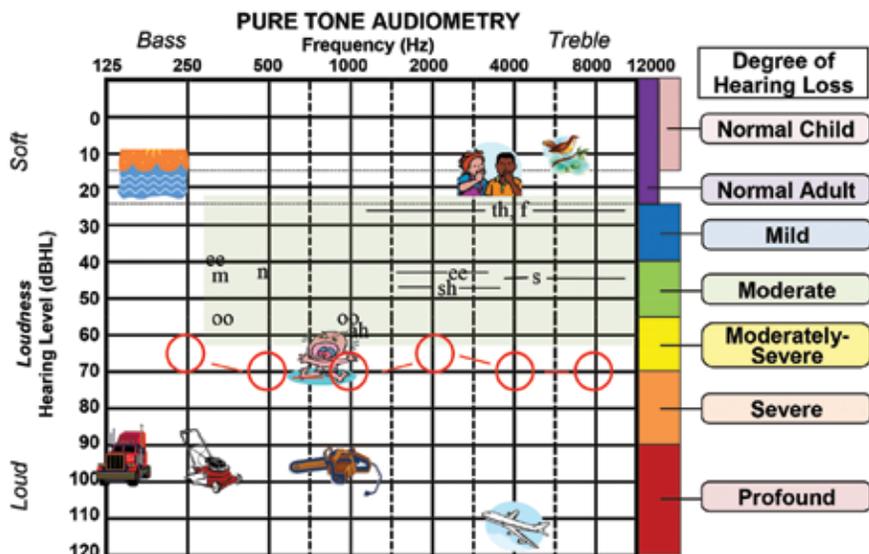


Figure 1. An audiogram representing the different levels and frequencies of some common environmental sounds as well as various speech sounds at a distance of five feet away from the talker. To illustrate the audibility of different sounds, right ear air-conduction thresholds have been plotted as well.

to what is referred to as Hearing Level, abbreviated as HL. The HL unit is based on research that ascertained the amount of dB SPL needed to derive the average threshold (i.e., softest level in which a sound can be heard) at each frequency for large groups of normal hearing individuals (usually college students), the “0 dB HL level.”

It should be noted that the ear’s sensitivity to sound actually varies as a function of frequency, such that the human ear is most sensitive to sounds in the mid-range of frequencies (1000-2000 Hz) and poorer at the lower and higher frequencies.

For example, at 125 Hz the average sound pressure level required to achieve threshold in normal hearing individuals is about 45 dB SPL, while only 7 dB SPL at around 1500 Hz. To make hearing results easier to understand, rather than using the SPL values to plot thresholds (which would result in numerous curved lines), audiologists use HL values (resulting in parallel horizontal lines), thus, making it much easier to visualize one’s hearing results.

In examining the verbiage next to the left vertical line (125 Hz), the closer one is to the top of the graph the less intense (softer) is the sound, while the closer to the bottom the greater (louder)

the intensity. In terms of environmental sounds:

- **Very soft sounds** are represented by calm ocean waves, whispers or birds chirping.
- **Moderately loud sounds** are represented by a baby cry.
- **Very loud sounds** are represented by a truck, lawnmower, chainsaw or airplane.

Listening to Speech

Most individuals would agree that speech represents the most important sounds they listen to. However, speech sounds vary in frequency and intensity. Some speech sounds are lower-pitched (such as /m/, /u/, while others are high-pitched (such as /t/, /s/). Please note that many of the speech sounds produced by male adults are of lower frequency than those produced by female adults and children.

For example, Boothroyd and Medwetsky (1992) found that the average /s/ sound produced by a male adult is approximately 4300 Hz and 7200 Hz for female adults. Depending on the neighboring vowel sound in which the /s/ might be produced, such as an /ee/, the frequency of the /s/ sound for some females in this study was shown to be as high as 8900 Hz.

Speech sounds also differ in their intensity. **Figure 1** reveals the intensity level of the different speech sounds when the talker is about five feet away from a listener (an average distance for typical conversations). You will note that sounds such as /ah/, /oo/ are among the loudest sounds produced, while sounds such as /f/, and /th/ are very soft (approximately 30 decibels softer than /a/).

Figure 1—Thresholds

Figure 1 also displays thresholds for someone’s right ear (as represented by the red circles). These results have been plotted against the intensity of speech sounds for a talker at a distance of five feet from the listener. All sounds occurring above this person’s thresholds (i.e., closer to the top of the audiogram) would be inaudible, while all sounds occurring below the threshold line would be able to be heard. If both ears exhibited similar thresholds for this individual, he or she would not be able to hear any of the speech sounds from five feet away, and consequently might not know that someone was speaking from this distance if the talker was not in view.

However, this does not mean that the individual wouldn’t be able to hear any sounds. For example, this individual would still be able to hear the baby cry (though somewhat softly), truck, lawnmower, chainsaw, and airplane as their intensities all fall below the threshold line.

As noted in **Figure 1**, the thresholds were plotted against speech sounds for a talker five feet from the listener. But what would happen if the talker was to move closer to the listener, for example, be only six inches from the listener’s right ear?

Figure 2—Explains a Number of Things

Figure 2 shows a shift in the level of the speech sounds (approximately 15 decibels louder). In examining this individual’s right ear thresholds against the level of these speech sounds, many of these speech sounds are now audible. For example, many of the stronger vowels, such as /a/, /u/ and some of the

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Audiogram *cont. from page 37*

consonants, such as /sh/ would now be able to be heard.

Figure 2 also helps to explain a number of phenomena. First, the distance between the talker and the listener affects the intensity level of sounds heard. To make speech louder one does not always have to raise one's voice but rather one can just get closer.

Second, the benefit of FM systems is not that they magically reduce background noise. By having a talker wear a microphone approximately two to six inches from one's mouth, one effectively reduces the distance between the talker's mouth and the listener's ears. Consequently, the speech signal increases in intensity by 15-20 decibels relative to the background noise which, in turn, makes it easier to hear the desired speech signal.

Pure Tone Audiometry

Pure tone audiometry is the procedure used by audiologists to present tones of different frequencies/levels. One goal is to find the softest level at which an individual hears various tones (i.e., one's threshold for the different frequencies). To derive important diagnostic information, this test is administered via two different mechanisms.

One technique referred to as Air Conduction Audiometry involves the

use of headphones (covering the ears) or insert phones (a foam tip is inserted into the ear). In either case, sounds are transmitted through the:

- **Outer Ear** (ear canal)
- **Middle Ear** (striking the eardrum causing it to vibrate and, in turn, the adjoining three middle ear bones—malleus (hammer), incus (anvil), and stapes (stirrup))

- **Inner Ear/Auditory Nerve** (where the sounds transmitted via the middle ear bones cause fluid to move and stimulate microscopic hair cells in the cochlea (i.e., the snail-shaped organ of the inner ear) and, in turn, excite the auditory nerve/transmit the impulses to the brain.

See **Figure 3** for a schematic of these anatomical features.

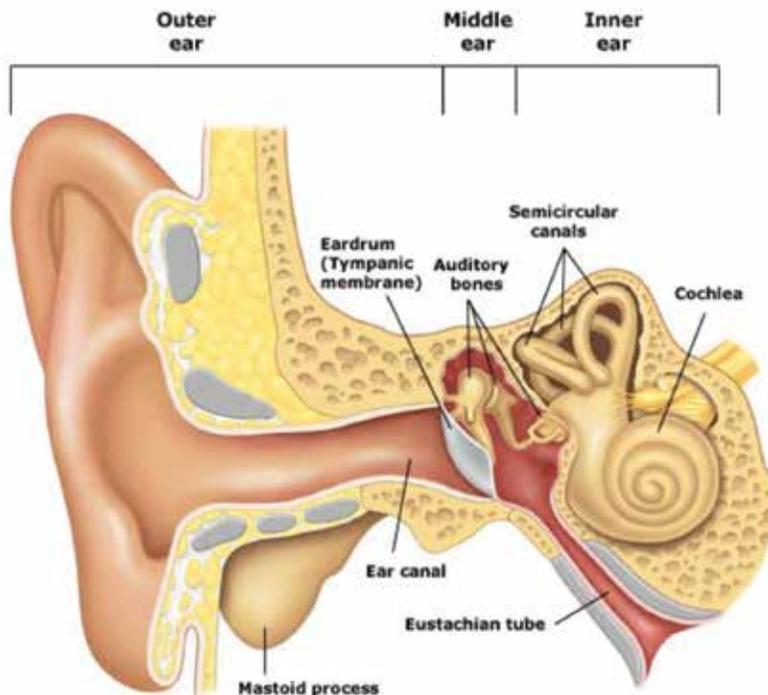


Figure 3. Main anatomical features of the ear

Figure 3—Bone Conduction Audiometry

A second technique, referred to as Bone Conduction Audiometry, involves placement of a vibrating device on a person's mastoid bone (i.e., the part of the skull behind the ear). By doing so, the presented sounds essentially bypass the outer and middle ear and are transmitted directly to the inner ear.

Figure 4—How Sound Travels

Figure 4 shows a schematic of how sounds presented via air conduction audiometry and bone conduction audiometry travel to their ultimate destinations.

The results from bone conduction audiometry inform the clinician as to whether there is an inner ear

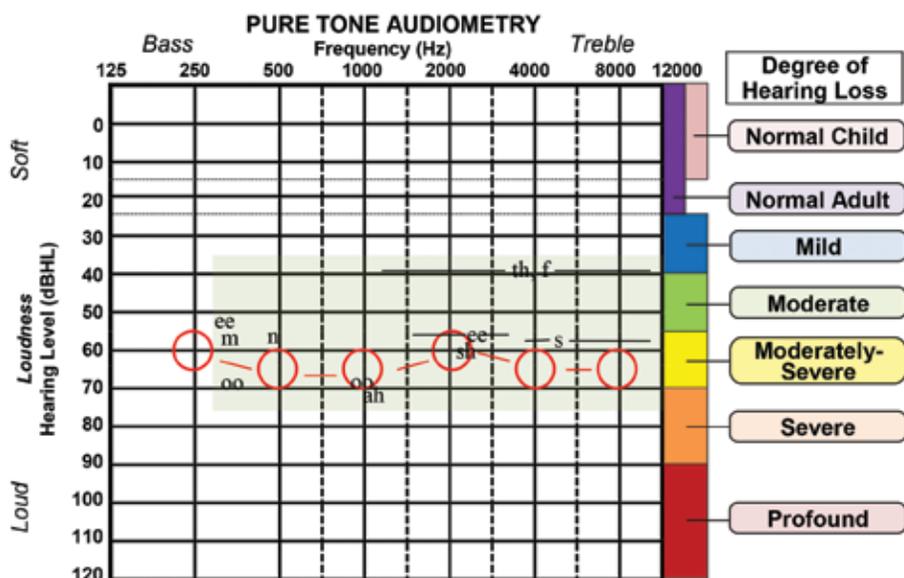


Figure 2. Audibility of various speech sounds at a distance of six inches away from the talker.

(sensorineural hearing) loss present. By comparing the results obtained from air conduction audiometry (transmission of sounds through the outer, middle, and inner ears) to those obtained from bone conduction audiometry (inner ear), one can determine if there is any difference between the results obtained.

If there is no difference between the air/bone conduction thresholds, one is fairly certain that there is no conductive (outer/middle ear) component, that is, some barrier such as wax or middle ear fluid impeding the conduction of sound through the outer canal and middle ear to its destination in the cochlea of the inner ear.

If the test results reveal that the bone conduction thresholds are significantly better for at least some frequencies than the air conduction thresholds, then this is consistent with the presence of some type of conductive component.

Figure 5—What Does it Show?

Figure 5 shows the results for an individual with a bilateral (i.e., in both ears) mild to moderately-severe sensorineural hearing loss. The left ear air conduction (AC) thresholds are represented by X, while the right ear AC thresholds are represented by O. The bone conduction (BC) thresholds can be represented by either < (right ear) or > (left ear).

The air and bone conduction thresholds are all within 10 decibels of each other, thus, there is no significant conductive component present. The observant reader might see that only the right BC thresholds were obtained. When both ear's AC thresholds are similar and the BC thresholds are within 10 dB of either AC threshold at any

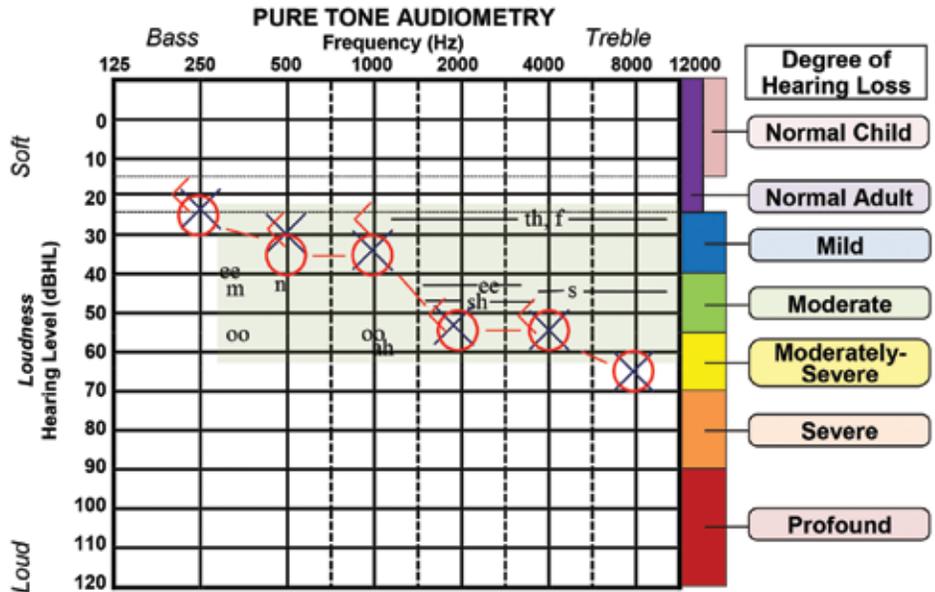


Figure 5. Audiometric results for an individual with bilateral sensorineural hearing loss

specific frequency, then one does not have to obtain BC thresholds from both ears with results from one ear sufficing. Thus, the hearing loss observed in this case arises only from the inner ear for both ears. When this occurs it is referred to as a sensorineural hearing loss.

One can see that this individual's thresholds are best in the lower frequencies. By examining the nomenclature next to the 12000 Hz vertical line one can see that the results at 250 Hz are actually within normal limits for an adult. However, at 500 Hz this individual displays a sensorineural hearing loss of a mild degree. As the frequency increases (remember this refers to going up higher on the piano scale), the hearing continues to decrease with the poorest thresholds occurring at 8000 Hz and is of a moderately severe nature.

All sounds falling below the threshold line (i.e., louder than the thresholds observed at all of the frequencies) are

audible. The further down the vertical axis that a sound occurs, the louder and, consequently more audible the sounds would be to this individual. On the other hand, any sound occurring above the threshold line (i.e., softer) would be inaudible to that individual.

For the individual represented in Figure 5 (at a talker's distance of five feet), many of the speech sounds (the vowels and low frequency consonants such as /b/, /m/) are audible; however, speech sounds such as /sh/, /s/, /f/, and /th/ would not be audible.

If the talker was not visible to the listener and said: 1) Shin; 2) Sin; 3) Fin; or 4) Thin, the listener would be able to hear the /n/ sound for each word uttered but none of the initial consonants. The listener would know that someone uttered a word but would not hear all of the speech sounds. He or she would know that a person was speaking; however, speech would not be clear and would sound as if the talker was mumbling.

Consequently, if the same talker was to face the individual and repeat these same four words **but without voice** (i.e., the listener would be engaging solely in speechreading), the listener would likely be able to identify each of these words correctly. Fortuitously, some of the speech sounds (such as the initial consonants for these four words) that are the hardest to hear are the easiest to speechread. It is

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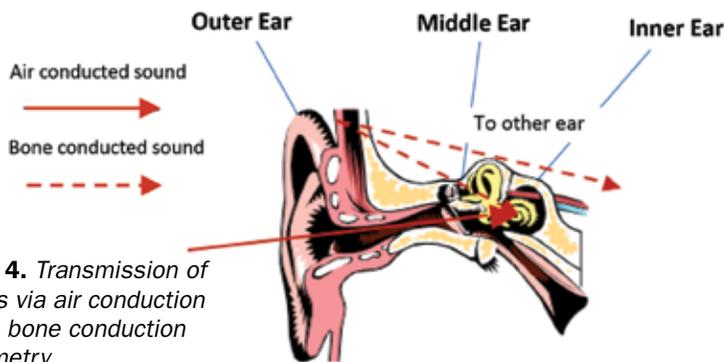


Figure 4. Transmission of sounds via air conduction versus bone conduction audiometry

Audiogram *cont. from page 39*

for this reason that when the talker does not face an individual with a hearing loss or is in another room, it often becomes significantly more difficult for the person with hearing loss to hear/understand.

The example presented here is somewhat of an oversimplification as there are many speech sounds that are not readily visible via speechreading; in addition, in everyday discourse the talker often presents information fairly quickly. This example, however, does show the benefit of combining both speechreading and hearing by someone with a hearing loss, or even by normal hearing individuals when there is much noise present, such as at a party or in a noisy restaurant.

Figure 5—Speech Sounds as Bands of Energy

Figure 5 also highlights another phenomenon that I'd like to share with you. Speech sounds do not occur at one frequency, though placing speech sound symbols on the audiogram might suggest this. In fact, speech sounds consist of bands of energy. In this figure, I have chosen to display the two energy bands for the speech sounds /oo/ and /ee/. For the /oo/ sound one band is centered at 300 Hz with the other band at 1000 Hz, while for the /ee/ sound one band is centered at 300 Hz with the other band at approximately 2700 Hz.

The parallel lines for the /ee/ sound that extend from approximately 1500 Hz (the average frequency for the second energy band for male adult speakers) to 3300 Hz (average frequency for the second energy band for female adult speakers).

On one hand, if this individual was asked to listen to a female talker five feet away without the talker's face being visible, both energy bands of the /oo/ sound would be audible and the listener would easily indicate /oo/ if asked.

On the other hand, what do you think this individual would hear and repeat back if the /ee/ sound was presented? In most likelihood, this listener would actually say /oo/.

Why is that? In the absence of being able to hear the second energy band of

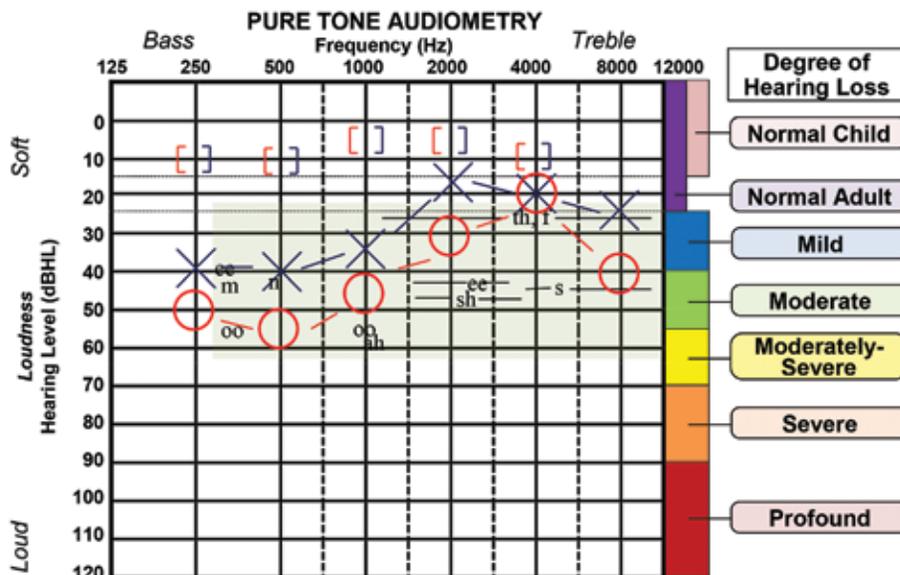


Figure 6. Audiometric results for an individual with a bilateral conductive hearing loss

/ee/, the listener would only be able to hear the first energy band of /ee/ located at 300 Hz. Since the first energy band for both the /oo/ and /ee/ sounds are located at approximately the same frequency, this individual might actually perceive the /oo/ sound. This is one of many examples as to why an individual, even when they are able to hear others, might not accurately perceive what has been presented.

Figure 6—Results

- The left ear exhibits a mild conductive hearing loss (250 to 1000 Hz) rising to normal hearing from 2000 to 8000 Hz.
- The right ear reveals a moderate (250 to 1000 Hz) rising to a mild (2000 Hz) conductive hearing loss and to normal hearing (4000 Hz) before falling to a mild hearing loss at 8000 Hz.

In Figure 6 the bone conduction thresholds are represented by [(right ear) and] (left ear). Both of these symbols indicate that the bone conduction thresholds were obtained by presenting noise (i.e., masking) to the non-test ear, that is, in the ear opposite to where the sounds are actually being presented.

Masking is done when sounds might be heard by the non-test ear. By masking the non-test ears, we ensure that the bone conduction thresholds are accurate

and arise from the corresponding test ear. A conductive hearing loss is said to be present when there is a difference of at least 15 decibels between the air and bone conduction thresholds.

For this individual, the greatest conductive hearing loss is present in the right ear at 250 to 1000 Hz with an air bone gap (i.e., the difference between air and bone conduction thresholds) being as great as 45 decibels at 500 Hz. This is an individual whom the audiologist would refer to an otolaryngologist (ear, nose and throat doctor). The hope would be that medical intervention could decrease this air bone gap and allow the individual to hear at his or her potential, that is, exhibit air conduction thresholds consistent with the level of his or her bone conduction thresholds.

The Audiogram is Only Part of the Picture

Hopefully, the information that has been presented allows you to better understand your audiogram and the implications of such in your everyday life experiences. Please note that the pure tone audiogram only provides part of the overall picture in that it only informs you as to which environmental and speech sounds might be audible.

However, in everyday life we must not only hear the various speech sounds but also rapidly decode the incoming speech signals, activate their

corresponding representations from long-term memory, hold/sequence the information momentarily in short-term memory, analyze/comprehend the information, and then possibly respond. And often, this must be done in the presence of competing noise/talkers. The reason why I have brought forth the latter information is to inform you that audibility is only one factor (though an extremely important one) in being able to hear/understand others.

Even if we make speech sounds audible (such as via a hearing aid) it does not mean that we have addressed all of the hearing related issues that you might have. But, we must address the audibility issue before tackling other issues.

So, Now What?

If there are any points that you feel after reading this article leaves you with

a So what?, please email me at larry.medwetsky@gallaudet.edu

Coming Next Issue... Understanding Your Test Results

In the next issue, I will provide an overview of the various audiometric procedures that are typically conducted during a hearing evaluation. Similarly to the audiogram, consumers often leave the office setting without a complete understanding of the various test procedures that have been administered and their purpose. My goal will be to help you better understand: a) the valuable information that is provided by each of these procedures, and, in turn, b) your own results. **HLM**

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doctorate in Speech and Hearing Sciences in 1994 from the Graduate Center, City University of New York. He has served as an educational audiologist, vice president of clinical services in a large speech and hearing clinic, and is presently an associate professor at Gallaudet University in the Department of Hearing, Speech and Language Sciences. Dr. Medwetsky has published and presented on many different topics with a special focus on the underlying speech processes and deficits in both individuals with normal hearing and hearing loss.



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