Encyclopedia of Perception

Audiology

Contributors: Kevin J. Munro
Edited by: E. Bruce Goldstein
Book Title: Encyclopedia of Perception
Chapter Title: "Audiology"
Pub. Date: 2010
Access Date: January 23, 2017
Publishing Company: SAGE Publications, Inc.
City: Thousand Oaks
Print ISBN: 9781412940818
Online ISBN: 9781412972000
DOI: http://dx.doi.org/10.4135/9781412972000.n47
Print pages: 129-132

The number of hearing-impaired people worldwide is estimated to be around 300 million and rising because of the growing global population and longer life expectancy. Hearing impairment is now the third leading chronic disability after arthritis and hypertension in the Western world. Therefore, most individuals, or members of their family, will attend an audiology service to have their hearing assessed at some point in their lives. *Audiology* is the science of hearing, but the term is used in a healthcare setting to generally mean the study and assessment of hearing and balance problems and the treatment and prevention of disorders of these functions. This entry describes various audiological assessment procedures.

Hearing Sensitivity

The human ear has an extremely wide perceptual dynamic range. The lower limit of hearing where sound is just detectable is referred to as the *threshold of hearing* (also known as absolute threshold or absolute sensitivity). The upper limit of hearing where sound begins to become uncomfortably loud is referred to as the *threshold of discomfort* (or uncomfortable loudness level). In quantitative terms, the difference in level between these two extremes is of the order of 10 million times. The human ear can hear single frequencies of vibration from around 20 to 20,000 hertz (Hz), although the upper limit, in particular, reduces during the natural ageing process.

The general relationship between the dynamic range of hearing and frequency has been well understood for many years. Studies measuring the minimum audible level of hearing have been made with stimuli presented to each ear separately or both ears together (usually via an earphone and loudspeaker, respectively). The results from the two methods are similar, but not identical, and show human hearing to be generally most sensitive between 500 and 10,000 Hz. The typical values obtained in a group of young healthy individuals, at individual frequencies, are used as the baseline reference level to which listeners with a suspected hearing impairment can be compared.

The Pure Tone Audiogram

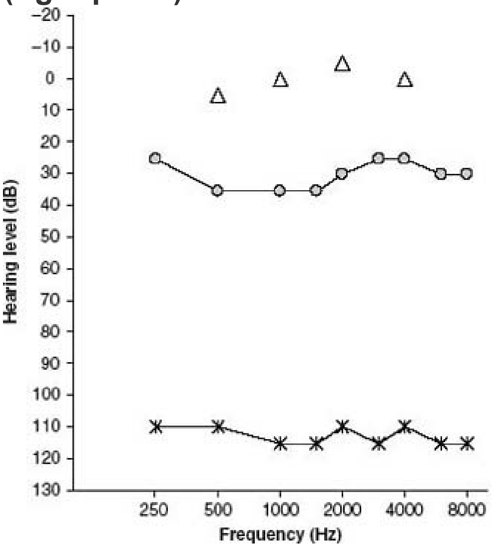
The most widely used assessment procedure in clinical audiology is known as pure tone audiometry. The listener's hearing threshold level, in decibels (dB), is plotted on a chart, known as a pure tone audiogram, with hearing threshold level plotted on the ordinate as a function of signal frequency on the abscissa. The conventional clinical audiogram plots hearing level with low values (normal hearing) at the top of the chart and raised levels closer to the abscissa. Therefore, raised hearing levels are plotted lower on the pure tone audiogram chart (see Figure 1, next page).

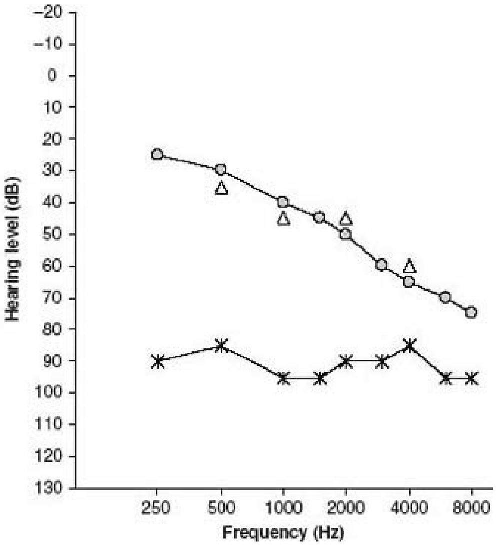
The reference baseline is called audiometric zero and represents the zero decibels hearing level line on the audiogram chart. If, for example, a listener's hearing threshold level for a particular signal is 60 dB, this means that the listener's hearing threshold is 60 dB higher than the median value obtained from a group of normal healthy young persons. Not every healthy young adult has a hearing threshold level that falls on the zero decibels line, however, and the range of normality is generally taken to be ±20 dB of the zero line.

For clinical purposes, the hearing threshold is usually measured for single frequency tones at discrete frequencies from 500 Hz to 8,000 Hz, in octave or half-octave intervals, and reported in step sizes of 5 dB. The signals are selected and presented to the listener using a classical measurement method known as the methods of limits. A series of signals are presented in an ascending or descending run (from loud to quiet, or vice versa), and the task for the listener is to respond every time he or she detects a signal. As with any psychophysical measurement, there will be a level above which the pure tone is always heard and a lower level where the tone is never heard. The threshold of hearing is taken as the lowest level at which the signal is detected at least 50% of the time. A whole host of extrinsic and intrinsic factors can influence the measurements (e.g., ambient noise level and duration of the test signal, respectively), so there are clearly defined procedures for clinical testing.

Although the measurement of hearing thresholds from each ear separately appears a relatively straightforward procedure, sound may cross from one side of the head to the other. For example, if a listener has poor hearing in the ear under test, the signal may be sufficiently intense that it may cross the skull and be detected by the opposite ear that has better hearing. In these circumstances, a masking noise is presented to the non-test ear to prevent *cross hearing* of the test signal. Standard procedures have been developed for when and how to use masking. If masking is insufficient, the test signal may continue to be detected by the non-test ear: if too much masking is used, this may result in *cross masking* and artificially raise the hearing threshold in the test ear.

Figure 1 Pure Tone Audiometry Data for a Listener With a Mild Hearing Impairment (left panel) and a Listener With a Moderate High-Frequency Sloping Hearing Impairment (right panel)





Notes: Only data from one ear of each listener is shown: right air conduction, circles; right bone conduction, triangles; loudness discomfort level, asterisks. The presence of an air-bone gap in the left panel means the listener has a conductive hearing impairment. The lack of an air-bone gap on the right panel means that this listener has a sensorineural hearing impairment. The ear with the conductive impairment has a normal dynamic range, that is, air conduction thresholds and loudness discomfort levels are both elevated (lower on the chart) by approximately 30 decibels compared with that of a normal listener. The loudness discomfort levels in the right panel are present at normal levels, despite the raised hearing thresholds: this listener has a greatly reduced dynamic range of hearing. The findings in the left panel are typical of an individual who has fluid in the middle ear space. The findings in the right panel are typical of a listener with a natural age-related hearing impairment.

The degree of hearing impairment can, and usually does, vary with frequency although it is usually summarized as mild, moderate, severe, or profound, based on an average of the hearing threshold levels. The ability to hear speech is related to the degree of impairment. Slight hearing impairment (26–40 dB hearing level) can cause some difficulty following speech, especially in noisy situations. Moderate hearing impairment (41–60 dB hearing level) can cause difficulty following speech without a hearing aid. Conversational speech will not be audible in cases of severe (61–80 dB hearing level) or profound (81 dB hearing level or greater) hearing impairment, and some of these listeners may need a special type of hearing aid known as a cochlear implant if they are to perceive speech. The proportion of speech that is audible and useable for a listener, with or without a hearing aid, can be quantified using a procedure known as the Speech Intelligibility Index. At relatively high presentation levels, the test signal can sometimes be perceived as a vibration, especially for low frequency stimuli. Therefore, sometimes it can be difficult to determine if a threshold measurement is an auditory or a vibrotactile perception.

Conductive and Sensorineural Hearing Impairment

Hearing impairment is generally categorized into two groups: conductive and sensorineural. Conductive hearing impairment occurs when there is a problem in the outer or middle ear that prevents sounds being conducted to the cochlea in the inner ear. Sensorineural hearing impairment involves a problem with either the *sensory* transducer cells in the cochlea or, less commonly, the *neural* pathway to the brain. Conductive hearing-impairment can often be corrected via surgery and is relatively common in childhood, but sensorineural hearing impairment is usually permanent. Therefore, it is important to distinguish between the two categories. One method of doing this is to compare air conduction and bone conduction hearing threshold levels. This involves measuring hearing sensitivity using two different types of earphone. When a pure tone is presented via an earphone (or a loudspeaker), the signal travels through the air in the outer ear to the middle ear and then to the cochlea in the inner ear. This is known as *air conduction testing*. Alternatively, the outer and middle ear can be largely bypassed by stimulating the cochlea via mechanical vibration of the skull. This is known as bone conduction testing. Instead of using an earphone, an electromechanical earphone is placed on the skull.

Normal hearing individuals will have a hearing threshold level close to zero decibels for both air and bone conduction. Disorders of any part of the auditory pathway will affect the air conduction threshold, but disorders of the conducting mechanism will have much less effect on bone conduction measurements because these generally bypass the outer and middle ear. When a hearing impairment is present but the air-bone gap (air conduction minus bone conduction) is close to zero, it is assumed that there is no impairment of the outer or middle ear and the listener has a sensorineural hearing impairment. The presence of an air-bone gap signifies a conductive hearing impairment.

The dynamic range between the threshold of hearing and loudness discomfort level is around 80 to 100 dB in normal hearing listeners. Listeners having a sensory hearing-impairment will have raised hearing thresholds, but their loudness discomfort levels are essentially similar to those of normal hearing listeners. Listeners with a sensory hearing impairment have a reduced dynamic range and an abnormal rate of loudness growth: This is known as loudness recruitment, that is, an abnormally disproportionate increase in loudness for a small increase in intensity. This has implications for the design of hearing instruments because soft sounds will require greater amplification than will loud sounds—that is, nonlinear amplification is required. Although a nonlinear hearing instrument can compensate by providing more amplification for soft sounds, it cannot compensate for the loss of supra-threshold abilities such as impaired frequency resolution. This means that hearing in background noise remains a problem for many listeners.

Pediatric Assessment Procedures

Between a developmental age of 6 months and 3 years, the measurement technique of choice is visual reinforcement audiometry. This involves pairing a head turn response to a sound with an interesting visual reward such as a flashing light or an animated toy animal. Once this classical conditioning has been established, operant conditioning then takes place where a visual reward is presented after an appropriate sound-elicited head turn. This technique is used to determine the minimum response level that will elicit a head turn. Although it is usual to attempt ear-specific measurements in children, in some cases, earphones will not be tolerated and the signal is presented from a loudspeaker: this is known as sound field audiometry. Hearing sensitivity in infants is slightly raised compared with that of young adults although there is debate about whether this is purely a physiological maturation or if it is related to nonsensory factors such as attention and motivation.

Before a developmental age of 6 months, behavioral testing is of limited use in determining hearing threshold levels. However, a small amount of sound is generated in the healthy cochlea, and this otoacoustic emission can be measured with a small sensitive microphone in the ear canal. This normal response from a healthy ear forms the basis of a clinical procedure that can be used, for example, to screen the hearing of a newborn baby. If no otoacoustic emission can be recorded, event-related potentials can then be used to estimate hearing sensitivity. This involves the measurement of electrical potentials via recording leads attached to the scalp. The method of choice in infants is the auditory brainstem response because this can be obtained during sleep. A typical procedure is to commence at a high level and reduce this until the evoked response can no longer be detected. The presence of a response is based on the tester's subjective interpretation of the waveform. An alternative technique that is gaining popularity is the auditory steady state response, and the presence of this response is based on statistical data. Event-related potentials can also be used to estimate hearing sensitivity in adults who are unable or unwilling to provide reliable information via pure tone audiometry. Historically, event-related potentials have had a valuable diagnostic role, especially when identifying tumors associated with the hearing nerve, but these have largely been replaced by advanced diagnostic imaging techniques.

A commonly used procedure that provides information about the condition of the eardrum and the middle ear is known as tympanometry. Although this can also be used in adults, it is particularly useful in children who are prone to fluid gathering in the normally air-filled middle ear space. The procedure works on the principle that some sound entering the ear canal is reflected back from the eardrum and this can be measured with a sensitive microphone. Stiffening the eardrum by changing the pressure of the air trapped in the ear canal should result in more sound being reflected by the eardrum. However, if there is fluid in the middle ear, then the stiffness of the ear drum will be unaffected by changing the air pressure in the ear canal.

Vestibular Assessment and Management

Sudden changes in the function of the vestibular organ in the inner ear can result in rotatory vertigo, which gives the illusion that the environment is spinning around. Useful information about vestibular function can be obtained by observing eye movements during certain visual and vestibular stimulation. The audiologist is particularly interested in the presence of a slowquick oscillatory movement of the eyes known as nystagmus. This eye movement will be present spontaneously after a change in vestibular function and may continue for days or weeks until the brain has time to compensate. Nystagmus may also be provoked by changes in body position such as getting out of bed in the morning. The sensitivity of the right and left vestibular organs can be compared by irrigating the external ear canal with hot or cold water to induce a response: This is known as the caloric test. Increasingly, audiologists are using a force platform to measure body sway because this can provide information about the use of the visual, vestibular, and proprioceptive systems for balance function and postural control. Rehabilitative procedures generally involve head and eye exercises that aid the central compensation mechanism.

- bone conduction
- hearing impairment
- middle ear
- ears
- loudness
- audiometry
- impairment

Kevin J. Munro
http://dx.doi.org/10.4135/9781412972000.n47

See also

- Ageing and Hearing
- Audition: Disorders
- Auditory Thresholds
- Cochlear Implants: Technology
- Evoked Potential: Audition
- Hearing Aids
- Tinnitus
- Vestibular System

Further Readings

British Society of Audiology (2008, March). Recommended procedure: Pure tone air and bone conduction threshold audiometry with and without masking and determination of uncomfortable loudness level. Retrieved from http://www.thebsa.org.uk/docs/RecPro/PTA.pdf
Gelfand, S. A. (2004). Hearing: An introduction to psychological and physiological acoustics (
4th ed.
). New York: Marcel Dekker.
Haughton, P. (2002). Acoustics for audiologists. Oxford, UK: Academic Press.
Katz, J. (2002). Handbook of clinical audiology (
5th ed.
). London: Lippincott, Williams and Wilkins.
Moore, B. C. J. (2007). Cochlear hearing loss: Physiology, psychology and technical issues (
2nd ed.
). London: Wiley Blackwell.
Newborn Hearing Screening Progamme (2008, March). Audiology protocols for newborn hearing screening: Visual reinforcement Audiometry testing of infants. Retrieved from http://hearing.screening.nhs.uk/cms.php?folder=21
Plack, C. J. (2005). The sense of hearing. Mahwah, NJ: Lawrence Erlbaum.

World Health Organization (2008, March). Factsheet: Deafness and hearing impairment. Retrieved from http://www.who.int/mediacentre/factsheets/fs300/en/index.html