Audiometry

Audiometry (from Latin: *audīre*, "to hear" and *metria*, “to measure") is a branch of Audiology and the science of measuring hearing acuity for variations in sound intensity and pitch and for tonal purity, involving thresholds and differing frequencies.[1] Typically, audiometric tests determine a subject's hearing levels with the help of an audiometer, but may also measure ability to discriminate between different sound intensities, recognize pitch, or distinguish speech from background noise. Acoustic reflex and otoacoustic emissions may also be measured. Results of audiometric tests are used to diagnose hearing loss or diseases of the ear, and often make use of an audiogram.

History and development

The basic requirements of the field were to be able to produce a repeating sound, some way to attentuate the amplitude, a way to transmit the sound to the subject, and a means to record and interpret the subject's responses to the test.

Mechanical "acuity meters" and tuning forks

For many years there were in desultory use various devices capable of producing sounds of controlled intensity. The first types were clock-like, giving off air-borne sound to the tubes of a stethoscope; the sound distributor head had a valve which could be gradually closed. Another model used a tripped hammer to strike a metal rod and produce the testing sound; in another a tuning fork was struck. The first such measurement device for testing hearing was described by Wolke (1802)

Pure tone audiometry and audiograms

Following development of the induction coil in 1849 and audio transducers (telephone) in 1876, a variety of audiometers were invented in United States and overseas. These early audiometers were known as induction-coil audiometers due to...

- Hughes 1879
- Hartmann 1878

In 1885, Arthur Hartmann designed an “Auditory Chart” which included left and right ear tuning fork representation on the abscissa and percent of hearing along the ordinate.

In 1899, Carl E. Seashore Prof. of Psychology at U. Iowa, United States, introduced the audiometer as an instrument to measure the “keenness of hearing” whether in the laboratory, schoolroom, or office of the psychologist or aurist. The instrument operated on a battery and presented a tone or a click; it had an attenuator set in a scale of 40 steps. His machine became the basis of the audiometers later manufactured at Western Electric.

- Cordia C. Bunch 1919

The concept of a frequency versus sensitivity (amplitude) audiogram plot of human hearing sensitivity was conceived by German physicist Max Wien in 1903. The first vacuum tube implementations, November 1919, two groups of researchers — K.L. Schaefer and G. Gruschke, B. Griessmann and H. Schwarzkopf — demonstrated before the Berlin Oto-logical Society two instruments designed to test hearing acuity. Both were built with vacuum tubes. Their designs were characteristic of the two basic types of electronic circuits used in most electronic audio devices for the next two decades. Neither of the two devices was developed commercially for some time, although the second was to be manufactured under the name "Otaudion." The Western Electric 1A, developed by <who> was built in 1922 in the United States. It was not until 1922 that otolaryngologist Dr. Edmund P. Fowler, and physicists Dr. Harvey Fletcher and Robert Wegel of Western Electric Co. first employed frequency at octave intervals plotted along the abscissa and intensity downward along the ordinate as a degree of hearing loss. Fletcher et al. also coined the term “audiogram” at that time.

With further technologic advances, bone conduction testing capabilities became a standard component of all Western Electric audiometers by 1928.

Electrophysiologic audiometry

In 1967, Sohmer and Feinmesser were the first to publish ABRs recorded with surface electrodes in humans which showed that cochlear potentials could be obtained non-invasively.

Otoacoustic audiometry

In 1978, David Kemp reported that sound energy produced by the ear could be detected in the ear canal. The first commercial system for detecting and measuring OAEs was produced in 1988.

The Auditory system

Components

The auditory system is composed of epithelial, osseous, vascular, neural and neocortical tissues. The anatomical divisions are external ear canal and tympanic membrane, middle ear, inner ear, VIII auditory nerve, and central auditory processing portions of the neocortex.

The process of hearing

Main article: Hearing

Sound waves enter the outer ear and travel through the external auditory canal until they reach the tympanic membrane, causing the membrane and the attached chain of auditory ossicles to vibrate. The motion of the stapes against the oval window sets up waves in the fluids of the cochlea, causing the basilar membrane to vibrate. This stimulates the sensory cells of the organ of Corti, atop the basilar membrane, to send nerve impulses to the central auditory processing areas of the brain, the auditory cortex, where sound is perceived and interpreted.

Sensory and psychodynamics of human hearing

Cocktail party effect

Understanding speech

Non-linearity

Temporal synchronization - sound localization and echo location

Parameters of human hearing

Frequency range

Amplitude sensitivity

Impulse response

Phase response

Temporal processing ("gap detection")

Distortion products

Types of Audiometry

Subjective Audiometry

Subjective audiometry requires the cooperation of the subject, and relies upon subjective responses which may both qualitative and quantitative, and involve attention (focus), reaction time, etc.

- Differential testing is conducted with a low frequency (usually 512hz) tuning fork. They are used to assess asymmetrical hearing and air/bone conduction differences. They are simple manual physical tests and do not result in an audiogram.
  - Weber test
  - Bing test
  - Rinne test
  - Schwabach test, a variant of the Rinne test
- Pure tone audiometry is a standardized hearing test in which air conduction hearing thresholds in decibels (db) for a set of fixed frequencies between 250hz and 8,000hz are plotted on an audiogram for each ear independently. A separate set of measurements is

made for bone conduction. There is also high frequency Pure Tone Audiometry covering the frequency range above 8000hz to 16,000hz.

- Speech audiometry is a diagnostic hearing test designed to test word or speech recognition. It has become a fundamental tool in hearing-loss assessment. In conjunction with pure-tone audiometry, it can aid in determining the degree and type of hearing loss. Speech audiometry also provides information regarding discomfort or tolerance to speech stimuli and information on word recognition abilities. In addition, information gained by speech audiometry can help determine proper gain and maximum output of hearing aids and other amplifying devices for patients with significant hearing losses and help assess how well they hear in noise. Speech audiometry also facilitates audiological rehabilitation management.

Speech audiometry may include:

-
    - Speech Awareness Threshold
    - Speech Recognition Threshold
    - Suprathreshold word-recognition
    - Sentence testing
    - Dichotic listening test
    - Loudness levels determination

- Békésy audiometry, also called decay audiometry - audiometry in which the subject controls increases and decreases in intensity as the frequency of the stimulus is gradually changed so that the subject traces back and forth across the threshold of hearing over the frequency range of the test.
- Audiometry of children
    - Conditioned play audiometry
    - Behavioral observation audiometry
    - Visual reinforcement audiometry

Objective Audiometry

Objective audiometry is based on physical, acoustic or electrophysiologic measurements and does not depend on the cooperation or subjective responses of the subject.

- Acoustic immittance audiometry
    - Tympanometry
    - Acoustic reflectometry
    - wide-band absorbance audiometry also called 3D tympanometry
- Evoked potential audiometry
    - N1-P2 Cortical Audio Evoked Potential (CAEP) audiometry
    - Auditory brainstem response (ABR) and Electrocochleography are neurologic tests of auditory brainstem function in response to auditory (click) stimuli.

    - Audio steady state response (ASSR) audiometry
- Otoacoustic emission audiometry
    - Distortion Product OtoAcoustic Emissons DPOAE audiometry
    - Transient Evoked OtoAcoustic Emissions TEOAE audiometry
- In situ audiometry: a technique for measuring not only the affliction of the person's auditory system, but also the characteristics of sound reproduction devices, in-the-canal hearing aids, vents and sound tubes of hearing aids.

Audiograms

Main article: Audiogram

The result of most audiometry is an audiogram plotting some measured dimension of hearing. The most common type of audiogram is the result of a pure tone audiometry hearing test, and plots frequency versus amplitude sensitivity thresholds for each ear, along with bone conduction thresholds.

Hearing assessment

Apart from testing hearing, part of the function of audiometry is in assessing or evaluating hearing from the test results. The most commonly used assessment of hearing is the determination of the threshold of audibility, i.e. the level of sound required to be just audible. This level can vary for an individual over a range of up to 5 Decibels from day to day and from determination to determination, but it provides an additional and useful tool in monitoring the potential ill effects of exposure to noise. Before carrying out a hearing test, it is important to obtain information about the person’s past medical history, not only concerning the ears but also other conditions which may have a bearing on possible hearing loss detected by an audiometric test. The hearing loss is usually bilateral, but variations in each ear can also be observed. Wax in the ear can also cause hearing loss, so the ear should be examined to see if syringing is needed; also to determine if the eardrum has suffered any damage which may reduce the ability of sound to be transmitted to the middle ear.

Hearing loss classification

The primary focus of audiometry is assessment of hearing status and hearing loss, including extent, type and configuration.

- There are four defined degrees of hearing loss: mild, moderate, severe and profound.
- Hearing loss may be divided into four types: conductive hearing loss, sensorineural hearing loss, central auditory processing disorders, and mixed types.
- Hearing loss may be unilateral or bilateal, of sudden onset or progressive, and temporary or permanent.

Hearing loss may be caused by a number of factors including heredity, congenital conditions, age-related (presbycusis) and acquired factors like noise-induced hearing loss, ototoxic chemicals and drugs, infections, and physical trauma.

Clinical Practice

Audiometric testing may be performed by a general practitioner medical doctor, an otolaryngologist (a specialized MD also called an ENT), a CCC-A (Certificate of Clinical Competence in Audiology) audiologist, a certified school audiometrist (a practitioner analogous to an optometrist who tests eyes), and sometimes other trained practitioners. Practitioners are certified by American Board of Audiology (ABA). Practitioners are licensed by various state boards regulating workplace health & safety, occupational professions, or ...

Noise-induced hearing loss

Workplace and environmental noise is the most prevalent cause of hearing loss in the United States and elsewhere.

Audiometer

An **audiometer** is a machine used for evaluating hearing acuity. They usually consist of an embedded hardware unit connected to a pair of headphones and a test subject feedback button, sometimes controlled by a standard PC. Such systems can also be used with bone vibrators, to test conductive hearing mechanisms.

Audiometers are standard equipment at ENT (ear, nose, throat) clinics and in audiology centers. An alternative to hardware audiometers are software audiometers, which are available in many different configurations. Screening PC-based audiometers use a standard computer. Clinical PC-based audiometers are generally more expensive than software audiometers, but are much more accurate and efficient. They are most commonly used in hospitals, audiology centers and research communities. These audiometers are also used to conduct industrial audiometric testing. Some audiometers even provide a software developer's kit that provides researchers with the capability to create their own diagnostic tests.

Functionality

An audiometer typically transmits recorded sounds such as pure tones or speech to the headphones of the test subject at varying frequencies and intensities, and records the subject's responses to produce an audiogram of threshold sensitivity, or speech understanding profile.

Types

Medical grade audiometers are usually an embedded hardware unit controlled from a PC. Software audiometers which run on a PC are also commercially available, but their accuracy and utility for evaluating hearing loss is questionable due to lack of a calibration standard.

The most common type of audiometer generates pure tones, or transmits parts of speech. Another kind of audiometer is the Bekesy audiometer, in which the subject follows a tone of increasing and decreasing amplitude as the tone is swept through the frequency range by depressing a button when the tone is heard and releasing it when it cannot be heard, crossing back and forth over the threshold of hearing. Bekesy audiometry typically yields lower thresholds and standard deviations than pure tone audiometry.

Parts of audiometer

Audiometers have:

(1) Attenuators / Hearing level dials to change dB HL level presented to the patient
(2) Interrupter Switch to turn the beep on and off and control the duration of the beep
(3) Function Selector to change between Air, Bone and Speech Sounds
(4) Talk Forward- To talk to the patient through the headphones
(5) Earphones/Headphones, Bone conduction oscillator receiver
(6) Frequency Indicator to change with frequency
(7)Presentation Indicator to change the tone from steady state, continuous, pulsed continuous to warble
(8) Microphone
(9) Voice VU Meter to change the volume of your own voice in the audiometer
(10) Masking indicator to produce white, narrow-band or speech noise

----

B. More In depth Audiometer Parts

(1) Oscillator- The part that generates the pure tones, very accurate +/- 3% accurate
(2) Equalization Circuit- Contains resisters that equalize the sound generated since the human ear more sensitive to its resonance frequencies around 2,700 Hz
(3) Output Power Amplifier- Signals produced by the amplifier are amplified here, almost no distortion produced here
(4) Output Transducers- The earphone, bone conduction receiver, loud speakers.