BEKESY AUDIOMETER

Authored by

mohammad looti

November 10, 2025

RECOMMENDED CITATION

mohammad looti (2025). *BEKESY AUDIOMETER*. PSYCHOLOGICAL SCALES. Retrieved from https://scales.arabpsychology.com/?p=65032

BEKESY AUDIOMETER

Primary Disciplinary Field(s): Audiology, Otolaryngology, Psychoacoustics

1. Core Definition

The Bekesy Audiometer is a highly specialized, self-recording instrument designed for the accurate detection and measurement of a person's auditory thresholds across a range of frequencies. Unlike traditional, manual audiometers, which rely heavily on the examiner to adjust intensity levels and record patient responses, the Bekesy model operates automatically, providing a continuous, graphic representation of the subject's hearing sensitivity. This device was a revolutionary development in clinical and research audiology, fundamentally changing the methodology of hearing assessment. The instrument is intrinsically linked to its inventor, the Nobel laureate Georg von Békésy, a Hungarian-born biophysicist and experimental psychologist whose extensive work on the mechanical properties of the cochlea laid the groundwork for modern audiological diagnostics.

At its essence, the device functions by presenting a tonal stimulus whose intensity changes continuously in response to the subject's feedback. The subject is provided with a control mechanism, typically a push button, which they manipulate to indicate whether they can hear the presented tone or not. When the button is depressed (indicating the tone is audible), the intensity of the signal automatically decreases; when released (indicating the tone is no longer audible), the intensity automatically increases. This continuous cycle of increase and decrease generates a characteristic "Bekesy tracing," a jagged line recorded on paper, which precisely tracks the upper and lower limits of the subject's instantaneous auditory threshold. This method provides a much more granular and dynamic measurement of hearing than older, fixed-frequency methods.

The resulting graph is not merely a static representation of threshold but captures the dynamic range and sensitivity fluctuation of the auditory system. This dynamic tracking of the hearing threshold is critical because the width of the excursions (the difference between the peaks and valleys of the jagged tracing) and the absolute threshold levels themselves offer diagnostic clues regarding the nature and location of the hearing impairment. For instance, the tracing can help distinguish between conductive hearing loss, sensorineural hearing loss, and specific pathologies related to retrocochlear lesions or cochlear damage, specifically those involving auditory fatigue or adaptation. Therefore, the Bekesy audiometer serves as more than just a measurement tool; it is a critical diagnostic instrument in differentiating specific auditory pathologies.

2. Etymology and Historical Development

The invention of the Bekesy audiometer is directly attributable to the pioneering work of **Georg von Békésy** (1899-1972), whose dedication to understanding the mechanisms of hearing spanned several decades. Békésy initially trained as a physicist but applied rigorous mechanical and experimental principles to the biological study of the inner ear. His foundational work, particularly his visualization and analysis of the traveling wave theory within the cochlea, led to his receipt of the Nobel Prize in Physiology or Medicine in 1961. The creation of the automatic audiometer was a practical application stemming from his broader interest in measuring auditory perception and the psychophysics of sound.

Prior to Békésy's development in the mid-20th century, standard audiometry was a manual, time-consuming process highly susceptible to operator error and subjective interpretation. An examiner would manually adjust the intensity of pure tones at specific, discrete frequencies (e.g., 500 Hz, 1000 Hz, 2000 Hz) and rely on the patient to provide a simple "yes" or "no" response to establish the threshold. Békésy sought a method that would not only automate the process but also eliminate the biases associated with the tester's interaction and judgment, thereby improving both the objectivity and efficiency of audiometric testing. His design integrated principles of continuous signal presentation and patient self-control to achieve this goal.

The automatic nature of the Bekesy audiometer represented a significant methodological shift. By allowing the patient to control the recording process directly through a simple feedback loop (push button), Békésy introduced the concept of self-recording or "tracking" audiometry. The original instruments utilized a motorized drive system that moved the recording paper (the audiogram) while a stylus, connected to the attenuator, plotted the intensity level against frequency or time, creating an indelible ink record. This innovation allowed for the rapid assessment of hearing thresholds across the entire audible spectrum, revealing fine details about threshold adaptation that manual methods simply overlooked.

3. Mechanism of Action and Design

The operational principle of the Bekesy audiometer centers on the concept of **continuous threshold tracking**. The instrument presents a pure tone that typically sweeps continuously across a range of frequencies, often from 100 Hz up to 10,000 Hz. Crucially, the intensity (in decibels) of this tone is modulated by a reversible motor controlled entirely by the subject's response button. This system creates a continuous feedback loop between the subject's perception and the instrument's output.

The core components facilitating this mechanism include the tone generator, the attenuator, the patient response switch, and the ink recorder. When the subject hears the tone, they press the button; this instantly reverses the motor controlling the attenuator, causing the tone intensity to drop, usually at a fixed rate (e.g., 2.5 dB per second). As soon as the tone becomes inaudible, the subject releases the button, which reverses the motor again, causing the intensity to rise. This constant oscillation around the true auditory threshold generates the characteristic "zigzag" tracing.

The amplitude of these excursions--the peaks and valleys--typically ranges between 5 and 10 dB in a normal hearing individual, representing the smallest perceptible change in intensity (the differential threshold).

The physical output is the Bekesy Tracing, recorded either on a calibrated paper chart (historically) or digitally (in modern adaptations). The horizontal axis of this chart typically represents frequency, and the vertical axis represents intensity (hearing level in dB). The resulting graph is a continuous line illustrating the subject's hearing sensitivity. Because the process is self-recording, the resulting trace is highly accurate and minimizes the potential influence of examiner bias or inconsistencies in instruction delivery, ensuring a high degree of reliability in threshold determination. The technical precision and automated nature of the device made it highly valuable for both clinical diagnosis and industrial hearing conservation programs, where rapid and reliable testing of large populations was necessary.

4. Testing Procedures and Interpretation

Bekesy audiometry employs several distinct testing modes, the most common being the continuous-frequency sweep and the fixed-frequency presentation. In the standard continuous-frequency test, the tone sweeps automatically across the frequency range. However, for diagnostic specificity, the test is often run twice: once using an interrupted (pulsed) tone and once using a continuous tone. Comparing the tracings generated by these two stimulus modes is the fundamental diagnostic power of the Bekesy test, particularly in distinguishing between cochlear and retrocochlear pathologies.

The diagnostic interpretation relies heavily on the work of audiologist **James Jerger**, who categorized the resulting patterns--known as Bekesy types--in the early 1960s. This classification system (Types I through V) directly relates the relationship between the continuous tone threshold and the interrupted tone threshold to specific anatomical locations of the pathology. For a normal or conductive hearing loss (Type I), the tracings for both continuous and interrupted tones generally overlap perfectly or remain within 10 dB of each other, exhibiting normal excursion widths.

Pathologies that demonstrate significant threshold adaptation--a key feature of certain auditory disorders--yield distinct patterns. For instance, a classic Type II tracing, often associated with cochlear pathology (sensory loss), shows that the continuous tone tracing drops significantly below the interrupted tone tracing, typically only in the higher frequencies, yet the excursion width remains near normal. In stark contrast, Type III or Type IV tracings--often associated with **retrocochlear lesions** (pathology of the auditory nerve or brainstem)--show a rapid and dramatic drop in the continuous tone threshold across all frequencies, often exceeding 20 dB or more below the interrupted tone tracing. This extreme decline is symptomatic of pathological auditory adaptation, a phenomenon known as tone decay, where the threshold rapidly elevates upon sustained stimulation. The rarest pattern, Type V, displays an unusual phenomenon where the continuous tone threshold is paradoxically better than the interrupted tone threshold, a pattern sometimes seen in non-organic (functional) hearing loss.

5. Significance and Impact in Audiology

The introduction of the Bekesy audiometer represented a watershed moment in the development of clinical audiology, moving the field away from purely subjective measurements toward objective, standardized procedures. Its primary impact was the ability to rapidly and reliably quantify **auditory threshold adaptation**, a property of hearing that could not be adequately measured using traditional fixed-frequency tests. By providing a continuous trace of threshold variation, the instrument allowed clinicians to observe the auditory system's dynamic response to prolonged stimulation, which became essential for site-of-lesion testing.

Furthermore, the device significantly contributed to the understanding and diagnosis of **recruitment**, a key phenomenon associated with cochlear hearing loss where the perception of loudness grows disproportionately quickly above the elevated threshold. While the Bekesy tracing doesn't directly measure recruitment, the characteristic patterns (like Jerger Type II) provided empirical evidence supporting the differentiation between purely mechanical conductive loss and sensory neural loss stemming from damage to the inner hair cells or cochlear structures. This diagnostic capability was paramount before the widespread availability of modern objective tests like Auditory Brainstem Response (ABR) and Otoacoustic Emissions (OAE).

The Bekesy method also served as a cornerstone in industrial and military audiology programs. Its automation allowed personnel to be tested efficiently and consistently, facilitating large-scale monitoring of noise-induced hearing loss. The speed and standardization offered by the self-recording design made it an invaluable tool for mass screening and establishing baseline audiograms in environments characterized by chronic noise exposure, reinforcing its role in preventative medicine and occupational health.

6. Debates and Criticisms

Despite its foundational importance, the Bekesy audiometer is not without its limitations, especially when compared to contemporary diagnostic methods. One primary criticism revolves around its reliance on **patient cooperation and cognitive function**. Since the threshold tracking mechanism depends entirely on the subject's ability to accurately and consistently press and release the response button in a timely manner, results can be compromised by inattention, fatigue, or cognitive deficits. This makes the test unsuitable for certain patient populations, such as very young children, individuals with developmental disabilities, or those with severe neurological impairments.

A second significant limitation emerged as audiological research advanced: the limitations of the Jerger classification system in modern diagnostics. While Bekesy types are powerful indicators, they are not infallible in precisely locating the site of lesion. Specifically, distinguishing between true retrocochlear lesions (e.g., acoustic neuromas) and certain severe cochlear losses can sometimes be ambiguous based solely on the Bekesy tracing. With the advent of highly objective measures like ABR and imaging technologies (MRI), which can physically visualize retrocochlear tumors, the Bekesy tracing has largely been superseded as the definitive test for ruling out these critical neurological pathologies.

Finally, the self-recording nature and the analog design of the original Bekesy units introduced technical maintenance challenges (e.g., ink tracing issues, motor calibration). While modern audiometers often incorporate computerized, digital tracking systems that mimic the Bekesy principle (often called automated threshold tracking), the dedicated, standalone Bekesy audiometer has become less common in standard clinical practice, replaced by multifunction audiometers that integrate multiple testing modalities, including manual, pulsed, and automated methods. Nevertheless, the underlying psychophysical methodology developed by Békésy remains integral to automated hearing assessment today.

7. Further Reading

Georg von Békésy (Wikipedia)
Audiometry (Wikipedia)
Auditory Threshold (Wikipedia)
Jerger's Classification of Bekesy Audiograms (NCBI)