Basics of Audiometry

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Overview

Psychoacoustic measurements

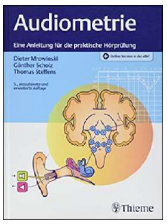
- Acoustics and hearing
- Pure tone audiometry
- Speech audiometry

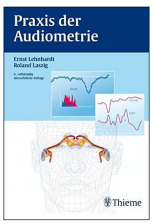
Objective Methods:

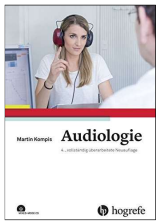
- Tympanometry
- Acoustically evoked potentials
- Otoacoustic emissions

- Just over 10 min per topic…

Textbooks on audiology in German





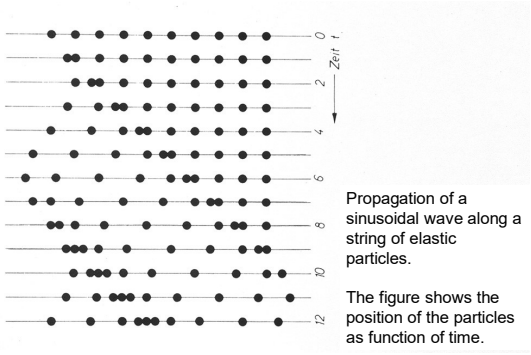


- Several text books are available
- You should have access to the current edition of one of them

The Basics: Acoustics and auditory perception

Acoustics = the science covering mechanical vibrations, wave propagations, generation and measurement in gases, liquids and solid materials

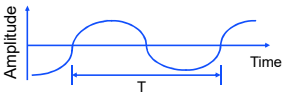
Longitudinal wave propagation



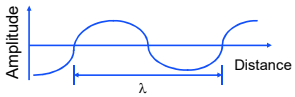
Propagation of a sinusoidal wave along a string of elastic particles.

The figure shows the position of the particles as function of time.

Physical features and percetion



- Frequency f = 1/T (Hz)



- Wave length λ (m)

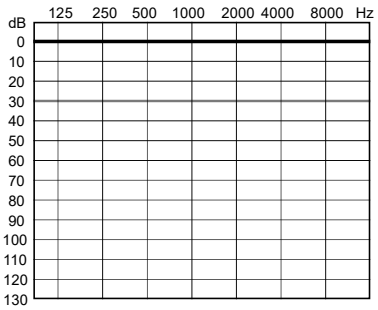
Amplitude corresponds to loudness

Frequency corresponds to pitch

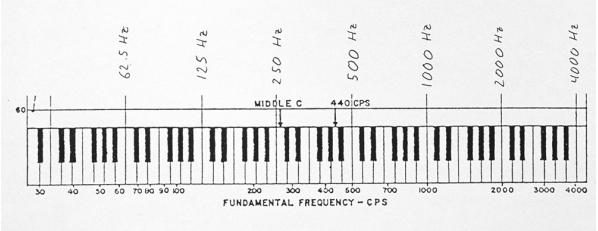
Frequency ranges

- Infrasound: … 20 Hz
- Audible sound: 20 Hz … 20 kHz
  - (Audiogram: only 125 – 8000 Hz)
- Ultrasound: 20 kHz …

Audiogramm



Logarithmic perception of frequencies



Logarithmic 8 tones (major)

Linear 8 tones (Nasca)

13 tones log & lin

Piano tuning

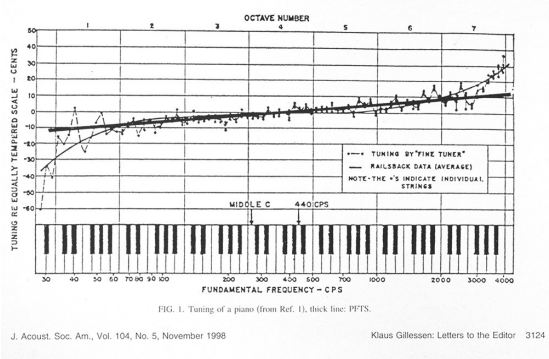


FIG. 1. Tuning of a piano (from Ref. 1), thick line: PFTS.

J. Acoust. Soc. Am., Vol. 104, No. 5, November 1998 Klaus Gillessen: Letters to the Editor 3124

dB = Logarithmic scale

- dB = dezibel = 1/10 Bell
- relative measure: requires a reference

- Calculation:

$L_{dB} = 10 \cdot \log_{10} (P_1/P_0)$ *(Power or energy)*

$= 20 \cdot \log_{10} (A_1/A_0)$ *(Amplitude)*

dB = logarithmic scale

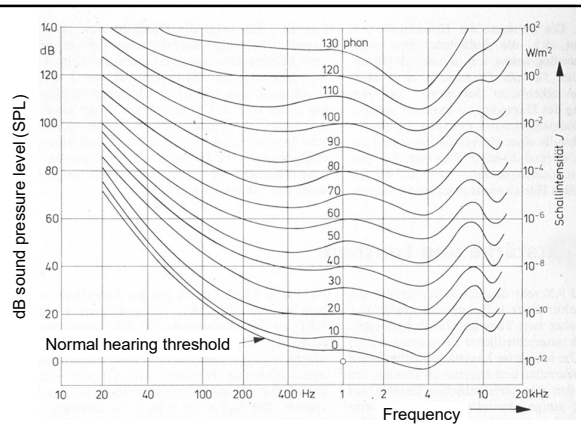
10 dB

= factor of 10 in power / energy

= approx. factor of 2 in subjective loudness

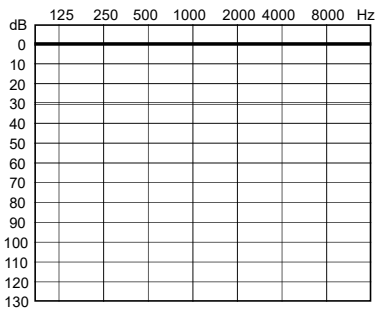
Examples: logarithmic perception of lodness

- Logarithmic: 20 steps of 1 dB
- Logarithmic: 12 steps of 5 dB
- Linear: 10 steps, reduction in amplitude10% per step



Isophonic curves (equal subjective loudness)

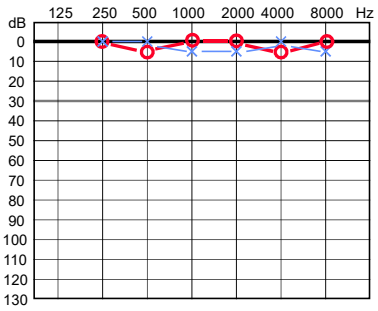
Audiogramm



Pure tone audiometry

= measurement of hearing thresholds as a function of the frequency

Normal audiogram



Audiometric symbols (CH, international)

	Left ear:	Right ear:
Air conduction (AC):	×	○
Bone conduction (BC):	>	<
Uncomfortable level:	⊗	⊖

Note: AC: right = red = round
BC: right: open to the right

Audiometric symbols (CH, international)

	Left ear:		Right ear:	
	No masking	*masking*	*No masking*	*masking*
Air conduction (AC):				
Bone conduction (BC):				
Uncomfortable level:				

Note: AC: right = red = round
BC: right: open to the right

Audiometric symbols (D)

	Left ear:	Right ear:
	With and without masking	*With and without masking*
Air conduction (AC):		
Bone conduction (BC):		
Uncomfortable level:		

Note: AC: right = red = round
BC: Left: looks like letter "L"

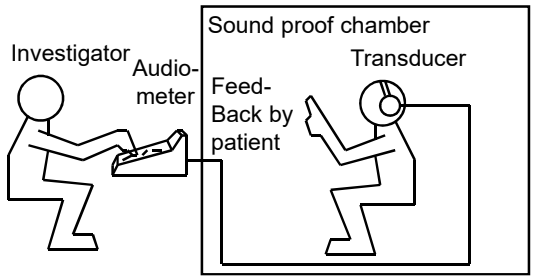
Audiometric symbols (D)

	Left ear:	Right ear:
	With and without masking	*With and without masking*
Air conduc		
Bone cond		
Uncomfor		

Always provide a legend listing all the symbols used in your audiogram

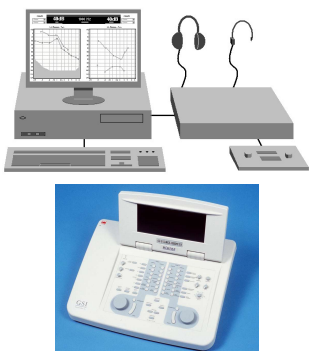
Note: AC: right = red = round
BC: Left: looks like letter "L"

Setting for Audiometry: Schematic view



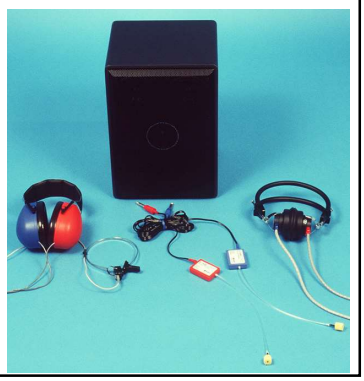
Sound proof chamber

Audiometer

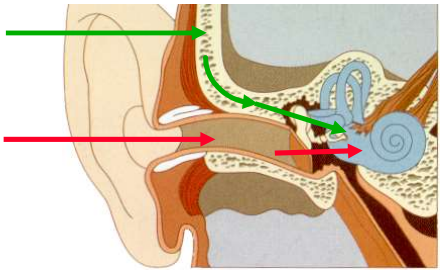


Transducers

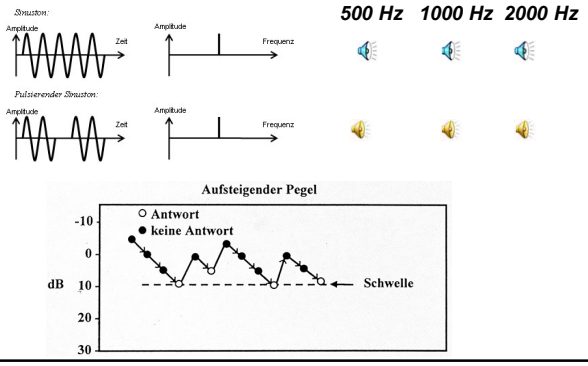
- Head phones
- Insert phones
- Bone vibrator
- Loudspeaker
  - (for sound field measurements)

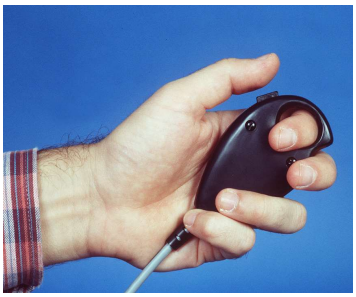


Air conduction and bone conduction

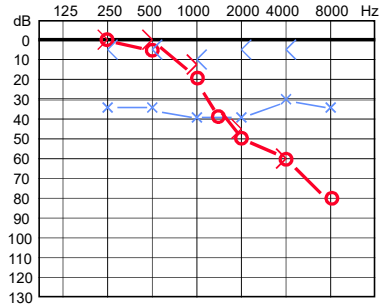


Signals and test paradigms

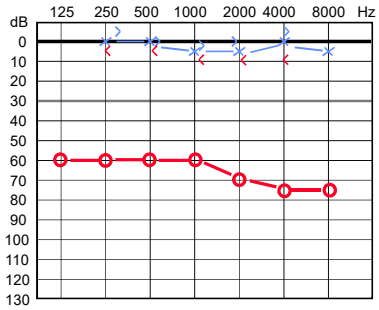




Conductive and sensorineural hearing loss in an audiogram

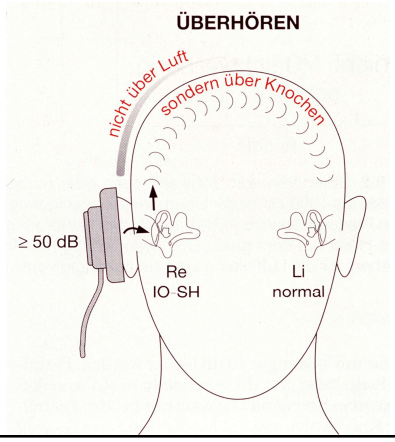


Shadow curves



Example for a measurement without masking

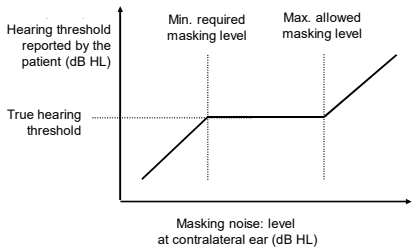
The right ear Is completely deaf…



Masking

- **Signal used for masking:** Narrow band noise in contralateral ear
- **When is it necessary:** As soon as you might measure the shadow curve (signal heard first by contralateral ear)
- **Requirement:** Masking level must be neither too low nor too high
- Different masking paradigms exist, and are in use. you should KNOW ONE OF THEM WELL

Preferred masking method in Switzerland: «Gleitenden Vertäubung»



Speech audiometry

= Evaluation of speech understanding using standardized tests

Some speech tests used in Switzerland

Tests in quiet:

- German:
  - Freiburger Wörter
  - Freiburger Zahlen
- French:
  - Fournier: Mots dissylabiques
  - Fournier: Mots monosylabiques
- Italian:
  - Bocca e Pellegrini: Parole
  - Bocca e Pellegrini: Numeri

Tests in Noise:

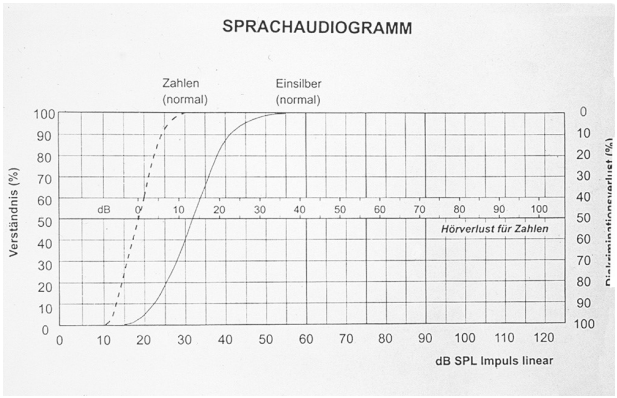
- Basler Satztest
  - In German only
- Words in noise (WIN)
  - German
  - French
  - Italian
- Matrix tests (OLSA)
  - many languages
- And several more…

Freiburger Zahlentest - Schweizeraufsprache 1987 nach F. Keller

dB	Grp.											% re	%
	1	98	22	54	19	86	71	35	47	80	63		
	2	53	14	39	68	57	90	85	31	72	46		
	3	51	36	43	17	99	45	82	24	60	48		
	4	67	83	55	13	28	92	34	70	49	76		
	5	62	58	23	16	41	37	89	30	95	74		
	6	32	65	83	50	91	27	18	44	79	56		
	7	59	77	62	40	96	73	19	84	38	25		
	8	93	78	13	66	57	39	80	75	62	24		
	9	88	42	65	23	76	15	94	87	29	60		
	10	33	18	64	52	97	45	30	69	26	78		

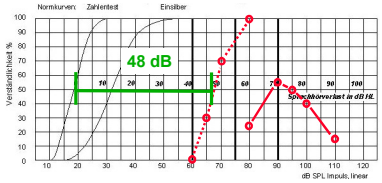
Freiburger Wörtertest - Schweizeraufsprache 1987 nach F. Keller

dB	Grp.		% re
	1	Nuss, Wolf, Braut, Kern, Fang, Klotz, Hund, Stück, Zahl, Ring, Lärm, Geiz, Durst, Bach, Schreck, Spott, Aas, Teig, Hanf, Stich	
	2	Holz, Russ, Mark, Stein, Glied, Fleck, Schloss, Fall, Busch, Werk, Dach, Eid, Knie, Traum, Pass, Kunst, Mönch, Bart, Los, Schrift	
	3	Blatt, Stift, Hohn, Zweck, Aal, Furcht, Leim, Dorf, Tat, Keil, Schutz, Wind, Maus, Klee, Schlitz, Bank, Stock, Wuchs, Reif, Gras	
	4	Schnee, Laub, Wurst, Fass, Griff, Fest, Mund, Kopf, Reiz, Heft, Grad, Frist, Oel, Fuss, Drang, Schleim, Takt, Kinn, Stoss, Ball	
	5	Ziel, Punkt, Fest, Schein, Darm, Torf, Lamm, Wehr, Glas, Huf, Spiess, Pfau, Block, Arm, Neid, Stroh, Wurf, Rest, Blick, Schlag	
	6	Seil, Pfand, Netz, Fluss, Schild, Ochs, Draht, Hemd, Schmutz, Tau, Rat, Milch, Rost, Kahn, Tier, Dunst, Brot, Haar, Feld, Schwein	
	7	Spiel, Moos, Lachs, Glut, Erz, Baum, Sand, Reich, Kuh, Wort, Schiff, Hecht, Bruch, Hang, Fels, Schopf, Kranz, Teich, Star, Dienst	
	8	Duft, Band, Kost, Ski, Feind, Herr, Pflug, Tal, Gift, Raum, Zeug, Ernst, Fach, Groll, Speck, Sitz, Moor, Last, Krach, Schwung	
	9	Specht, Eis, Funk, Rahm, Weg, Thron, Rind, Spass, Klotz, Blei, Markt, Schilf, Hut, Korb, Zank, Lauf, Kies, Dank, Schnur, Pech	
	10	Horn, Pfeil, Kamm, Gips, Turm, Spiess, Recht, Sprung, Zopf, Schall, Stau, Bass, Fell, Pracht, Mais, Gramm, Sieb, Ohr, Lump, Dreck	
	11	Bild, Ast, Frosch, Ruhm, Herz, Mond, Garn, Bau, Sicht, Huhn, Kreis, Lack, Pferd, Schlacht, Pelz, Teil, Witz, Rand, Stuhl, Zorn	
	12	Brett, Saft, Schuss, Pilz, Ort, Kraut, Schwert, Gleis, Tag, Vieh, Spalt, Sohn, Druck, Held, Bahn, List, Flug, Narr, Kork, Reis	
	13	Staub, Tracht, Herd, Licht, Not, Wein, Fluch, Kalk, Lehm, Grund, Fass, Schmied, Amt, Ross, Puls, Meer, Graf, Bier, Schweiss, Dolch	
	14	Schritt, Ruf, Gas, Wert, Brust, Korn, Dieb, Schrei, Pfahl, Blech, Faust, Rang, Pult, Nest, Heu, Schicht, Zoll, Stand, Lohn, Angst	
	15	Knecht, Schaf, Lust, Berg, Zeit, Schlamm, Docht, Preis, Kind, Uhr, Mal, Speer, Sinn, Fluss, Rock, Haupt, Gang, Trieb, Schmalz, Boot	
	16	Bund, Stiel, Wachs, Reim, Tor, Geld, Luft, Stück, See, Trotz, Pfad, Heil, Brief, Arzt, Haus, Bund, Fracht, Stern, Loch, Zahn	
	17	Fink, Schlauch, Stab, Reh, Floss, Hirn, Fuchs, Beil, Napf, Teer, Stolz, Art, Wurm, Ding, Trab, Kleid, Bett, Schatz, Wut, Pflock	
	18	Schnitt, Bucht, Land, Helm, Bock, Scherz, Keil, Rast, Gruss, Wohl, Plan, Krieg, Abt, Pfiff, Bein, Sturm, Tee, Mann, Frost	
	19	Frucht, Leib, Zins, Fee, Schar, Gold, Wunsch, Malz, Ton, Stier, Dachs, Heer, Bauch, Kreuz, Akt, Glück, Pfund, Sekt, Molch, Rad	
	20	Fleisch, Gniess, Welt, Rohr, Park, Flut, Saum, Schmerz, Hand, Most, Schuh, Film, Damm, Zeit, Koch, Bad, Spruch, Leid, Biss, Axt	



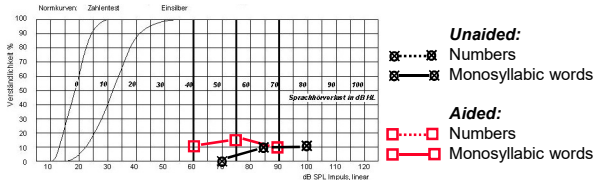
"Hearing loss for speech" (Sprachhörverlust") – link between speech- and pure tone audiogram

- Difference in dB between measured level for 50% speech understanding for numbers and the average level for normal hearing subjects
- Corresponds (mostly) to average hearing threshold at 500,1000 and 2000 Hz in pure tone audiogram



Is the number test really useful?

- Cochlear implant candidate with useful hearing only below 1000 Hz.
- Test with and without hearing aids



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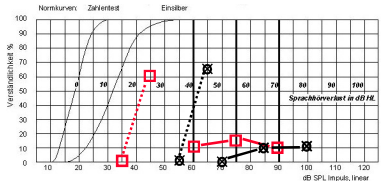


Unaided:
Numbers
Monosyllabic words

Aided:
Numbers
Monosyllabic words

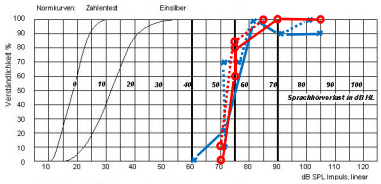
Is the number test useful?

- Provides relatively little additional information in
  - cooperative patients with
  - relatively good hearing

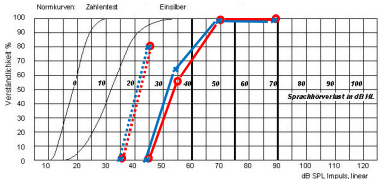
But:

- It can provide important information in patients with poor speech understanding
- It is a very fast and useful tool for
  - quality control and
  - to check the plausibility – can give e.g. important clues in cases of aggravation or simulation

Aggravation in speech audiogram



•With aggravation



•After solution of problems

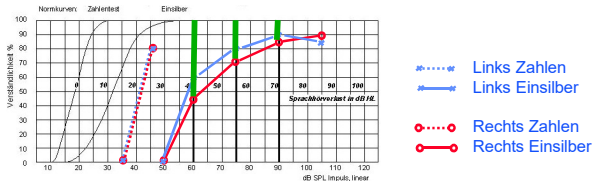
Left numbers
Left words

Right numbers
Right words

Sozialindex: % Hearing loss

- Freiburger Wörter: Average loss at 60, 75, 90 dB
- Example right ear: (55% + 30% + 15%) / 3 = 33.3%

- French monosyllabic words: levels are 5 dB lower



Electric Response Audiometry (ERA)

= Electrical response of the central nervous system to acoustic stimuli

Book chapter 11

Abbreviations and terms

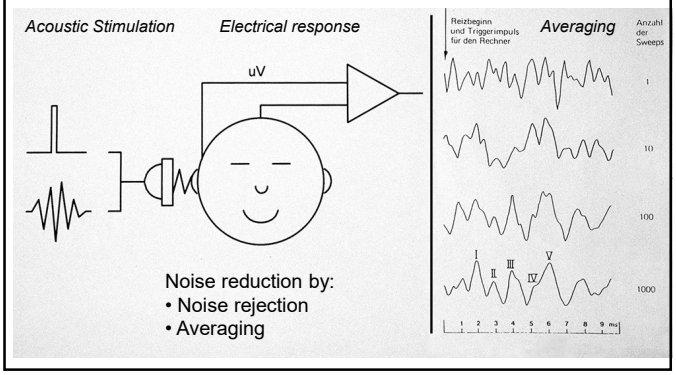
For the measurement procedure:

- ERA = Electric response audiometry
- ERA = Elektrische Reaktions Audiometrie

For the potentials:

- AEP = Acoustically evoked potential
- AEP = Auditorisch evozierte Potentiale

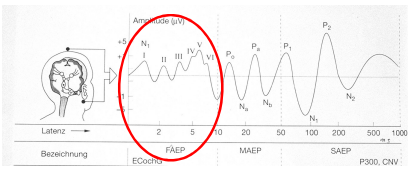
Electric Response Audiometry: Schematic view



Noise reduction by:
- Noise rejection
- Averaging

Different acoustically evoked potentials (AEP)

- Short latency response AEP (1ms - 10 ms)
  - Most frequently used
  - Broadband hearing threshold
  - Vigilance independent
- Middle latency response AEP (10 ms - 50 ms)
  - Partly myogenic source
  - Variable in children
- Late or long-latency response AEP (50 ms – 500 ms)
  - Cognitive effects
  - Vigilance effects



Short latency response acoustically evoked potential

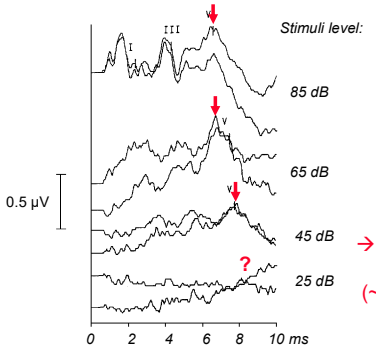
Still more names and abbreviations:

Potentials:
- Auditory brainstem response (ABR)
- Frühe auditorisch evozierte Potentiale (FAEP)

Measurement:
- Brainstem electric response audiometry (BERA)
- Hirnstammaudiometrie

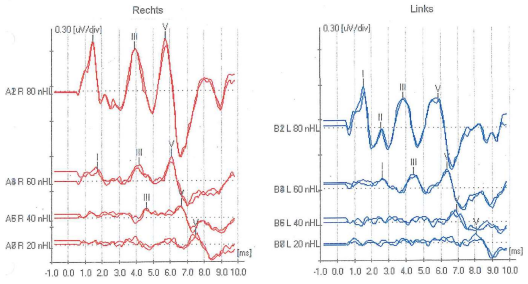
Book chapter 11.1

Short latency response AEP

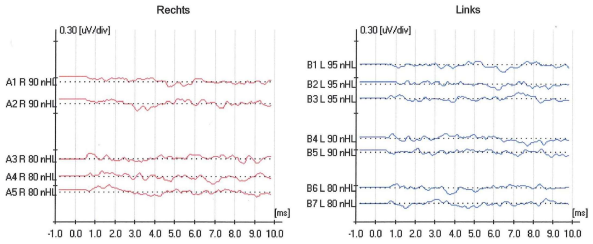


→Hearing threshold at 30-40 dB (~2000 – 4000 Hz)

Example of ABR: normal hearing



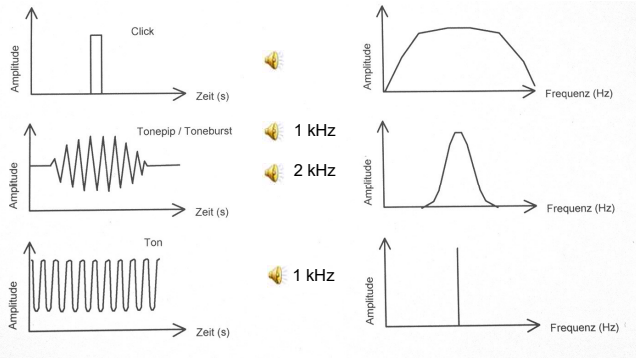
Example of ABR: profound deafness



Where can ABR be used? Examples

- **Children:**
  - To determine (or: to confirm) hearing threshold (frequent: after failed newborn hearing screening using OAE!)
  - Diagnosis of auditory neuropathy
- **Adults:**
  - Suspected malingering or hysterical deafness (Simulation and aggravation)
  - Before cochlea implantation
  - Retrocochlear pathologies
  - Subjects who are unable to cooperate in audiometry

Some signalg in the time- and frequency domain



Frequency specific ERA measurement

(Book chapter 11.2)

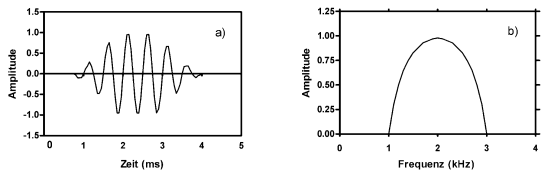
- **Generally:**
  - Measurements take longer
  - Limited reliability below 1000 Hz
  - Used increasingly
- **Selected methods:**
  - ABR with tone-pips
  - Auditory steady state potentials (ASSR)
  - Chirp-ERA

Frequency specific ERA: 3 methods

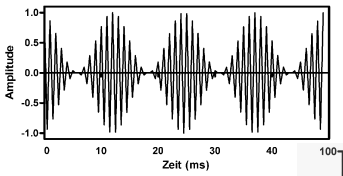
- **ERA with tone-pips instead of clicks:**
  - Limited frequency specificity (can be improved with notched noise)
  - Long duration of measurement
- **Auditory steady state potentials (ASSR):**
  - Simultaneous measurement of several frequencies is possible
  - Could become method of choice in the future
- **Chirp ERA**

(Book chapter 11.2)

ERA with tone-pips

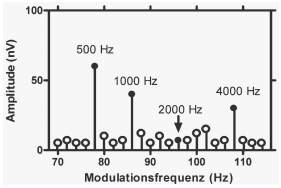


ASSR / MASTER



1000 Hz / 80 Hz

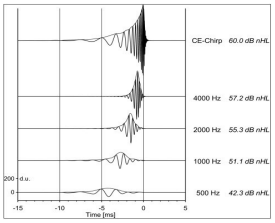
2000 Hz / 84 Hz

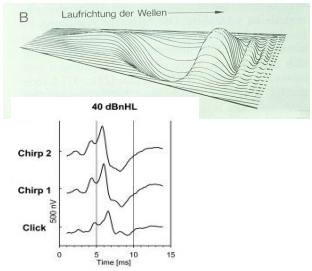


182 ff

Chirp-ERA

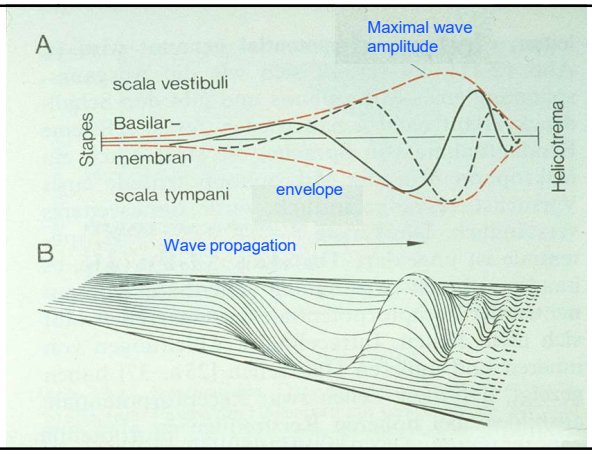
- Rationale:
  - Wave propagation along the Basilar membrane stretches response
  - This can be compensated by presenting low frequencies earlier



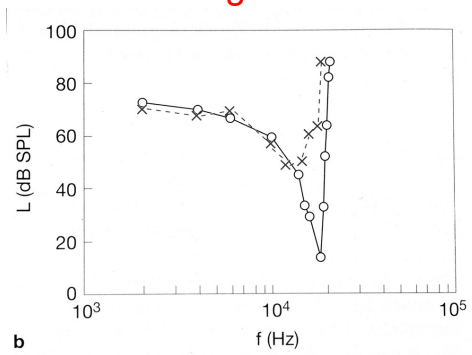


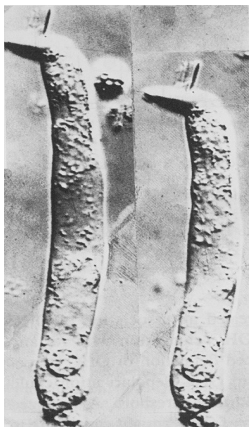
186 f

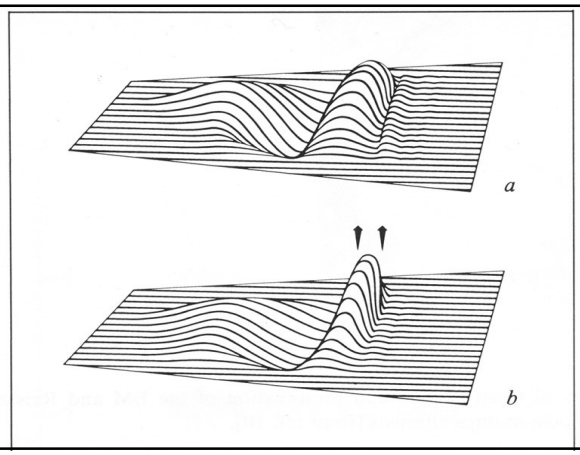
Otoacoustic emissions (OAE)



Tuning curves







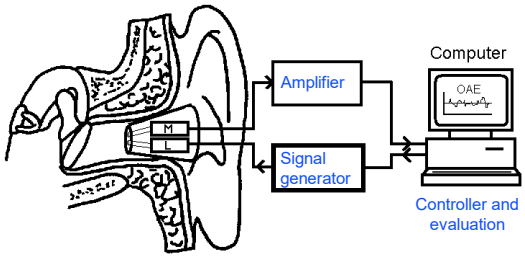
Types of OAE

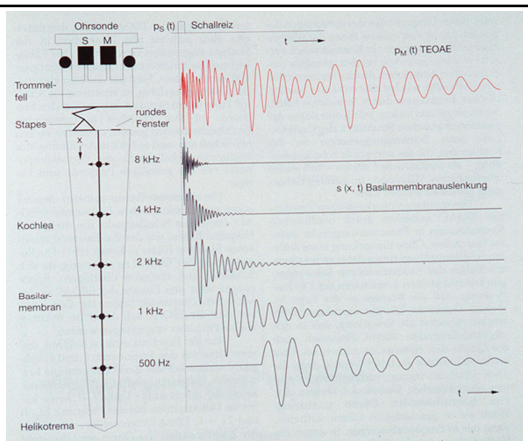
- *(SOAEs*
  = spontaneous otoacoustic emissions)
- *TEOAE*
  = transiently evoked otoacoustic emissions
- *DPOAE*

TEOAE
= transiently evoked OAE

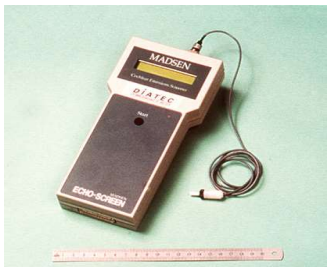
- How to measure: click into ear and measurement of acoustic response
- sound level: approx. 10 dB SPL (infant 20 dB)
- Present in: normal hearing and hearing loss less than 20-30 dB

Principle of OAE measurement

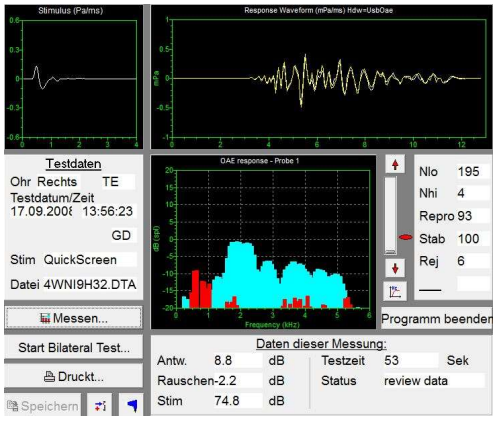


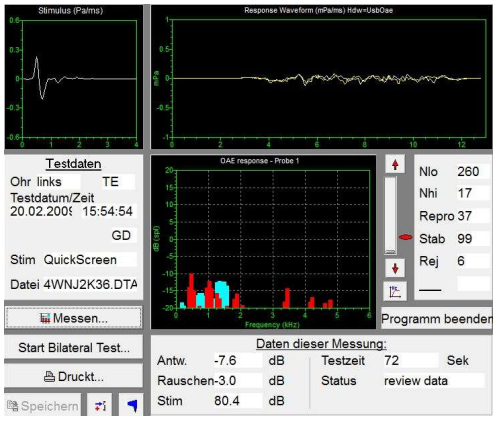


OAE-Measurement



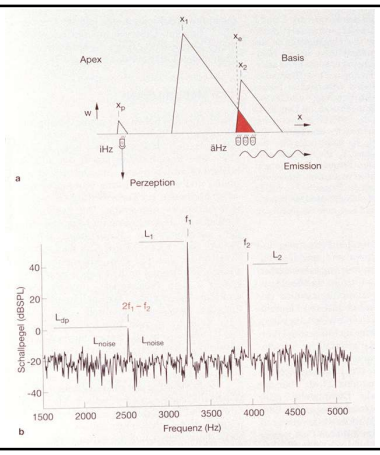
OAE-Measurement



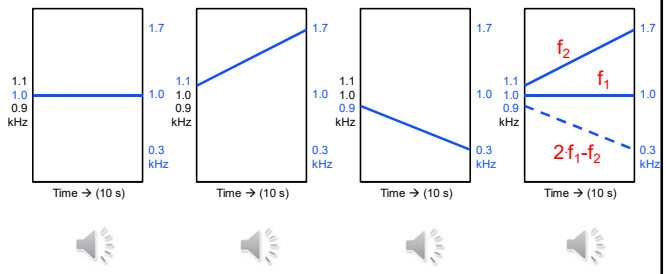


DPOAE
= distortion product emissions OAE

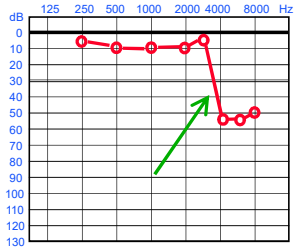
- How to measure: 2 Sinus tones into ear and measurement of distortion
- Present in: normal hearing and hearing loss below approx. 30-50 dB



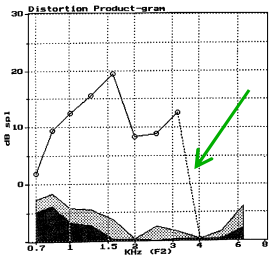
Trying to hear your own DPOAE



DPOAE-Measurement: Example



Audiogram



DP-Gram

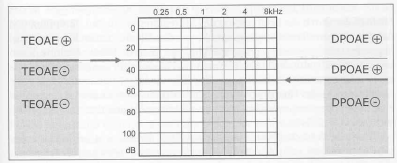
Comparison TEOAE - DPOAE

TEOAE

- Up to 20-30 dB hearing loss
- poorer frequency sensitivity

DPOAE

- Up to 30-50 dB hearing loss
- better frequency sensitivity



OAE: What do we really measure?

- Middle ear function (2x sound transmission)
- Active function of the inner ear

NOT overall hearing

Some frequent uses of OAE

- Screening of newborns
- Verification of subjective hearing test
  - in children (very frequent!)
  - in adults

Tympanometry

Acoustical impendence measurement of tympanic membrane

Book: chapter 9

Acoustical impedance

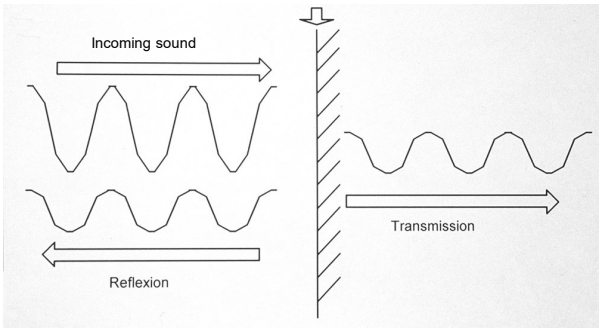
- ***Definition:*** ratio of:

  sound pressure amplitude : motion amplitude

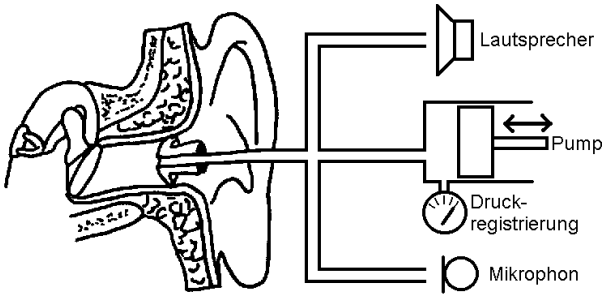
  (low acoustical impendence = soft medium
  high acoustical impendence = stiff medium)

- Characteristic of the material, not of the signal

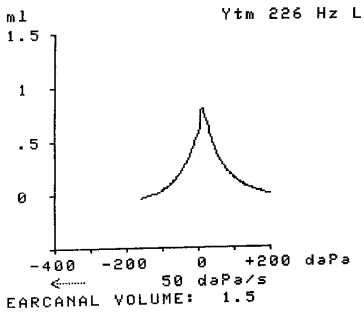
Two media with different acoustical impedances



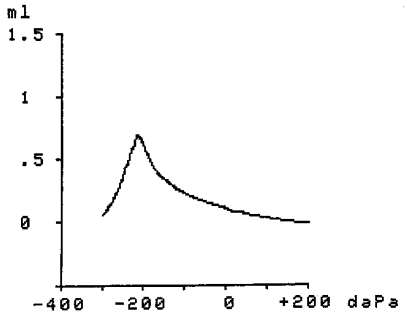
Schematic view of tympanometry



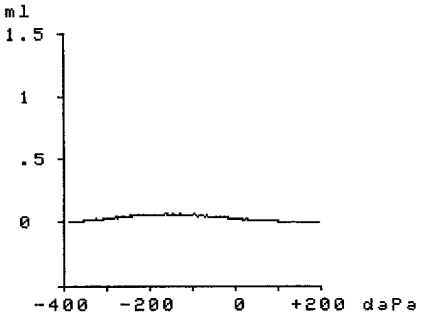
Normal tympanogram (Type A)

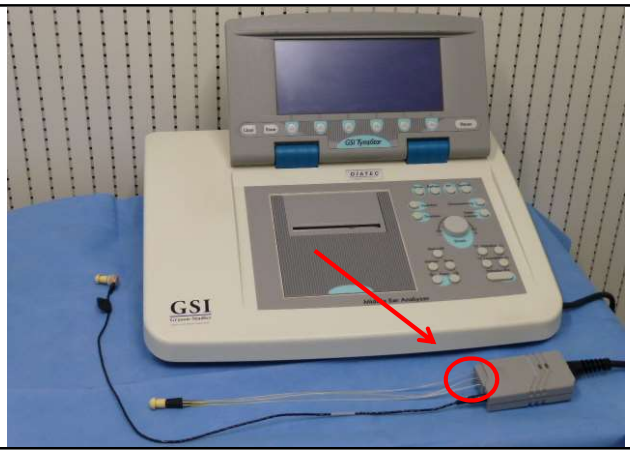


Low pressure in middle ear (Type C)



Middle ear effusion(Type B)





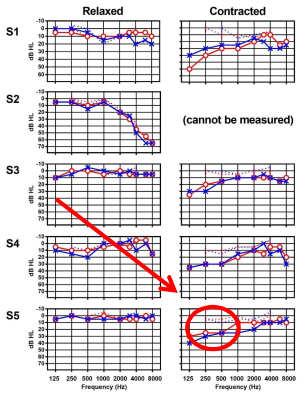
Stapedius reflex measurement

M. Stapedius reflex measurement with tympanometry

Some characteristics of the stapedius reflex

- Always bilateral releasing, even if unilateral loud stimuli (70-100 dB)
- Latency approx. 100 ms
- Does not normally relax within measurement time
- also: 100 ms before your own voice sets in
- Rare:
  - No reflex at all (rare without pathology)
  - voluntary control

Voluntary contraction of middle ear muscles [1]

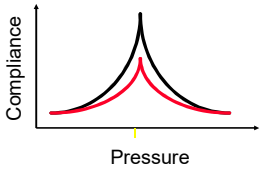


[1] Kompis M et al. Voluntary increase of acoustic middle ear impedances with simultaneous sound attenuation associated with mild hyperacousis (VIMH). Acta otolaryngol. 139(4): 373-378 (2019)

Probable Physiological benefit of stapedius reflex

- Protection of the ear from acoustic trauma by:
  - Loud external stimuli (does not work for very short stimuli!)
  - Own voice (loud!)
- Possible better understanding in noise
  - Higher attenuation of low frequencies

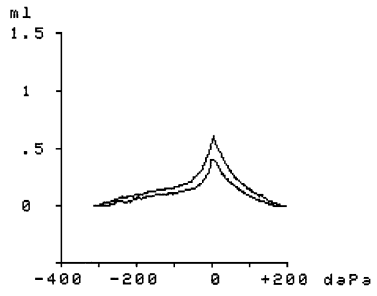
Principle of stapedius reflex measurement



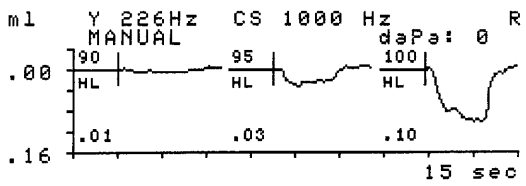
- white: normal
- red: M. Stapedius activated
- Measurement:
  - Height of peak as a function of time

Tympanometry

with and without noise (90dB) at contralateral ear

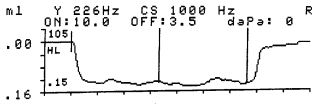


Stapedius reflex

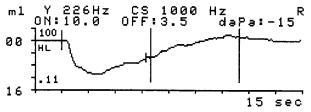


Reflex - decay

Normal –
No decay:



Pathological decay:



Stapedius reflex measurements can give valuable information on:

- Hearing at high levels at ear side of stimulus
- Fixation of stapes
- Recruitment (Metz-Recruitment)
- Sensorineural- vs. conductive hearing loss
- Signs of retrocochlear hearing disorder

Thank you for your attention