

Basics of Audiometry – part 1

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Overview

Psychoacoustic measurements

- Acoustics and hearing
- Pure tone audiometry
- Speech audiometry

Objective Methods:

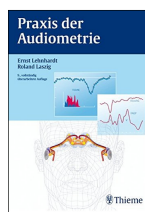
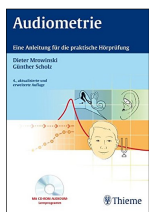
- Tympanometry

Part 2 by Dr. Oppermann

- Otoacoustic emissions
- Acoustically evoked potentials

- Only 10 min per topic

Textbooks on audiology in German

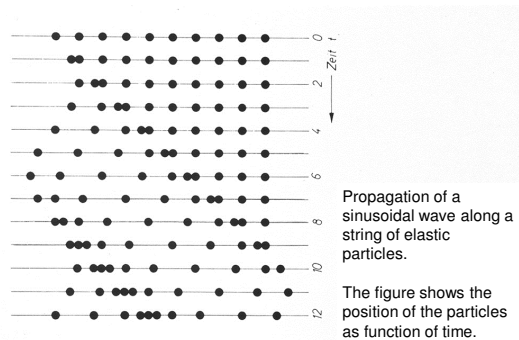


- Several text books are available
- You should own preferably the newest edition of one of them

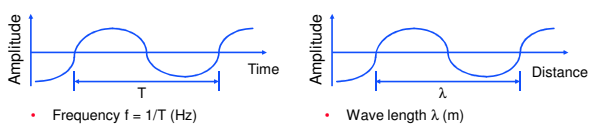
The Basics: Acoustics and auditory perception

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

Longitudinal wave propagation



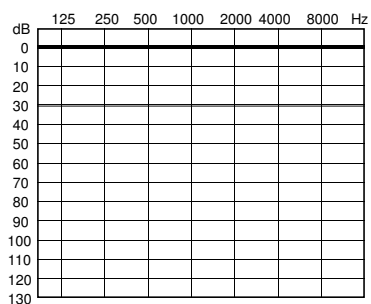
Physical features and perception



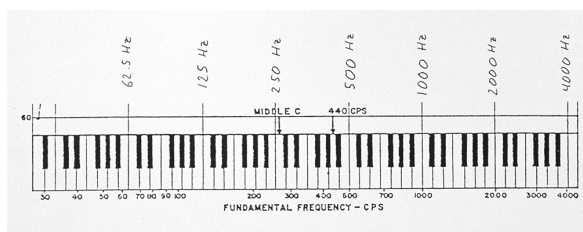
Amplitude corresponds to Loudness

Frequency corresponds to pitch

Audiogramm



Logarithmic perception of frequencies



- 🔊 Logarithmic 8 tones (major)
- 🔊 Linear 8 tones (Nasca)
- 🔊 13 tones log & lin

Tuning of a piano

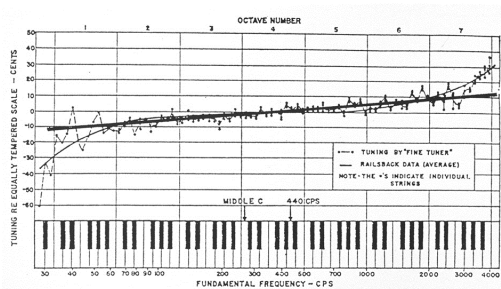


FIG. 1. Tuning of a piano (from Ref. 1), thick line: PFTS.
J. Acoust. Soc. Am., Vol. 104, No. 5, November 1998
Klaus Gillesen: Letters to the Editor 3124

dB = Logarithmic scale

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




$$L_{dB} = 10 \cdot \log_{10} (P_1/P_0) \quad (\text{Power or energy})$$
$$= 20 \cdot \log_{10} (A_1/A_0) \quad (\text{Amplitude})$$

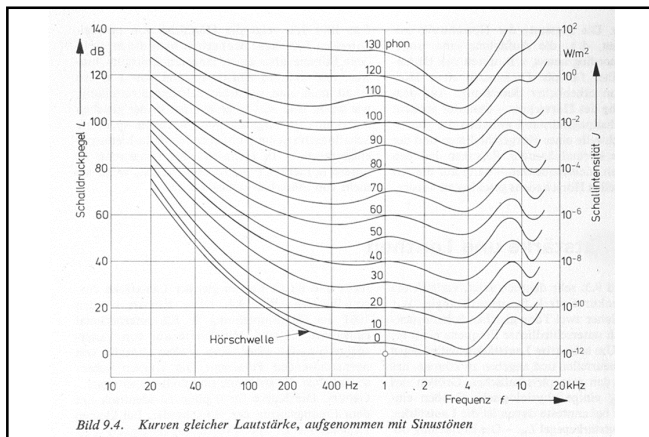
dB = logarithmic scale

10 dB

- = factor of 10 in power / energy
- = approx. factor of 2 in subjective loudness

Examples: logarithmic perception of loudness

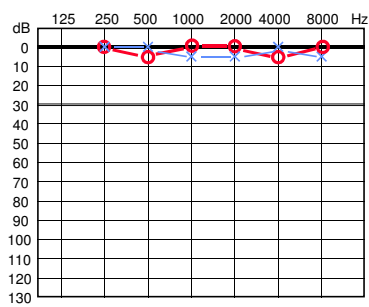
- Logarithmic: 20 steps of 1 dB 
- Logarithmic: 12 steps of 5 dB 
- Linear: 10 steps, reduction in amplitude 10% per step 



Pure tone audiometry

= measurement of hearing thresholds as a function of the frequency

Normal audiogram



Audiometric symbols (CH, international)

	Left ear:		Right ear:	
	No masking	masking	No masking	masking
Air conduction (AC):	×	□	○	△
Bone conduction (BC):	>	◻	<	◻
Uncomfortable level:	✕		⊖	

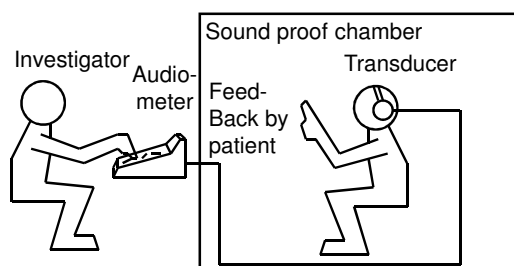
Note: AC: right = red = round
BC: right: open to the right

Audiometric symbols (D)

	Left ear:		Right ear:	
	With and without masking	With and without masking	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"

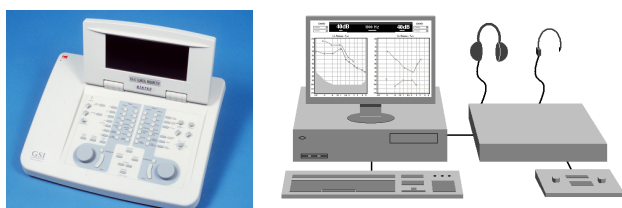
Set-up for Audiometry: Schematic view



Sound proof chamber



Audiometer

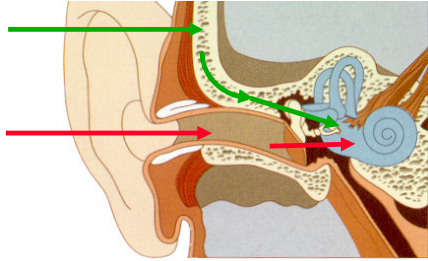


Transducers

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

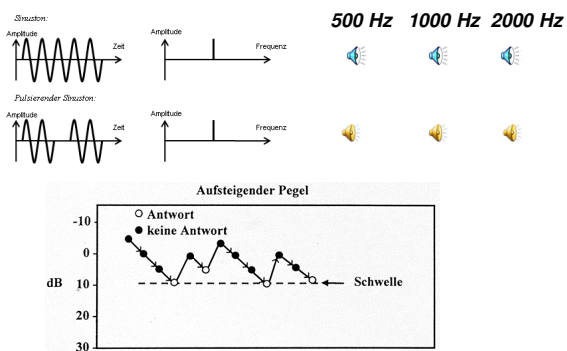


Air conduction and bone conduction



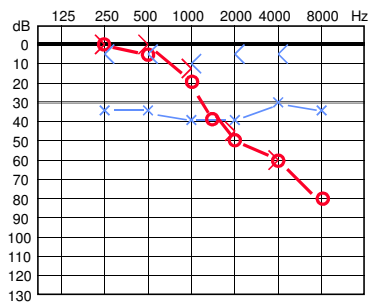


Signals and test paradigms

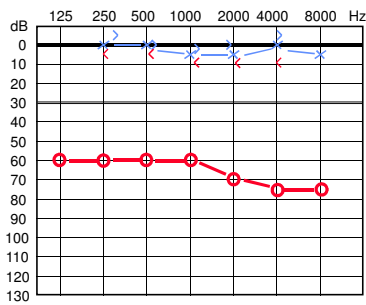




Conductive and sensorineural
hearing loss in an audiogram

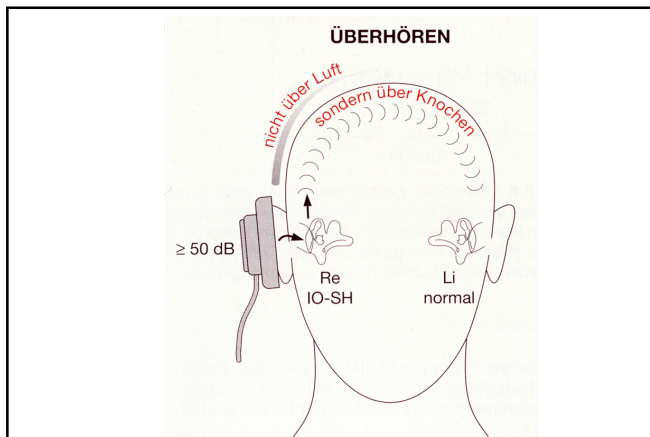


Shadow curves



Example for a
measurement
without masking

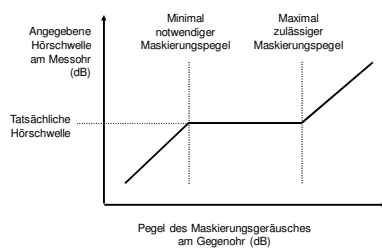
The right ear
is completely
deaf...



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

Prinzip der gleitenden Vertäubung



Speech audiometry

= Evaluation of speech understanding
using standardized tests

Some speech tests used in Switzerland

Test in quiet:

- German:
 - Freiburger Wörter
 - Freiburger Zahlen
- French:
 - Mots dissyllabiques
 - Mots monodissyllabiques
- Italian:
 - Bocca e Pellegrini: Parole
 - Bocca e Pellegrini: Numeri

Test in Noise:

- Basler Satztest
- Words in noise (WIN)
- Matrix tests (OLSA in German)
- 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		

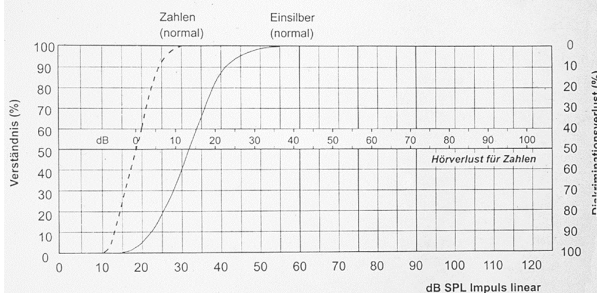
Freiburger Wörtestest - Schweizeraufsprache 1987 nach F. Keller

dB	Orp	% 14
1	Nuss Wolf Braut Kern Fang Klotz Hund Stuck Zahi Ring Lärm Geiz Dursl Bach Schveck Spott Aas Teig Hart Stich	
2	Holz Russi Meix Stern Gled Fleck Schloss Fall Busch Weik Dach Eid Knie Traum Pass Kunst Mönch Bart Los Schrift	
3	Bier Stih Mohn Zweck Aal Furcht Leim Dorf Tal Keil Schutz Wind Maus Klee Schiltz Bank Stock Wuchs Ref Glas	
4	Schnee Laub Kunst Fass Gift Peil Mund Kopf Reiz Heil Grot Frot Del Fluss Dang Schlem Takt Korn Stoss Ball	
5	Ziel Punkt Fest Schein Darm Torf Lamm Wehr Glas Huf Spess Plau Block Arm Neid Stroh Wurf Rest Bick Schlag	
6	Sel Pfand Netz Fluss Schild Ochs Draht Hemd Schmutz Tau Rat Milch Rost Kahn Ter Dursl Brot Haar Feld Schwein	
7	Spel Moss Lachs Gut Erz Baum Sand Reiz Kuh Wort Schil Hecht Bruch Hang Fels Schopf Kranz Teich Star Dienst	
8	Du! Band Kost Ski Feind Herl Pfug Tal Gift Raum Zeug Ernst Fach Grot Speck Sitz Moor Last Krach Schwung	
9	Specht Eis Funk Rahm Weg Thron Rind Spass Klotz Blei Markt Schil Hut Korb Zank Lauf Kies Dank Schnur Pech	
10	Horn Pfeil Kamm Gips Turm Spess Recht Sprung Zopt Schall Stau Bass Fell Pracht Mas Gramm Sieb Chi Lump Dreck	
11	Ble Ast Fresh Puhm Herz Mond Cam Bau Sohn Vuh Kress Lack Pfend Schlacht Pelz Teil Witz Rand Stuhl Zorn	
12	Brett Saft Schuss Pliz Ort Kraut Schwert Gless Tag Vieh Spat Sohn Druck Held Bahn List Flug Narr Kork Reis	
13	Staub Tracht Herd Licht Not Wein Fluch Kalk Lehm Grund Fass Schmed Amt Ross Puls Meer Graf Bier Schweis Dolch	
14	Schm Rul Gas Wert Brud Korn Dieb Schrei Pfahl Blech Faust Rang Pulf Nest Heu Schicht Zoll Stand Lohn Angst	
15	Knecht Schaf Lust Berg Ziel Schlemm Docht Preis Kind Uhr Mai Speer Sinn Fluss Rock Haupt Gang Treib Schmalz Boot	
16	Bund Stel Wachs Rem Tor Geld Luß Stück See Trotz Pfad Heil Brief Arzt Haus Bund Fracht Stern Loch Zahn	
17	Fink Schlauch Stab Reh Floss Hen Fuchs Bel Nagel Teer Stolz Art Wurm Ding Trab Kleid Bett Schaltz Wuf Ploock	
18	Schmit Bunt Land Helm Bock Scherz Keil Rast Gruss Wapf Plan Krieg Ast Pfid Bein Sturm Tee Mann Frosch	
19	Frucht Leib Zins Fee Schar Gold Wunsch Malz Ton Stier Dachs Heer Bauch Kreuz Ast Glück Pfund Sekl Molch Rad	
20	Fleisch Gress Welt Rohr Paik Flut Saum Schmerz Hand Mast Schuh Film Damm Zeit Koch Bad Spruch Leid Blas Ast	

Freiburger Wörtestest - Schweizeraufsprache 1987 nach F. Keller

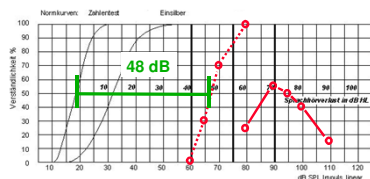


SPRACHAUDIOGRAMM



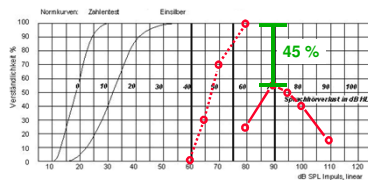
1st Important term: Sprachhörverlust
("hearing loss for speech")

- Difference in dB between measured level for 50% speech understanding for numbers and the average level for normal hearing subjects
- Usually corresponds well to threshold average at 500/1000 and 2000 Hz in pure tone audiogram



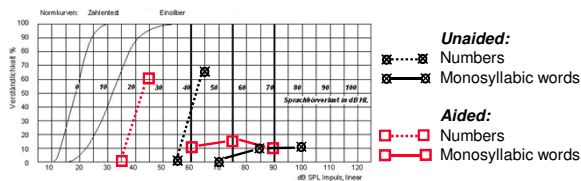
2nd Important term: Diskriminationsverlust ("loss of discrimination")

- Difference between maximal understanding for monosyllabic words and 100 %



Is the number test really useful?

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



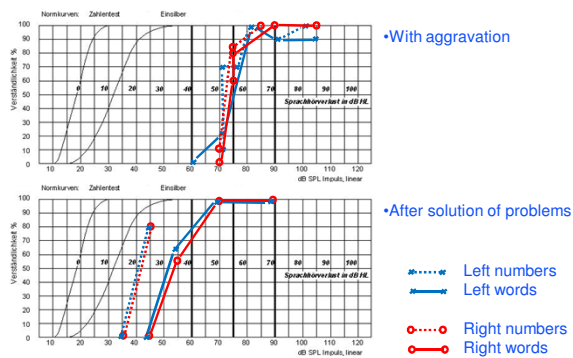
Is the number test really useful?

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

But:

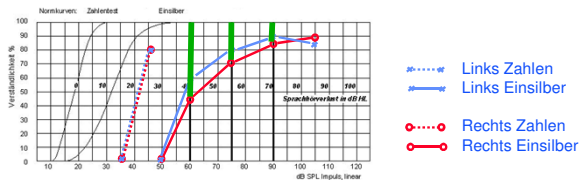
- It provides important information in patients with poor speech understanding
- It is a very fast and useful tool for
 - quality control and
 - to check the plausibility of your measurement (e.g. can give important clues in cases of aggravation or simulation)

Aggravation in speech audiogram



Sozialindex: % Hearing loss

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



Tympanometry

Acoustical impedance measurement of tympanic membrane

Book: chapter 9

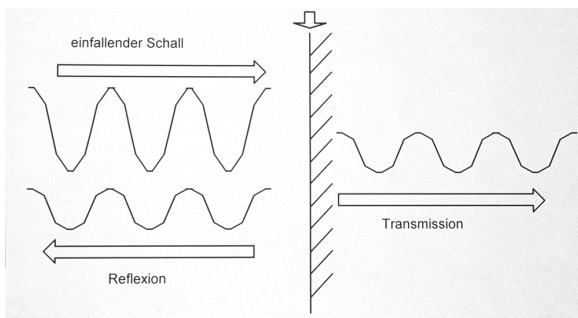
Acoustical impedance

- **Definition:** ratio of:

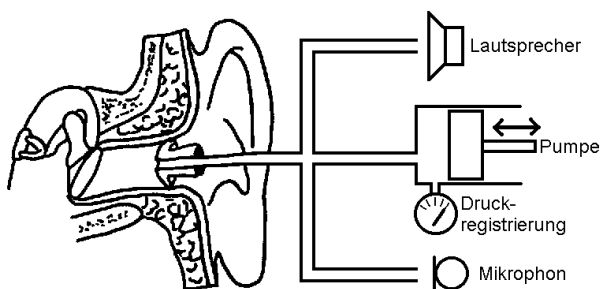
sound pressure amplitude : motion amplitude

(low acoustical impedance = soft medium
high acoustical impedance = stiff medium)
- Medium characteristic, not signal characteristic

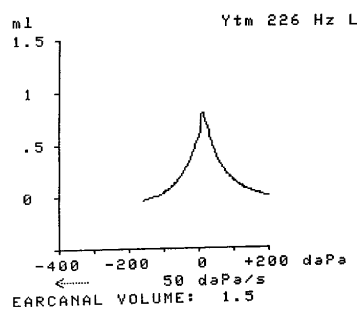
Sudden change acoustical impedance



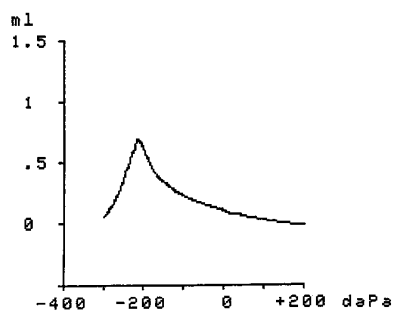
Schematic view of tympanometry



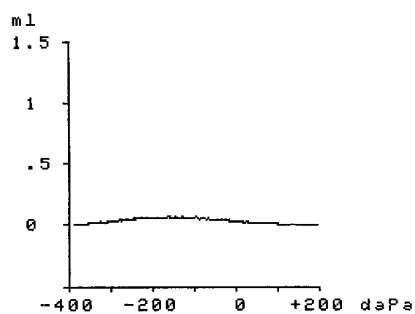
Normal tympanogram (Type A)



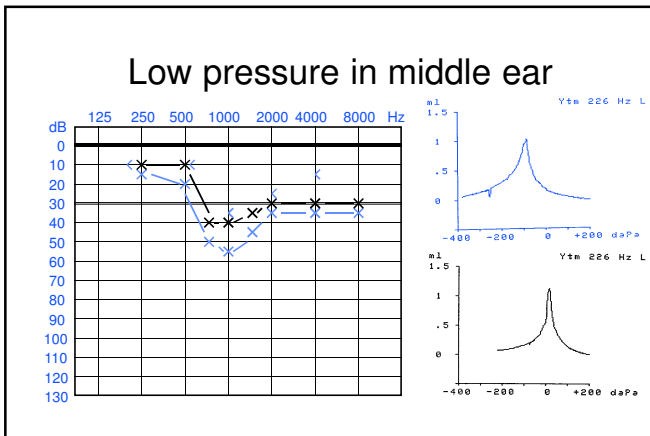
Low pressure in middle ear (Type C)



Middle ear effusion (Type B)







Tympanometry: Characteristics and limits

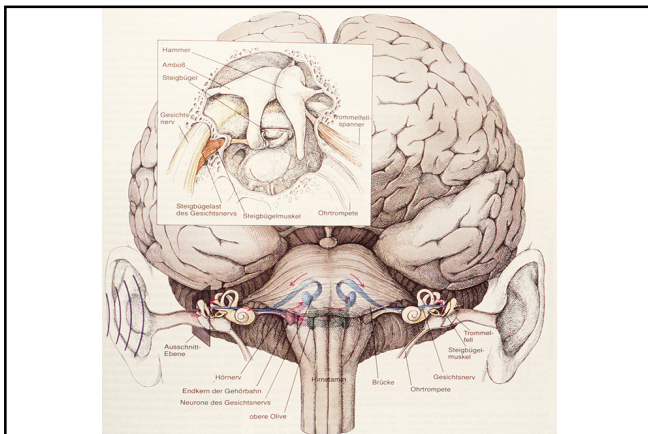
- Fast (< 1 min)
- Non-invasive
- Provides useful information about middle ear

requirements:

- Free external ear channel, intact tympanic membrane
- measuring probe can be properly placed

Stapedius reflex measurement

M. Stapedius reflex measurement with tympanometry



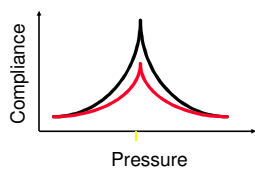
Some characteristics of the stapedius reflex

- 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 of reflex (extremely rare)

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

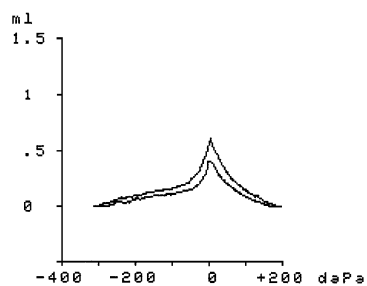
Principle of stapedius reflex measurement



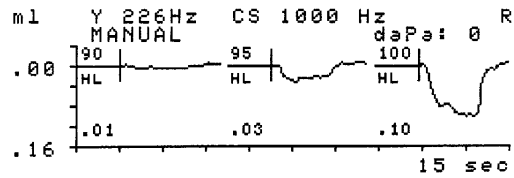
- white: normal
- red: M. Stapedius activated
- Measurement:
 - Height of peak as a function of time

Tympanometry

with and without noise (90dB) at contralateral ear

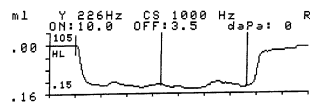


Stapedius reflex

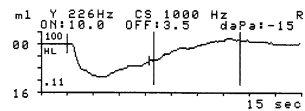


Reflex - decay

Normal –
No decay:



Pathological
decay:



Stapedius reflex measurements can convey valuable information on:

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