Applications of OAE in the prediction of hearing threshold

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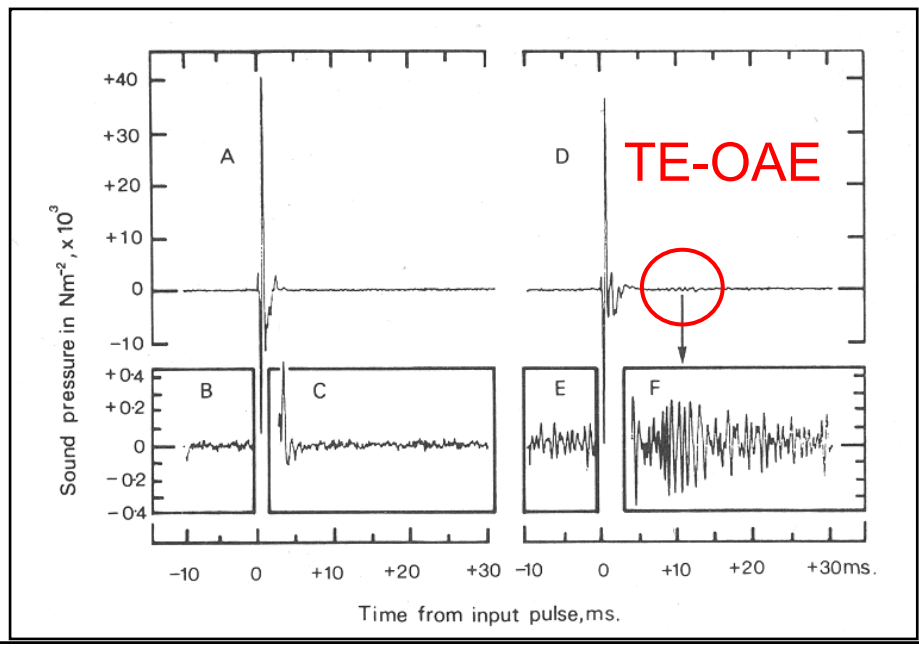
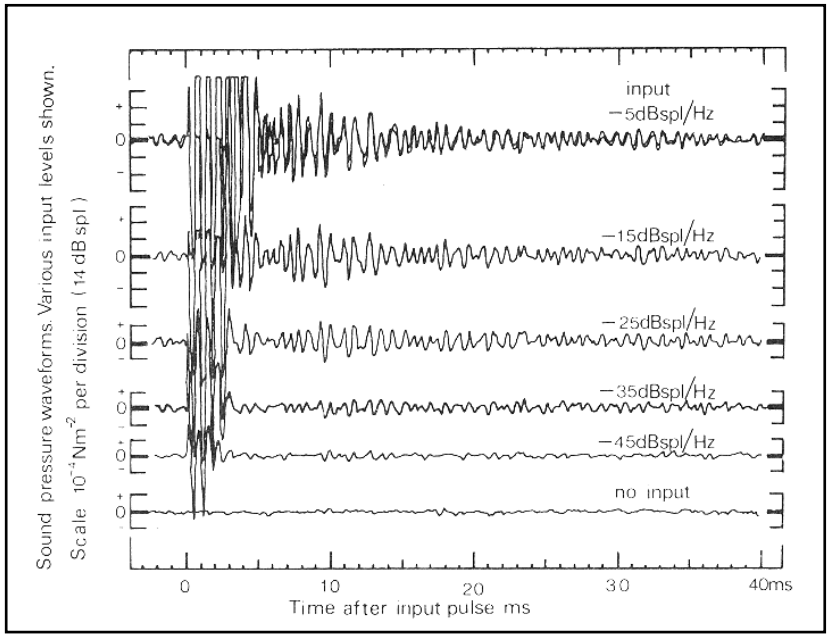
Kemp, J Acoust Soc Am 1978; 64:1386-91: Fig. 1



Kemp, J Acoust Soc Am 1978; 64:1386-91: Fig. 3



Important characteristics of OAEs

- OAEs are objective tests (only passive participation of subjects require).
- OAEs are weak acoustic signals in relatively noisy and changing background.
- OAEs are non-neural, cochlear mechanical signals, they do not depend on neural structures or consciousness.
- OAEs are recorded through the middle ear, they depend on the middle ear transfer properties.

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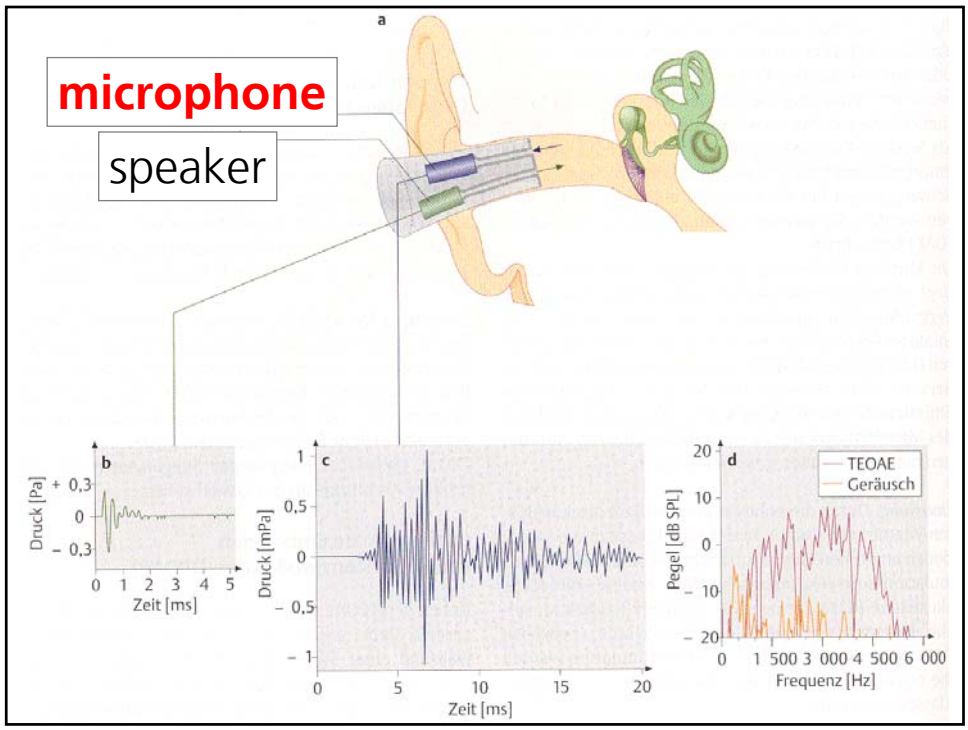
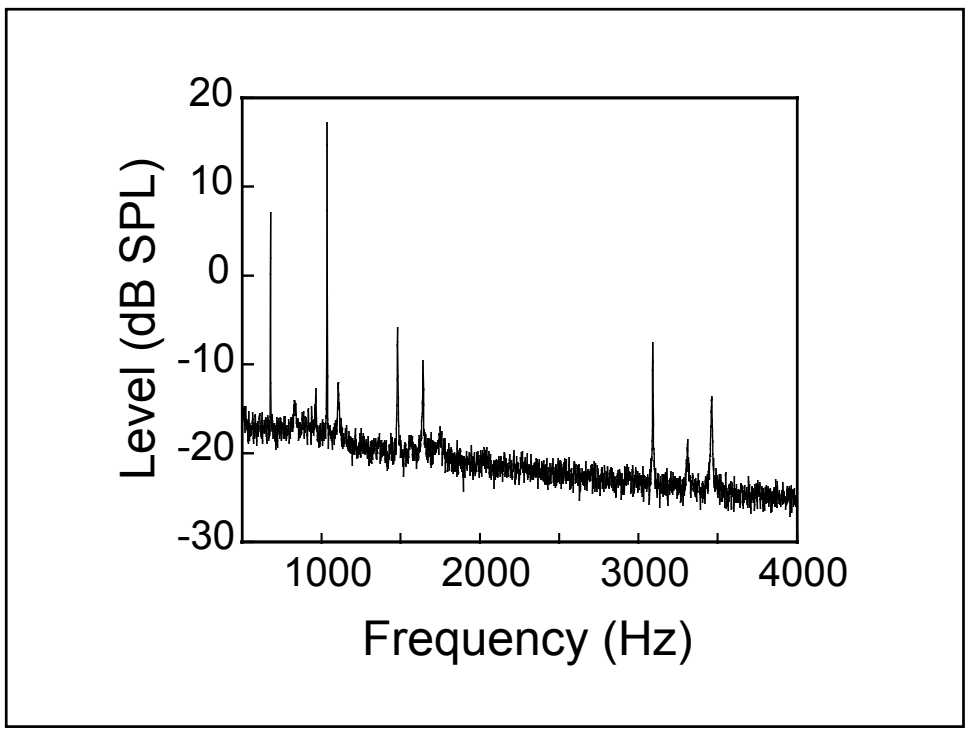
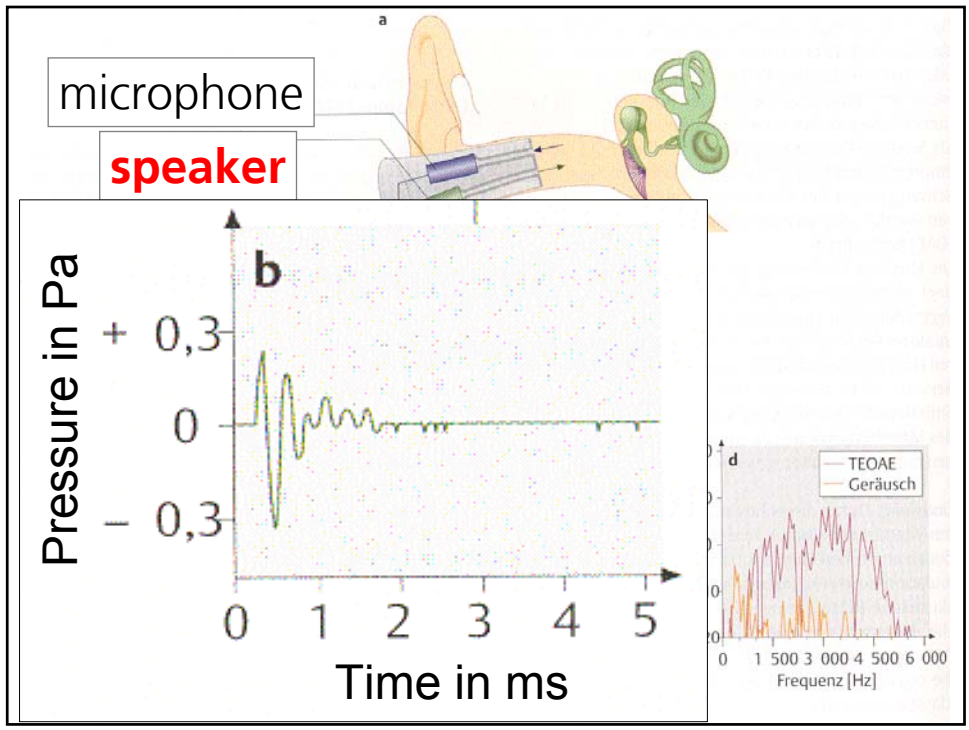
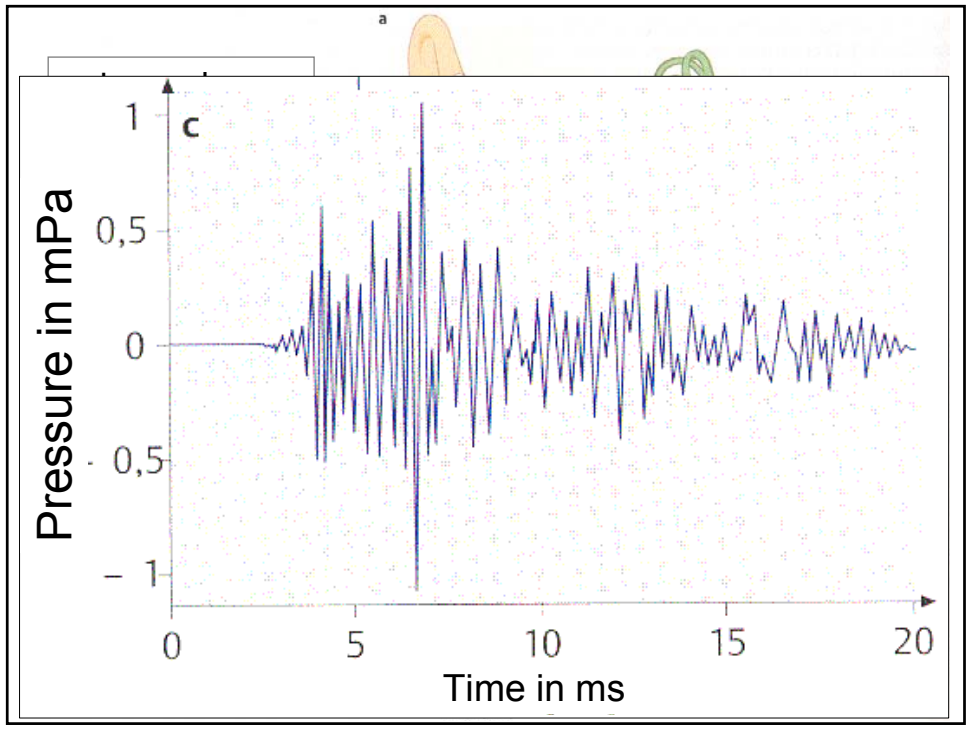
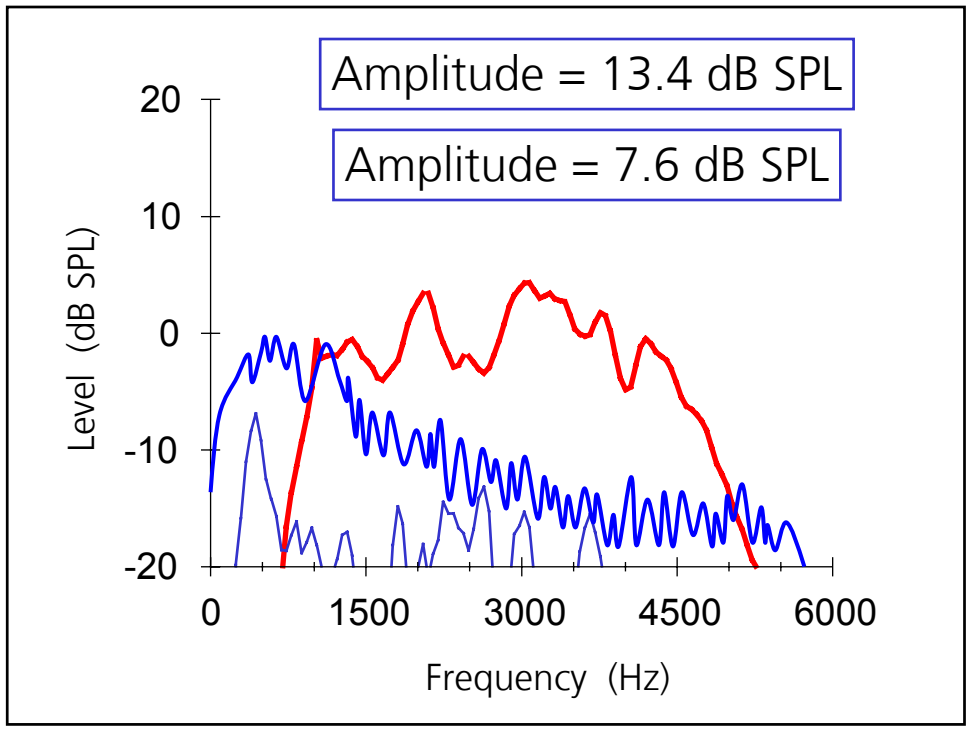
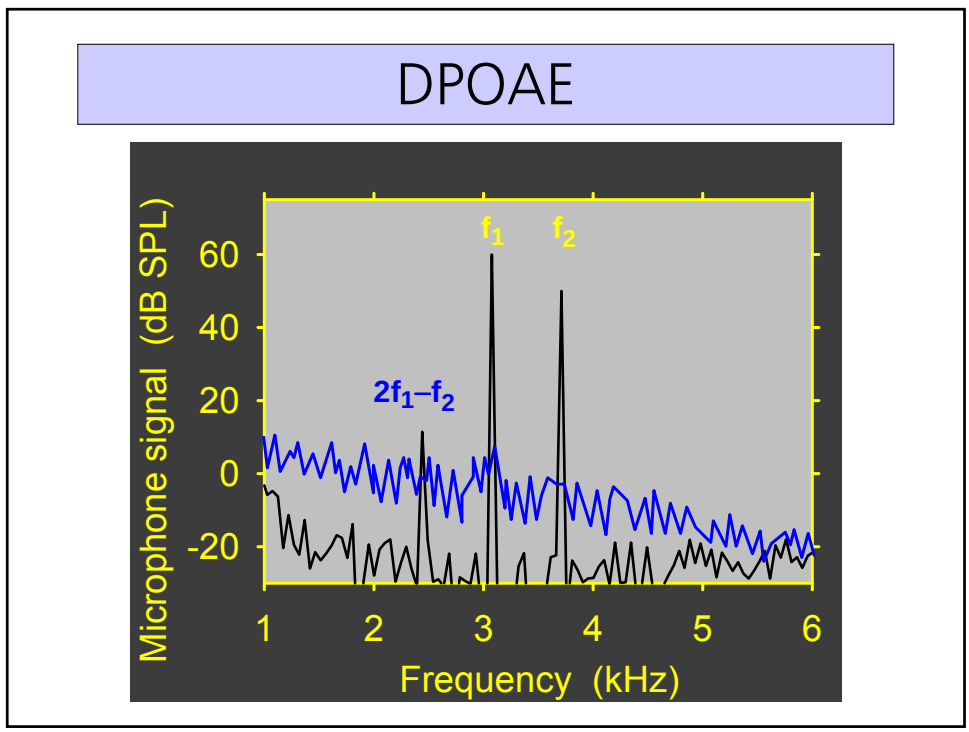

a
microphone
speaker
b
Druck [Pa]
+ 0,3
0
– 0,3
0 1 2 3 4 5
Zeit [ms]
c
Druck [mPa]
1
0,5
0
– 0,5
– 1
0 5 10 15 20
Zeit [ms]
d
Pegel [dB SPL]
20
10
0
– 10
– 20
TEOAE
Geräusch
0 1 500 3 000 4 500 6 000
Frequenz [Hz]


Level (dB SPL)
20
10
0
-10
-20
-30
1000
2000
3000
4000
Frequency (Hz)


a
microphone
speaker
b
Pressure in Pa
+ 0,3
0
– 0,3
0 1 2 3 4 5
Time in ms
d
TEOAE
Geräusch
0 1 500 3 000 4 500 6 000
Frequenz [Hz]


a
c
Pressure in mPa
1
0,5
0
– 0,5
– 1
0 5 10 15 20
Time in ms


Amplitude = 13.4 dB SPL
Amplitude = 7.6 dB SPL
Level (dB SPL)
20
10
0
-10
-20
0
1500
3000
4500
6000
Frequency (Hz)


DPOAE
Microphone signal (dB SPL)
60
40
20
0
-20
f1
f2
2f1–f2
1
2
3
4
5
6
Frequency (kHz)

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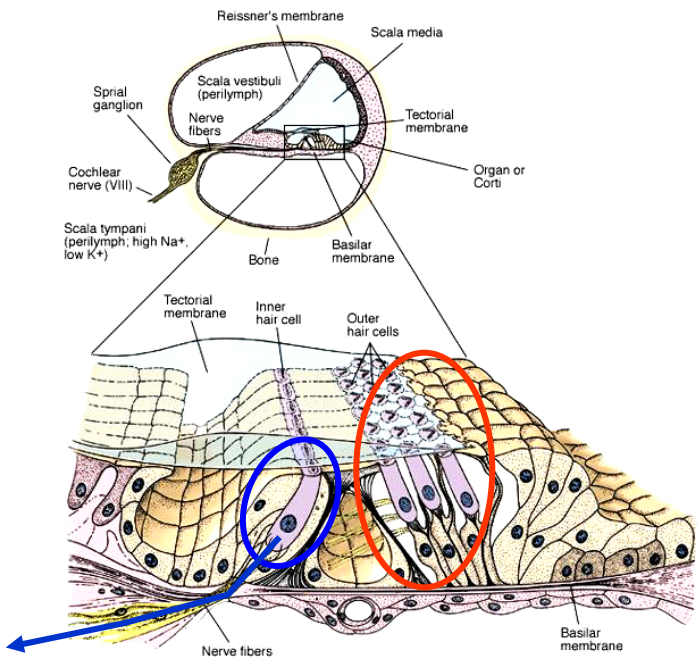
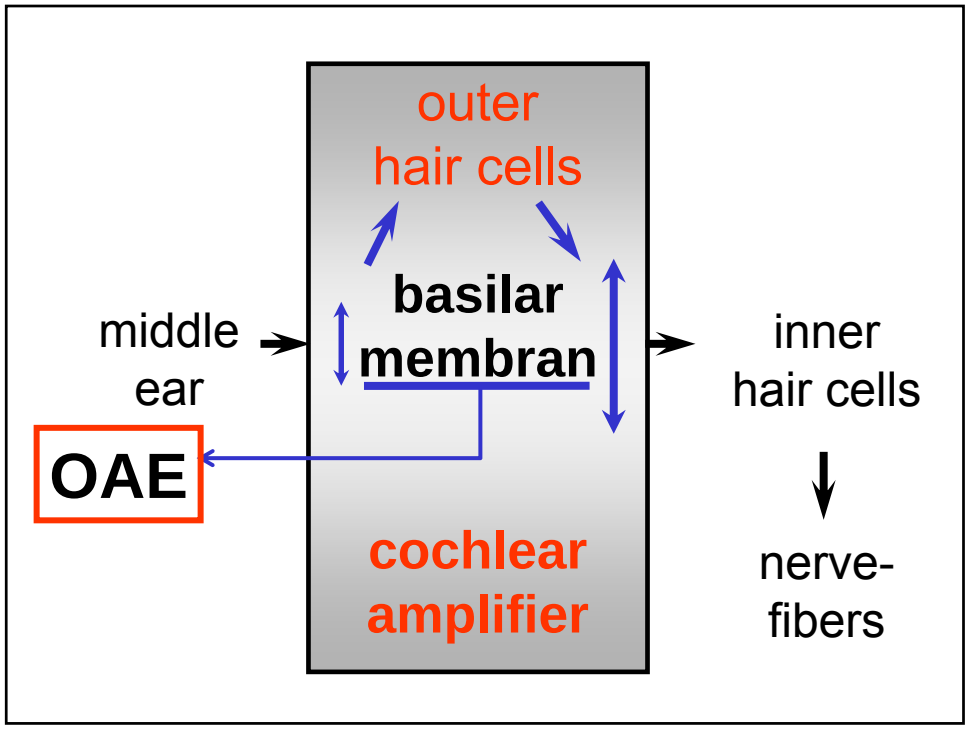
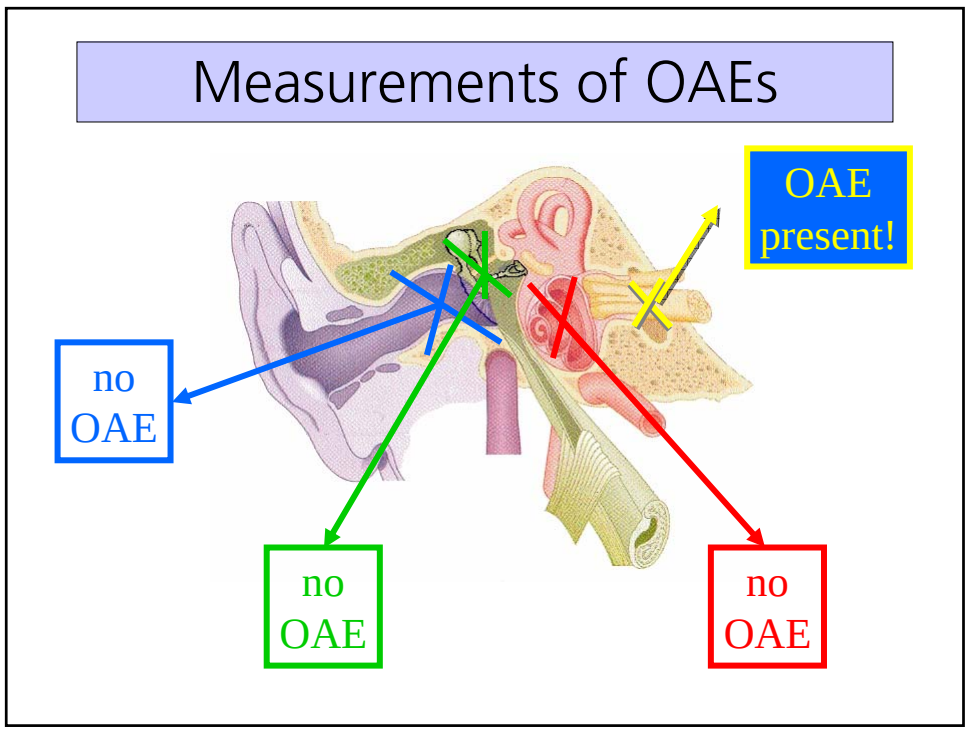



outer
hair cells
basilar
membran
middle
ear
OAE
inner
hair cells
nerve-
fibers
cochlear
amplifier


Measurements of OAEs
OAE
present!
no
OAE
no
OAE
no
OAE

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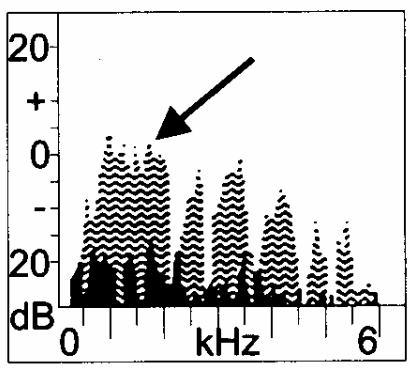
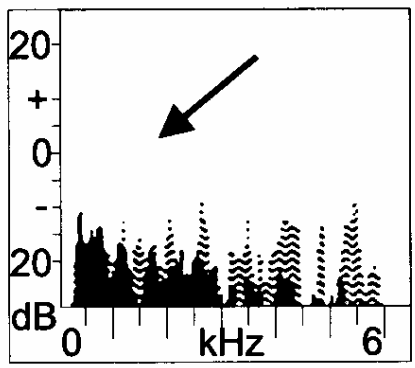
Influence of pressure on TEOAE



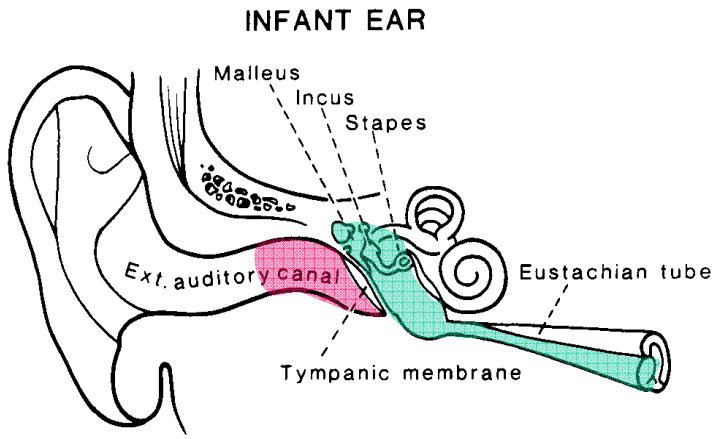
normal ambient
air pressure (0 kPa)



raised ambient
air pressure (8 kPa)

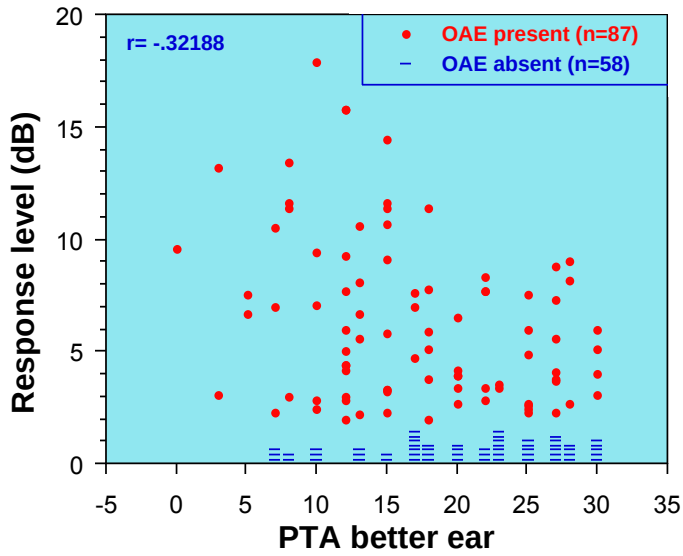
Hauser et al., 1993

OAE Screening in Newborns

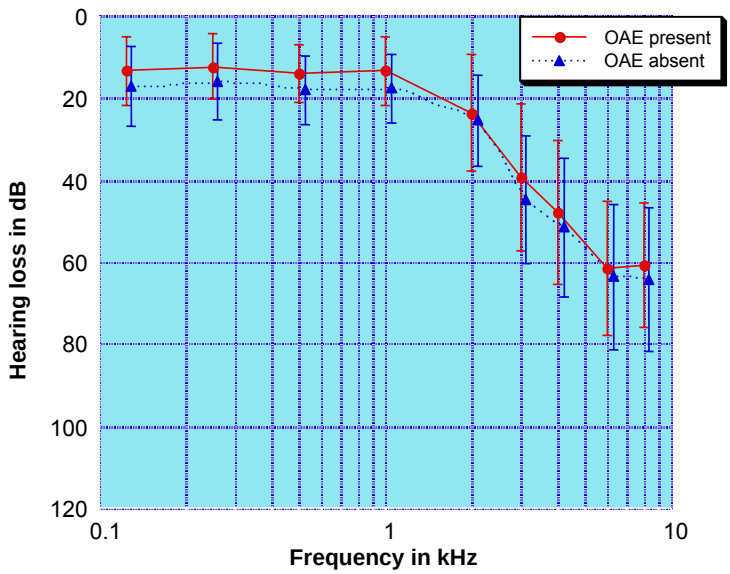


OAE measurements in the first 2 days unrelaible

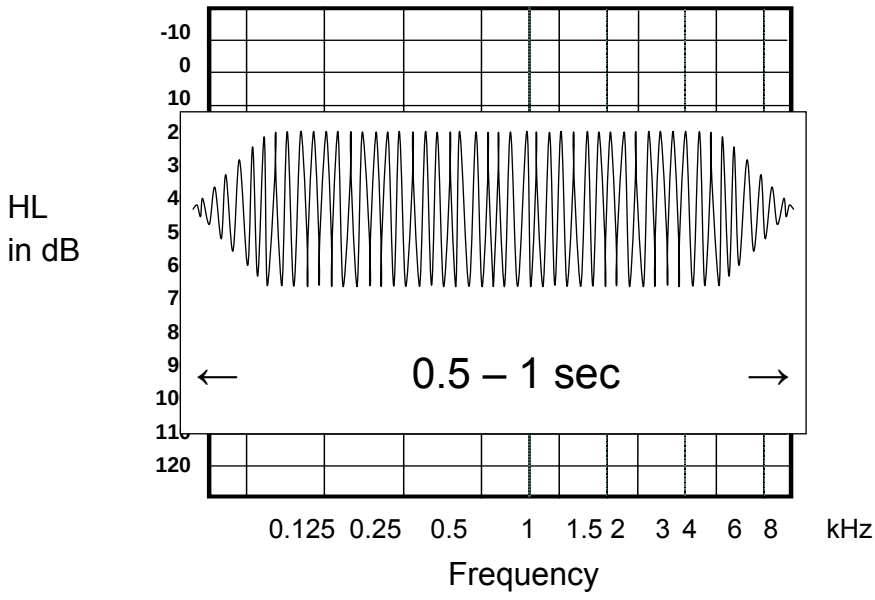
Response level as a function of hearing threshold (for ears with PTA < 30 dB)



Pure-tone audiogram of ears with a PTA <30 dB



Pure tone audiometry

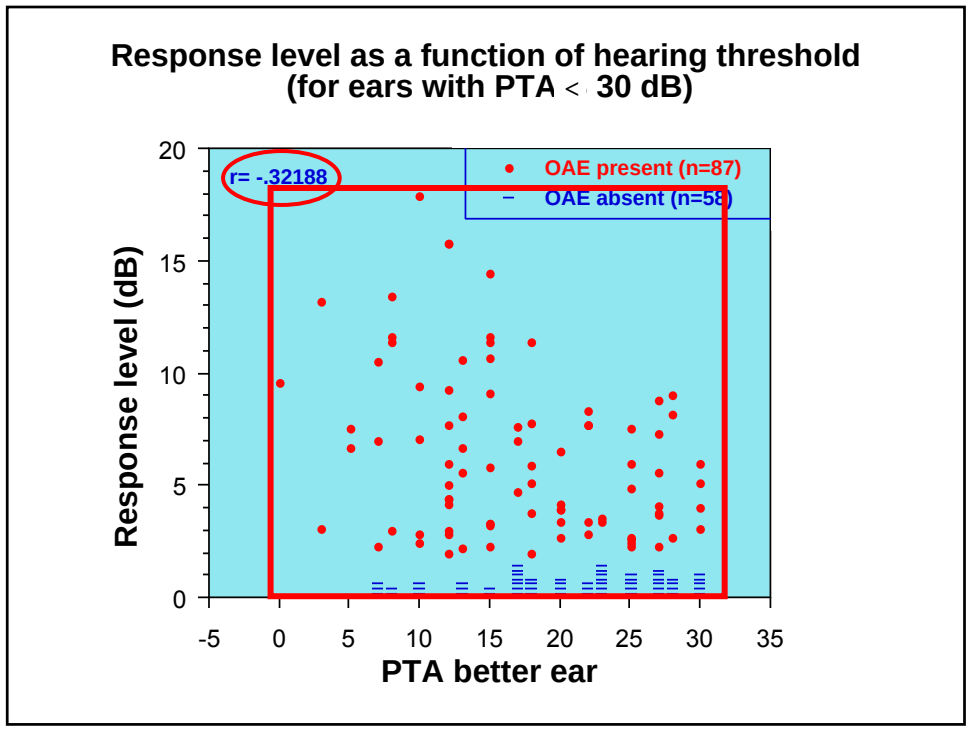


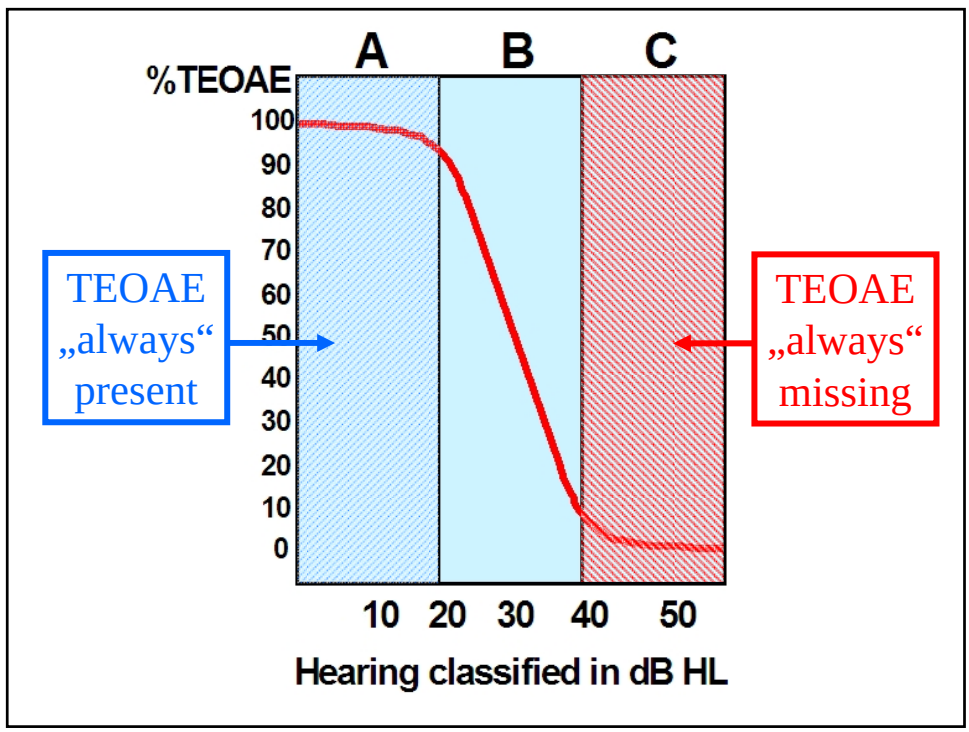
TEOAE und pure tone audiogram

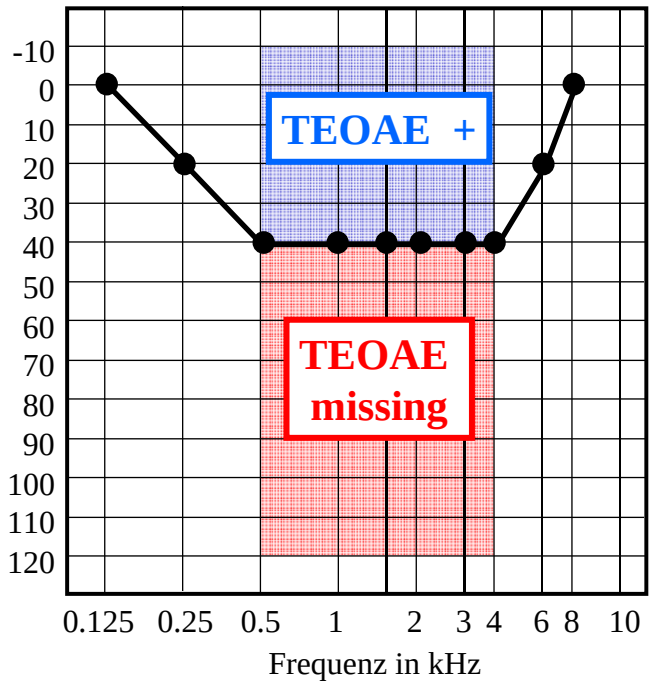
TEOAE:
- click, transitory (5 ms)
- supra threshold stimulus
- broadband response

Tone audiogram:
- long stimulus (0.5 s)
- hearing threshold test
- single frequencies

Common basis – clear differences


Response level as a function of hearing threshold
(for ears with PTA < 30 dB)
r= -.32188
OAE present (n=87)
OAE absent (n=58)
Response level (dB)
PTA better ear
0
5
10
15
20
-5
0
5
10
15
20
25
30
35

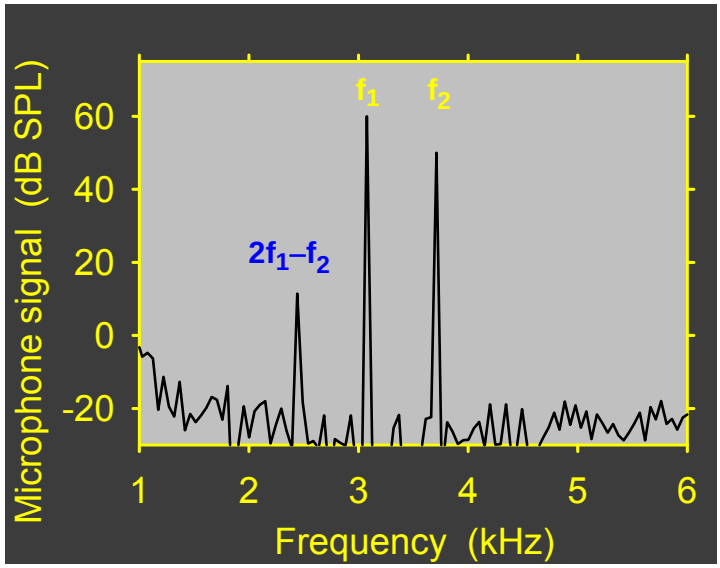

%TEOAE
A
B
C
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
Hearing classified in dB HL
TEOAE „always“ present
TEOAE „always“ missing



TEOAE and threshold

- Thresholds can be estimates by TEOAEs between around 800 Hz and 4.5 kHz.
- Thresholds are better than 35 dB in frequencies, in which TEOAEs are present.
- Missing of TEOAEs at certain frequencies is unspecific, the threshold cannot be estimated.
- The threshold must be further evaluated if no TEOAEs can be recorded.

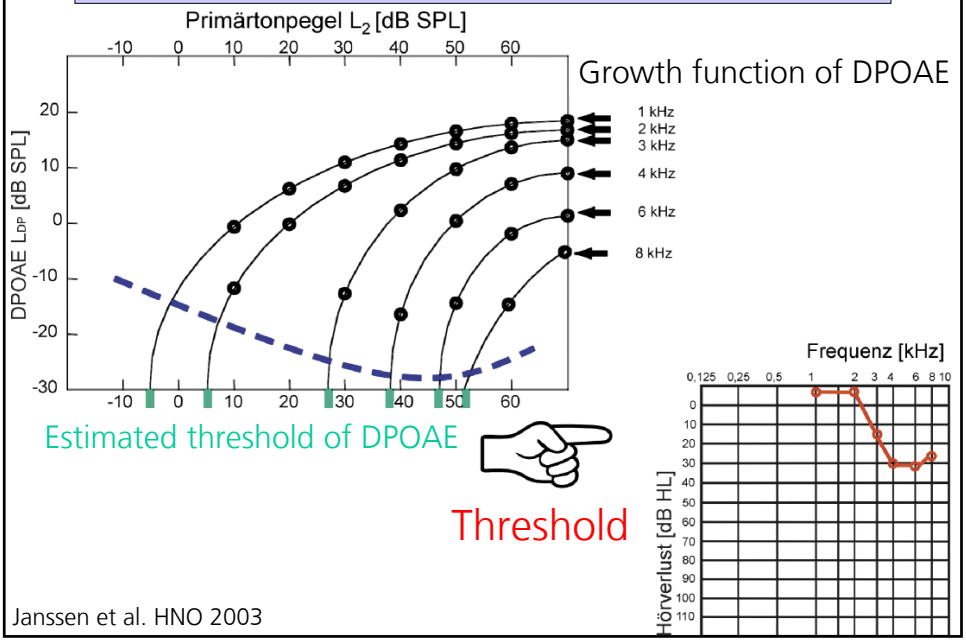
DPOAE



Characteristics of DPOAEs

- DPOAEs use long pure tones as stimuli, allowing to concentrate acoustic energy at a narrower frequency range.
- DPOAE can be recorded up to a hearing threshold of 45-50 dB HL at individual frequencies.
- DPOAEs have better responses at higher frequencies, up to 6 kHz.
- DPOAEs are prone to artifacts at higher stimulus levels (~ 65-70 dB SPL).

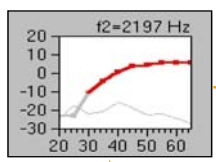
Estimation of threshold by DPOAEs



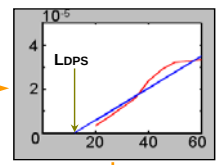
Janssen et al. HNO 2003

DPOAE-threshold measurements

Meßtechnik: Etymotic System
Parameter:
- 10 Reizpegelkombinationen (Pegelschere nach Janssen et al.)
- Frequenzbereich 0,5-8 kHz (4 Oktaven, 8 Punkte/Okt.)
- Mittelungszeit 4 s
- Meßzeit ca. 22 min/Ohr



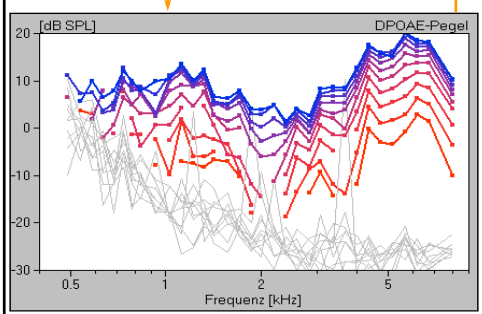
$p_{DP}(L_2;f_2)$ linear regression

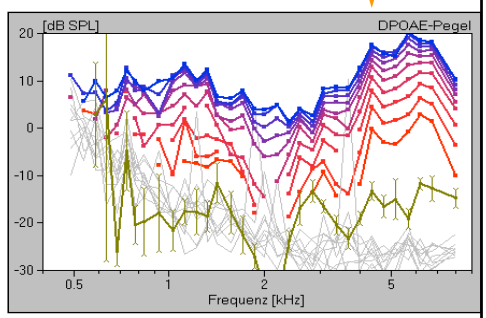


DP- gram

DP-growth function $L_{DP}(L_2;f_2)$

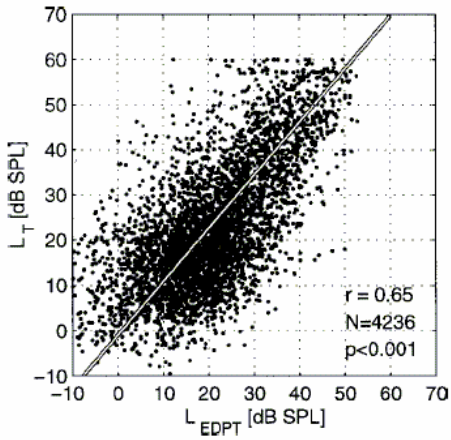
Extrapolated DP-threshold $L_{DPS}=L_2(p_{DP}=0)$



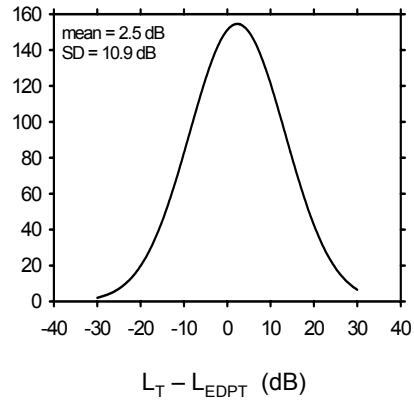


M. Ganz, H. von Specht 2000

Hearing threshold estimation with DPOAEs



n



DPOAE input-/output function
51 frequencies between 0.5-8 kHz (L2)
30 normal hearing
119 sensorineural hearing loss

Boege & Janssen 2002, JASA

DPOAE and pure tone audiogram

DPOAE:
- two frequencies
- supra threshold stimulus
- acoustic measurement

Tone audiogram:
- one frequency
- hearing threshold test
- behavioral

Common basis – clear differences

Conclusions

- OAEs allow for a categorical estimation of hearing threshold (screening).
- OAEs have the advantage and disadvantage of cochlear specificity.
- Missing of OAEs is unspecific.
- DPOAEs may help to estimate thresholds below 50 dB HL, uncertainties remain.
- OAEs cannot estimate moderate or sever hearing loss.