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Revolutionizing Auditory Hearing Screening: Methods and Best Practices

Prof. Stavros Hatzopoulos, PhD
Dept. of NeuroSciences & Rehabilitation, University of Ferrara, Italy

2025/05/07

inventis
Audiology & Balance

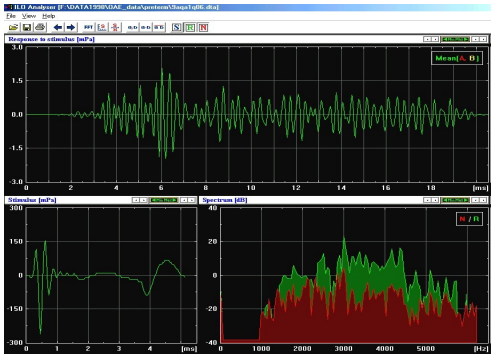
Learning Outcomes

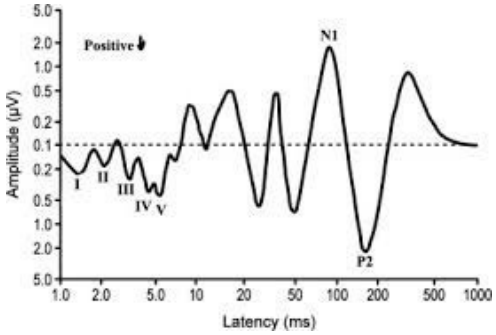
- After this course, participants will be able to identify the appropriate patient categories for auditory hearing screening and explain the statistical concepts underlying effective screening programs.
- After this course, participants will be able to differentiate between advanced auditory screening technologies, including ABR, ASSR, and genetic testing, with emphasis on their clinical applications and limitations.
- After this course, participants will be able to discuss the impact of AI-powered innovations in hearing screening, including how machine learning and data-driven approaches are transforming early diagnosis.

Risks/Benefits

- The applicability and accuracy of the course content may vary by the clinical, geographical, and cultural context; you should evaluate the course accordingly.
- As healthcare is rapidly evolving, new findings may change the validity of the information presented in this course. Providers should always consult the latest research and guidelines from professional associations.
- The interventions discussed in this course may be limited in generalizability, requiring practitioners to consider specific individual and population factors.
- The course may not cover all possible risk factors, diagnostic methods, or treatment options, and complex cases may require additional considerations.
- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

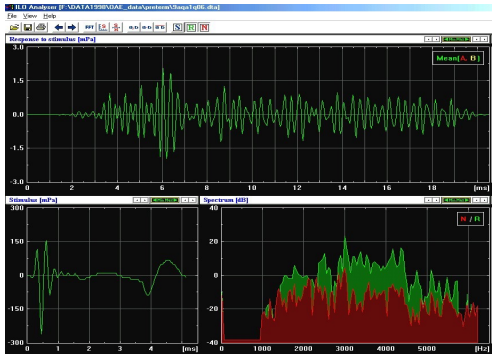
Introduction

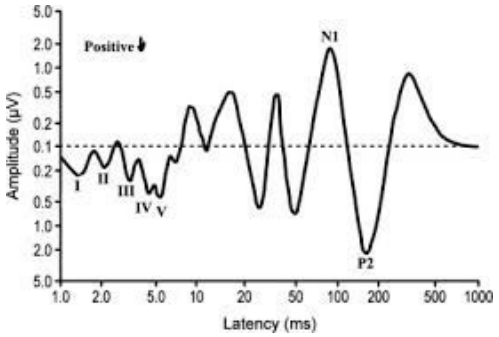




Why do we need to implement Hearing Screening practices ??

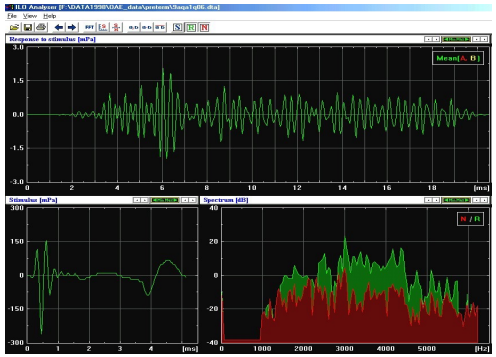
Introduction

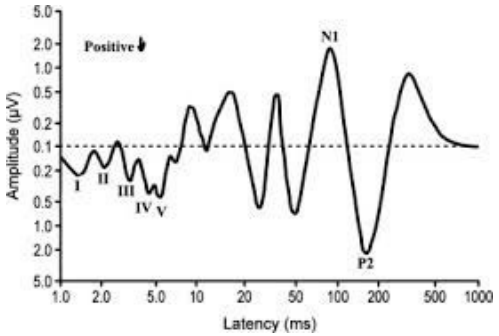




The proper answer depends on the age of the subjects in question.

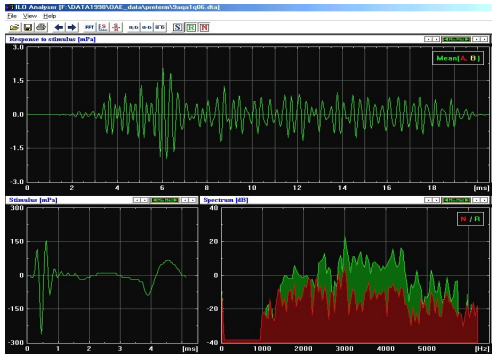
Introduction

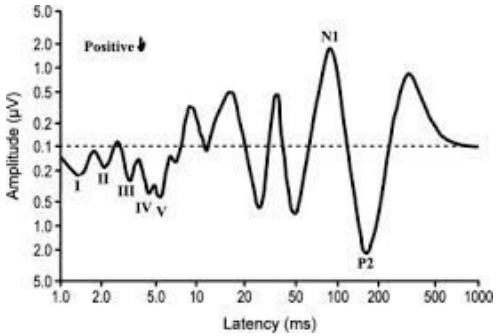




The data collected from the WHO (World Health Organization) suggest that Hearing Loss is as present as ever, in early and late ages.

Introduction

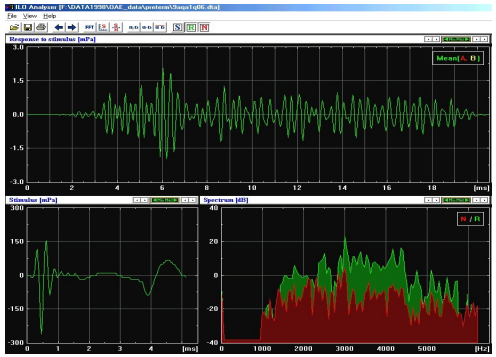


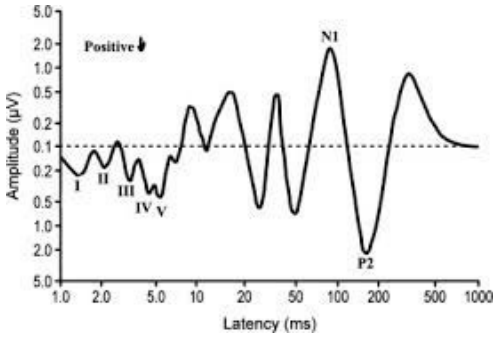


Hearing Loss in the early ages (0-2 y) AFFECTS significantly the linguistical development of the child.

Christine Yoshinaga-Itano , 1999

Intro to the Webinar

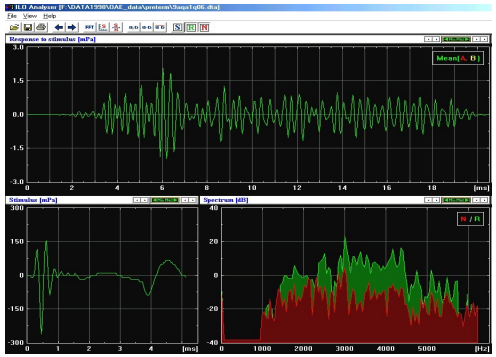


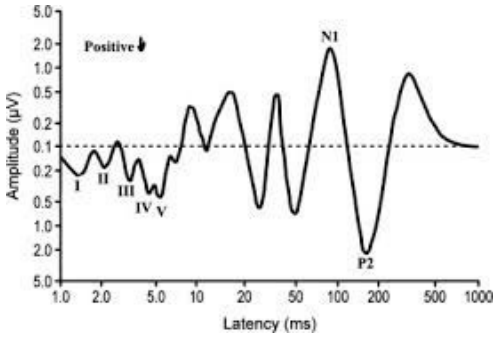


Hearing Loss in the late ages (> 65 y) AFFECTS issues related to well-being, social-integration, balance etc.

Ciorba et al, 2019

Intro to the Webinar





Therefore, the EARLY Detection of Hearing Loss results in an optimization of the possible INTERVENTION strategies.

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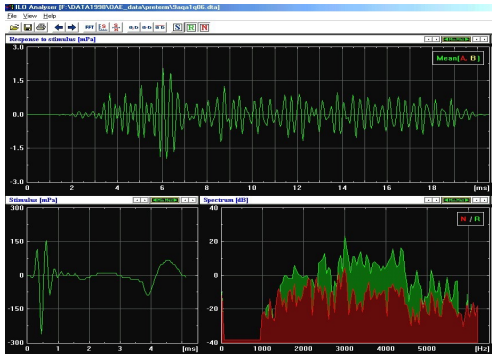
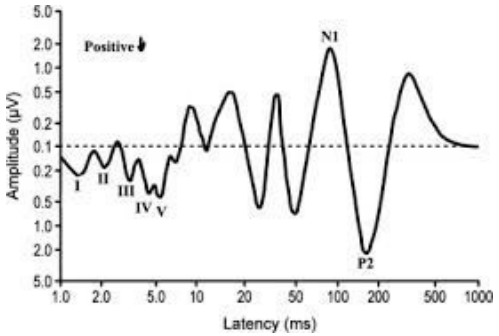
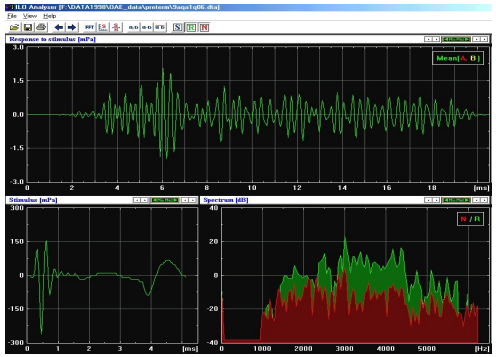
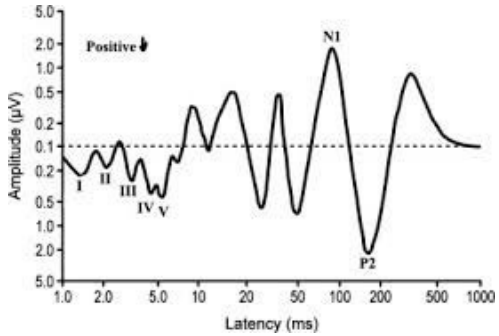




Unfortunately, Hearing Screening in the older group ages (>65 y) has not received the necessary attention so far.

Intro to the Webinar





The emphasis of the lecture will be placed ONLY in the HL detection in the very Early years of life. A second lecture in 2025-2026 will affront screening in CHILDREN & ADULTS

Nomenclature used in the lecture

ABR: Auditory Brainstem Response (Audiology version)

AABR: Automated ABR usually at 30 nHL.

BAER: Brainstem Auditory Evoked Response (Neuroscience version).

BAEPs: Brainstem Auditory Evoked Potentials (Neuroscience).

ASSR: Auditory Steady State Responses.

Nomenclature used in the lecture

OAEs: Otoacoustic Emissions

- TEOAEs: Transient (click, chirp) Otoacoustic Emissions. Sometimes called CEOAEs
- DPOAEs: Distortion Product Otoacoustic Emissions

AOAEs: Automated OAEs, usually from transients.

Nomenclature used in the lecture

NHS: Neonatal Hearing Screening programs

UNHS: Universal Hearing Screening programs

- These programs include screening of Well babies (WB) and babies in the Neonatal Intensive care Unit (NICU).

EHDI: Early Hearing Detection & Intervention (hearing aids, cochlear implants) programs.

Nomenclature used in the lecture

Auditory Neuropathy (AN). A disease condition involving Inner Hair Cells (on the organ of Corti) and Neural fibers. Results in reduced OAEs and altered ABR.

Connexin 26 and mutation variants. Connexin 26 (Cx26) is a protein that forms channels, called gap junctions, between cells. Cx26 is particularly important in the inner ear, where it helps maintain potassium levels crucial for hearing. Mutations **in the GJB2** gene, which encodes Cx26, are a common cause of autosomal recessive hearing loss.

Nomenclature used in the lecture

Measurement Units

dB SPL: The reference level **0 dB SPL** is usually the quietest sound pressure that the average human ear can hear (defined as 20 micropascals). This is considered as the threshold of human hearing.

Most calibrations are conducted in dB SPL

Nomenclature used in the lecture

Measurement Units

- **dB nHL (normal Hearing Level):** the level in decibels relative to the subjective click threshold level of the stimulus in subjects with normal hearing.
- In the ABR-based hearing screening we usually **make reference** to 30 or 40 dB nHL

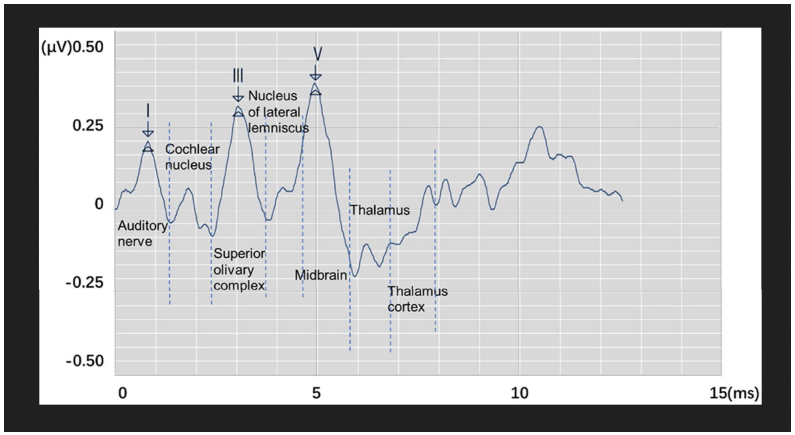
Concepts of Statistics

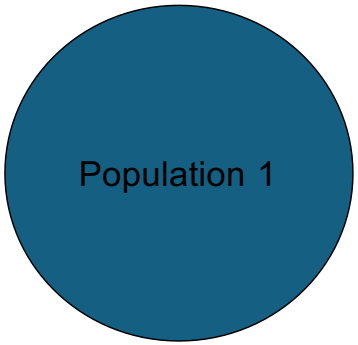
Screening: The **meaningful** separation of **two**

populations of subjects

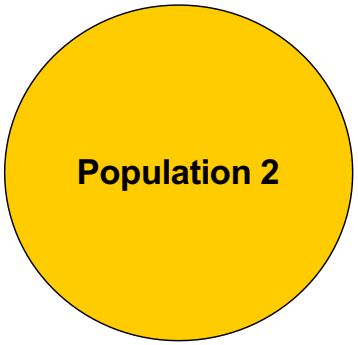
(normal hearing vs. *subjects with a hearing impairment*)

Concepts of Statistics





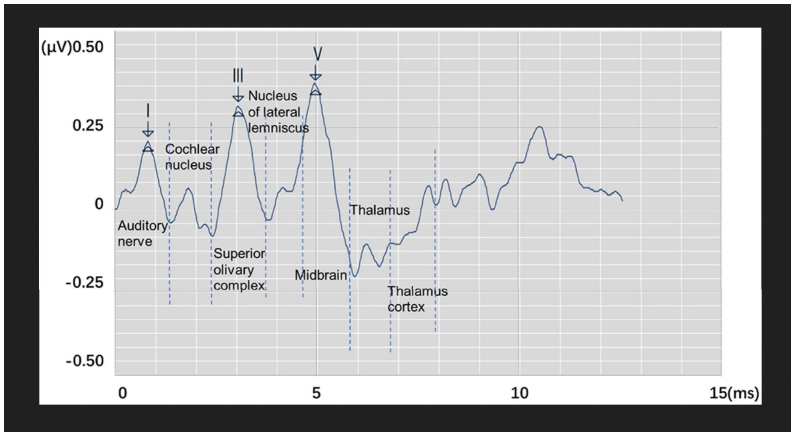
Applying our criteria ----------



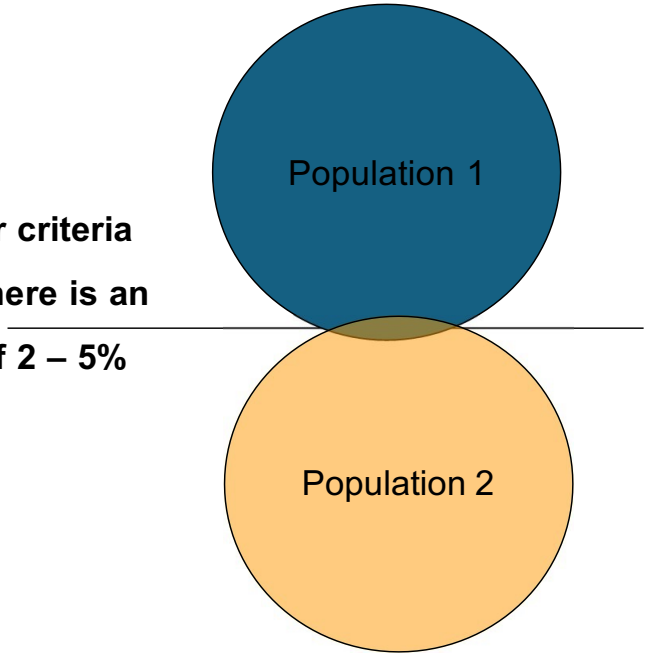
Scenario 1: IDEAL

Correct discrimination / screening

Statistical concepts of Screening



Applying our criteria we see that there is an OVERLAP of 2 – 5%



Scenario 2: Almost Ideal

STILL Acceptable

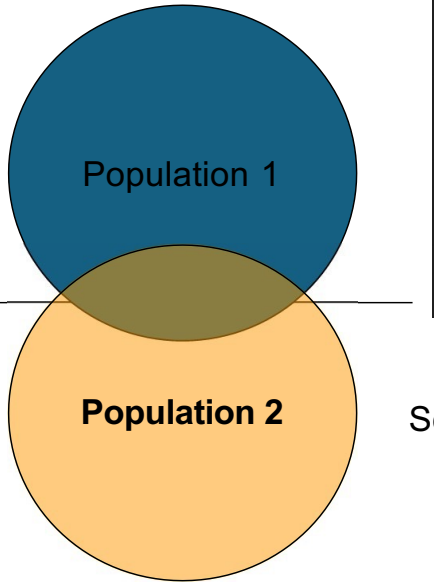
discrimination/screening

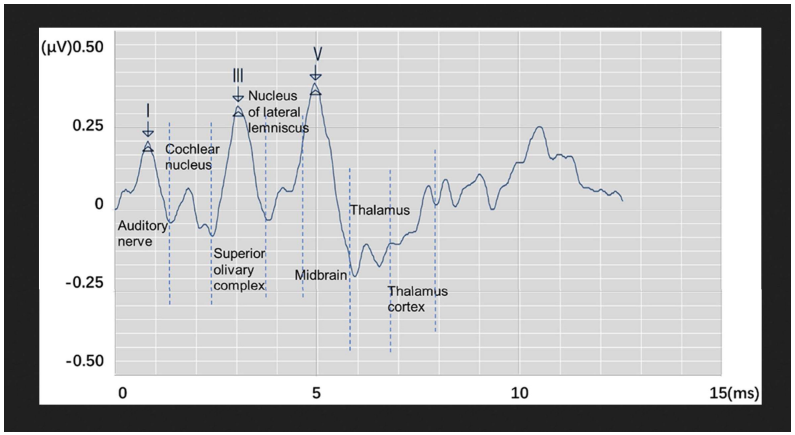
Statistical concepts of Screening

Applying our criteria

we see that there is an

OVERLAP > 10 %





Scenario 3: REAL Life scenario

NOT acceptable

Discrimination / screening

We cannot say **with CERTAINTY** what response belongs to which group

Statistical concepts of Screening

For newborn / adult Hearing screening

	Hearing Loss Present	Non Present
Positive Result (HL present)	TRUE positive	FALSE positive
Negative Result (No HL)	FALSE negative	TRUE negative

Condition = presence of hearing loss (Positive result)

Statistical concepts of Screening

Specificity : The percentage of Normal Hearing subjects, Identified by the screening procedure. It varies from 90 - 97 %.

Sensitivity: The percentage of subjects presenting a Hearing Loss, Identified by the screening procedure. It varies between 90 -95 %

Problems in NHS

According to various studies, **false positives** (normal subjects who are under-estimated) are about less than 1%, and this is mainly due to technical problems.

As we will see later on a NHS / UNHS program with 3 phases (OAE, OAE, ABR) normally does not have problems of this kind. For **false negatives** (hearing loss cases which are over-evaluated), the percentage rises to about 5% .

NHS Today

What is the Status of NHS TODAY

NHS Today

HL Percentages (averages) to consider (WHO 2022)

- Incidence of hearing loss in the WB population 0.7- 1.5 / 1000
- Incidence of hearing loss in the NICU population 3.5 / 1000
- Incidence of Auditory Neuropathy : 1.0 -1.6 / 10000

NHS Today

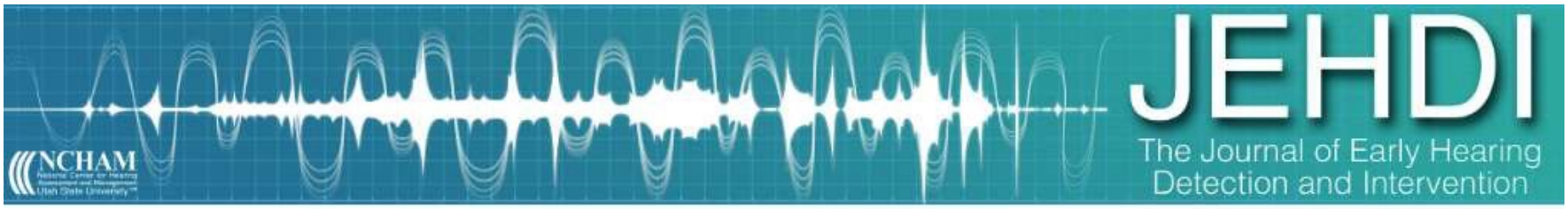
European NHS data (2024)

Country	Participants (n)	Screening Protocol	Bilater. Deafness Cases and Prevalence	Causes	Intervention Policies
Germany	296,700	TEOAE, AABR	2368/296,700 = 0.007 **7 per 1000**	NA	NA
Italy: *Emilia Rom.*	7775	TEOAE, AABR	WB: 4/6759 = 0.0005 **0.5 per 1000** NICU: 8/1016 = 0.0078 **7.8 per 1000**	NA	Cochlear Implants
Italy: *Umbria*	20,841	TEOAE, AABR	WB: 40/20,051 = 0.00199 **1.99 per 1000** NICU: 33/790 = 0.041 **41 per 1000**	Non-syndromic genetic mutations without familiarity (10) Unknown: (22)	WB: Hearing Aids (28) Cochlear Implants (2) NICU: Hearing Aids (28) Cochlear Implants (3)
Poland	7,149,809	TEOAE, AABR	10,367/7,149,809 = 0.00145 **1.44 per 1000**	NA	Cochlear Implants
Russian Fed	1,232,137	TEOAE, ABR	3002/1,232,137 = 0.0024 **2.43 per 1000**	NA	Cochlear Implants
Second sample (Chibisova 2024)	NA	NA	1292/NA = NA NA	GJB2 genotype profile	NA
Switzerland #	12,080	TEOAE, ABR	253/12,080 = 0.02094 **20.94 per 1000**	NA	Cochlear Implant (1) Hearing Aids (14)
UK	4,645,823	TEOAE, AABR	Exact numbers not available **<1 per 1000 (well babies)** **5–7 per 1000 (NICU)**	NA	NA

[1] See comments in the Section 3.1.1.; * pilot study; # sample only from Zurich.

Hatzopoulos et al, Children, 2024

NHS today



2020; 5(2): 63-84

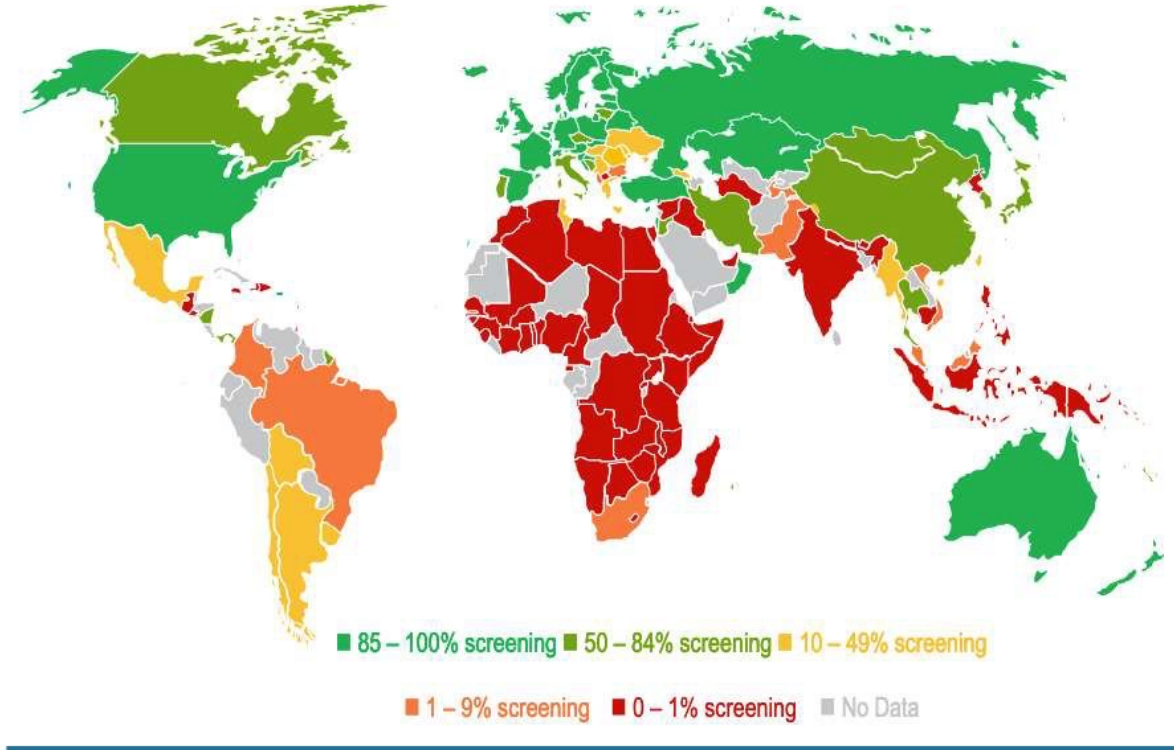
A Survey on the Global Status of Newborn and Infant Hearing Screening

Katrin Neumann, MD[1]
Harald A. Euler, PhD[1]
Shelly Chadha, MD[2]
Karl R. White, PhD[3]
The International Newborn and Infant Hearing Screening (NIHS) Group[4]

[1]Department of Phoniatrics and Pedaudiology, University Hospital Münster, University of Münster, Münster, Germany
[2]Sensory functions, Disability and Rehabilitation, Department of Noncommunicable Diseases, World Health Organization, Geneva, Switzerland
[3]National Center for Hearing Assessment and Management, Utah State University, Logan, UT, USA
[4]Please see Appendix A for the complete list of contributing NIHS authors and their affiliations.

NHS today

Figure 1
Country Specific Coverage of NIHS Programs



Neuman et al, JEHDI, 2020

NHS today

children

MDPI

Review

The Otoacoustic Emissions in the Universal Neonatal Hearing Screening: A Scoping Review Update on the African Data (2004 to 2024)

Stavros Hatzopoulos [1], Ludovica Cardinali [2], Piotr Henryk Skarzynski [3,4,5] and Giovanna Zimatore [6,*]

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2 Department of Life Science, Health, and Health Professions, Link Campus University, 00165 Rome, Italy; l.cardinali@unilink.it
3 Heart Failure and Cardiac Rehabilitation Department, Faculty of Medicine and Dentistry, Medical University of Warsaw, 02-005 Warsaw, Poland; piotrhskarzynski@gmail.com
4 Institute of Sensory Organs, 05-830 Kajetany, Poland
5 World Hearing Center, Department of Teleaudiology and Screening, Institute of Physiology and Pathology of Hearing, 02-042 Warsaw, Poland
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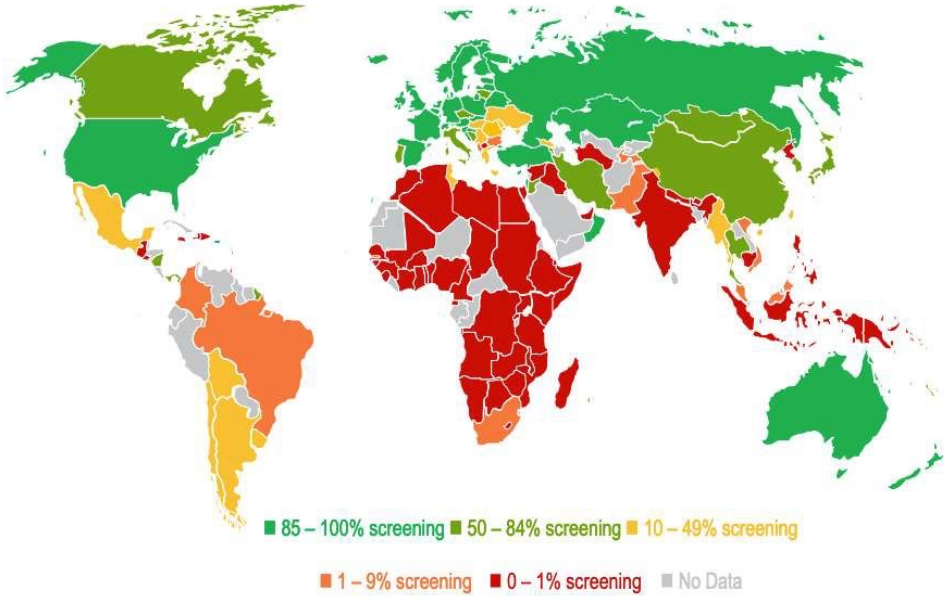
NHS today

Hatzopoulos et al, Children, 2025

Figure 2. Political map of Africa showing the countries, in green, where NHS activities have been reported in the literature. These African states are reported alphabetically in Table 2.

Figure 1
Country Specific Coverage of NIHS Programs



NHS development

Evolution of the NHS programs

AND the relative technologies

NHS Development after 1990

National Institute of Health (NIH), 1993. It is strongly recommended that all infants within the first three months of life should be screened for hearing.

Joint Committee on Infant Hearing (JCIH), 1994. It is recommended to use of technologies like Otoacoustic Emissions and ABR in neonatal hearing screening alone or in combination.

Definitions from the European Consensus, Milan, 1999. NHS is The possibility to correctly identify cases with sensorineural hearing loss, presenting a threshold higher than 40 dB HL in the 1.0, 2.0, 4.0 kHz frequencies.

NHS Development after 1990

The 2000 Position Statement and Guidelines developed by the Joint Committee on Infant Hearing (JCIH).

- All infants have access to hearing screening using a physiologic measure. Newborns who receive routine care have access to hearing screening **during** their hospital birth admission.
- Newborns in alternative birthing facilities, including home births, have access to and are referred for screening **before 1** month of age.
- All newborns or infants who require neonatal intensive care receive hearing screening **before** discharge from the hospital.
- These components constitute **universal** newborn hearing screening (UNHS).

NHS Technologies**

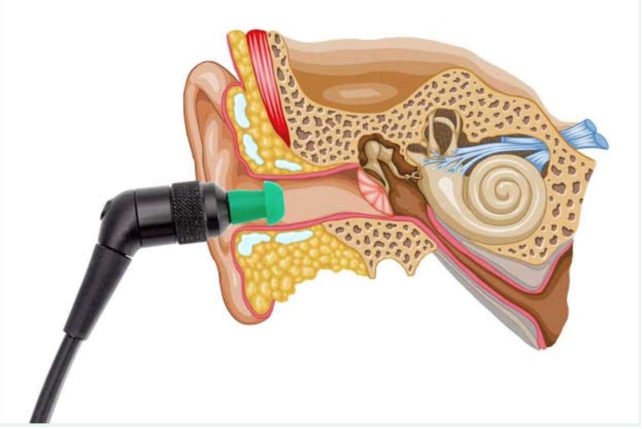
1. Otoacoustic Emissions

** NOTE: Pure Tone measurements **cannot be used** in Infants, only in children and adults

NHS Technologies

OAEs = Otoacoustic Emissions.

Acoustic energy produced by non-linear cochlear processes and recorded in the external auditory canal

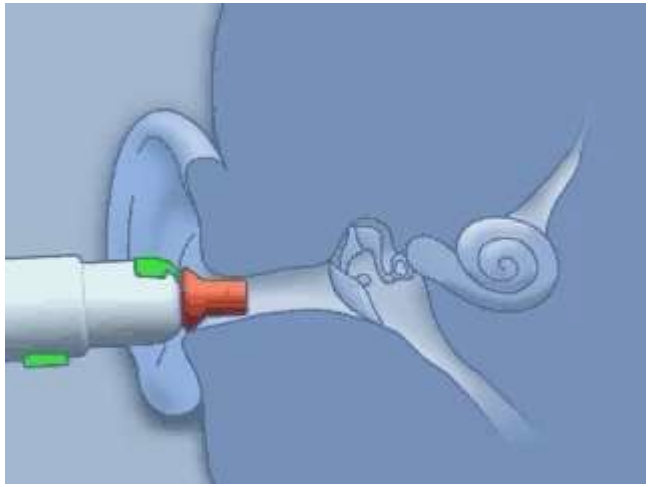


© *Interacoustics*

NHS Technologies

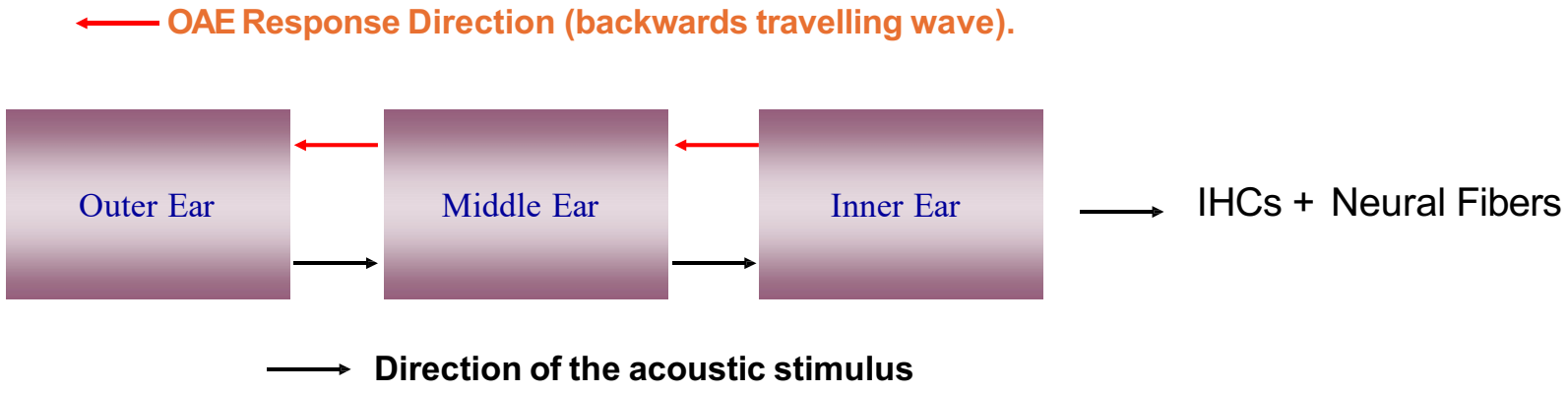
WHY OAEs as a FIRST NHS ASSESSMENT

1. Fast Recording Times
2. Inexpensive testing compared to ABR
3. Easy technique to master (no extensive training) BUT
   the probe position (good Meatus SEAL) is CRUCIAL



Natus, 2015

NHS Technologies



- **We can identify problems through the transmission chain.**

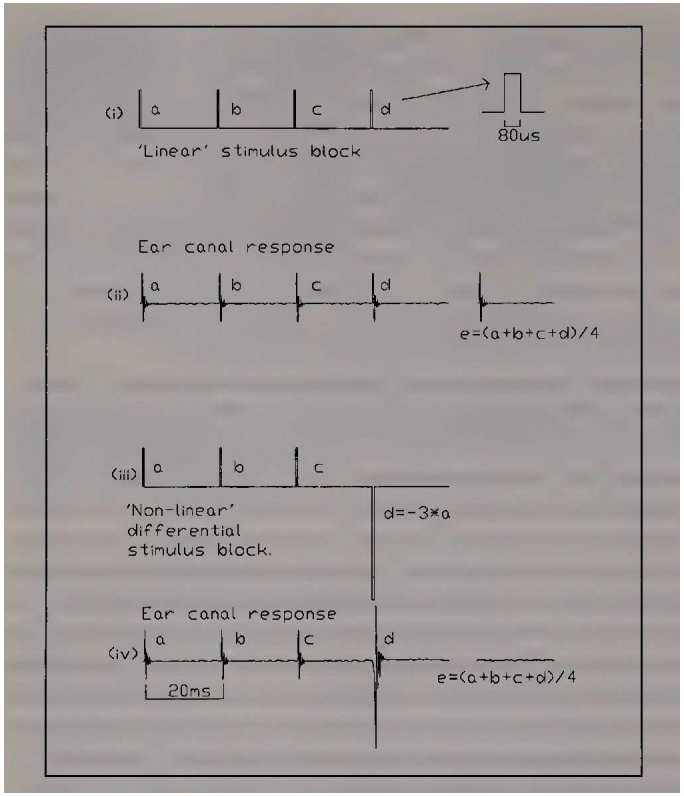
With OAEs

- We cannot get information about the state of the IHCs or neural fibers. In order to do this, we need to use the EFFERENT pathways and different stimulus paradigms

Clinical types of OAEs used in NHS

- *Transient* (TEOAEs): **Evoked by stimulating the cochlea with a transient signal (i.e. click, gated tone pip, chirp).**
- *Distortion Product* (DPOAEs): **Evoked by stimulating the cochlea with two pure tones of different frequency.**
- *Spontaneous* (SOAEs): **Recorded at the absence of any stimulus.**

OAEs evoked by a Click-TEOAEs

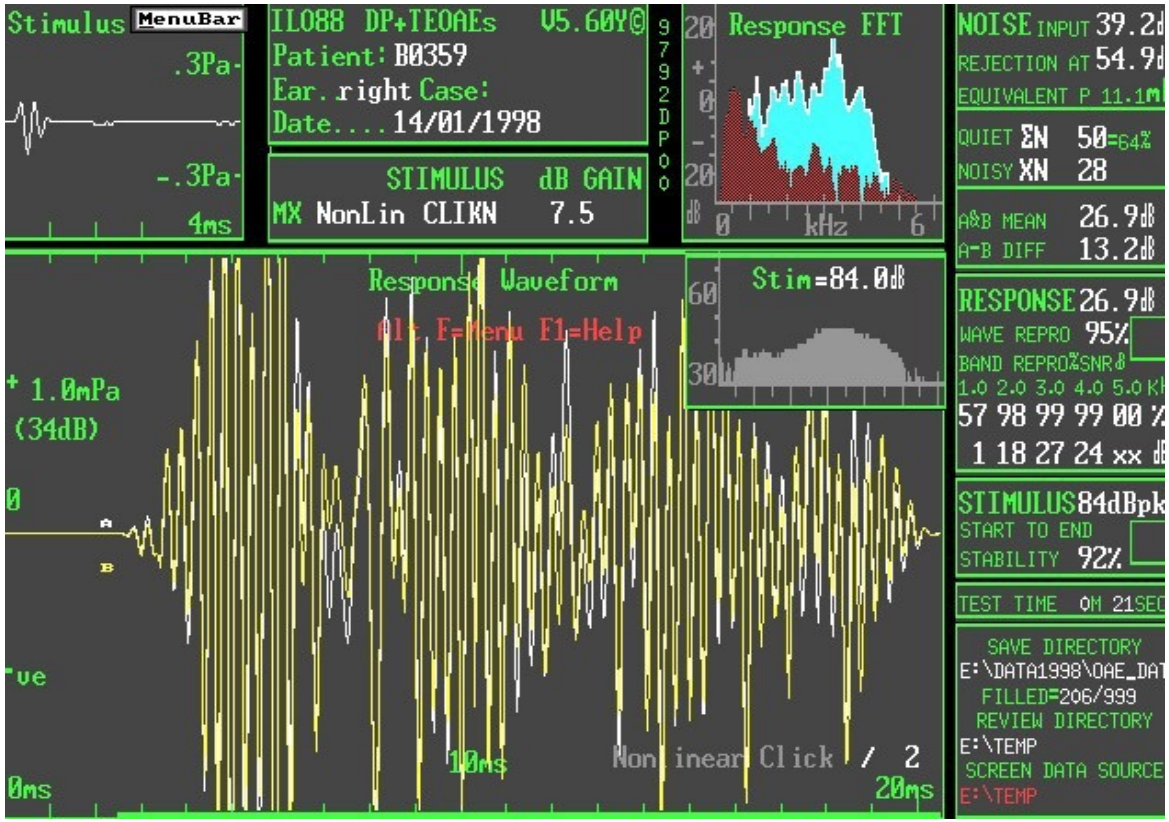


Linear

Non-Linear

Modified by Kemp et al (1990) as a 10 ms window (2.5 -12.5 ms) response called QuickScreen

OAEs evoked by a Click-TEOAEs



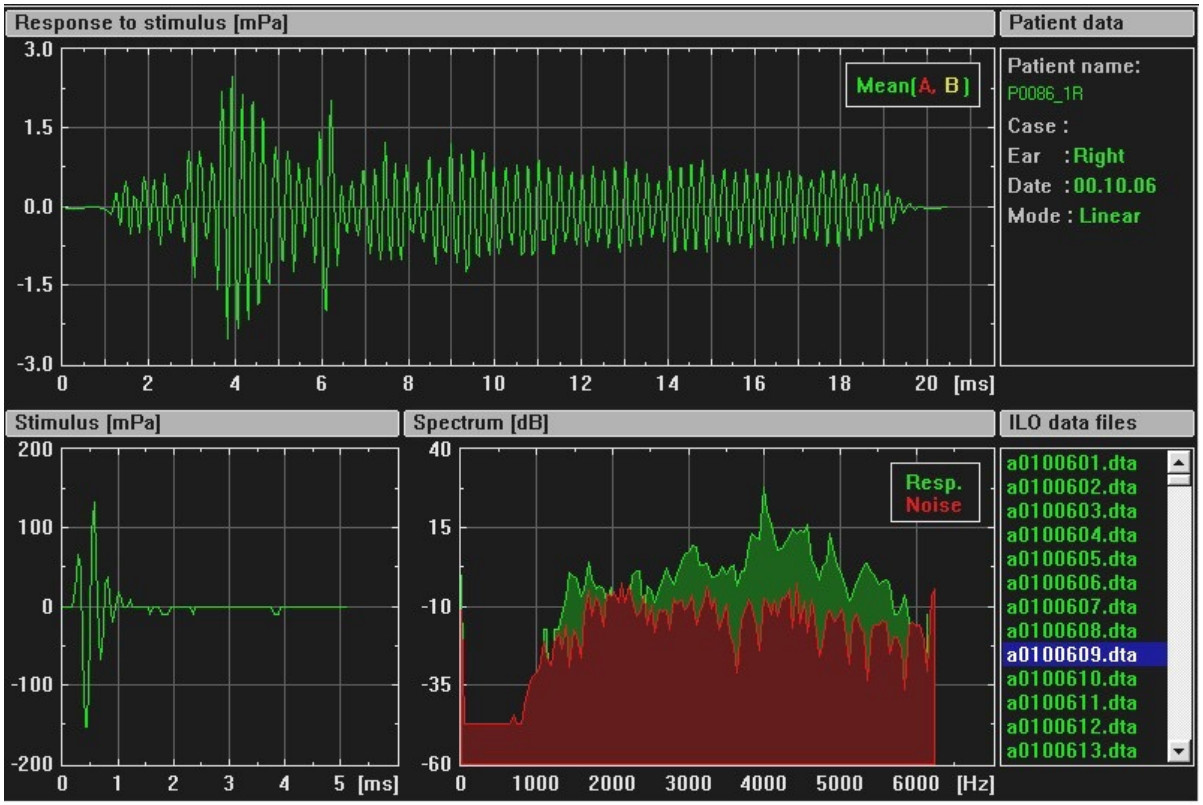
Well Baby

39 W

Post Gestational Age (PGA)

Stimulus : 84 dB SPL

OAEs evoked by a Click - TEOAEs

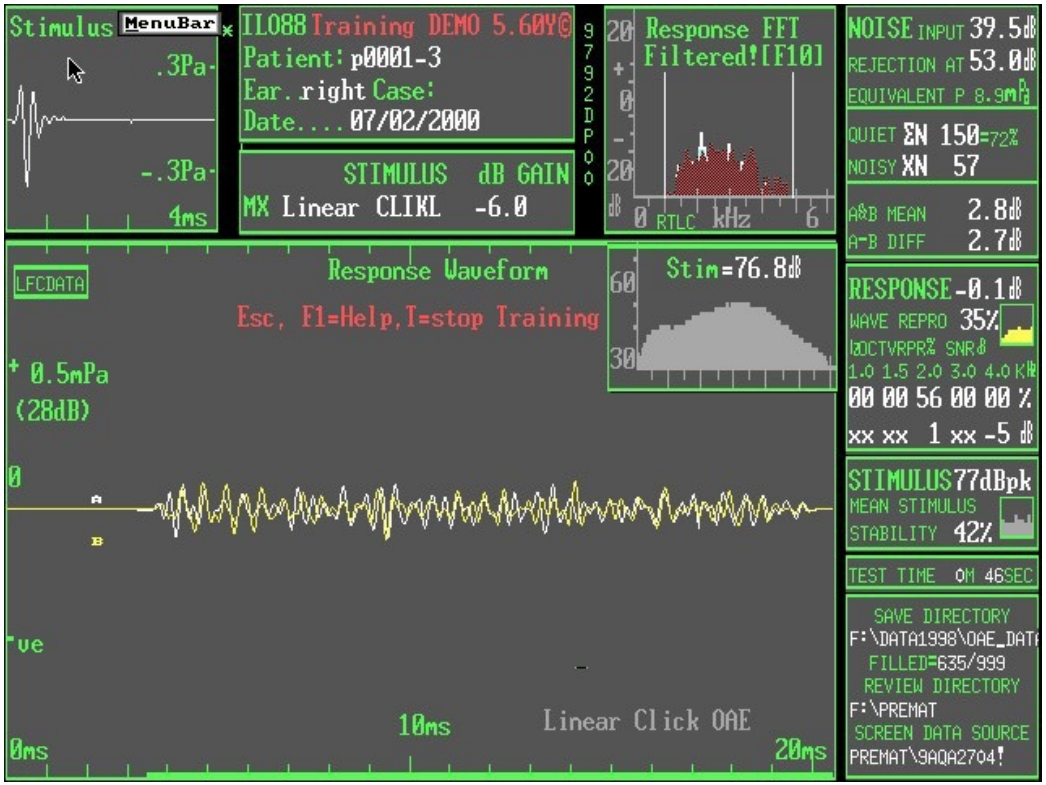


Premature Infant

32 W PGA

Stimulus : 80 dB SPL

OAEs evoked by a Click -TEOAEs

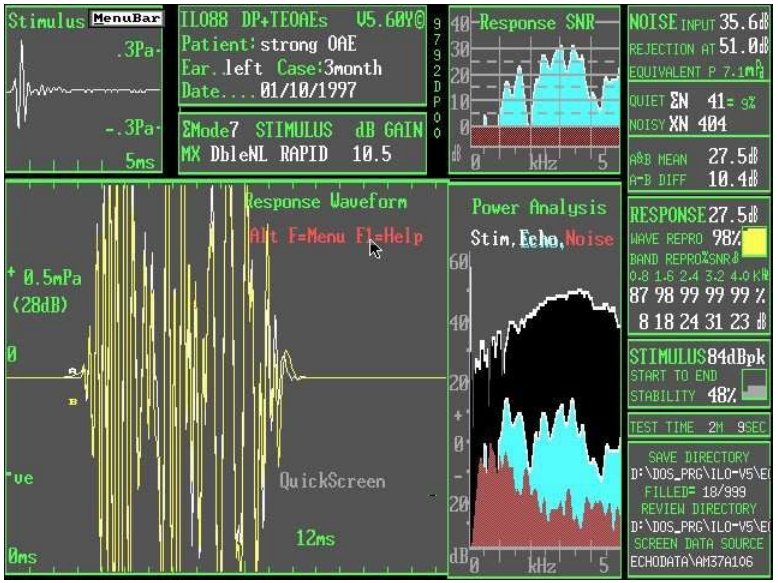


Premature Infant

28 W PGA

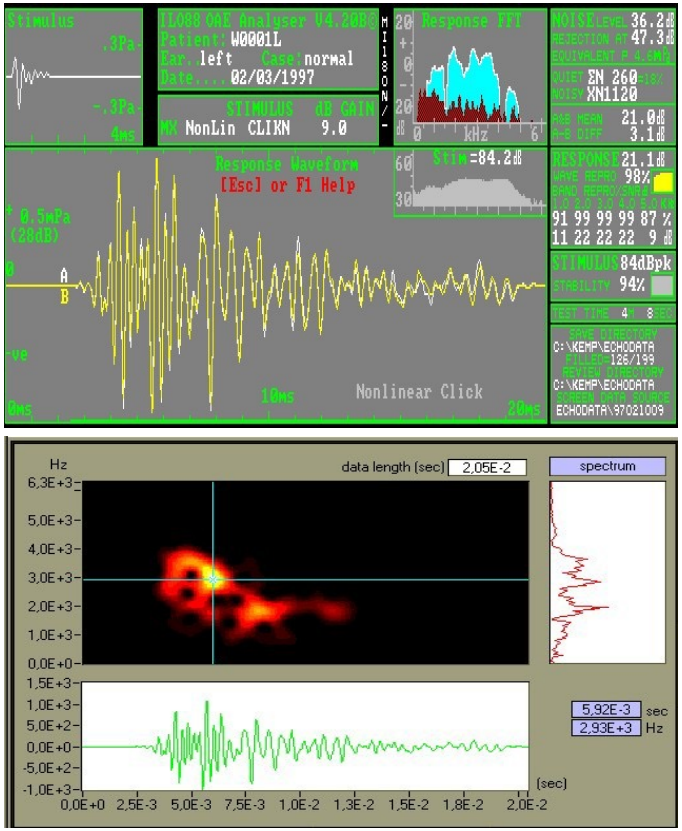
Stimulus : 77 dB SPL

OAEs evoked by a Click -TEOAEs



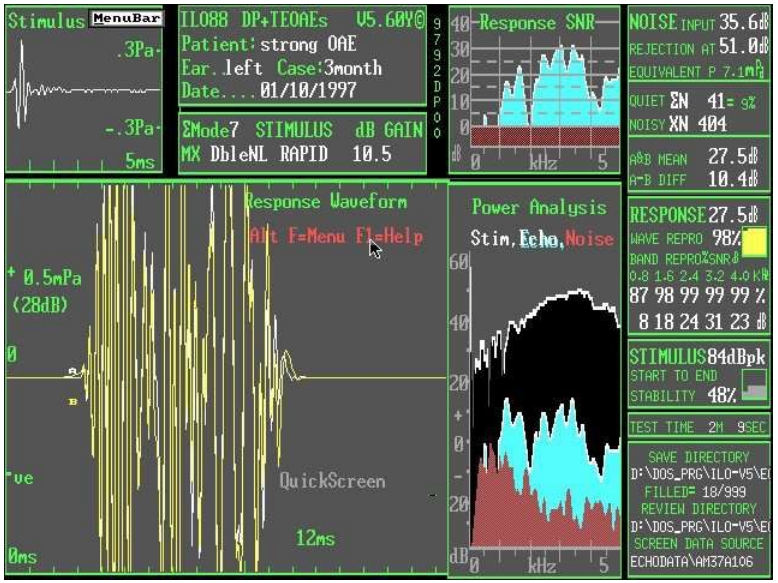
- The testing protocols can be 3 (linear, nonlinear, Quickscreen), but usually are set **automatically to the third one** (10 ms window, non-linear stimulus)
- The response is evaluated as PASS or REFER according to the signal-to-noise ratio (S/N) at frequencies 2, 3, 4 kHz.
- Minimum S/N values > 6 dB or correlation > 70% per tested frequency.
- Specificity level (normal hearing subjects) > 95%.

OAEs evoked by a Click –TEOAEs -Adults



- The testing protocols can be 3 (linear, nonlinear, Quickscreen), but usually are set automatically to the first one (10 ms window -4-14 ms -, non-linear stimulus)
- The response is evaluated as PASS or REFER according to the signal-to-noise ratio (S/N) at frequencies 2, 3, 4 kHz.
- Minimum S/N values > 3 dB or correlation > 70% per tested frequency.
- Specificity level (normal hearing subjects) > 95%.

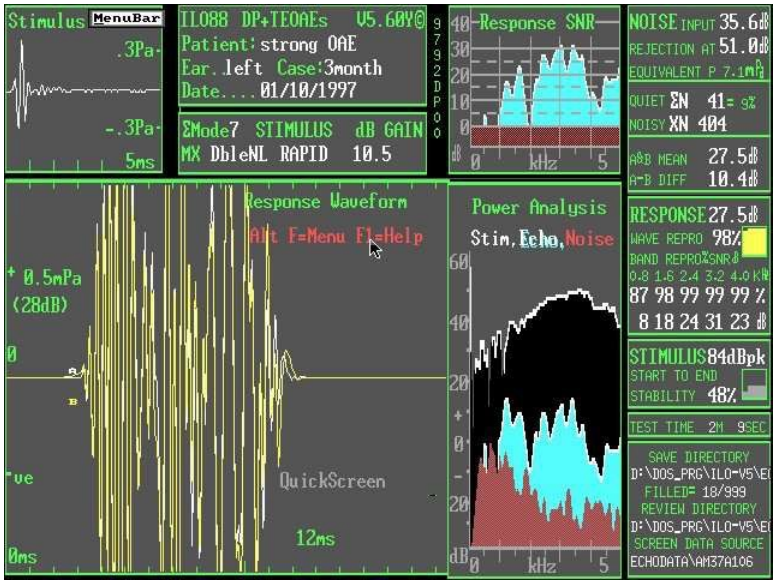
OAEs evoked by a Click -TEOAEs



TAKE HOME MESSAGE

1. Test as early as possible (>24 h) and clean the external ear from wax debris.
2. TEOAE S/N values > 6 dB are considered VALID. **PASS criteria** are considered in a minimum of 2/3 test frequencies.

OAEs evoked by a Click -TEOAEs



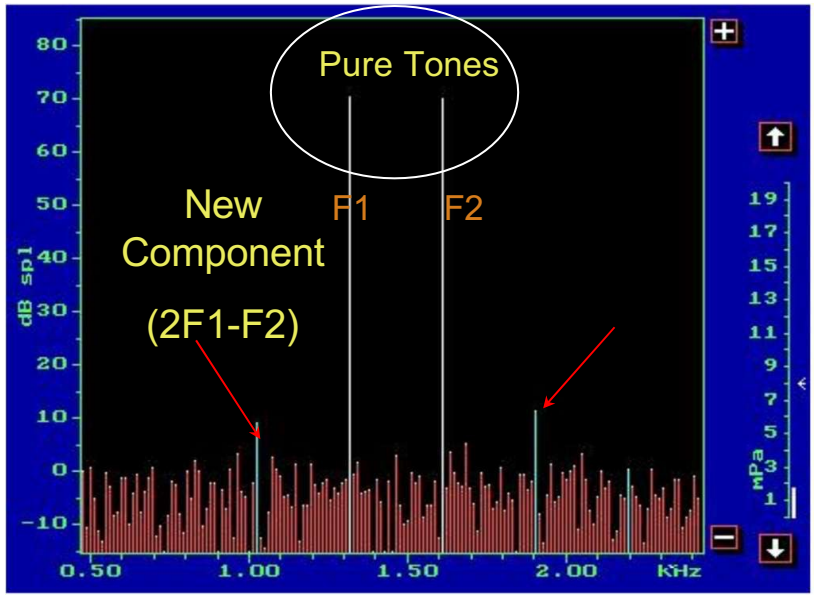
TAKE HOME MESSAGE 2

3. Automated screeners (AOAE) offer an optimized evaluation, BUT border-line cases** require the **attention of a human operator**.

** It occurs that in some cases the PASS criteria are valid in only 1, or 2 frequencies. Since **OAEs are PRESENT or NOT**, these are valid cases which need to be re-tested.

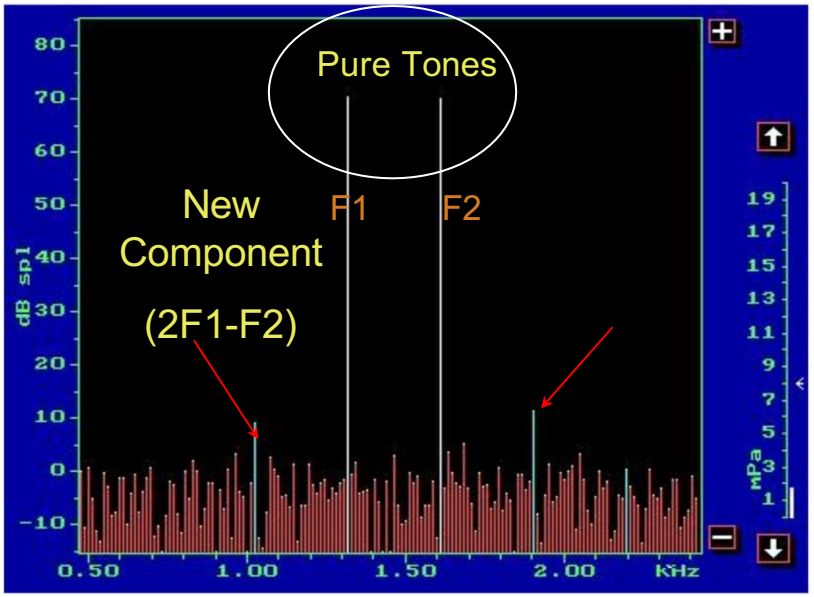
OAEs evoked by a 2 tones-DPOAEs

- Two discrete pure tone frequencies, F1 and F2 are introduced into the external meatus.
- Each tone has a specific amplitude (L1 or L2) ranging from 50 -75 dB SPL.
- The pure tone frequencies are related by a pre-determined ratio , called Fratio (1.1 - 1.3)



OAEs evoked by a 2 tones-DPOAEs

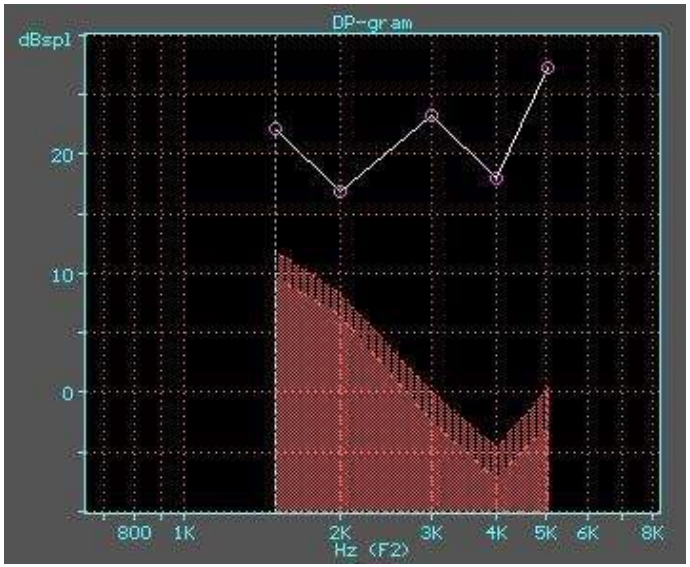
- If the amplitudes (L1 or L2) the two tones are equal (i.e. L1 =60, L2=60 dB SPL) the protocol is called symmetrical.
- Data in the literature have suggested that cases of sensorial HL are better identified by asymmetrical DPOAE protocols (i.e. L1=65, L2=55 dB SPL etc.)



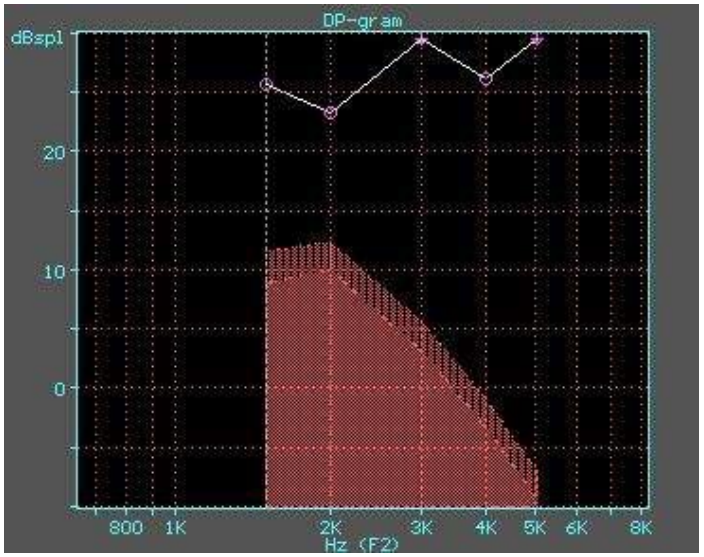
OAEs evoked by a 2 tones-DPOAEs

DPOAE 2F1-F2 values (DP-gram) for the F2 frequency of 2.0, 3.0, 4.0, 5.0 kHz, at 2 different stimulus levels.

Protocol 65-55 dB SPL



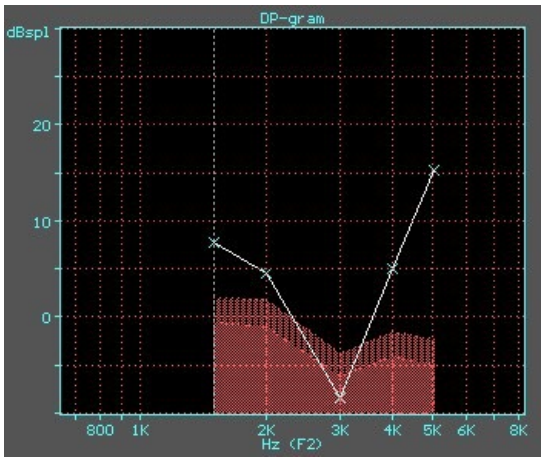
Protocol 75-65 dB SPL

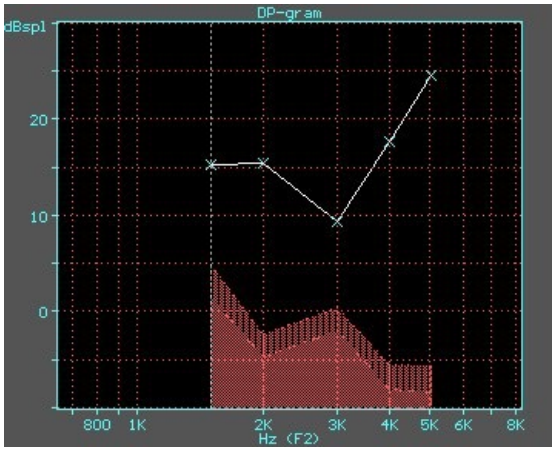


Fratio = 1.2

F2	F1
1500	1250
2000	1666
3000	2500
4000	3333

OAEs evoked by a 2 tones-DPOAEs

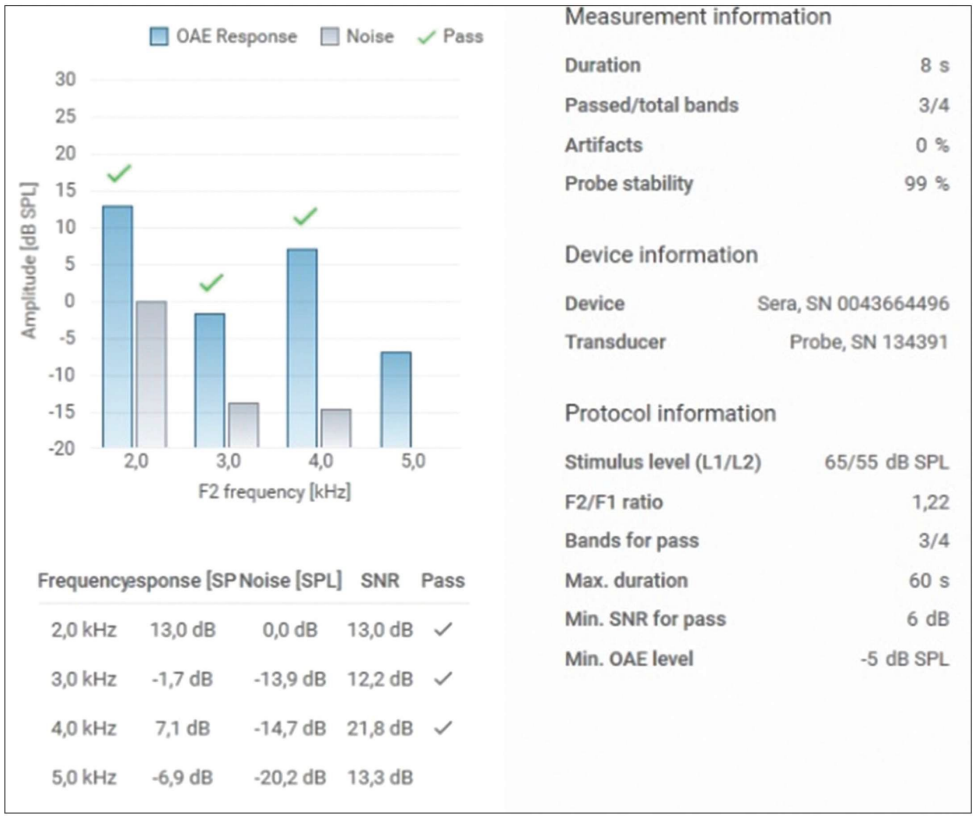




Often in the DP-gram we see a phenomenon similar to a frequency NOTCH near 3 kHz, which is **caused by standing waves** in the external meatus.

The software of the devices after 2005, changes slightly the testing F2 frequency (to 3.2 - 3.4 kHz) and re-assess the 2F1-F2 product in this new F2 frequency value.

OAEs evoked by a 2 tones-DPOAEs



Frequency	esponse [SP	Noise [SPL]	SNR	Pass
2,0 kHz	13,0 dB	0,0 dB	13,0 dB	✓
3,0 kHz	-1,7 dB	-13,9 dB	12,2 dB	✓
4,0 kHz	7,1 dB	-14,7 dB	21,8 dB	✓
5,0 kHz	-6,9 dB	-20,2 dB	13,3 dB	

Measurement information

Duration	8 s
Passed/total bands	3/4
Artifacts	0 %
Probe stability	99 %

Device information

Device	Sera, SN 0043664496
Transducer	Probe, SN 134391

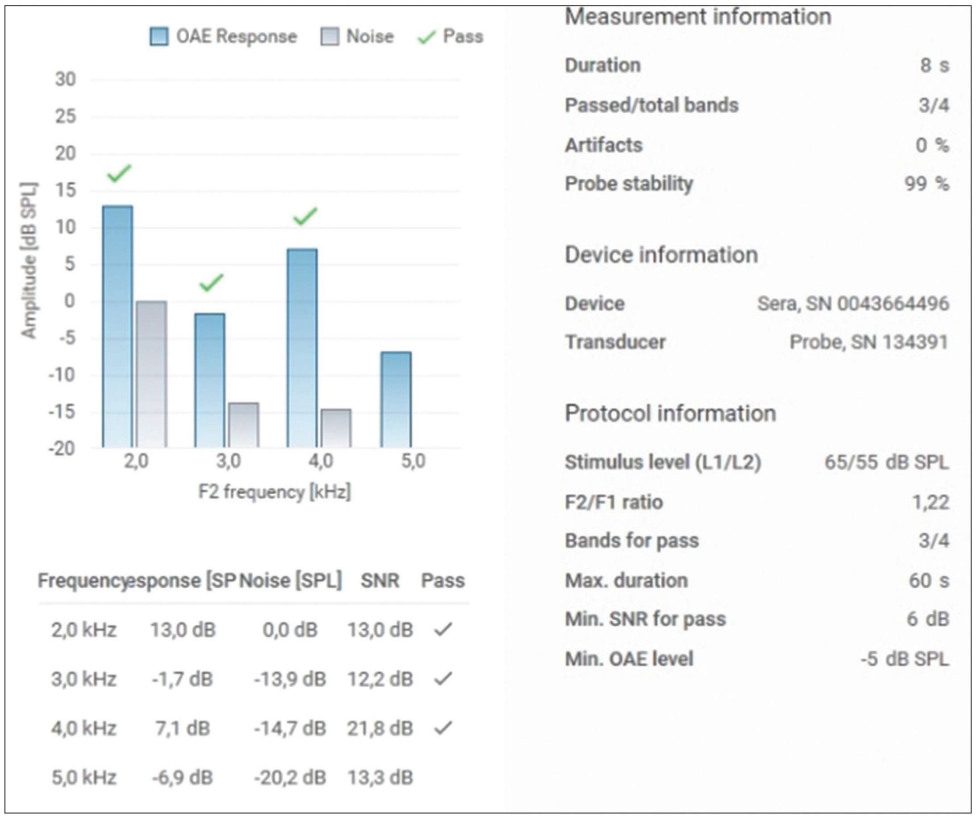
Protocol information

Stimulus level (L1/L2)	65/55 dB SPL
F2/F1 ratio	1,22
Bands for pass	3/4
Max. duration	60 s
Min. SNR for pass	6 dB
Min. OAE level	-5 dB SPL

TAKE HOME MESSAGE

1. Usually DPOAEs show higher S/Ns, than TEOAEs.
2. High-level DPOAE protocols, such as 65-55 or even 75-65 dB SPL, can be used to compensate for noisy NICU or WB environments.
3. PASS criteria, consider valid responses (> 6 dB) at a minimum of 3/5 frequencies (and the level of the noise floor).

OAEs evoked by a 2 tones-DPOAEs



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Bands for pass	3/4
Max. duration	60 s
Min. SNR for pass	6 dB
Min. OAE level	-5 dB SPL

TAKE HOME MESSAGE 2

The DPOAEs responses are more specific in frequency of TEOAEs ?

No, both responses are **equally frequency specific** BECAUSE the cochlea is tonotopic.

OAEs evoked by a 2 tones-DPOAEs

Original Paper

Audiology & Neurotology

Audiol Neurotol 514
DOI: 10.1159/000XXXXXX

Received: July 27, 2007
Accepted after revision: May 14, 2008
Published online: ■■■

Optimizing Otoacoustic Emission Protocols for a UNHS Program

S. Hatzopoulos[a] J. Petruccelli[b] A. Ciorba[a] A. Martini[a]

[a]Audiology Department, University of Ferrara, Ferrara, Italy; [b]Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, Mass., USA

Original Article

Re-evaluating the scoring criteria of the Interacoustics Sera Neonatal Hearing Screener

Giovanna Zimatore, Piotr Henryk Skarzynski[1,2,3], Federica di Berardino[4], Anna Maria Gasbarre[4,5], Eliana Filipponi[4,5], Gabriella Araimo[5,6], Stavros Hatzopoulos[7]

TAKE HOME MESSAGE 3

Are the current PASS / SCORING published criteria **good across all OAE devices** ?

Unfortunately, no due to differences in the various OAE probe characteristics.

NHS Technologies

Can we do better ?

Yes, by employing a Multifrequency Tympanometry assessment *

* See book reference in the last section of this presentation

NHS Technologies-WAI

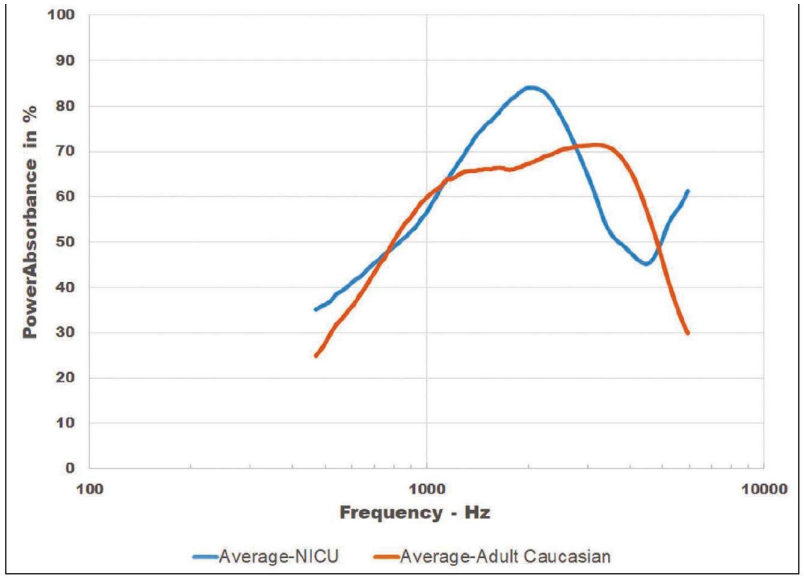


FIGURE 2.4 Mean power absorbance (PA) in neonatal intensive care (NICU) babies and mean PA in adults as a function of frequency (in Hz). Adapted, modified, and replotted in PA.

Navid Shanaz, Application of Wideband Acoustic Immittance ..

In Advances in Audiology & Hearing Science, 2022

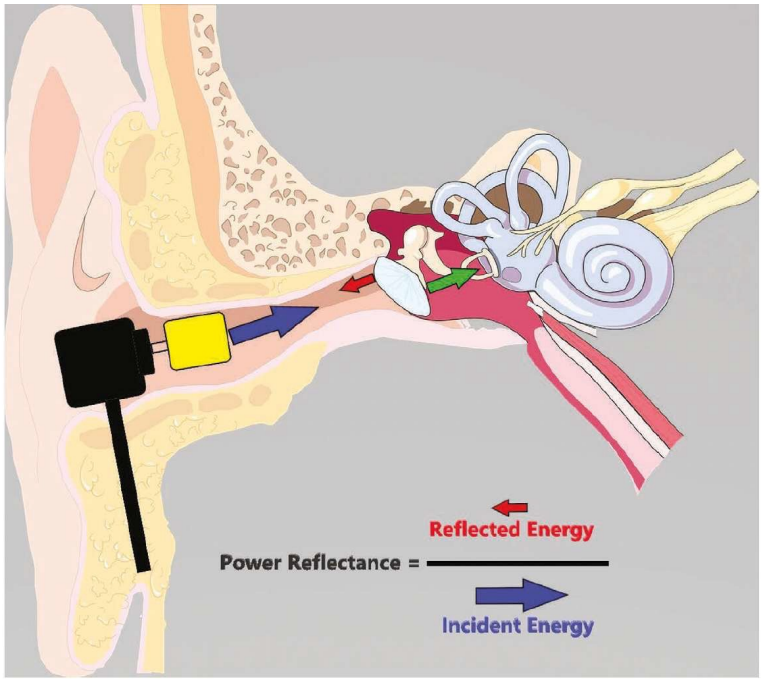


FIGURE 2.3 Power reflectance/energy reflectance is the ratio of backward (reflected) to the forward (incident) energy waves which vary from zero, where all sound energy is absorbed by the middle ear, to one, where all sound energy is reflected by the middle ear.

NHS Technologies-WAI (or WBT)

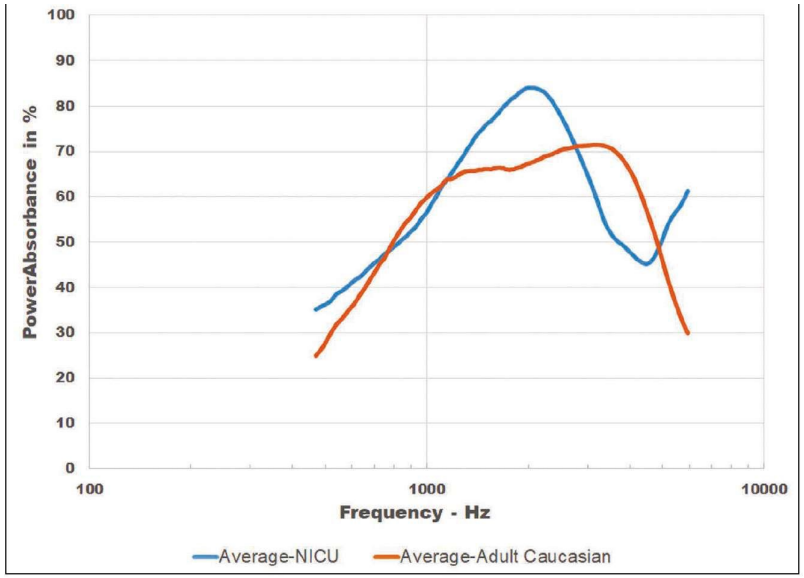


FIGURE 2.4 Mean power absorbance (PA) in neonatal intensive care (NICU) babies and mean PA in adults as a function of frequency (in Hz). Adapted, modified, and replotted in PA.

Navid Shanaz, Application of Wideband Acoustic Immittance ..

In Advances in Audiology & Hearing Science, 2022

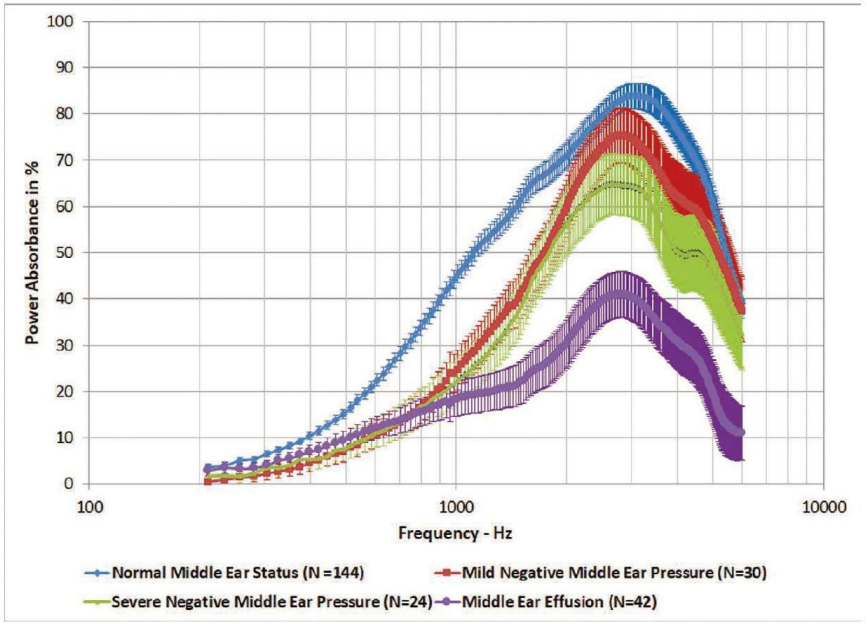
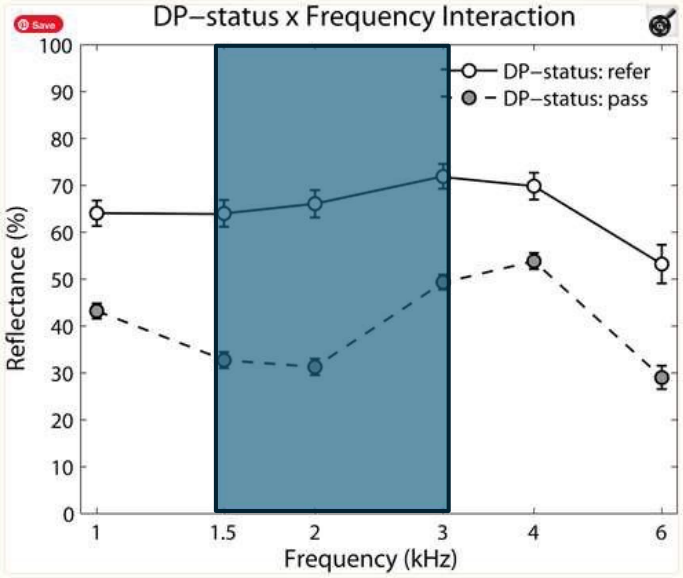


FIGURE 2.9 The mean PA values and 95% confidence intervals between normal school-aged children, mild negative middle-ear pressure, severe negative middle ear pressure, and middle-ear effusion as a function of frequency.

Source: Adapted, modified, and replotted in PA from Beers et al. (2010).

NHS Technologies – WAI & DPOAEs

Figure 1.



Open in a new tab

Frequency × DP-status interaction for the 479 ears with tone-stimulus reflectance results. Ears that achieved a DP pass result had significantly lower reflectance than ears that were referred. Error bars are 95% confidence intervals.

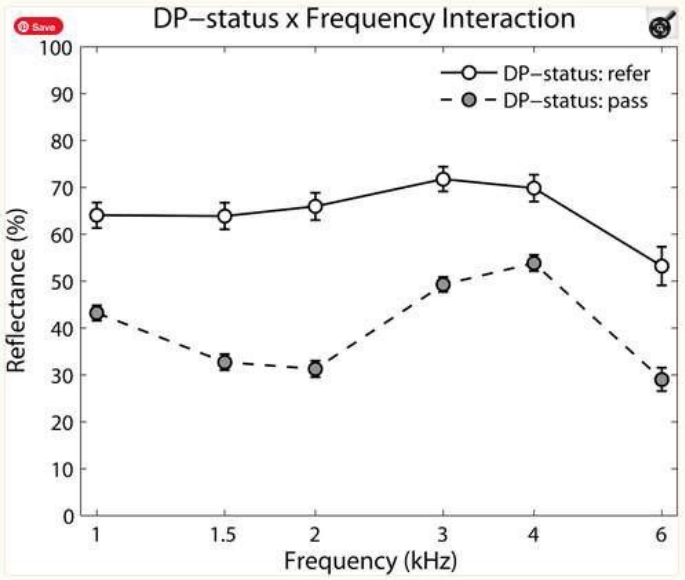
The authors measured WAI at atmospheric pressure using the Mimosa Acoustics MEPA system, 1-kHz tympanometry, and DPOAEs in 324 infants. The purpose of their study was to establish normative data for WAI in infants and to compare the test performance of WAI to 1-kHz tympanometry for prediction of the outcome of DPOAE (pass/refer).

They found that the WAI is a more accurate predictor of DPOAE outcome than 1-kHz tympanometry with absorbance at 2 kHz providing the best prediction for DPOAE referral. They reported that power absorption between 1.5 and 3 kHz is strongly correlated to DPOAE screening outcome and recommended that newborns with low power absorption between 1.5 and 3 kHz **who fail the OAE screening be re-screened within few hours** to few days of the initial screen as most middle-ear problems in newborns are **transient and resolve spontaneously**.

Hunter et al: Wideband reflectance in newborns: Normative regions and relationship to hearing screening results. Ear & Hear , 2010

NHS Technologies – WAI & DPOAEs

Figure 1.

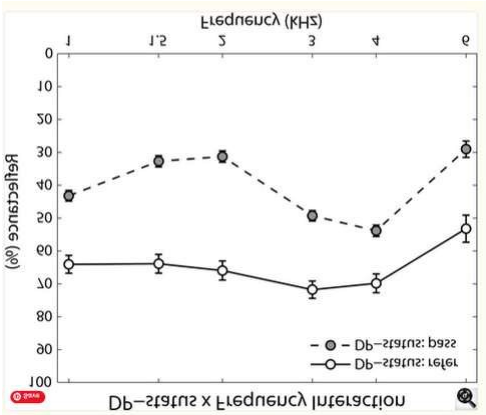


Open in a new tab

Frequency × DP-status interaction for the 479 ears with tone-stimulus reflectance results. Ears that achieved a DP pass result had significantly lower reflectance than ears that were referred. Error bars are 95% confidence intervals.

Please NOTE that Hunter et al, used REFLECTANCE in their graphs which is the OPPOSITE OF ABSORBANCE.

FLIP Vert.



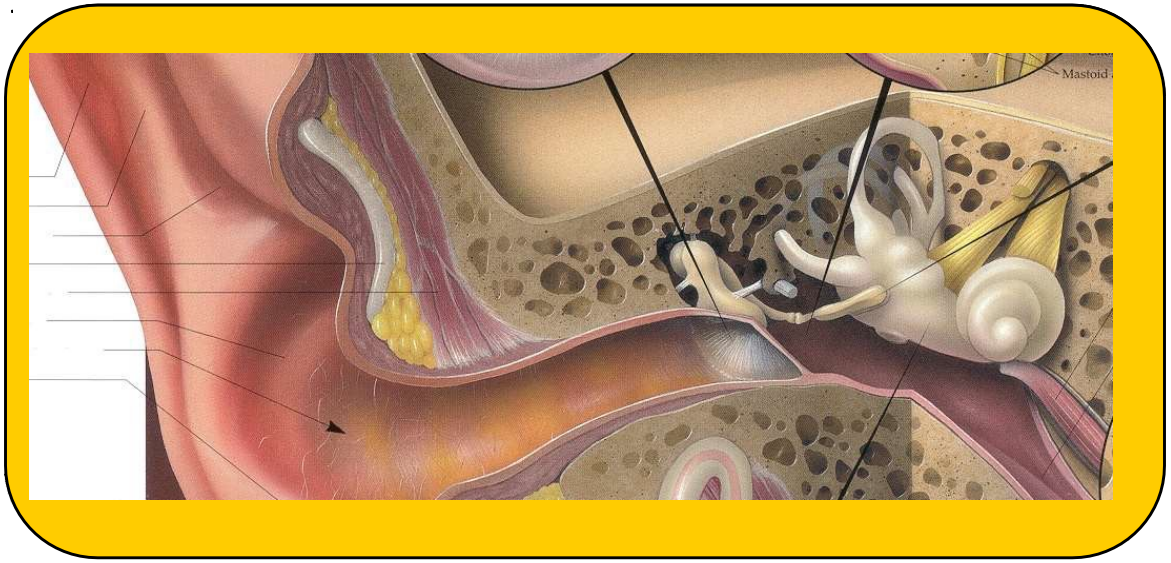
Data in ABSORBANCE-like FORM

Hunter et al: Wideband reflectance in newborns: Normative regions and relationship to hearing screening results. Ear & Hear , 2010

NHS Technologies - AABR

2. Automated Auditory Brainstem Responses

NHS Technologies - AABR



Sound Field Propagation Path ***© copyright Beltone Inc 2001***

IF OAE screening is so efficient

why do use any other techniques ?

ANSWER: OAE screening provides Information ONLY

of the **Auditory periphery till the level of IHCs.**

NHS Technologies – Why AABR
the presence of AN

Brain (1996), **119**, 741–753

Auditory neuropathy

Arnold Starr,[1] Terence W. Picton,[4] Yvonne Sininger,[2] Linda J. Hood[3] and Charles I. Berlin[3]

[1]*Department of Neurology, University of California, Irvine, the* [2]*House Ear Institute, Los Angeles, the* [3]*Kresge Hearing Research Laboratory, Louisiana State University Medical Center, New Orleans, USA and* [4]*Rotman Research Institute of Baycrest Centre, University of Toronto, Toronto, Canada*

Correspondence to: Arnold Starr, Department Neurology, University of California Irvine, Irvine, CA 92717, USA

Auditory Neuropathy (AN) causes a lack of fiber-**synchronization** in ABR.

In the above paper only ADULT subjects were assessed, but the evidence was adequate to **extend** the studies to the pediatric population.

IF OAE screening is so efficient

why use any other techniques ?

ANSWER: OAE screening provides

Information ONLY

of the Auditory periphery.

Problems in the Screening outputs began appearing back in the late 90s, due to **AN**

NHS Technologies – Why AABR
the presence of AN

American Journal of Medical Genetics 139A:13–18 (2005)

Connexin 26 Variants and Auditory Neuropathy/ Dys-Synchrony Among Children in Schools for the Deaf

Xing Cheng, Li Li, Shanda Brashears, Thierry Morlet, San San Ng, Charles Berlin, Linda Hood, and Bronya Keats*

Departments of Genetics and Otolaryngology, Kresge Hearing Research Laboratory, Louisiana State University Health Sciences Center, New Orleans, Louisiana

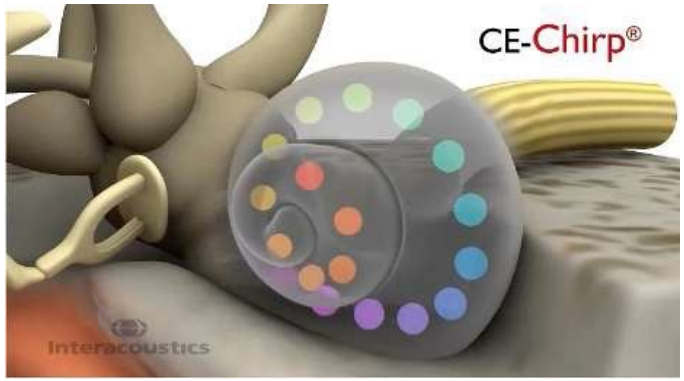
Auditory Neuropathy causes **initially** a lack of fiber-**synchronization** in ABR and **later lack** of OAEs.

Basic concepts of ABR

- The Evoked Potentials are minute electrical signals (potentials = differential signals), generated by groups of neurons, in response to an ear stimulation.
- These small signals are acquired by surface electrodes, are averaged and then amplified.

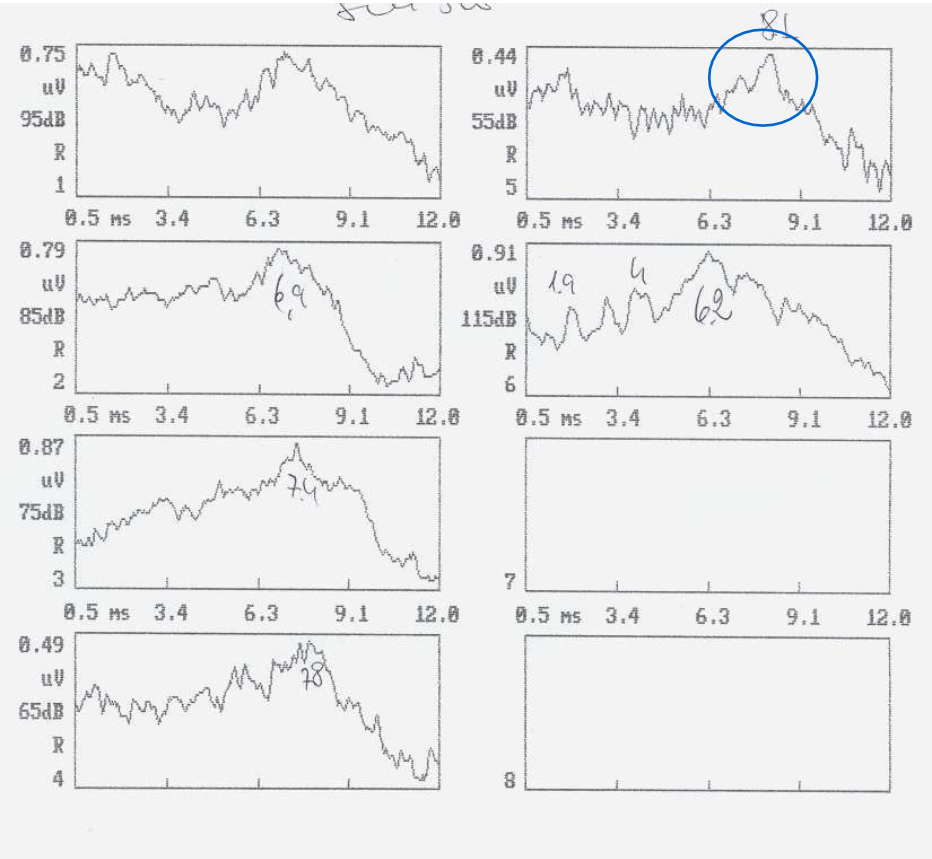
Basic concepts of ABR

- The ABR evoked with highly transient stimuli (clicks) cannot be used to define hearing sensitivity or cochlear status at specific frequency regions.
- Tone bursts and filtered chirps are necessary in adult / pediatric applications of the ABR.



Transients stimulate **multiple** Cochlear partition

Old Clinical ABR data

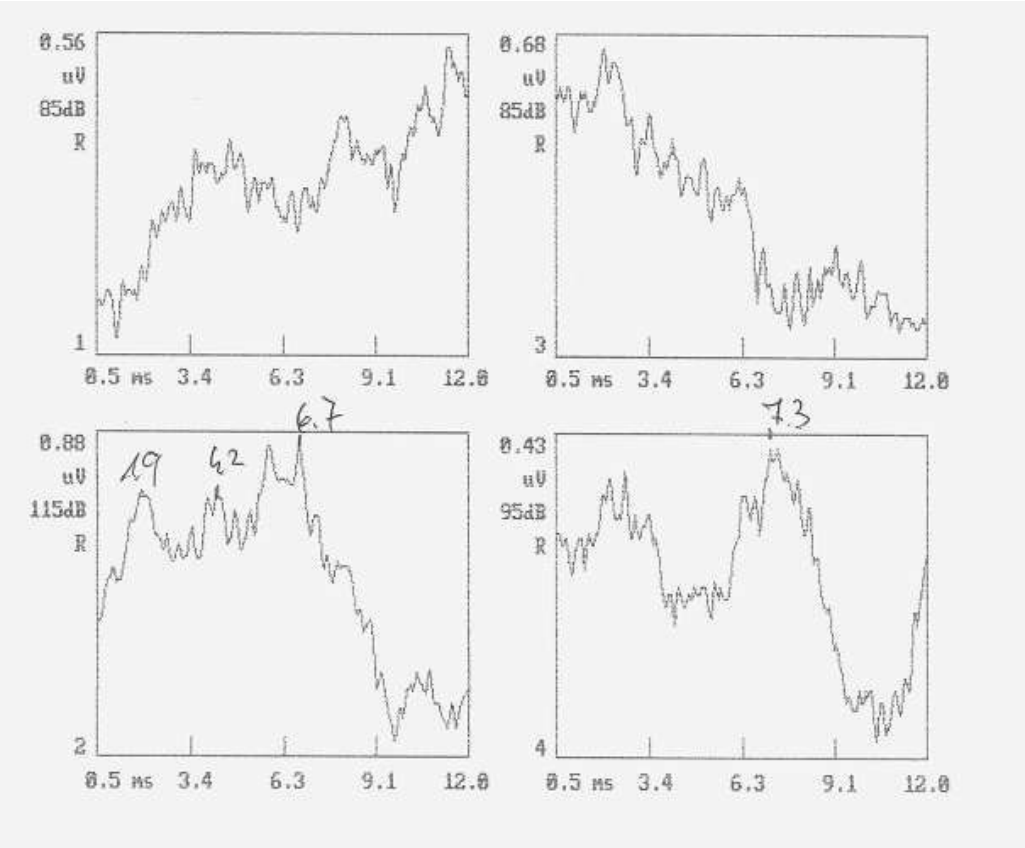


We know that it is difficult to get "good" ABR data with a PGA age < 32 wks.

This fact complicates the comparison of data OAE / ABR.

For the NICU cases the two methods are 95% in agreement.

Old Clinical ABR data



A Case of a premature infant where thetwo protocols of evaluation are in agreement.

30 week

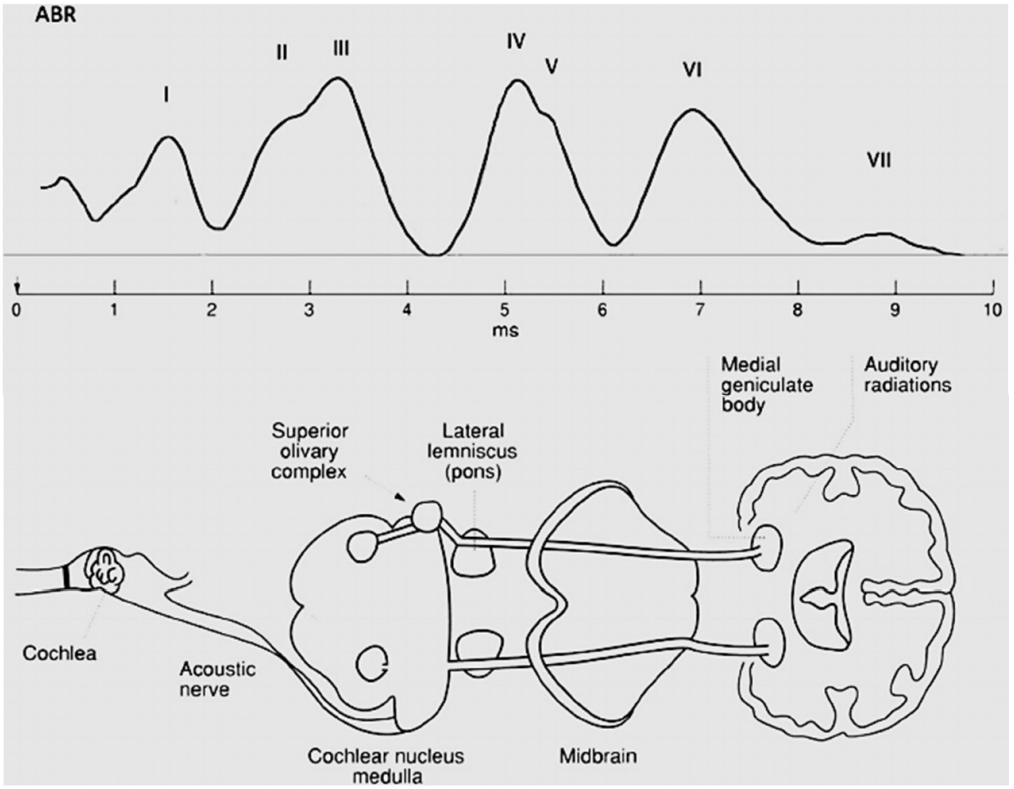
ABR: Fail

OAEs: Fail

ABR Waveform Terminology

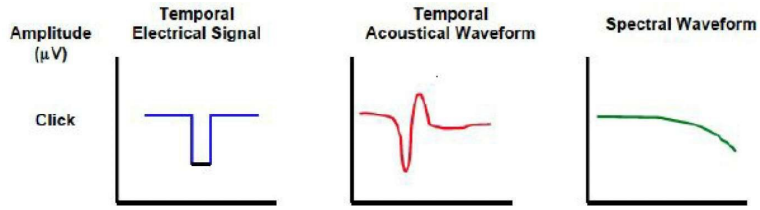
Wave VI & VII: The exact spatial contributors of these two ABR components are still not well-defined. Some early observations in the 70s suggested that the generators might be located within the Thalamus in the Medial Geniculate Body (MGB).

Other research (i.e Møller) suggests that these peaks originate from neurons in the Inferior Colliculus.

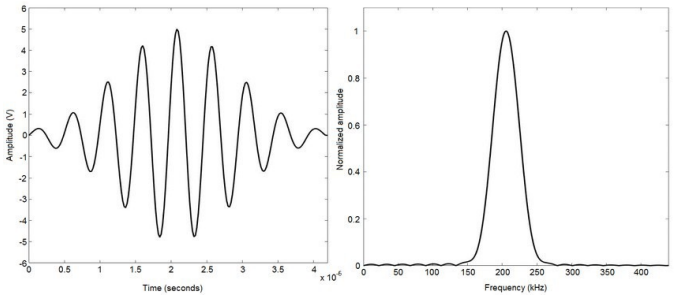


Common ABR stimuli (air conduction)

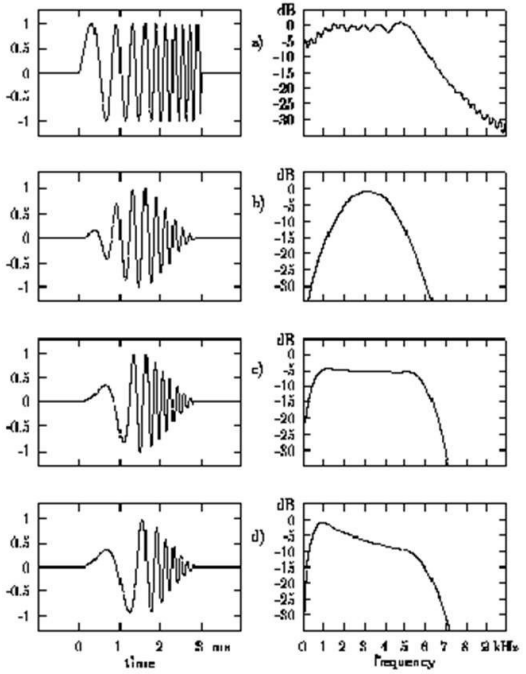
Clicks (max 2 KHz)



Tone-bursts (max = Fc)



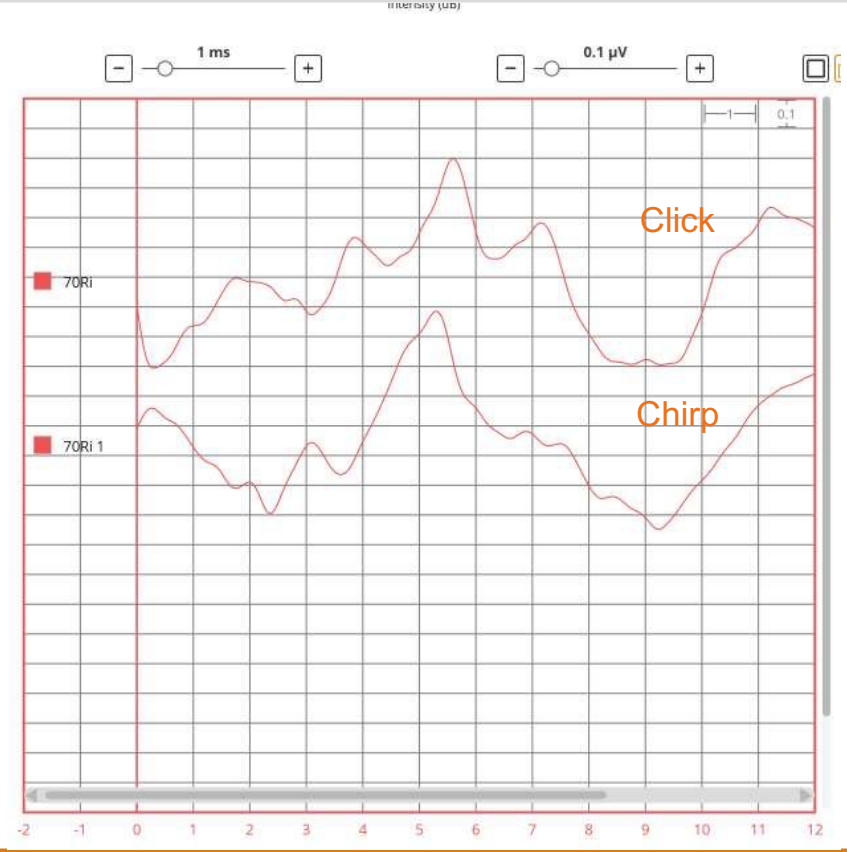
Chirp types



Filtered

Obviously with different stimuli we <u>record relatively DIFFERENT</u> ABR morphologies !!!!

Section 2 : Chirp vs Click stimuli



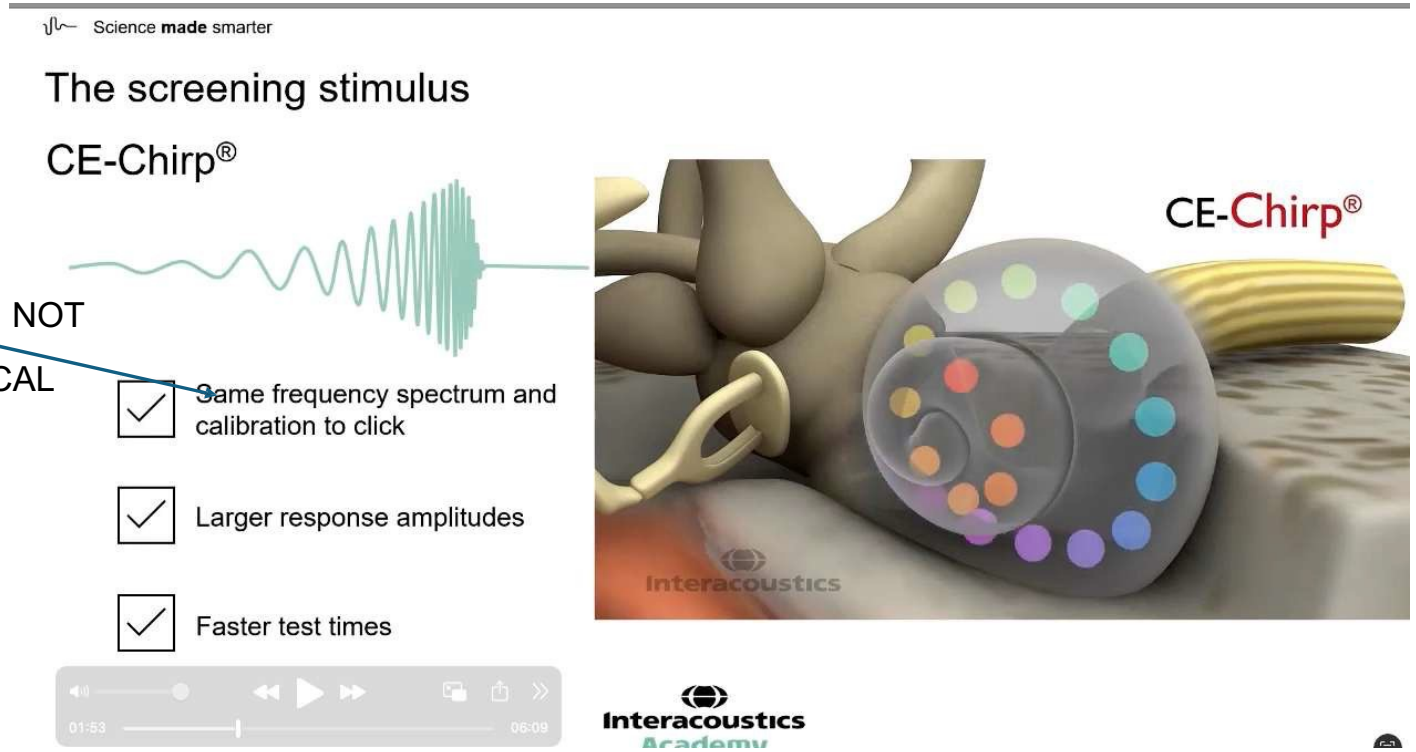
With chirp stimuli **wave V** registers as a much larger response. often as a doubling in amplitude. This offers a number of clinical advantages including:

1)a more confident **identification** of wave V near the minimum response level or threshold;

2) the detection of an ABR at **lower intensity** levels for presumably more accurate estimations of thresholds;

3) a **decreased ABR acquisition time**. The latter is crucial in the Pediatric ABR applications.

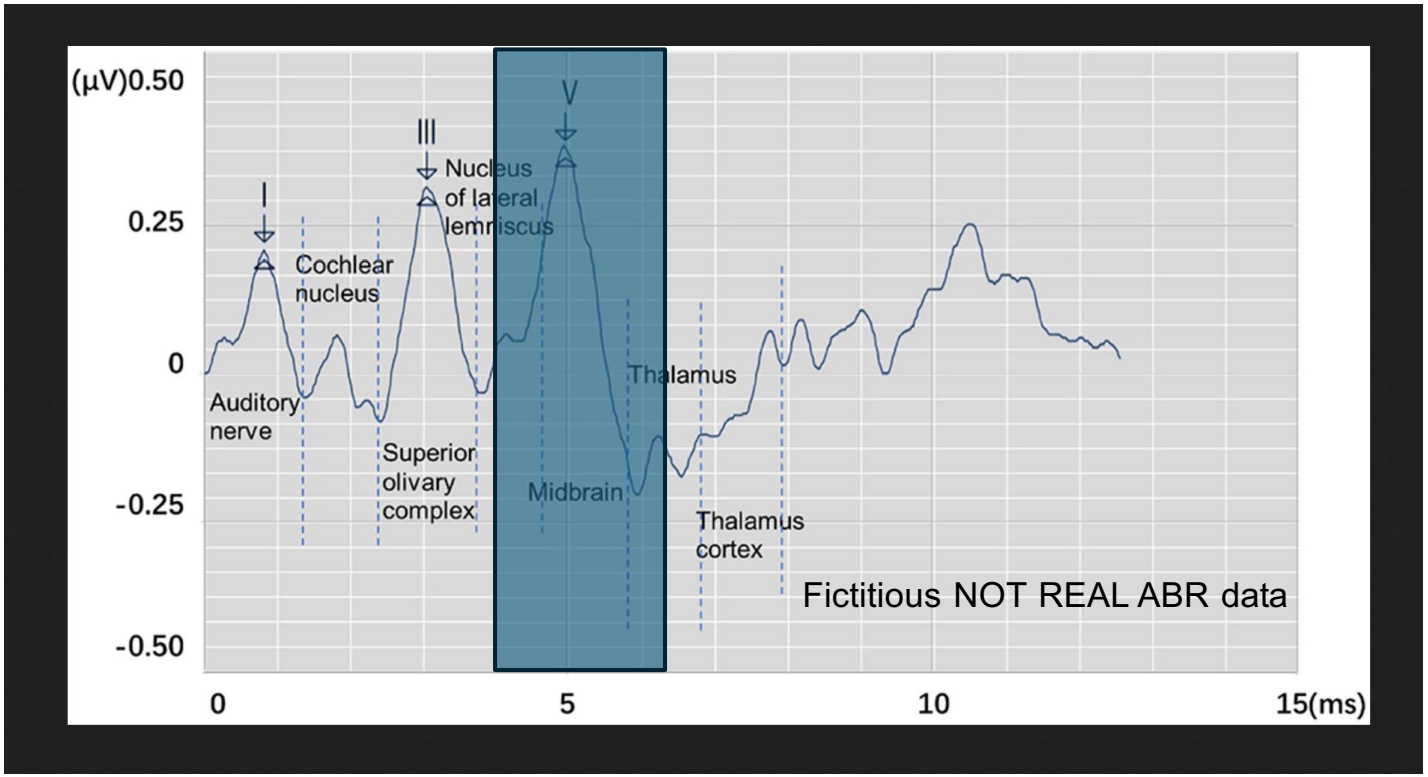
CE-Chirps for NHS



Same IS NOT IDENTICAL

https://www.interacoustics.com/academy/evoked-potentials/abr-training/role-of-ce-chirp-in-newborn-hearing-screening

How AABR algorithms work

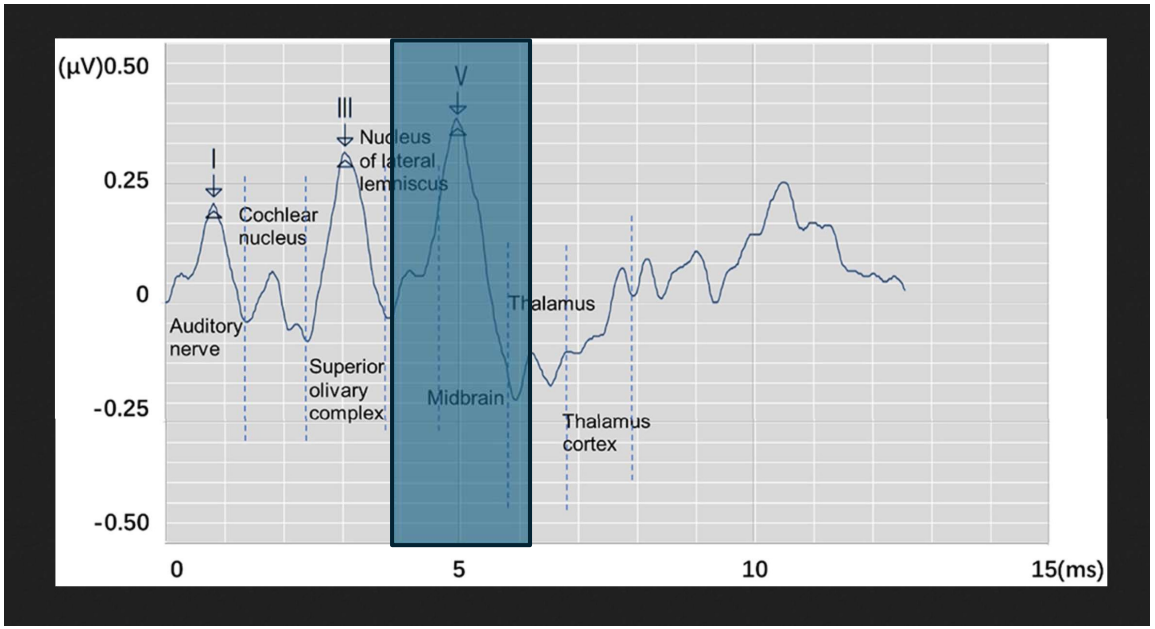


The AABR algorithms use ABR responses from known stimuli levels and **Latencies.**

They seek in a particular **Latency range** a coherent signal related to the presence of **Wave V.**

The coherence is validated **statistically**

How AABR algorithms work

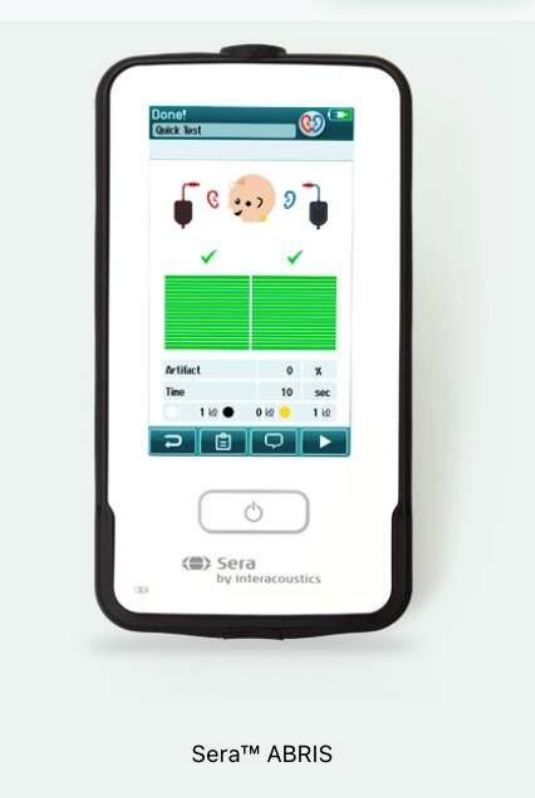


TAKE HOME MESSAGE

The obtained AABR response does NOT Resemble the classical 5 – wave response we are accustomed to see.

Many manufacturers do not even **present it.**

How AABR algorithms work



Sera™ ABRIS

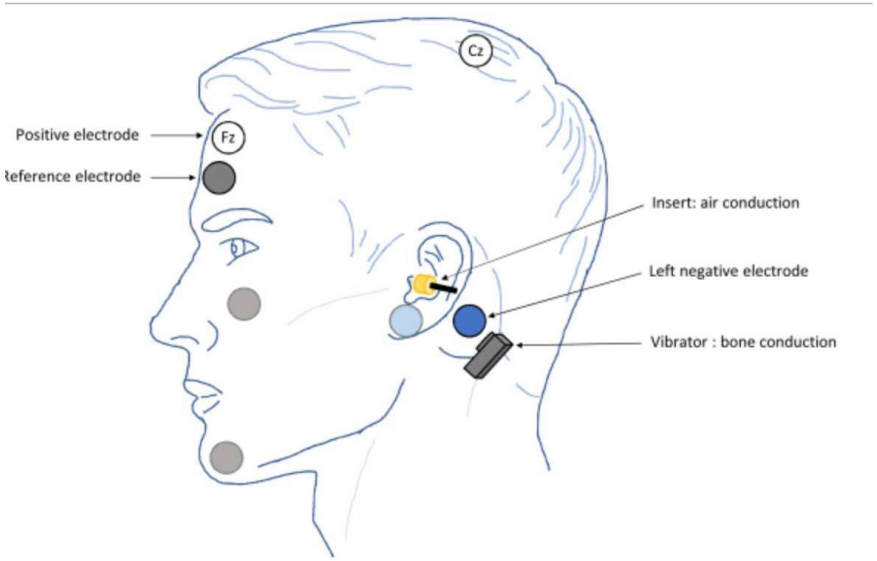
TAKE HOME MESSAGE 2

The obtained AABR response can be recorded in very short times (in 50, 70 90, 110 s !!!!).

The recent technological developments make the costs of AABR and AOAE very similar.

Personally, I would use AABR in all phases of screening (and OAE controls for all REFERs) . This option is kind of cost-prohibitive (disposable electrodes)

Classical Electrode Montage-infants



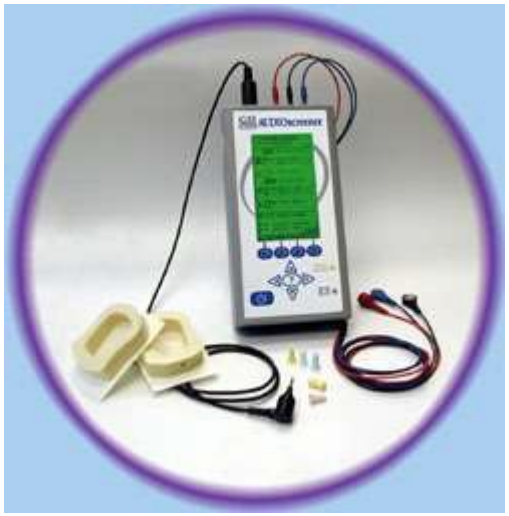
Usually, RED is the **positive electrode**

BUT NOT ALWAYS

NHS AABR Screeners

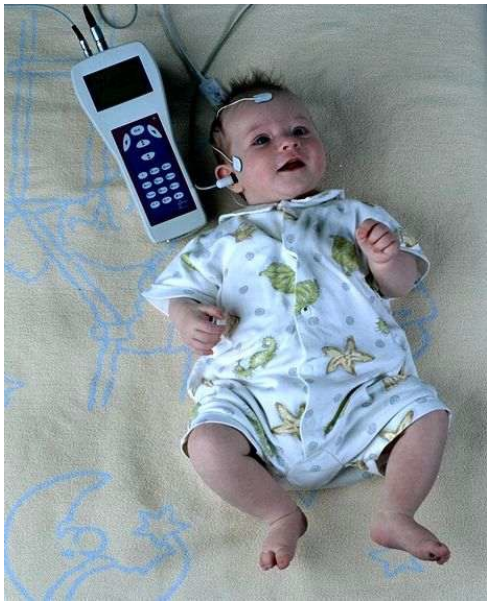
Since it is necessary to assess both WB & NICU populations, portable screening devices are highly recommended

Fourth Generation (ABR +OAEs)



Everest audio-screener

www.euromedicalaudio.com



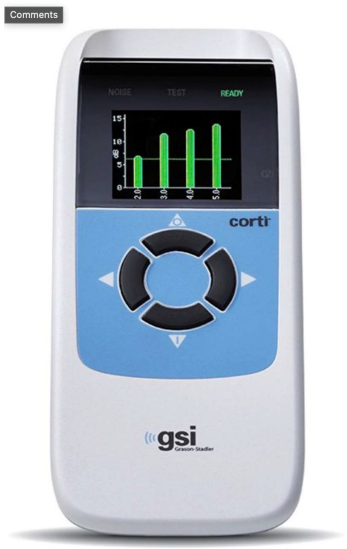
Acu-Screen

www.gnresound.it

NHS AABR Screeners

Since it is necessary to assess both WB & NICU populations, portable screening devices are highly recommended

Sixth Generation (ABR +OAEs)



NOVUS

NHS AABR Screeners

Main characteristics of the 6th / 7th generation devices

1. Small size.
2. Very fast hardware, offering **AOAE**, **AABR** and probably **A-ASSR** protocols. Some companies are considering to add multi-frequency tympanometry capabilities (a feature of the clinical devices).
3. **Low-cost** electrodes and efficient acoustic probes.
4. Better **detection algorithms** and possible AI implementation (if the device can be connected to Internet).

NHS Technologies-ASSR

3. Automated Auditory Steady State Responses

Section 3 : ABR vs ASSR

		ABR	ASSR
Stimulus			
	Type	Click or tone burst	Pure tone
	Duration	0.1-ms (click) 4 cycles (tone burst)	Steady state
	Modulation	None	Amplitude = 100%; frequency = 10%
	Frequency	Tone bursts at octave frequencies from 500 to 4000 Hz	Pure tones at octave frequencies from 250 to 8000 Hz
	Intensity	Maximum effective intensity of 90 dB nHL	Maximum effective intensity > 120 dB HL
Acquisition	Filtering	30–3000 Hz	Different filter settings are used among manufacturers
	Analysis time	~ 15 ms	Variable among manufacturers
Detection		Visual inspection of waveform peaks	Automated statistical confirmation
Analysis		Manual calculation of wave peak latencies, interwave latencies,	Mathematical calculation of stimulus versus response phase, stimulus versus response frequency, or stimulus repetition rate versus response repetition rate
Maximum estimated threshold (dB HL)		Approximately 80 dB HL	> 120 dB HL
Patient state		Quiet with minimal movement	Sleeping, sedated, or anesthetized
Gender		Shorter latencies for females than males after puberty	Lower ASSR thresholds for females versus males under selected stimulus conditions (Zakaria et al., 2016)

Hall & Momtaz: Current & Emerging clinical applications of ASSR, in Advances of Audiology & Hearing Science

NHS Technologies

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

Prognostic validity of dichotic multiple frequencies auditory steady-state responses versus distortion product otoacoustic emissions in hearing screening of high risk neonates☆

Saeid Mahmoudian [a,b,*], Mohammad Farhadi [a], Malihe Kadivar [c], Babak Ghalehbaghi [a], Farzad Rahimi [d], Mohsen Rezaei Hemami [a], Seyed Kamran Kamrava [a], Alimohamad Asghari [a], Ebrahim Amintehran [a], Parisa Mohagheghi [e]

[a] Department & Research Center of Otolaryngology, Hazrat Rasoul Akram Hospital, Tehran University of Medical Sciences (TUMS), Tehran, Iran
[b] Medical School of Hanover (MHH), Department of Otolaryngology, Hanover, Germany
[c] Department of Pediatrics, Division of Neonatology, Newborn Intensive Care Unit (NICU), Children's Medical Center Hospital, Tehran University of Medical Sciences (TUMS)
[d] Audiology Division, Kalntary Polyclinic related to Ministry of Road and Transportation
[e] Department of Pediatrics, Division of Neonatology, Newborn Intensive Care Unit (NICU), Hazrat Rasoul Akram Hospital, Tehran University of Medical Sciences (TUMS), Tehran, Iran

NHS ASSR papers

5 results

Page 1 of 1

1 Cite Share

Hearing screening using **auditory steady state responses** obtained by simultaneous air- and bone-conduction stimuli.

Mijares E, Báez L, Cabrera L, Pérez-Abalo MC, Torres-Fortuny A.

Acta Otorrinolaringol Esp. 2015 Jan-Feb;66(1):8-15. doi: 10.1016/j.otorri.2014.02.006. Epub 2014 Apr 22.

PMID: 24766784 **Free article.** Clinical Trial. English, Spanish.

2 Cite Share

New system for neonatal **hearing screening** based on **auditory steady state responses**.

Pérez-Abalo MC, Rodríguez E, Sánchez M, Santos E, Torres-Fortuny A.

J Med Eng Technol. 2013 Aug;37(6):368-74. doi: 10.3109/03091902.2013.810787. Epub 2013 Jul 5.

PMID: 23829772

3 Cite Share

Prognostic validity of dichotic multiple frequencies **auditory steady-state responses** versus distortion product otoacoustic emissions in **hearing screening** of high risk neonates.

Mahmoudian S, Farhadi M, Kadivar M, Ghalehbaghi B, Rahimi F, Hemami MR, Kamrava SK, Asghari A, Amintehran E, Mohagheghi P.

Int J Pediatr Otorhinolaryngol. 2011 Sep;75(9):1109-16. doi: 10.1016/j.ijporl.2011.05.026. Epub 2011 Jun 29.

PMID: 21719120

4 Cite Share

[Newborn **hearing screening** test with multiple **auditory steady-state responses**].

Mijares Nodarse E, Herrera Alonso D, Gaya Vázquez J, Santos Febles E, Pérez Abalo MC, Mendez Alarcón L, Robertson Terry R.

Acta Otorrinolaringol Esp. 2011 Mar-Apr;62(2):87-94. doi: 10.1016/j.otorri.2010.10.005. Epub 2011 Jan 6.

PMID: 21215381 **Free article.** Clinical Trial. Spanish.

5 Cite Share

Test accuracy and prognostic validity of multiple **auditory steady state responses** for targeted **hearing screening**.

Savio G, Perez-Abalo MC, Gaya J, Hernandez O, Mijares E.

Int J Audiol. 2006 Feb;45(2):109-20. doi: 10.1080/14992020500377980.

PMID: 16566249

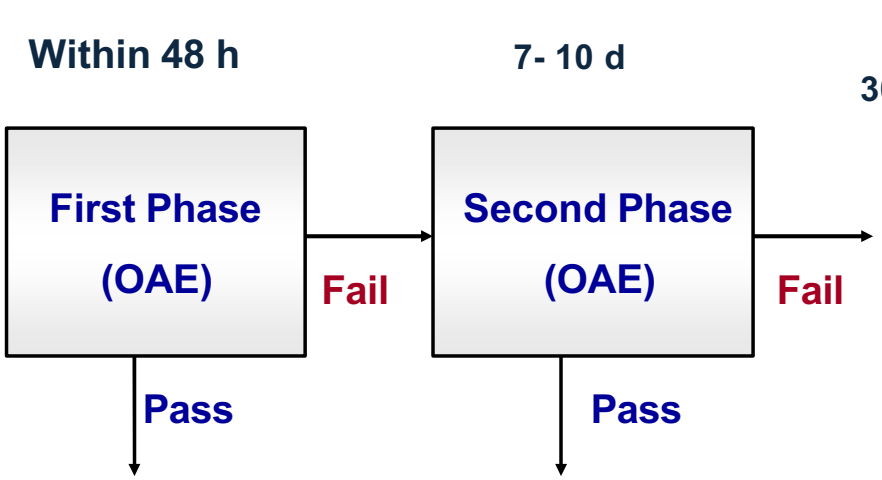
NHS Technologies

HOW and WHEN we apply the

NHS protocols

NHS 3-phase protocol

Phases of a screening program in WB

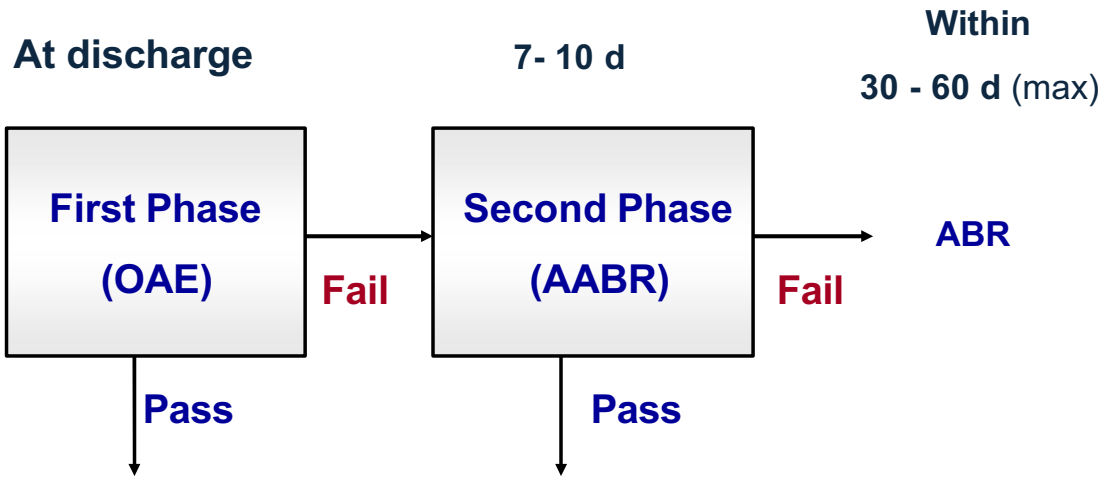


ATTENTION

In this **population** the incidenc of Auditory Neuropathy Is considered **negligible**

NHS 3-phase protocol

Phases of a screening program in preterms (at discharge > 35 w PGA)



Section 4

Artificial Intelligence in the Auditory Signal Processing

AI in AABR

An Open-Source Deep Learning-Based GUI Toolbox for Automated Auditory Brainstem Response Analyses (ABRA)

Abhijeeth Erra[1*], Jeffrey Chen[1*], Cayla M. Miller[2], Elena Chrysostomou[2], Shannon Barret[2], Yasmin M. Kassim[2], Rick A. Friedman[3], Amanda Lauer[4], Federico Ceriani[5,6], Walter Marcotti[5,6], Cody Carroll[1,7], Uri Manor[2,3,8°]

[1] *Data Institute, University of San Francisco, San Francisco, CA*
[2] *Dept. of Cell & Developmental Biology, University of California San Diego, La Jolla, CA,*
[3] *Dept. of Otolaryngology, University of California San Diego, La Jolla, CA*
[4] *Depts. of Otolaryngology-Head and Neck Surgery and Neuroscience and Center for Functional Anatomy and Evolution, Johns Hopkins University School of Medicine, Baltimore, MD*
[5] *School of Biosciences, University of Sheffield, Sheffield, S10 2TN, UK.*
[6] *Neuroscience Institute, University of Sheffield, Sheffield, S10 2TN, UK*
[7] *Dept. of Mathematics and Statistics, University of San Francisco, San Francisco, CA*
[8] *Halıcıoğlu Data Science Institute, University of California San Diego, La Jolla, CA*
[°] *Corresponding author: uri@ucsd.edu*

[*] *denotes equal contribution*

AI in ABR analysis

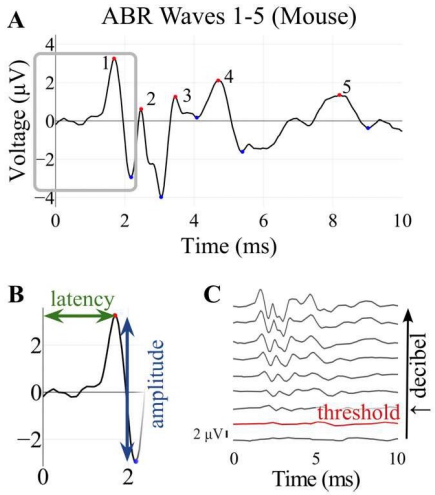


Figure 1: Example of ABR waveforms recorded from a mouse, showing its characteristic features. (A) One 10 ms ABR recording, with the five characteristic peaks denoted by red dots, and their corresponding troughs with blue dots. (B) A close up of the boxed region in (A), showing how latency (time to peak) and amplitude (peak to trough height) are defined for wave 1. (C) Several ABR recordings at varying decibels, for the same mouse and frequency. The threshold level above which the ABR response is indicative of hearing is shown in red.

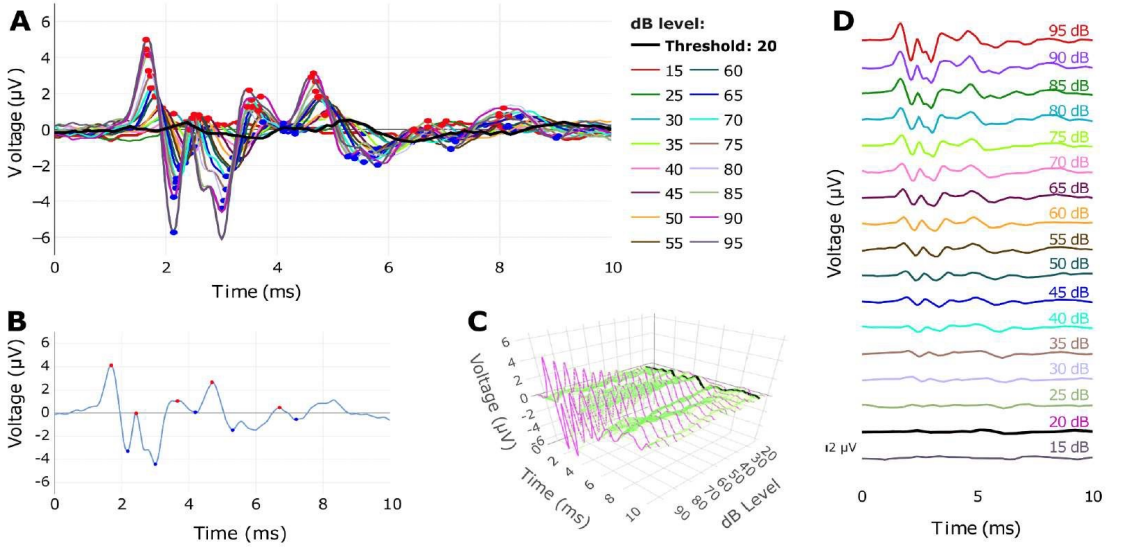


Figure 2: Visualizations from the ABRA app highlighting the various plotting functionalities on the same data. (A) visualizing several ABR waveforms from one 1 mo male C57Bl/6N mouse across different togglable dBs at 18 kHz with predicted peak locations (red points) and predicted threshold (thick black line). (B) plotting a single ABR waveform at a specific sound frequency (18 kHz) and intensity (85 dB) with peaks and troughs labeled. (C) 3D plotting of the same ABR waveforms in (A), with the predicted threshold (20 dB) highlighted in black (can be interactively rotated in the app) (D) stacked plotting of the same ABR waveforms at a single frequency, across increasing dB, with the predicted threshold (20 dB) highlighted in black.

Link in the additional Resources Section at the end

European Archives of Oto-Rhino-Laryngology
https://doi.org/10.1007/s00405-025-09272-5

MISCELLANEOUS

Artificial intelligence in otorhinolaryngology: current trends and application areas

Emre Demir[1] · Burak Numan Uğurlu[2] · Gülay Aktar Uğurlu[3] · Gülçin Aydoğdu[1]

Received: 30 December 2024 / Accepted: 3 February 2025

AI research topics were found to be : cochlear implant, head and neck cancer, magnetic resonance imaging (MRI), hearing loss, patient education, diagnosis, radiomics, surgery, hearing aids, laryngology, otitis media.

Recent trends in ENT research reflect a dynamic focus, **progressing** from hearing-related technologies such as hearing aids and cochlear implants in earlier years, to diagnostic innovations like audiometry, psychoacoustics, and narrow band imaging.

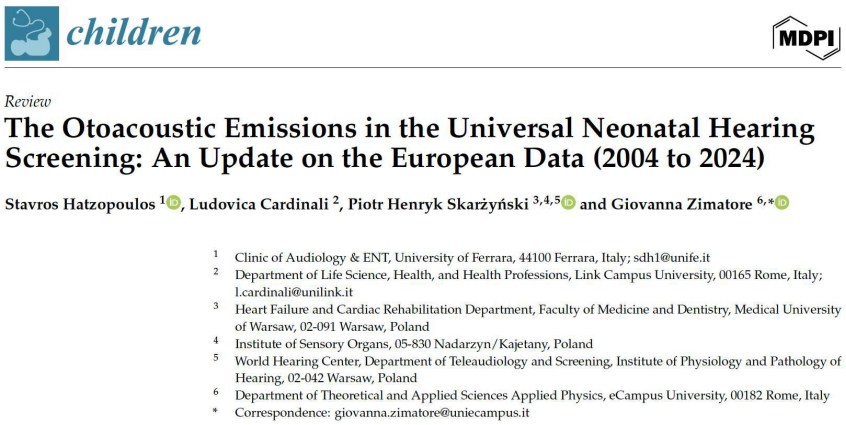
In addition to NHS

Is there more to

Hearing Screening ?

Absolutely YES : There are suggestions in the literature to conduct in parallel GENETIC SCREENING for HL

In addition to NHS



children

MDPI

Review

The Otoacoustic Emissions in the Universal Neonatal Hearing Screening: An Update on the European Data (2004 to 2024)

Stavros Hatzopoulos [1], Ludovica Cardinali [2], Piotr Henryk Skarżyński [3,4,5] and Giovanna Zimatore [6,*]

1 Clinic of Audiology & ENT, University of Ferrara, 44100 Ferrara, Italy; sdh1@unife.it
2 Department of Life Science, Health, and Health Professions, Link Campus University, 00165 Rome, Italy; l.cardinali@unilink.it
3 Heart Failure and Cardiac Rehabilitation Department, Faculty of Medicine and Dentistry, Medical University of Warsaw, 02-091 Warsaw, Poland
4 Institute of Sensory Organs, 05-830 Nadarzyn/Kajetany, Poland
5 World Hearing Center, Department of Teleaudiology and Screening, Institute of Physiology and Pathology of Hearing, 02-042 Warsaw, Poland
6 Department of Theoretical and Applied Sciences Applied Physics, eCampus University, 00182 Rome, Italy
* Correspondence: giovanna.zimatore@uniecampus.it

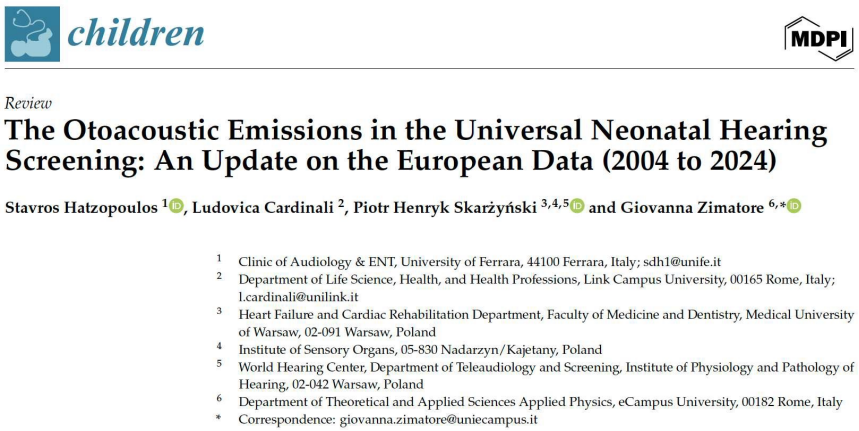
In 2024, Chibisova et al. presented a more in-depth analysis of the data collected by the Russian national UNHS.

*The authors analyzed genetic, audiological and NHS data of **1292** pediatric patients with bilateral sensorineural hearing loss born from 2008 to 2021.*

***GJB2** sequencing was conducted on all subjects, resulting in **644** patients with a pathological GJB2 genotype profile.*

*Four hundred and six (**406**) of these patients were found homozygous for the **c.35delG** variant.*

In addition to NHS



children

MDPI

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3 Heart Failure and Cardiac Rehabilitation Department, Faculty of Medicine and Dentistry, Medical University of Warsaw, 02-091 Warsaw, Poland
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6 Department of Theoretical and Applied Sciences Applied Physics, eCampus University, 00182 Rome, Italy
* Correspondence: giovanna.zimatore@uniecampus.it

The authors reported that “the most frequent genes were STRC (21.8%), USH2A (16.1%),nOTOF (8%) and SLC26A4 (6.9%).

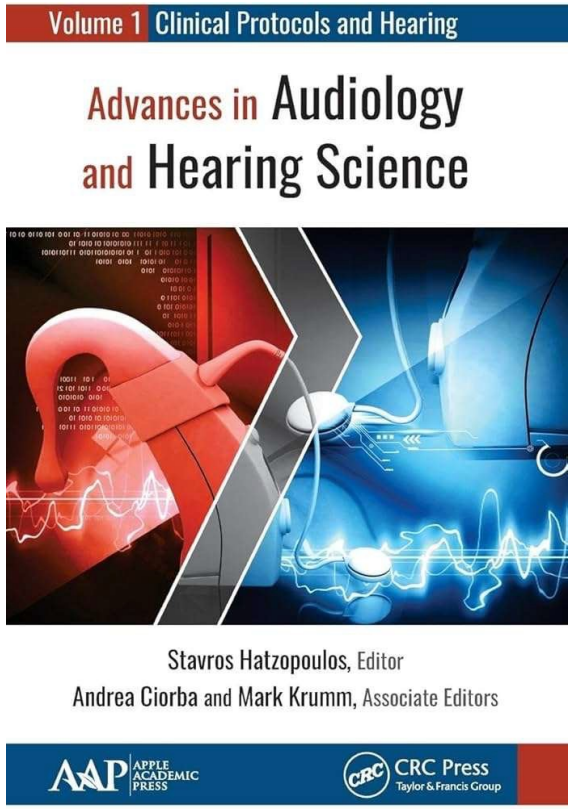
Children with confirmed genetic etiology passed NHS in 21% of cases”.

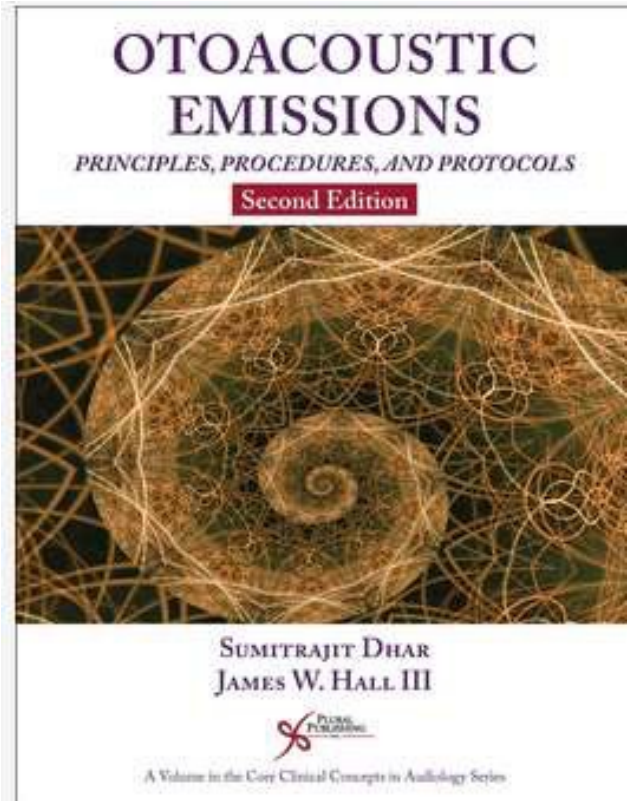
These data suggest that genetic screening of the most frequent Connexin 26 mutations **should be CONDUCTED** in parallel with NHS.

Statistical concepts of Screening

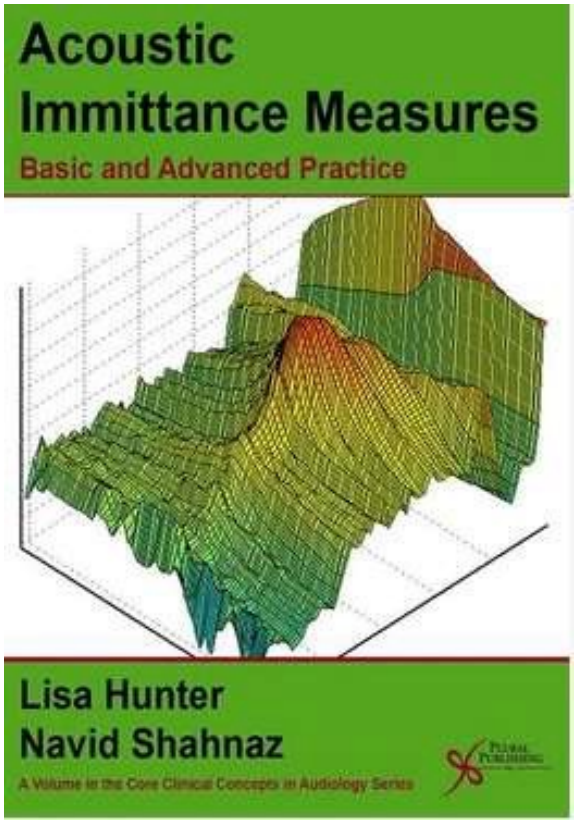
References Section

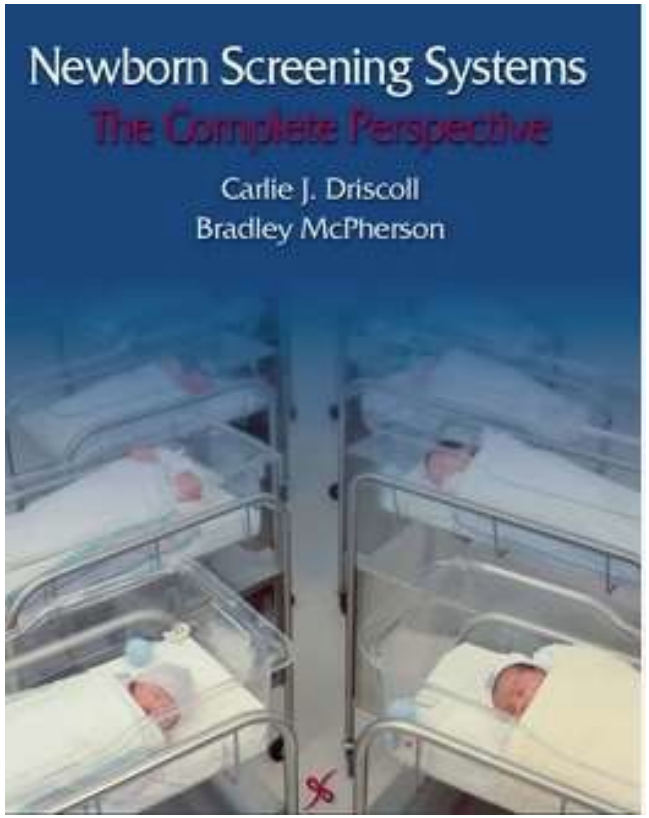
References for further study





References for further study





This is the End

That's all Folks !!

For extra questions

sdh1@unife.it

Auditory Screening

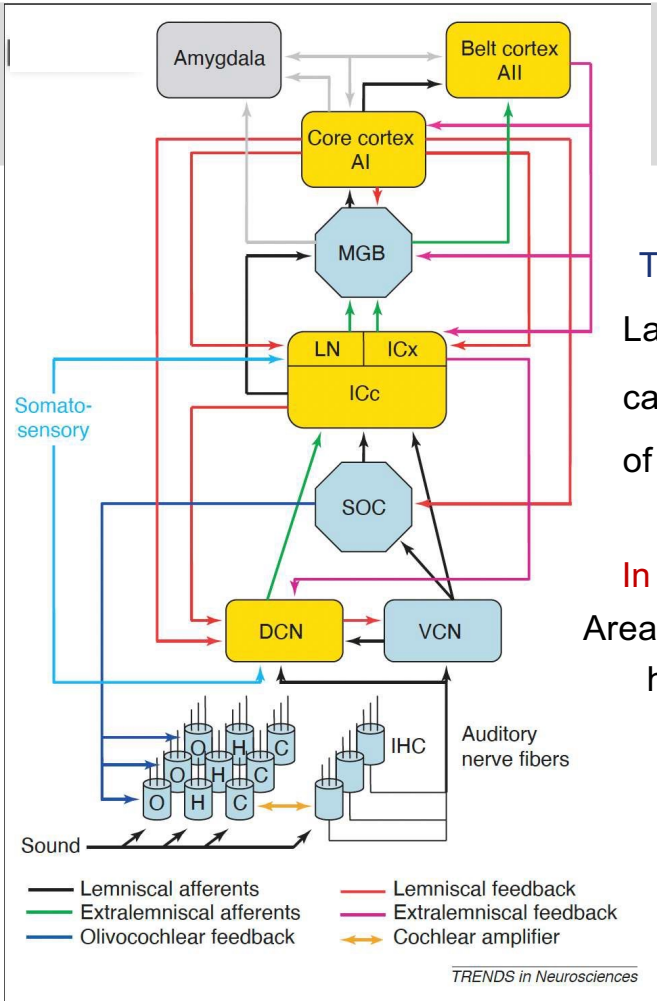
Extra Information

Neural & Efferent Pathways

Food for thought

1. The OAEs reflect cochlear activity till the OHCs.

2. Feedback pathways from the Superior Olivary Complex (SOC) can affect the OHC motility. These pathways require a particular testing OAE protocol.



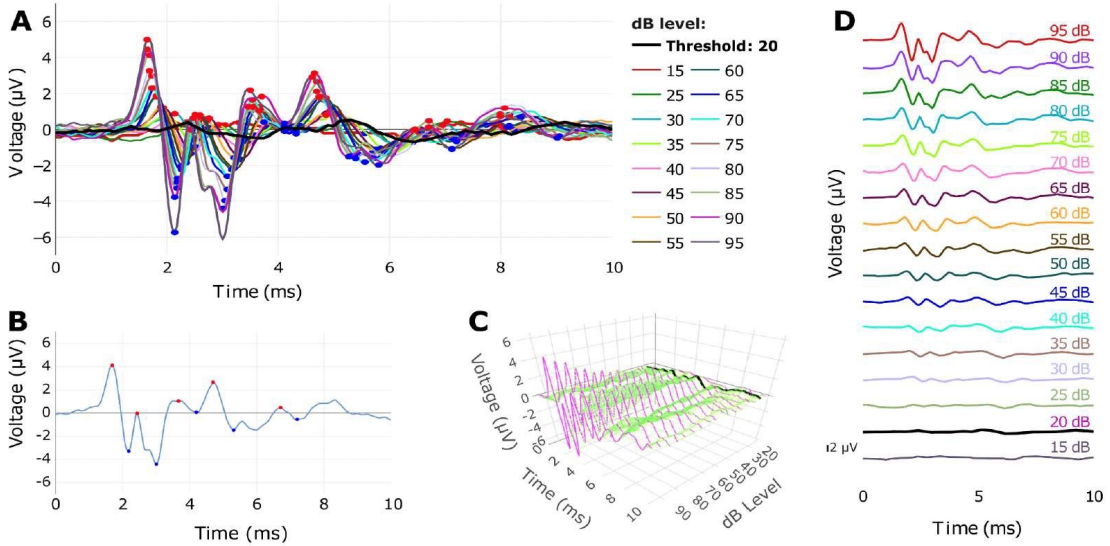
The Central Gain model

Lack of Inhibitory activity caused by a propagation of a peripheral damage.

In Yellow the Auditory system Areas, where Tinnitus connections has been INVESTIGATED

Eggemont & Roberts. The Neuroscience of Tinnitus. Trends in NeuroScience , 2004

AI in ABR analysis



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Play with your ABR data (animal model)

using the

Author's application

https://abra.ucsd.edu.