"♪ CHIRP, CHIRP ♪"

A Little Birdie Told Me About Developments in ABR & ASSR Testing;

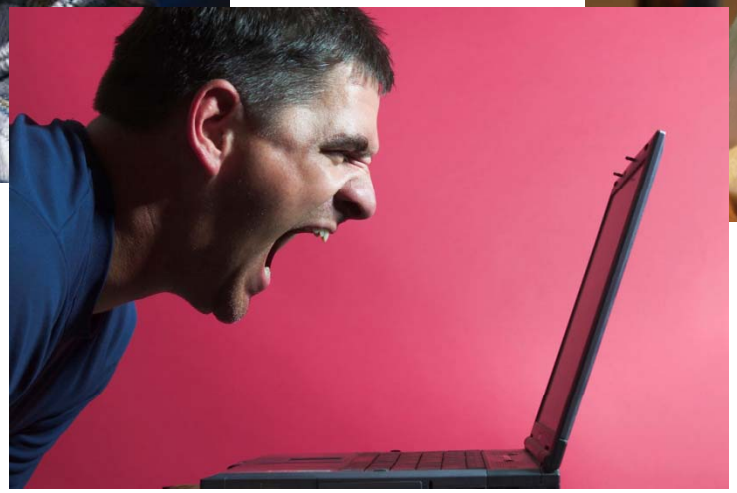
Using the CE Chirp Stimulus for Faster Test Times

Jill Craig, MA
2010 EHDI Meeting-Chicago
March 1, 2010

Interacoustics®
leading diagnostic solutions

In a Perfect World

In the Real World



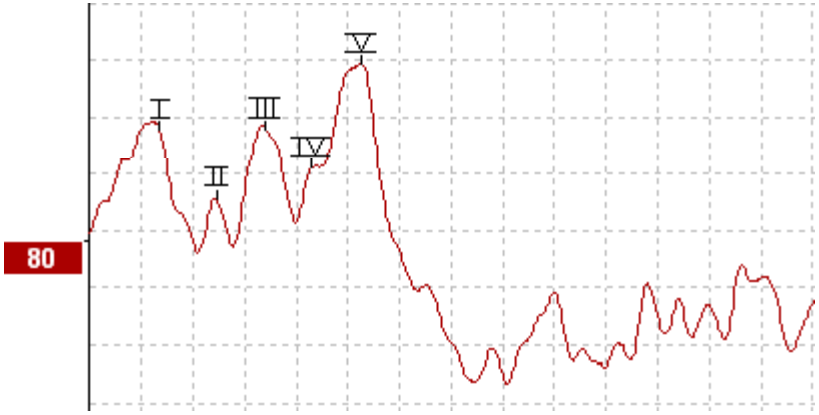
Challenges of Diagnosing Hearing Loss

- Can take multiple visits to finalize results
- Each appointment can take sometimes hours to complete
- Sedation or no sedation?
- Objective vs Subjective?
- “Peak Picking” Experience

The Auditory Brainstem Response (ABR)

- An evoked potential is an electrical response induced by sound; it arises from the structures within the ear, nerve, and brain at some distance from skin electrodes.
- It is measured in the time domain
- Relies on synchronous nerve firing

ABR….the good



- Historical, Gold Standard
- Normative Data/Research Supported
- Differential diagnosis ANSD
- Comfortable!

ABR…..the challenges

- Can Be Time Consuming
- Peak Picking Experience
- Intensity limitations
- Single Intensity and Frequency

The Auditory Steady State Response

- Similar to ABR, but EEG activity is analyzed in frequency domain
- Stimulus is modulated pure tone
- EEG activity modulating at same frequency as the stimulus is representative of a response
- The presence or absence of a response is determined by a statistical computer algorithm

ASSR History

- Late 1970's and Early 1980's-Initial Research
  - Galambos
- 1991-First clinically available system
- Today-Several Clinical Systems
  - Biologic, GN Otometrics, GSI, IHS, Interacoustics

ASSR…..the good

- More Frequency Specific
- No peak picking—Objective Detection
- Multiple and Simultaneous Frequency Testing
- Can test at higher intensities than ABR

ASSR…..the challenges

- Limited normative/research data as compared to ABR
- Small amplitude response; maybe more sensitive to noise
- Exact Neural Generators not defined
- CHANGE!!

Testing Considerations

- Stimulus Methods
- Detection Methods

ABR Stimulus

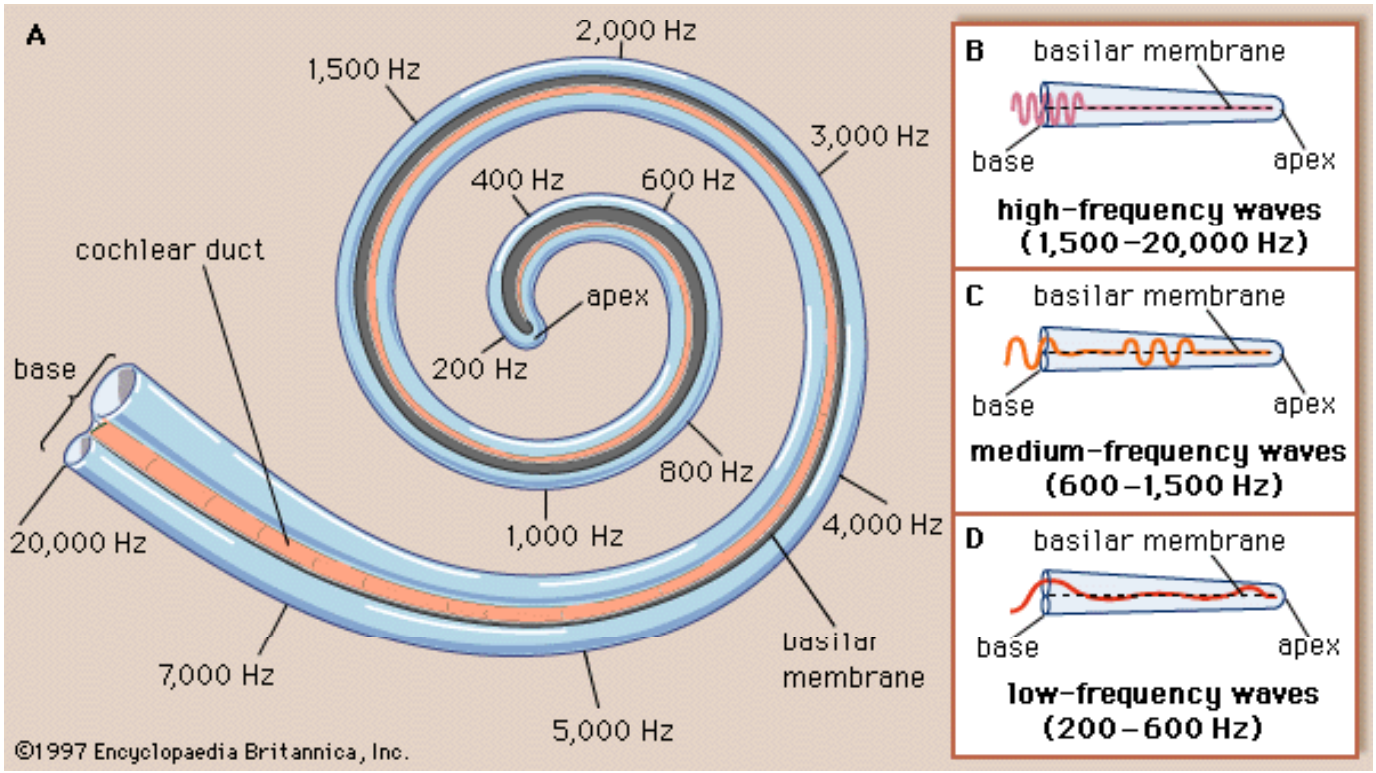
- Click
  - Abrupt and rapid onset
  - Broad spectrum (theoretically stims the entire basilar membrane) *NOT FREQUENCY SPECIFIC!!!*
    - Test 2000-4000Hz frequency range!
  - The greater number of neurons that fire results in a larger response amplitude.
  - *Need Good Neural Synchrony*

ABR Stimulus

- Tone Burst
  - Provides more frequency specific information
  - High correlation between behavioral and TB responses
  - Can diagnosis low and high frequency HL
  - 500Hz can be difficult!
    - Repeatability is difficult because there is less synchronous activity at that region on the cochlea
    - Requires longer window
    - Response can be 4-8ms later than a click

New Stimulus for ABR & ASSR

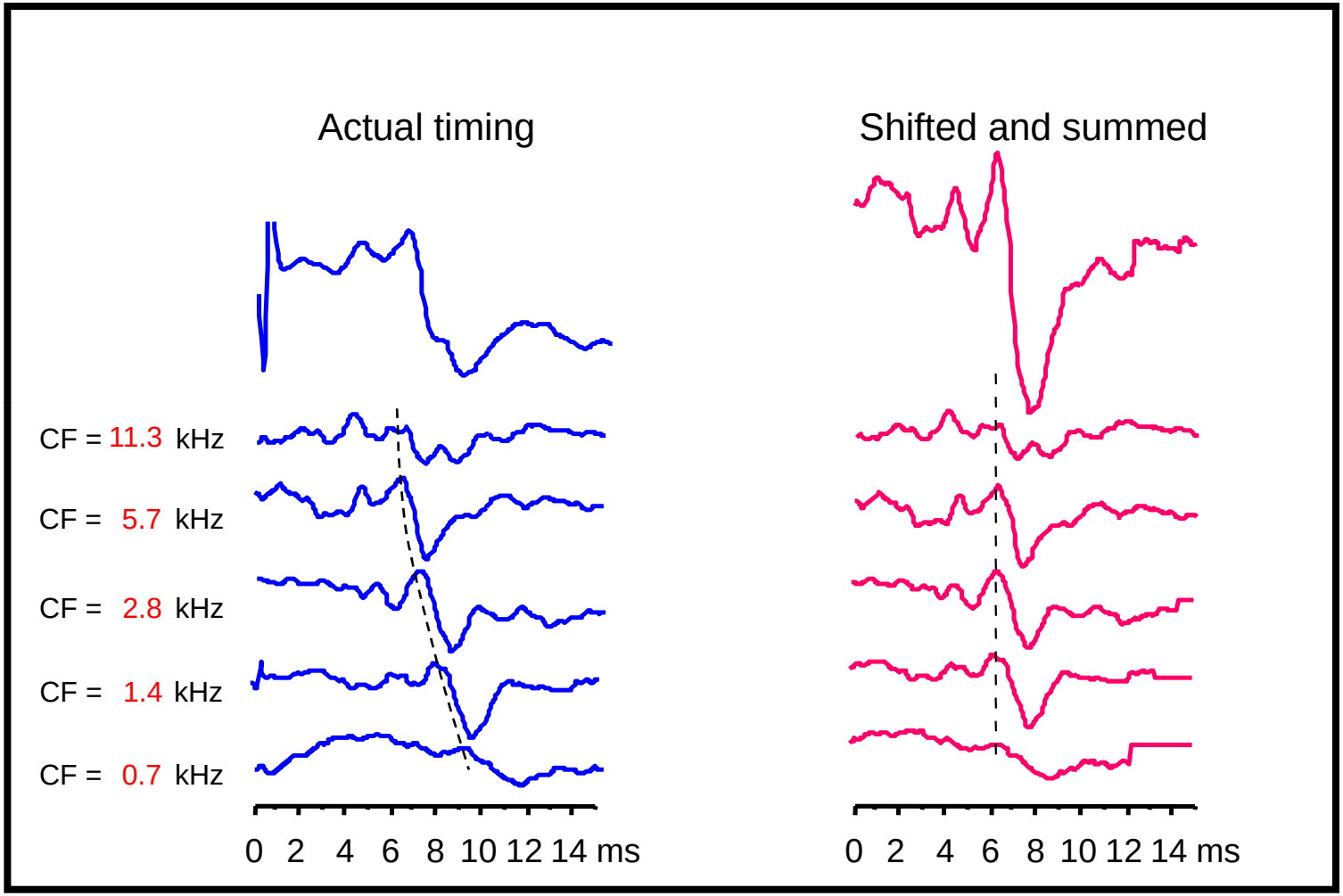
Travel time in the cochlea is different for different frequencies



Output compensation for traveling time

- If the narrow band activity is recorded, compensation for the traveling time can be obtained by time-shifting the narrow band activity
- After summation the so-called *Stacked ABR* is obtained
- The Stacked ABR is significantly larger than the normal ABR
- The procedure to obtain the Stacked ABR is complex and needs considerable recording time – and has therefore not become clinically popular.

Stacked ABR – effective but impractical



M. Don – House Ear Institute, 2002

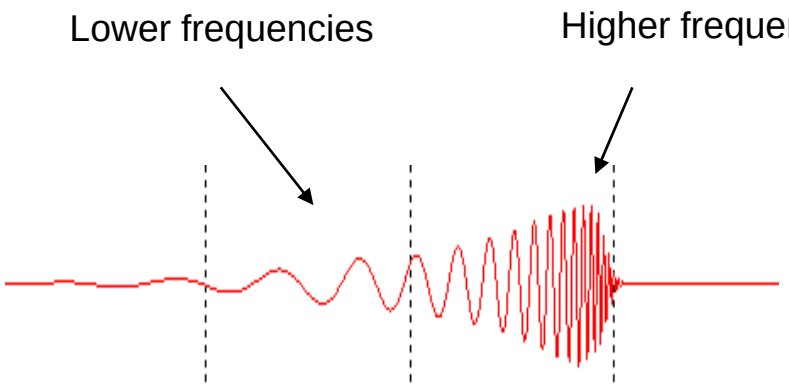
Input compensation for traveling time

- Another way to compensate for the traveling time is to time-shift the different frequency components of the stimulus
- This is done by allowing the low-frequencies to appear before the high-frequencies
- Such a click with re-shuffled frequency components is called a *Chirp.*
- A *chirp* stimulus is particularly effective at lower stimulation levels , where response amplitude almost doubles compared to an equal bandwidth click stimulus.*

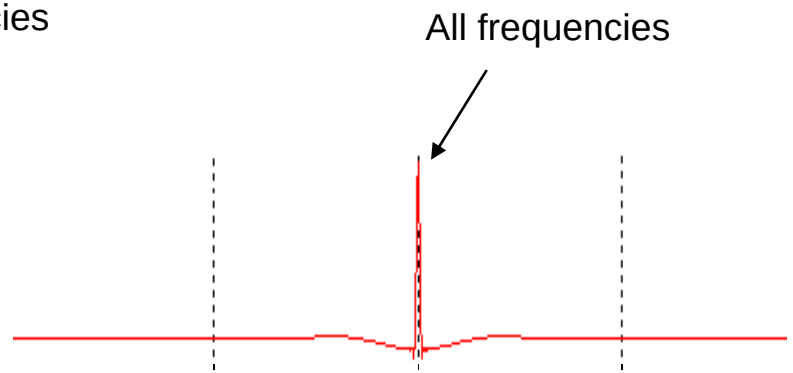
** Elberling and Don 2008, J. Acoust. Soc. Am.*

Instead of Synchronizing the Response….
……..Synchronize the Stimulus!

Lower frequencies are sent a bit earlier into the cochlea than the higher frequencies

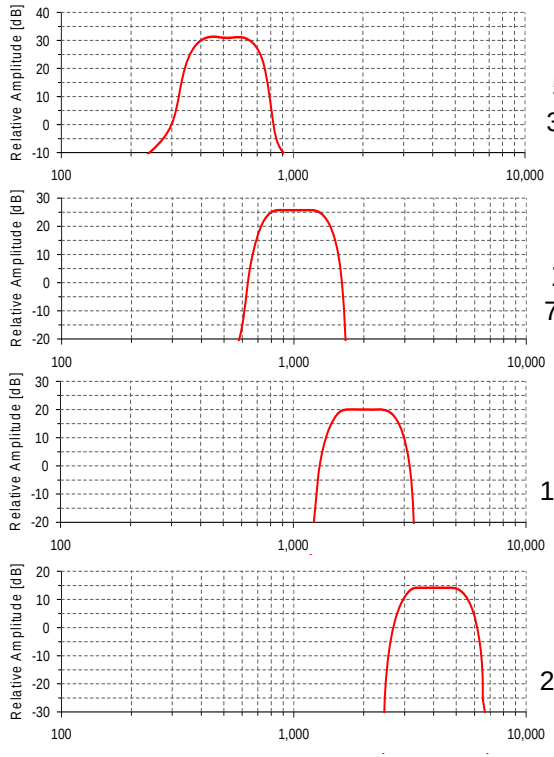


Chirp



Click

Frequency Specific Narrow Band CE-Chirps

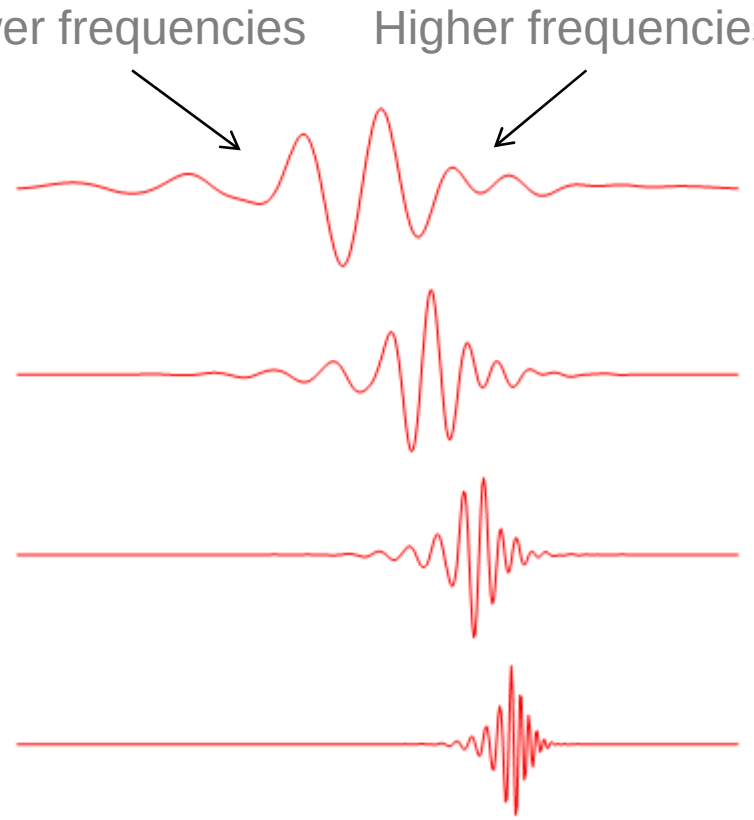


500 Hz
360 - 720

1,000 Hz
720 – 1,440

2,000 Hz
1,440 – 2,880

4,000 Hz
2,880 – 5,760



Understanding the CE Chirp

Animation of the CE Chirp

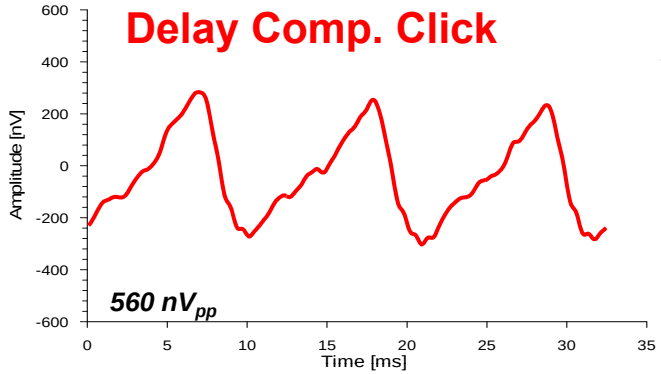
Supporting literature

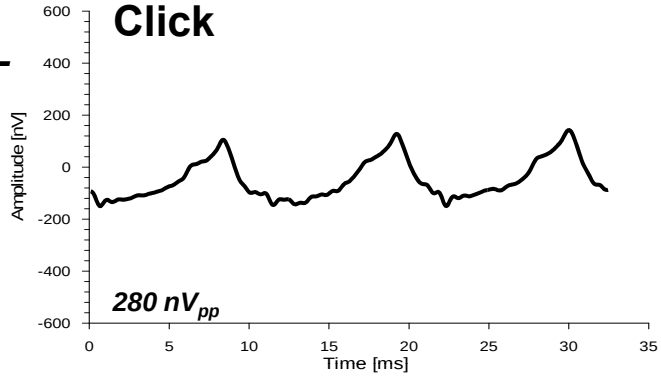
Study #1 on adults

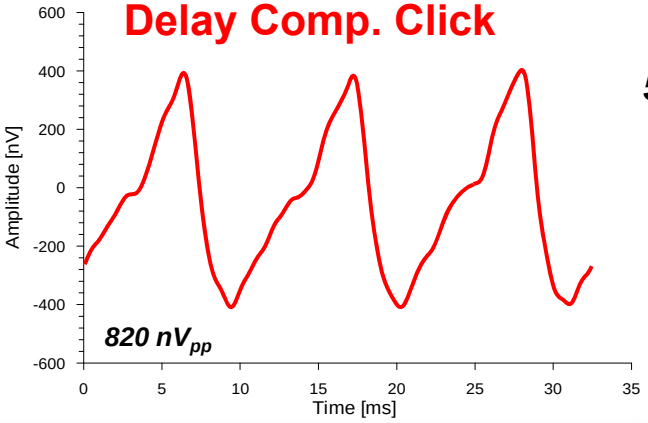
- Testing:
  - **Delay Comp. Click** vs. **Click** **(= full frequency range)**
  - 49 normal-hearing younger adults

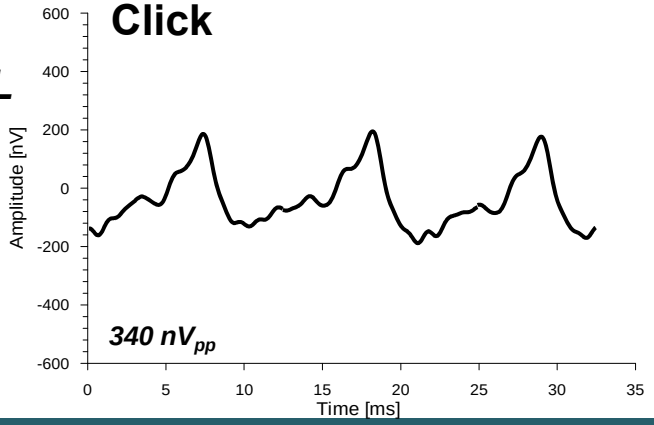
Supporting literature

Grand Average ASSR temporal waveforms









Supporting literature

Conclusion study #1

30 dBnHL

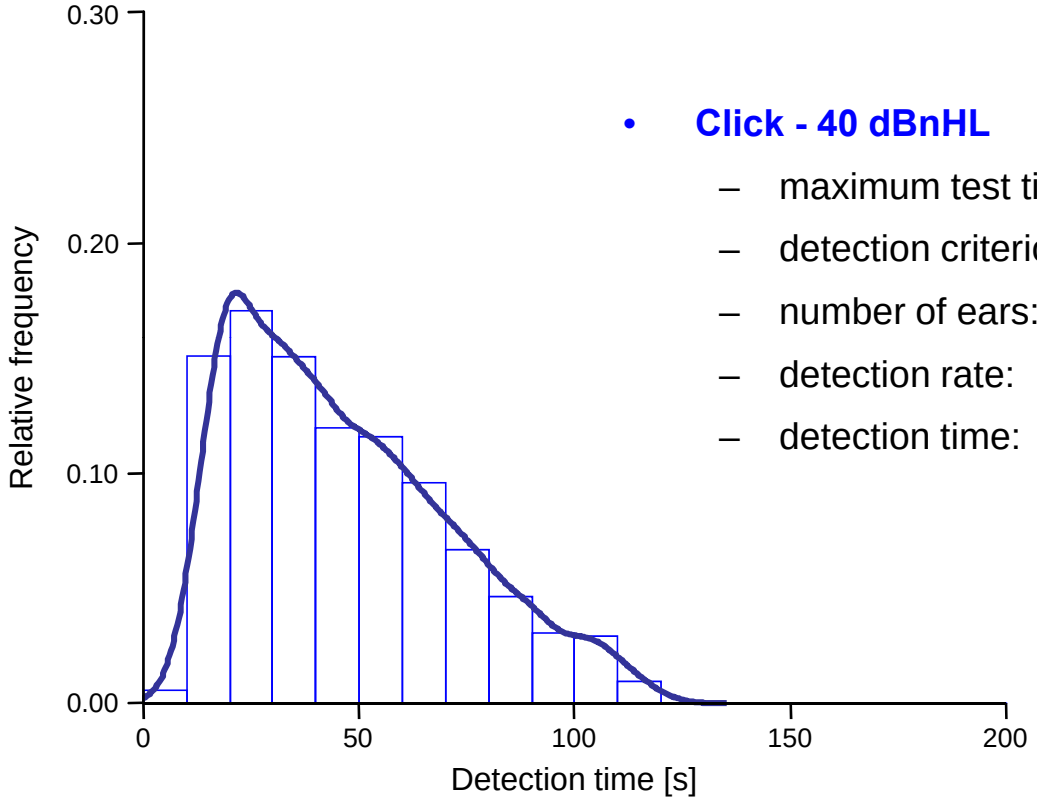
	Detection Rate	Detection Time
Click	**83.3 %**	**72 s**
Delay Comp. Click	**97.7 %**	**30 s**

Supporting literature

Study #2 on newborns

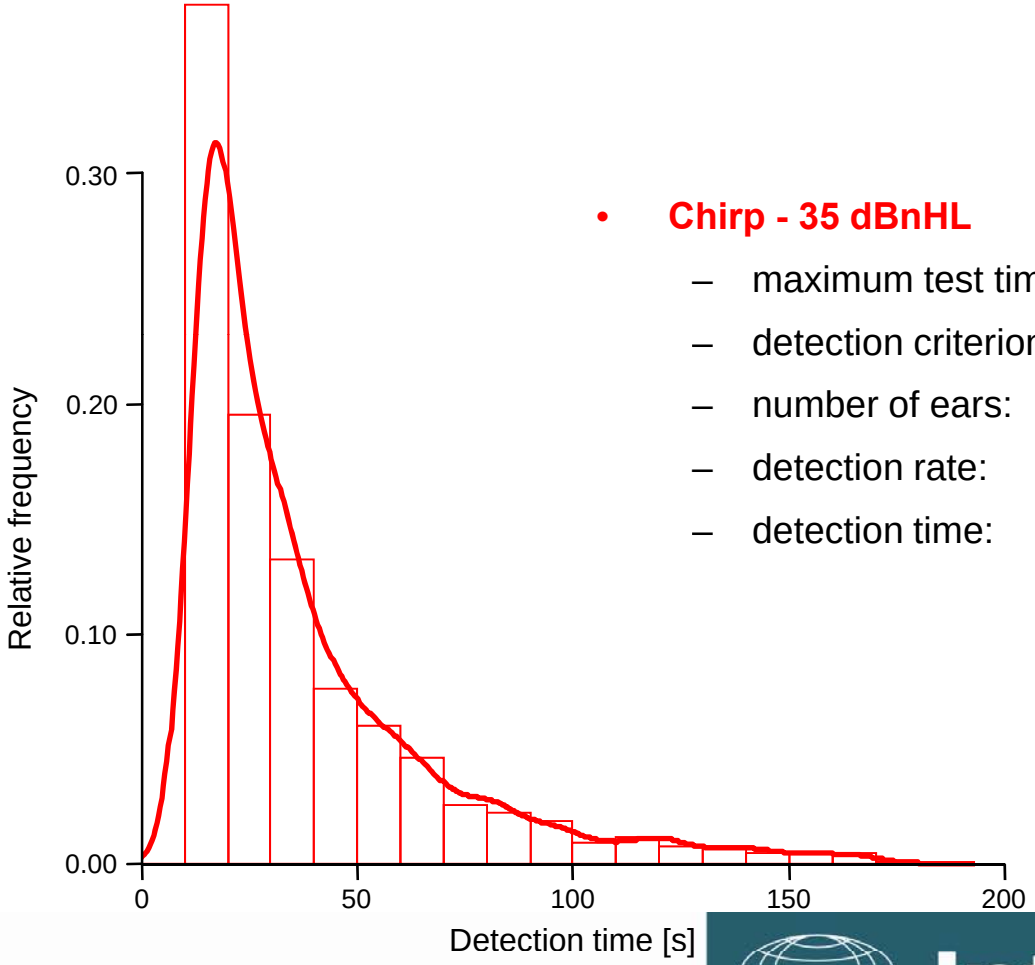
- **Screening:**
  - **Click** (40 dBnHL) and **Chirp** (35 dBnHL)
  - Several studies – incl two groups of newborns (each of about N = 1,800)

Supporting literature



- **Click - 40 dBnHL**
  - maximum test time: 120 s
  - detection criterion: 0.1 %
  - number of ears: 1744
  - detection rate: 95.4 %
  - detection time: **42 s** (median)
    47 s (mean)

Supporting literature



- **Chirp - 35 dBnHL**
  - maximum test time: 180 s
  - detection criterion: 0.1 %
  - number of ears: 1833
  - detection rate: 96.3 %
  - detection time: **28 s** (median)
    38 s (mean)

Supporting literature

Conclusion study #2

	Detection Rate	Detection Time
Click 40dBnHL	**95.4 %**	**42 s**
Delay Comp. Click 35dBnHL	**96.3 %**	**28 s**

Documenting Efficiency of CE-Chirp® family

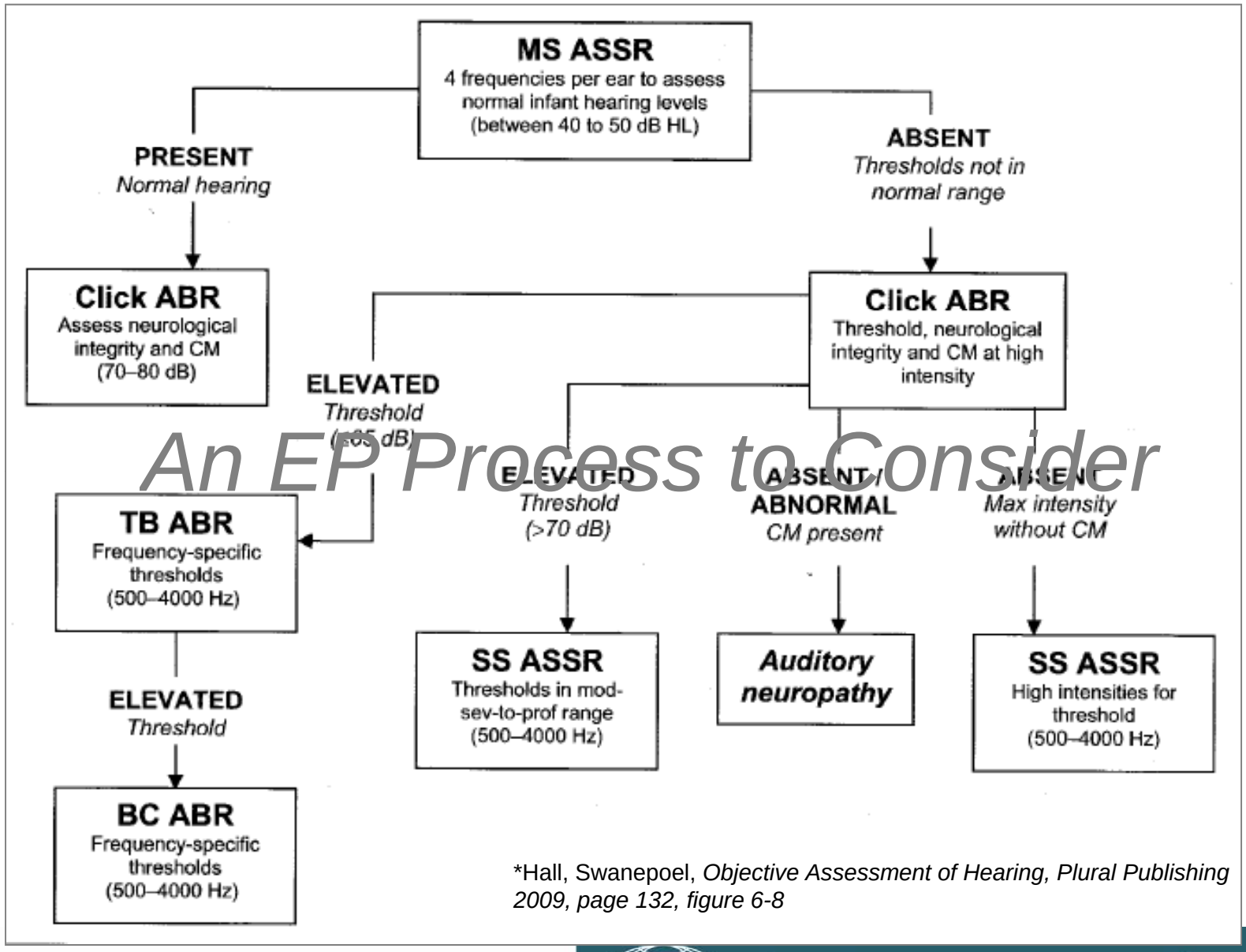
The efficiency of these new stimuli are documented in a series of publications:

1. *Don, M., Elberling, C., and Maloff, E. (2009). "Input and output compensation for the cochlear traveling wave delay in wide-band ABR recordings: Implications for small acoustic tumor detection," J. Am. Acad. Audiol. 20, (2).*
2. *Elberling, C., and Don, M. (2008). "Auditory brainstem responses to a chirp stimulus designed from derived-band latencies in normal-hearing subjects," J. Acoust. Soc. Am. 124, 3022-3037.*
3. *Elberling, C, Don, M, Cebulla, M, & Stürzebecher, E. (2007). Auditory steady-state responses to chirp stimuli based on cochlear traveling wave delay. J. Acoust. Soc. Am. 122, 2772-2785*
4. *Stürzebecher, E, Cebulla, M, Elberling. C, & Berger, T. (2006). New efficient stimuli for evoking frequency-specific auditory steady-state responses. J. Am. Acad. Audiol. 17, 448-461.*
5. *Cebulla, M, Stürzebecher, E, Elberling, C, & Berger, T. (2006). New click-like stimuli for newborn hearing screening. J. Am. Acad. Audiol. 18, 725-738*

Implementation of ASSR into the Clinic

ASSR is an additional tool in the "Cross Check Principle"

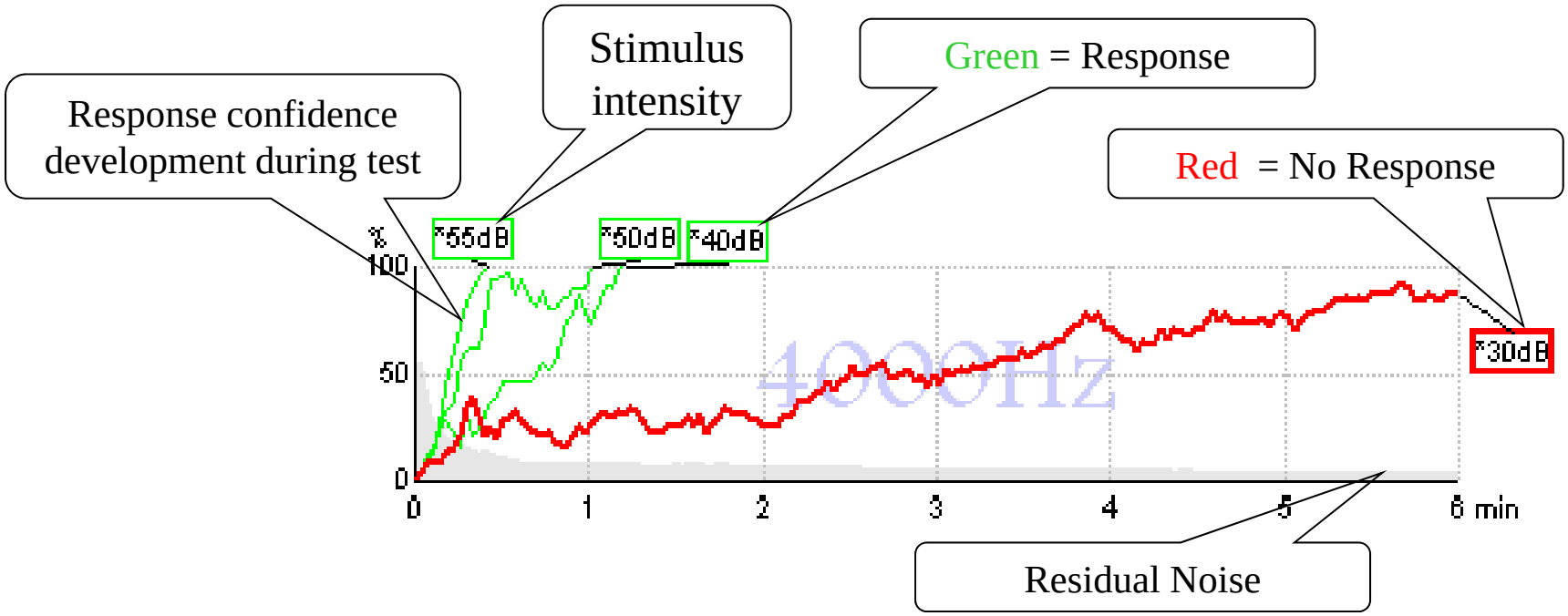
"In summary, we believe that the unique limitations of conventional behavioral audiometry dictate the need for a 'test battery' approach. The key concept governing our assessment strategy is the cross-check principle. The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure. . . . We believe that the application of the cross-check principle to our clinical population has had an appreciable effect on the accuracy with which we can identify and quantify hearing loss during the critical years for language-learning." (Jerger and Hayes, 1976, p. 65)



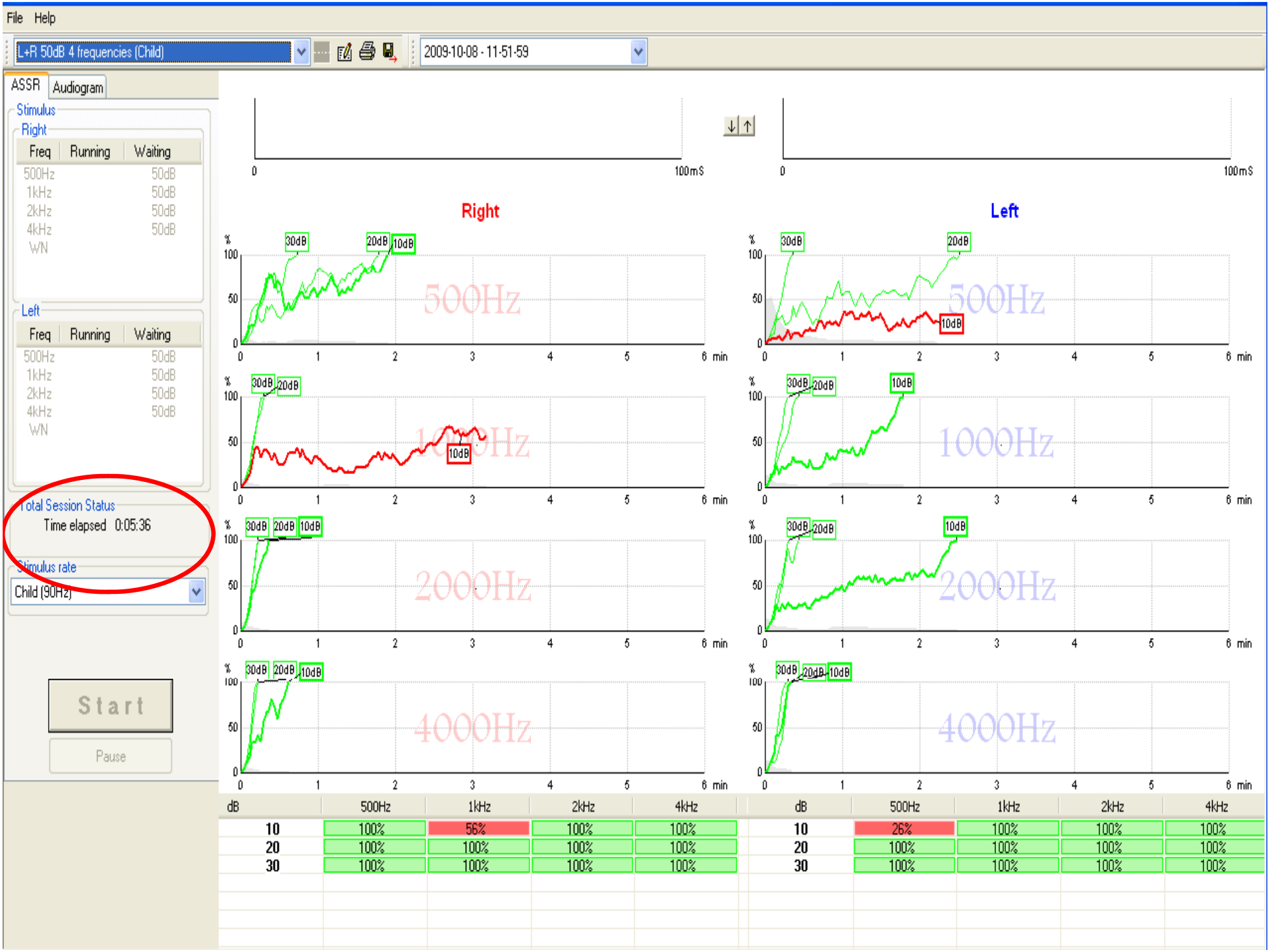
*Hall, Swanepoel, *Objective Assessment of Hearing, Plural Publishing 2009, page 132, figure 6-8*

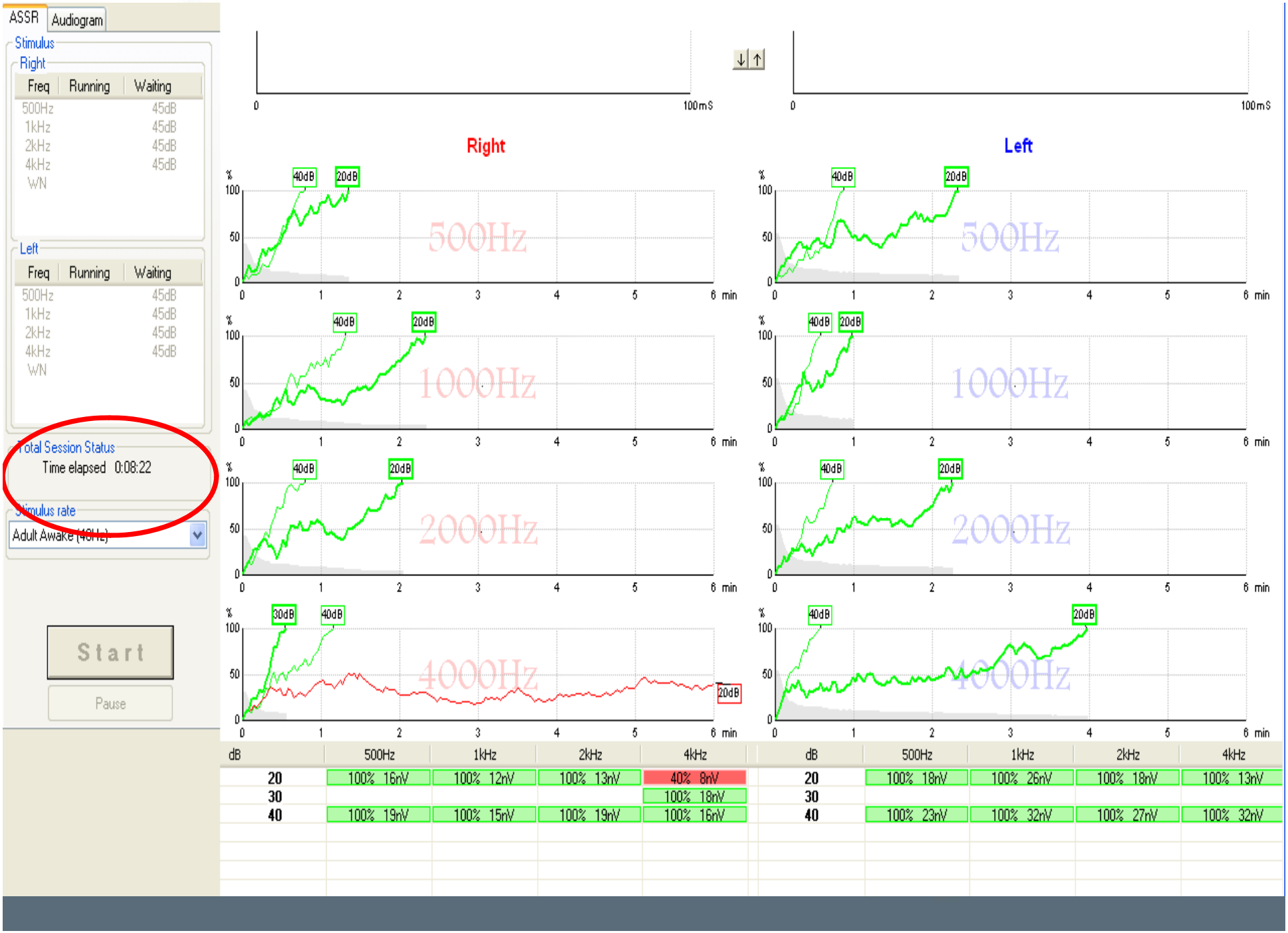
Data Samples

The ASSR Screen



To optimize session strategy decisions as test progresses, the response confidence is tracked over time for each test frequency.


File Help
L+R 50dB 4 frequencies (Child)
2009-10-08 - 11-51-59
ASSR
Audiogram
Stimulus
Right
Freq Running Waiting
500Hz 50dB
1kHz 50dB
2kHz 50dB
4kHz 50dB
WN
Left
Freq Running Waiting
500Hz 50dB
1kHz 50dB
2kHz 50dB
4kHz 50dB
WN
Total Session Status
Time elapsed 0:05:36
Stimulus rate
Child (90Hz)
Start
Pause
0
100mS
Right
Left
30dB
20dB
10dB
500Hz
1000Hz
2000Hz
4000Hz
%
min
dB 500Hz 1kHz 2kHz 4kHz
10 100% 56% 100% 100%
20 100% 100% 100% 100%
30 100% 100% 100% 100%
dB 500Hz 1kHz 2kHz 4kHz
10 26% 100% 100% 100%
20 100% 100% 100% 100%
30 100% 100% 100% 100%


ASSR
Audiogram
Stimulus
Right
Freq Running Waiting
500Hz 45dB
1kHz 45dB
2kHz 45dB
4kHz 45dB
WN
Left
Freq Running Waiting
500Hz 45dB
1kHz 45dB
2kHz 45dB
4kHz 45dB
WN
Total Session Status
Time elapsed 0:08:22
Stimulus rate
Adult Awake (48Hz)
Start
Pause
0
100mS
Right
Left
500Hz
1000Hz
2000Hz
4000Hz
40dB
20dB
30dB
min
dB 500Hz 1kHz 2kHz 4kHz
20 100% 16nV 100% 12nV 100% 13nV 40% 8nV
30 100% 18nV
40 100% 19nV 100% 15nV 100% 19nV 100% 16nV
dB 500Hz 1kHz 2kHz 4kHz
20 100% 18nV 100% 26nV 100% 18nV 100% 13nV
30
40 100% 23nV 100% 32nV 100% 27nV 100% 32nV

They can’t all be good!

- Failed UNHS (OAE and AABR)
- Full Term
- No Family History
- 5 months old at time of testing
- Normal Tymps/Absent Reflexes

OAE Results

f2	DP	L1	L2	DP level	Noise level	S/N level
500 Hz	318 Hz	65 dB	55 dB	16.5 dB	13.0 dB	3.5 dB
1000 Hz	638 Hz	65 dB	55 dB	9.9 dB	7.2 dB	2.7 dB
2000 Hz	1278 Hz	65 dB	55 dB	9.1 dB	2.5 dB	6.6 dB
4000 Hz	2556 Hz	65 dB	55 dB	-3.2 dB	-9.4 dB	6.2 dB
6000 Hz	3836 Hz	65 dB	55 dB	-3.2 dB	-12.4 dB	9.2 dB
8000 Hz	5114 Hz	65 dB	55 dB	-12.0 dB	-9.5 dB	-2.5 dB

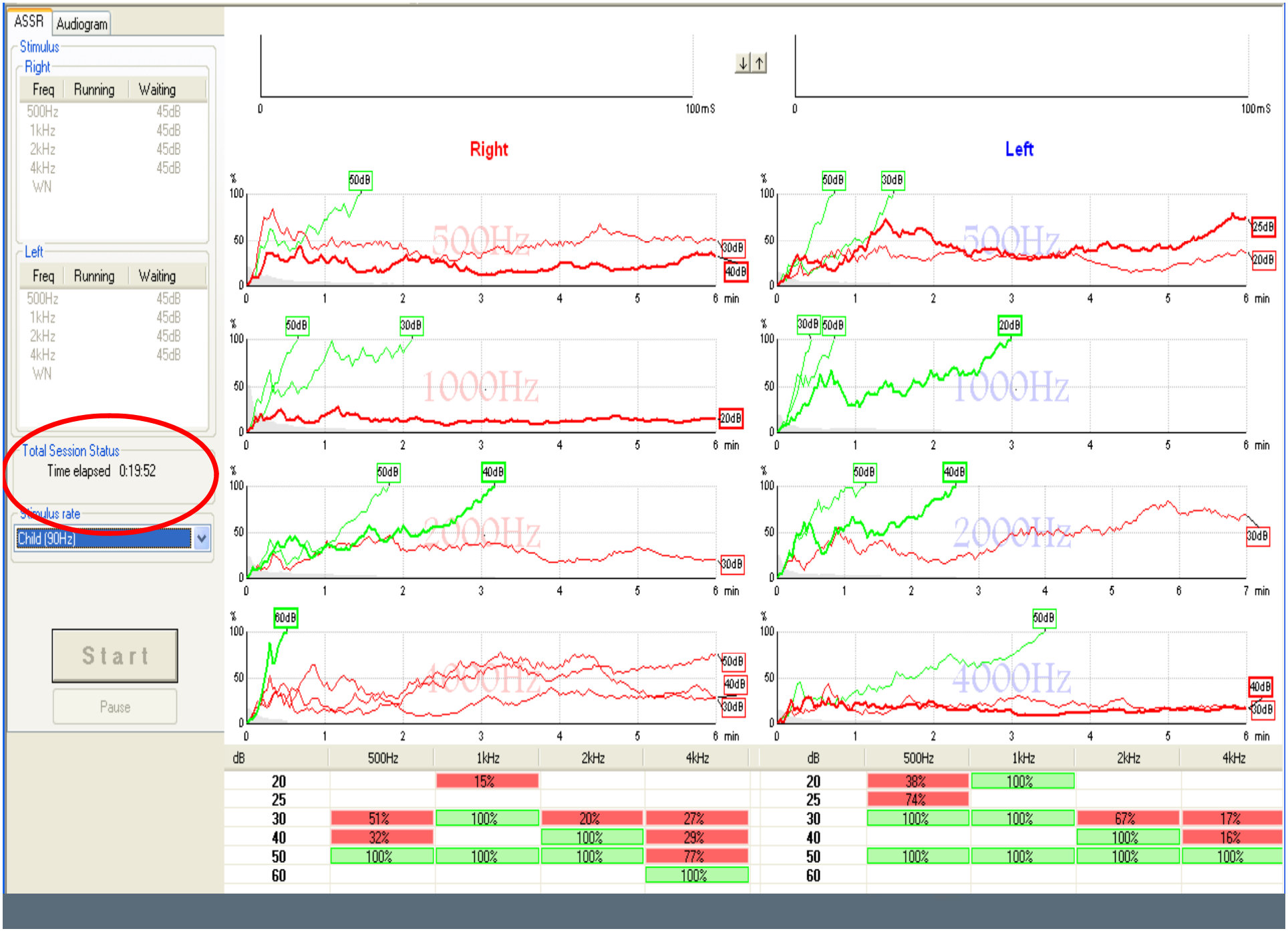
S/N stop criteria	Rejection level	Stimulus tolerance
7 dB	20 dB	±3dB

Right Ear

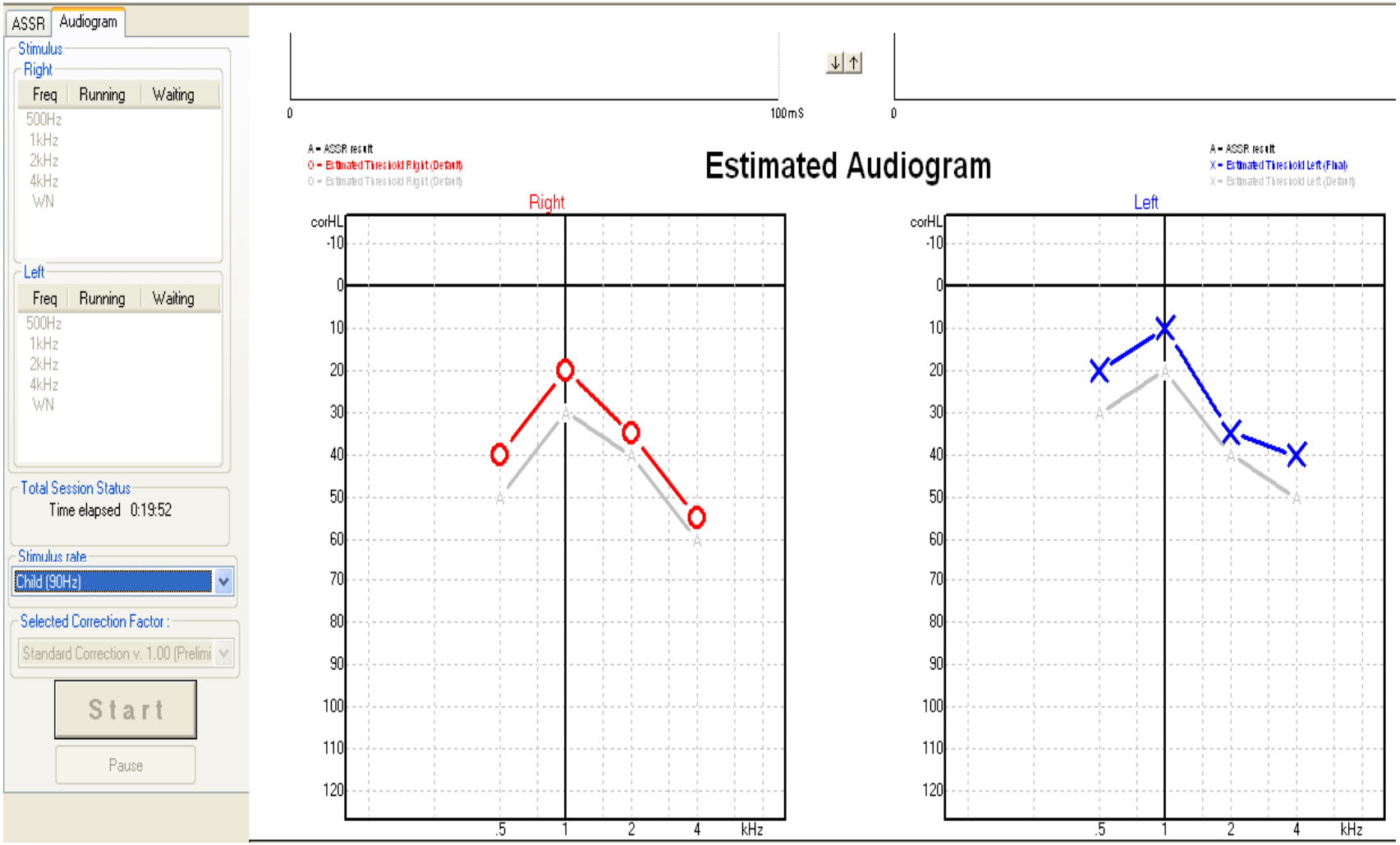
f2	DP	L1	L2	DP level	Noise level	S/N level
500 Hz	318 Hz	65 dB	55 dB	19.5 dB	14.6 dB	4.8 dB
1000 Hz	638 Hz	65 dB	55 dB	4.3 dB	-1.2 dB	5.5 dB
2000 Hz	1278 Hz	65 dB	55 dB	-8.4 dB	-6.5 dB	-1.9 dB
4000 Hz	2556 Hz	65 dB	55 dB	2.7 dB	5.0 dB	-2.2 dB
6000 Hz	3836 Hz	65 dB	55 dB	6.9 dB	5.7 dB	1.3 dB

S/N stop criteria	Rejection level	Stimulus tolerance
7 dB	20 dB	±3dB

Left Ear


ASSR
Audiogram
Stimulus
Right
Freq Running Waiting
500Hz 45dB
1kHz 45dB
2kHz 45dB
4kHz 45dB
WN
Left
Freq Running Waiting
500Hz 45dB
1kHz 45dB
2kHz 45dB
4kHz 45dB
WN
Total Session Status
Time elapsed 0:19:52
Stimulus rate
Child (90Hz)
Start
Pause
0
100mS
Right
Left
500Hz
1000Hz
2000Hz
4000Hz
min
dB 500Hz 1kHz 2kHz 4kHz
20 15%
25
30 51% 100% 20% 27%
40 32% 100% 29%
50 100% 100% 100% 77%
60 100%
dB 500Hz 1kHz 2kHz 4kHz
20 38% 100%
25 74%
30 100% 100% 67% 17%
40 100% 16%
50 100% 100% 100% 100%
60

Generates an Audiogram



ASSR AC Thresholds

- Many studies published and in process
  - Recently, Van Maanen & Stapells, 2009 found:

	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Infants and Children		50	45	40	40

Must find this level or better to be called normal!!

MORE RESEARCH IS NEEDED!!
There is NOT sufficient evidence to support the use of ASSR only!

ASSR BC Thresholds

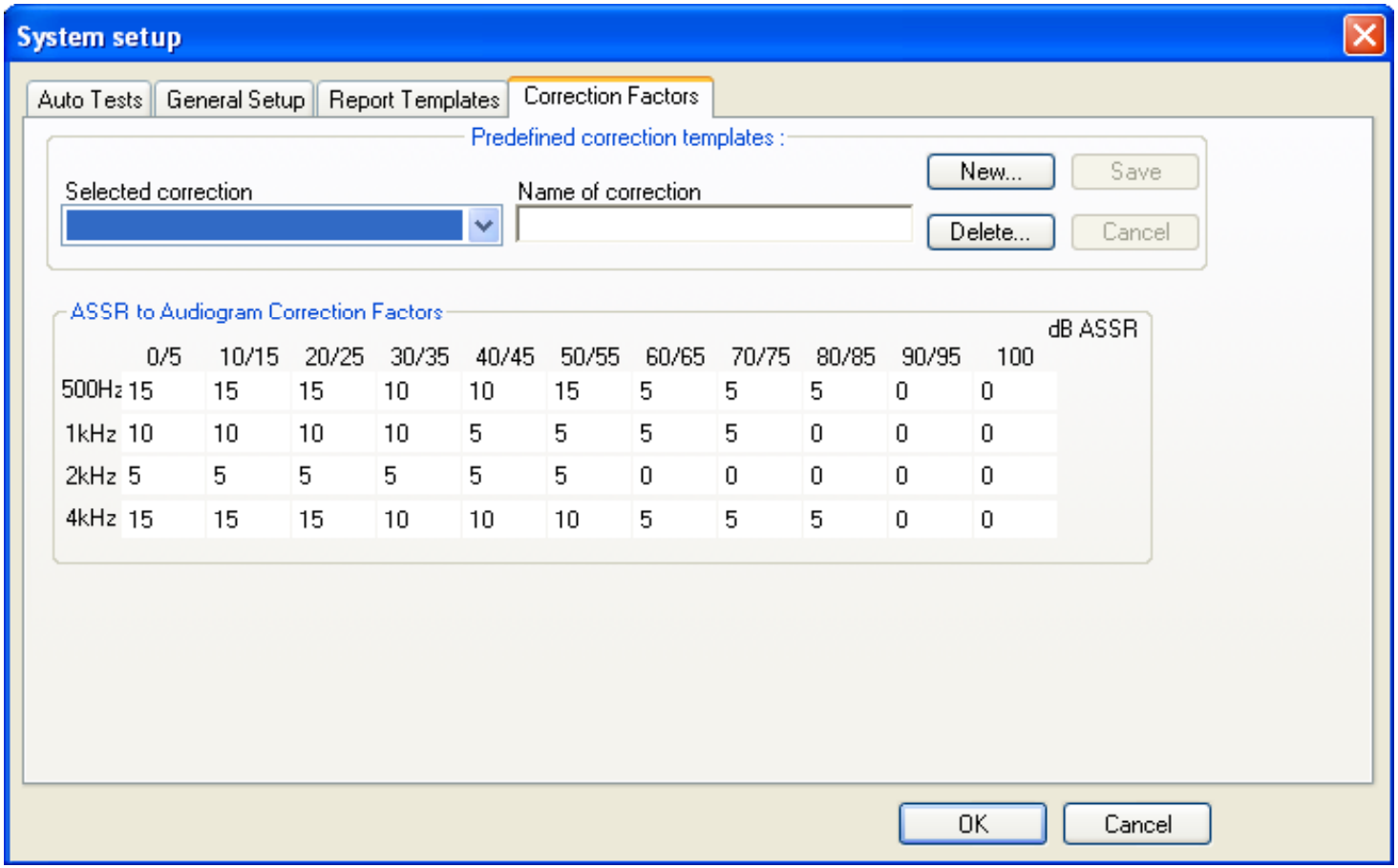
- Few studies published

	500Hz	1000Hz	2000Hz	4000Hz
Preterm Infants	≤30	≤30	≤50	≤50
Post-term infants (0-11 months)	≤30	≤20	≤40	≤30
Infants (12-24 months)	≤40	≤20	≤40	≤30
Adults	≤50	≤40	≤30	≤30

Source: Recommendations from: Small, S.A. & Stapells, D.R. (2005). Multiple auditory steady-state response thresholds to bone-conduction stimuli in adults with normal hearing *Journal of the American Academy of Audiology*, 16(3): 172-183; Small, S.A & Stapells, D.R. (2006). Multiple auditory steady-state response thresholds to bone-conduction stimuli in young infants with normal hearing. *Ear and Hearing,* 27: 219-228; Small, S.A.& Stapells, D.R. (2008). Maturation of bone-conduction multiple auditory steady-state responses. *International Journal of Audiology,* 47: 476-488 ,

Adapted from: Hall, Swanepoel, *Objective Assessment of Hearing, Plural Publishing 2009, page 128, figure 6-11*

Correction Factors Are Not All The Same!



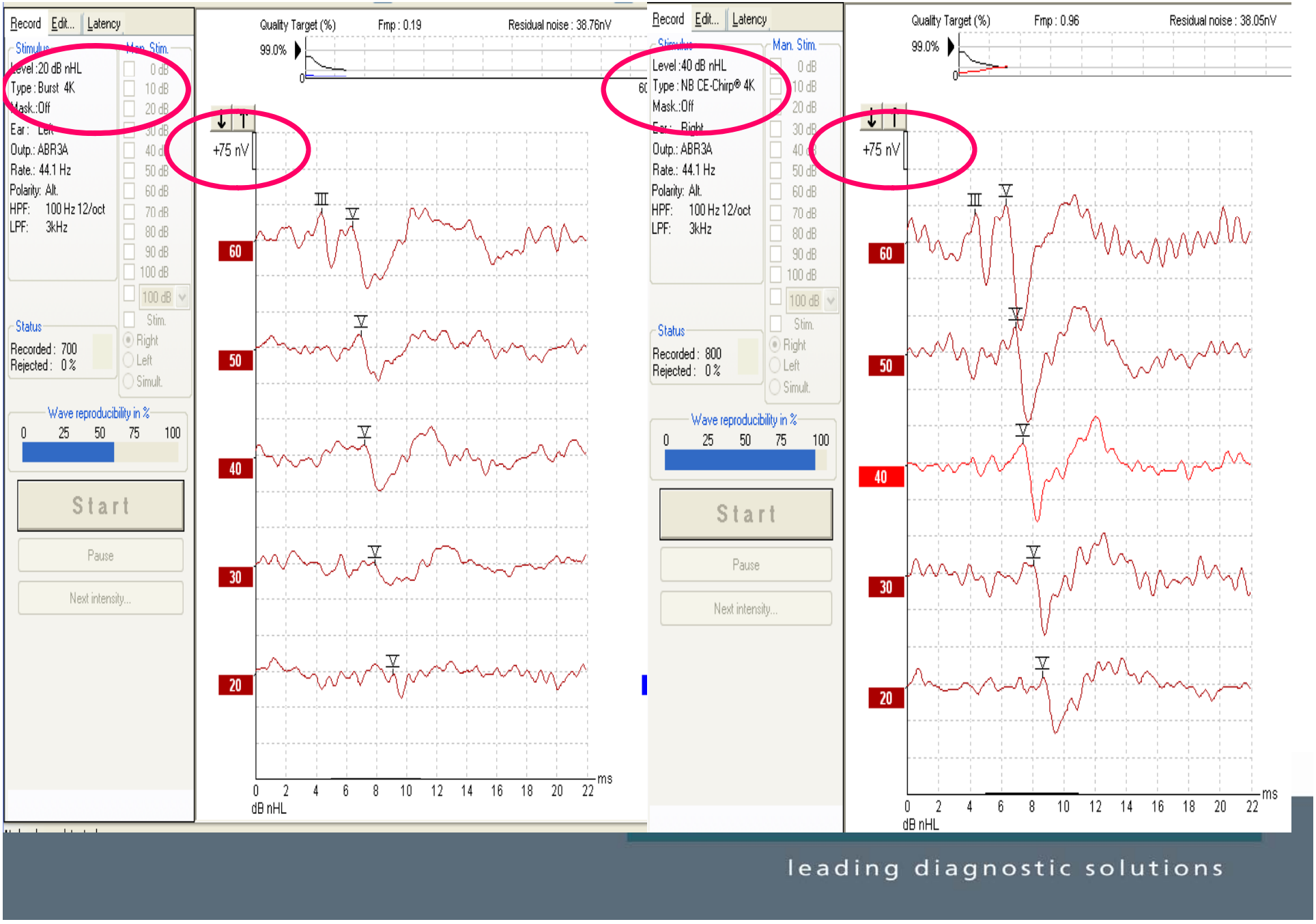
Other Considerations for ASSR

- Future Research
  - Hearing Aid Fittings
  - Hearing Screening
  - Assessing Suprathreshold Hearing
  - ANSD

One Step Further……

- If we can generate larger response amplitudes for ASSR…….

…….how about for ABR???



leading diagnostic solutions

Take Home Messages

- Use of the CE Chirp is well documented in the literature
- Use of the CE Chirp can increase response amplitudes resulting in a shorter test time
- ASSR can be a part of the cross check principle

THE END!

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