

Using cortical responses to inform management

Harvey Dillon, Bram Van Dun, Lyndal Carter, Kirsty Gardner-Berry

HEARing CRC

National Acoustic Laboratories (NAL)

With thanks to John Seymour, Suzanne Purdy, Maryanne Golding, Hsiuwen Chang

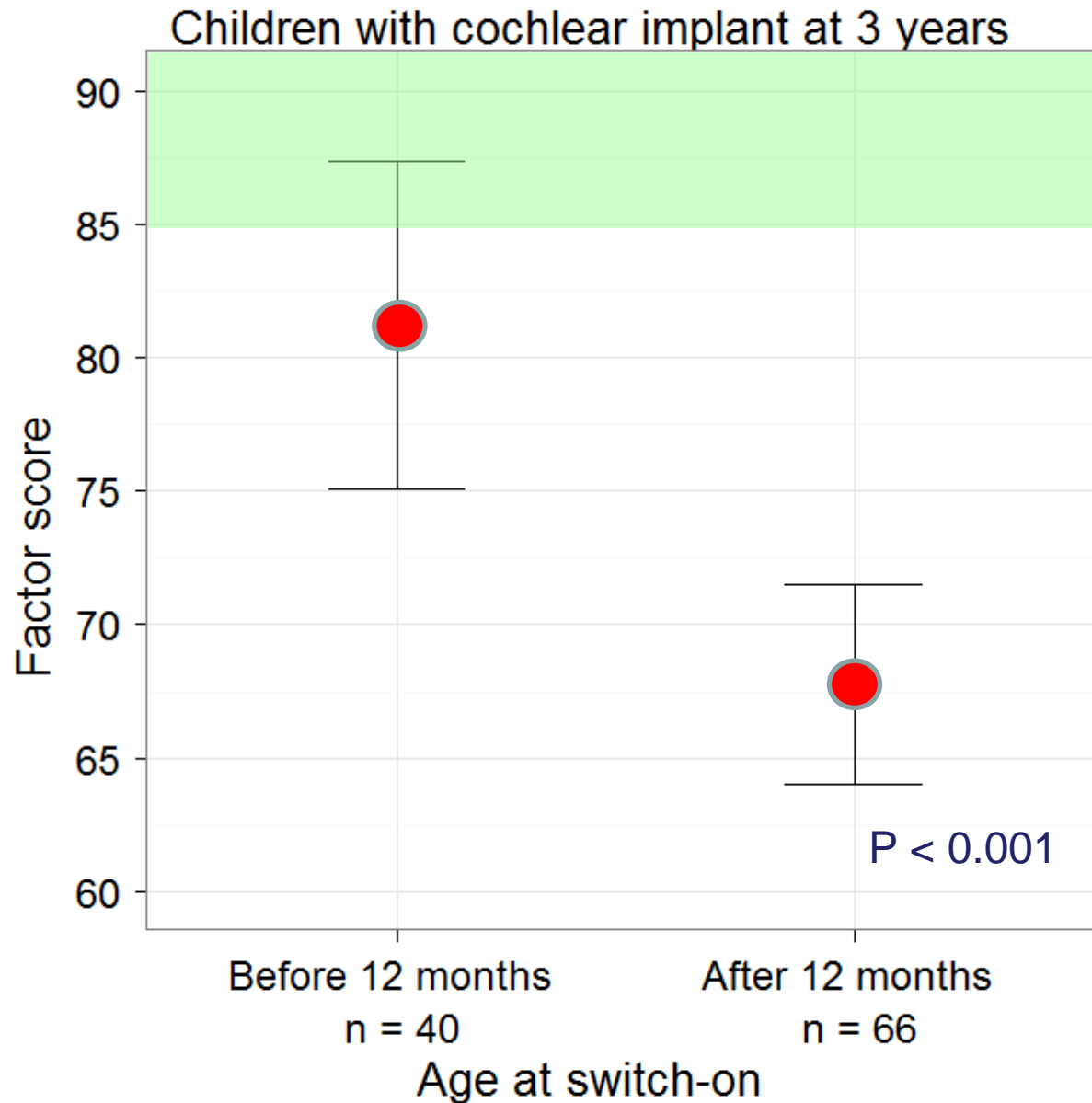
So baby, how does it sound?

Objective hearing aid
evaluation for:

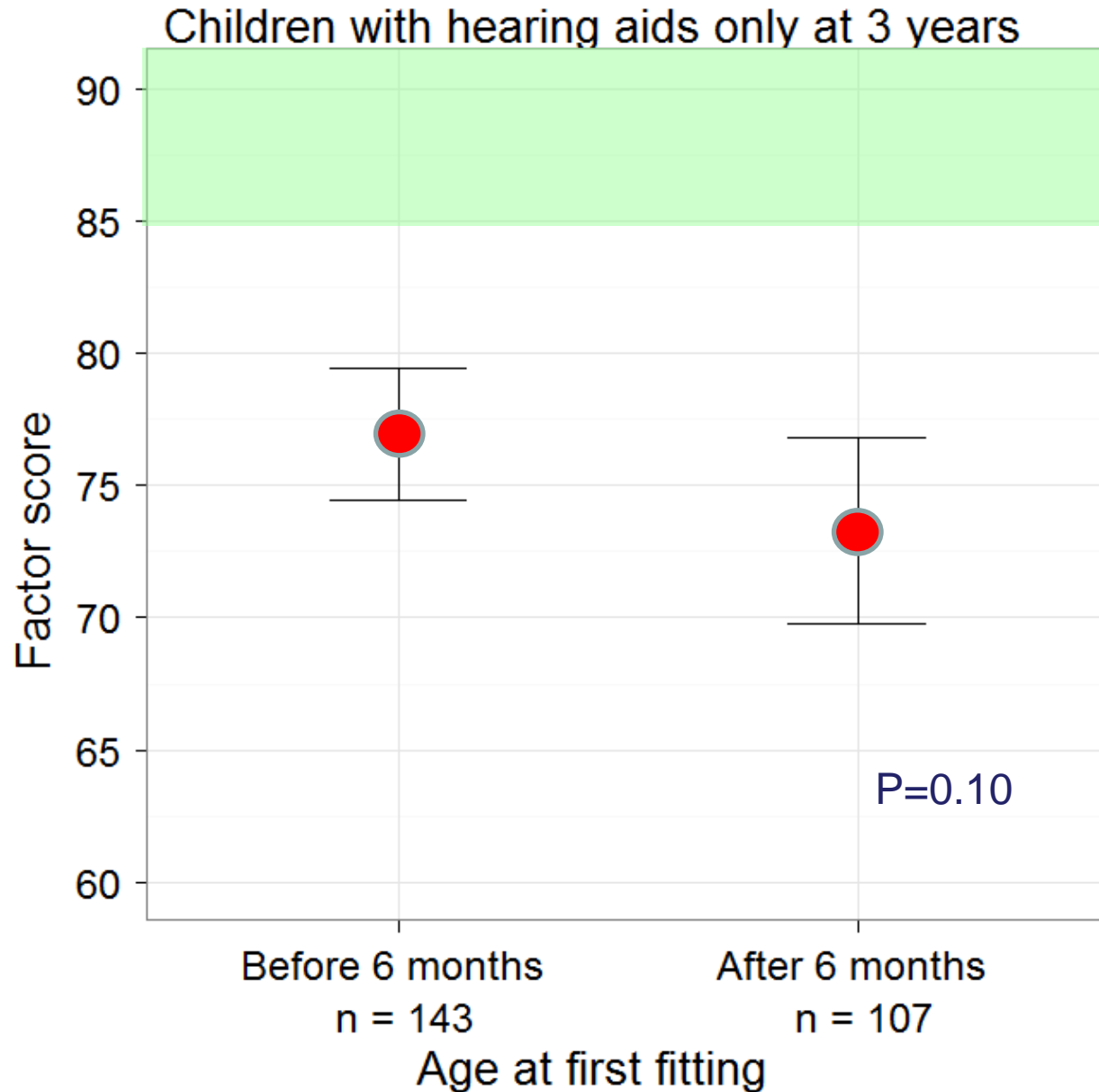
- young infants
- difficult-to-test
people



Global language ability – cochlear implants



Global language ability – hearing aids

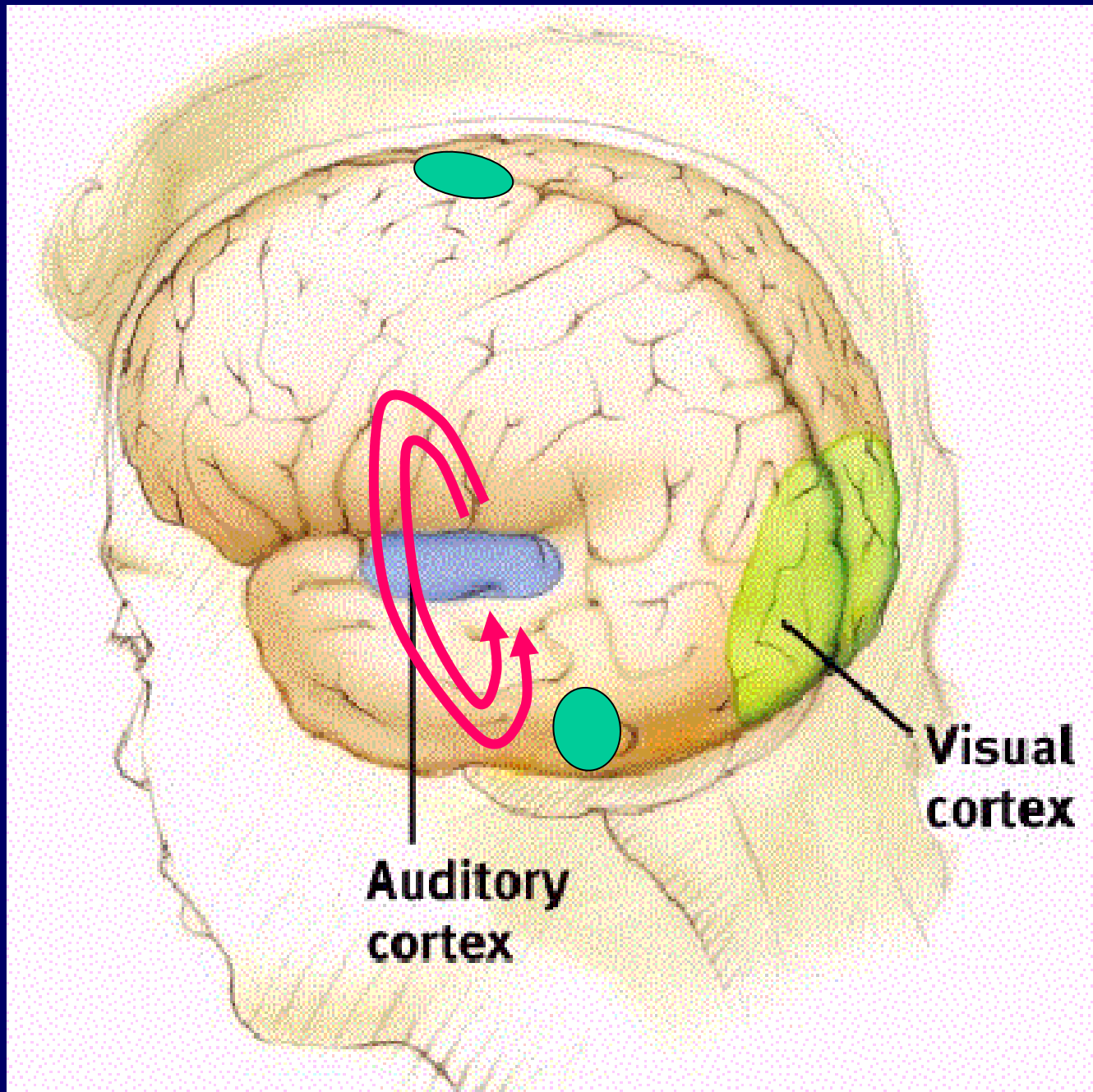


Why cortical responses to evaluate hearing aid fitting in infants?

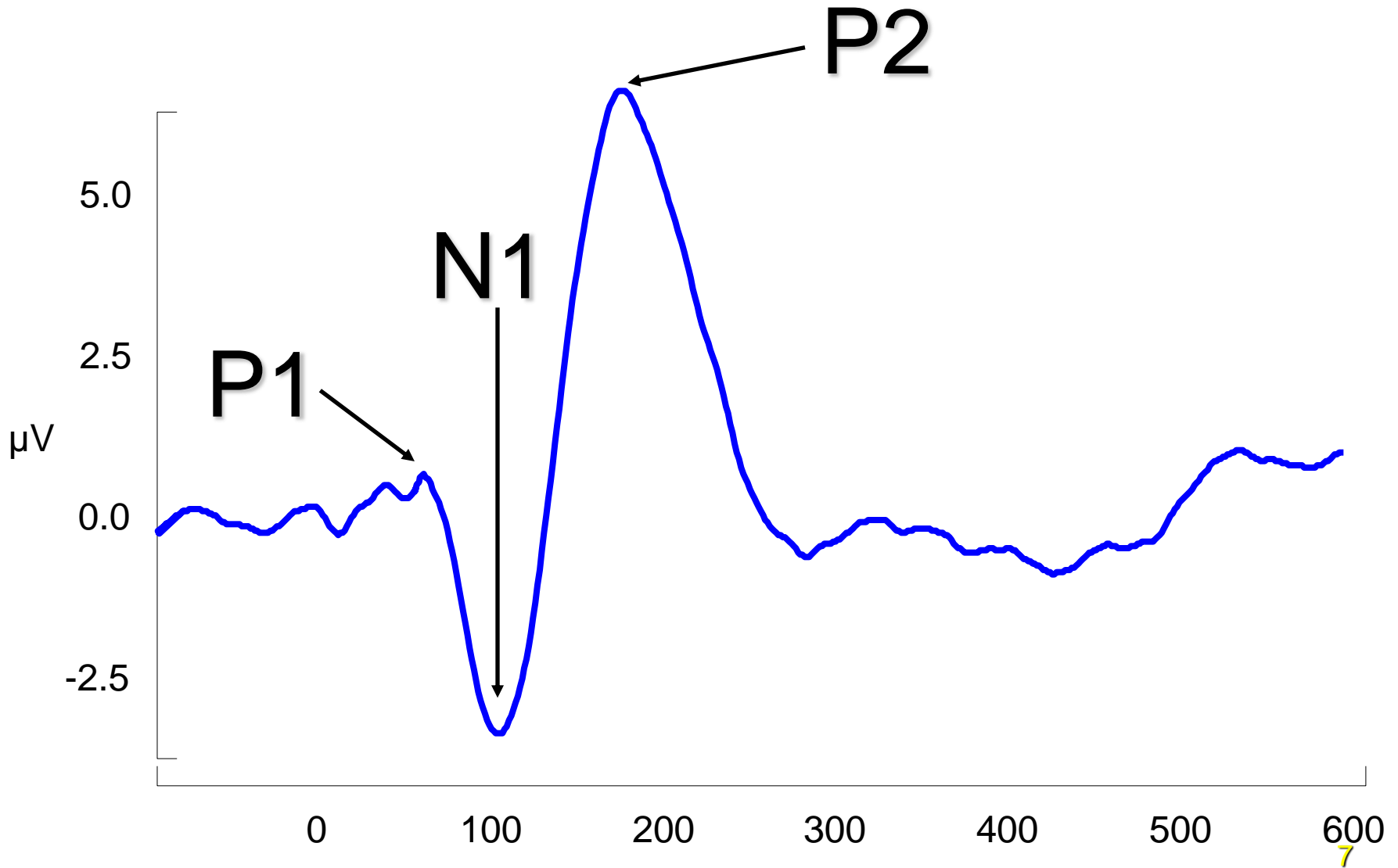
- Reliably present in awake young infants
- More likely to correlate well with perception
- Can be elicited by a range of speech phonemes – close to desired outcomes
- Stimuli handled reasonably by hearing aids
- Can be very frequency specific if needed



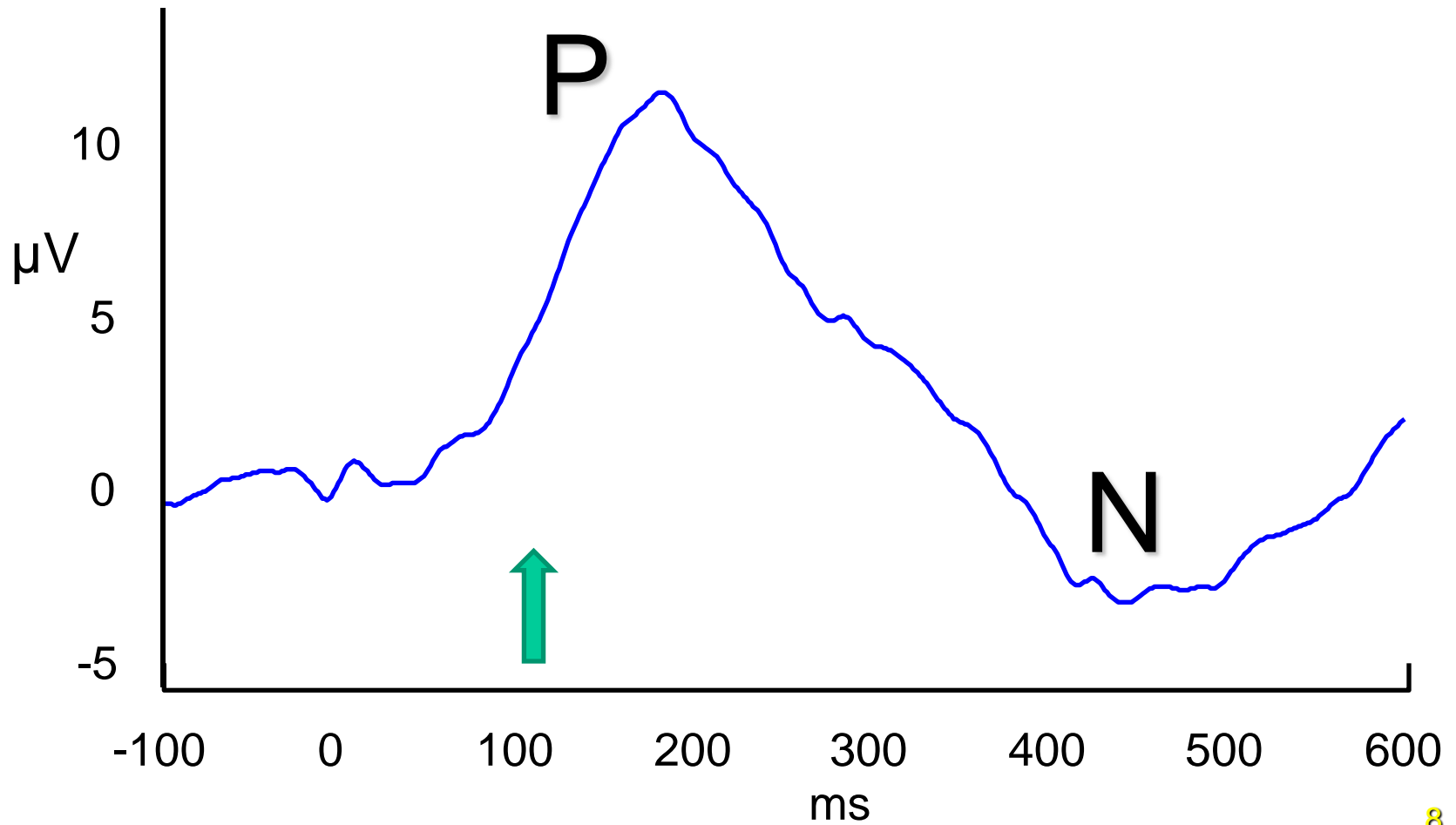
The end of the road



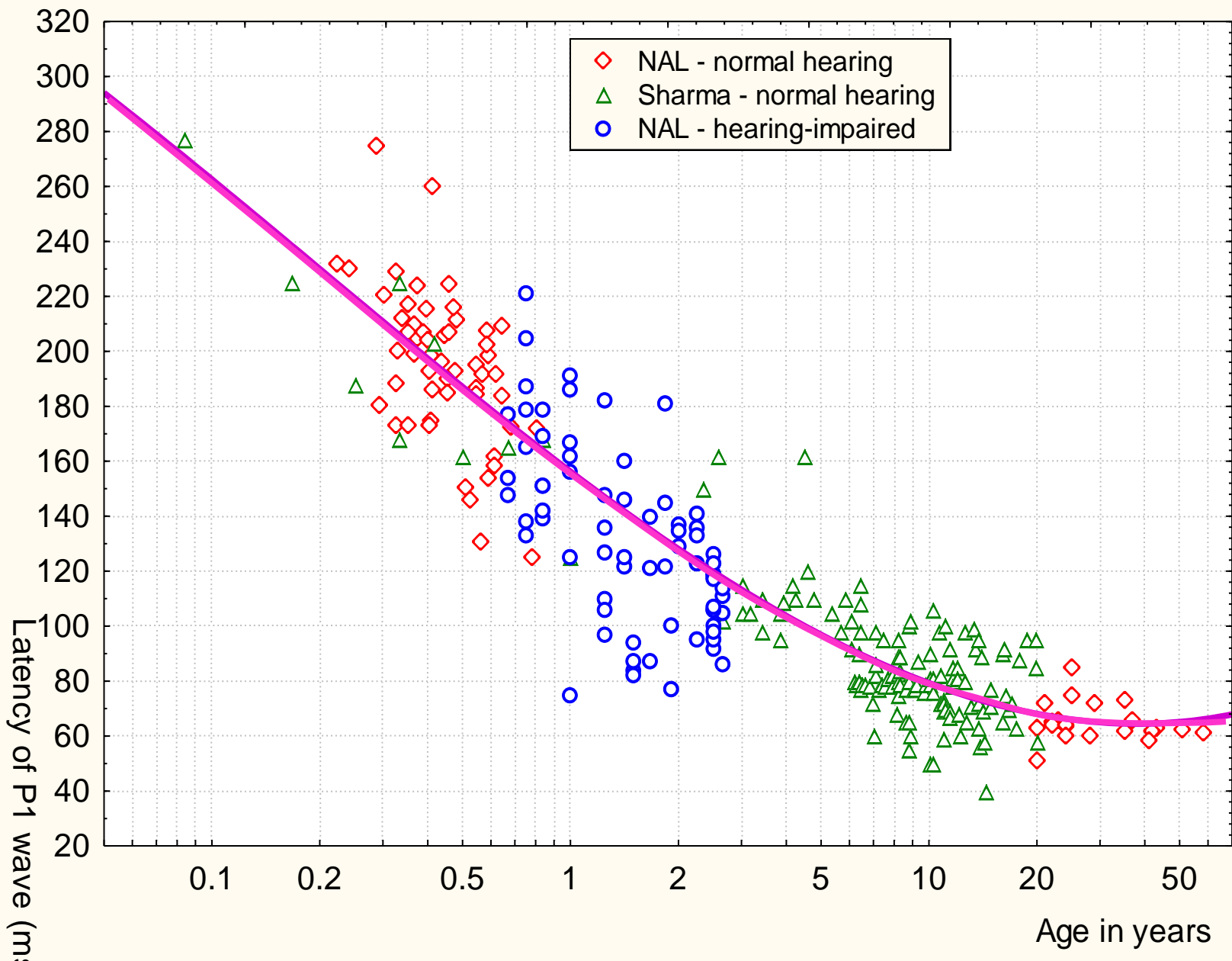
Adult



Infants



Latency versus age



A practical system for infants





Practical implementation of cortical testing: HearLab

Disclosure: NAL will get a royalty for each unit sold.

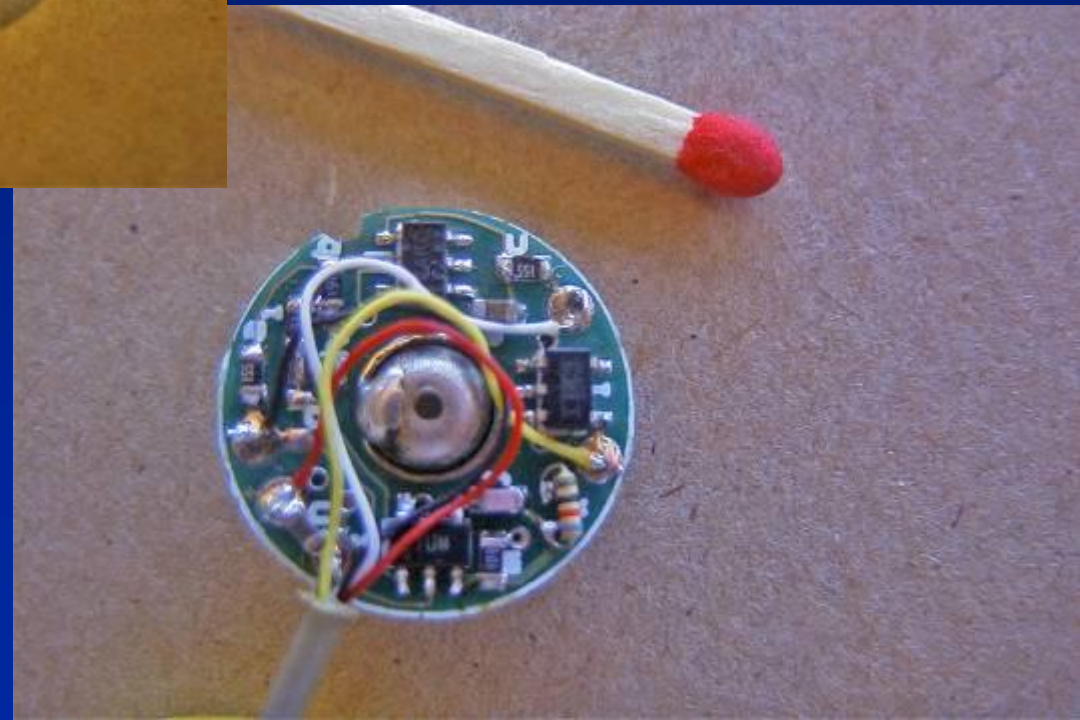
Thank you: The HearLab development team –
Teck Loi, Barry Clinch, Isabella Tan, Ben Rudzyn,
Lyndal Carter, Dan Zhou, Scott Brewer



Innovations

- Automatic response recognition
- Residual noise level monitoring
- Active on-scalp electrodes
- Interspersed presentation of speech stimuli
- Auto-calibration of room and speaker

Active electrodes





Assessment Control

Start Pause Stop

Test Status

Acceptance Ratio

Current Stimulus

Type /m/

Level 65 dB SPL

Epochs Obtained

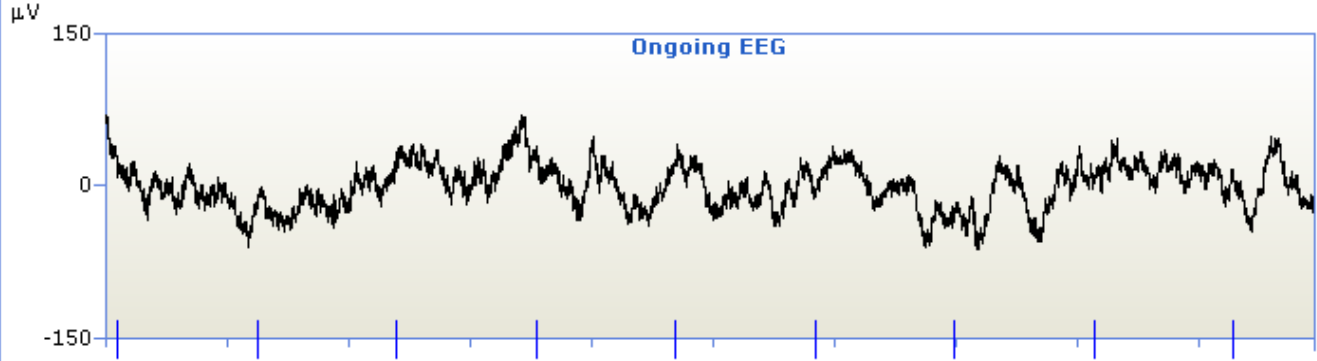
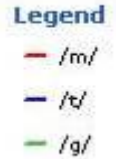
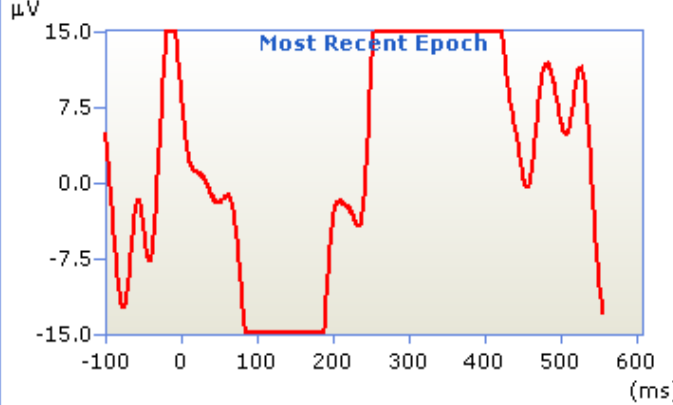
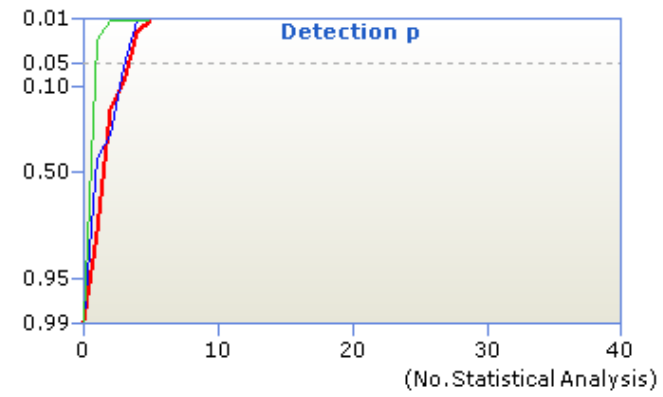
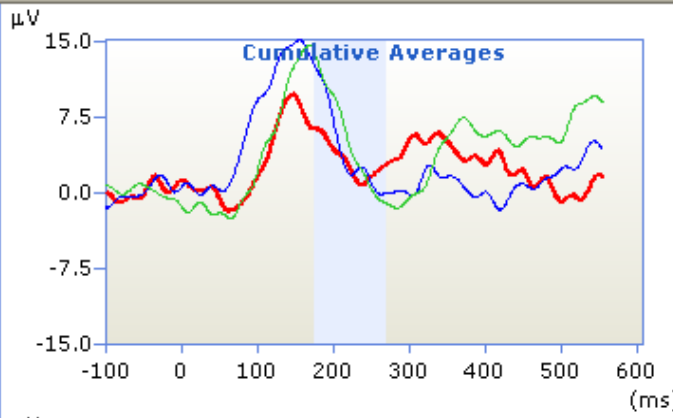
Stim	Accept	Reject
/m/	117	3
/t/	120	5
/g/	117	8

p Values Obtained

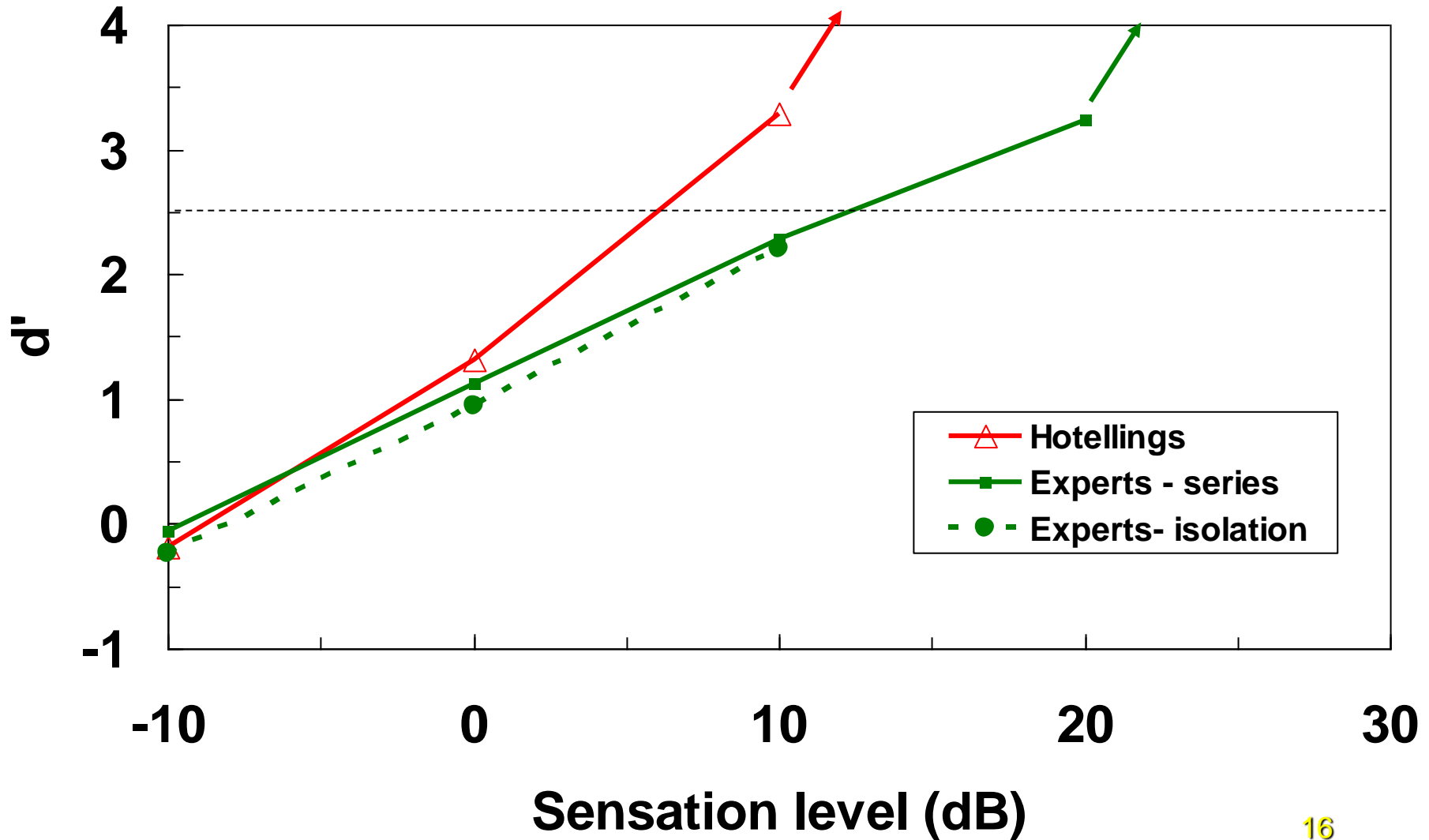
/m/	0.011
/t/	0.000
/g/	0.000
/m/ vs /t/	0.663
/m/ vs /g/	0.030
/t/ vs /g/	0.078

Time Elapsed for Run

8 (min)

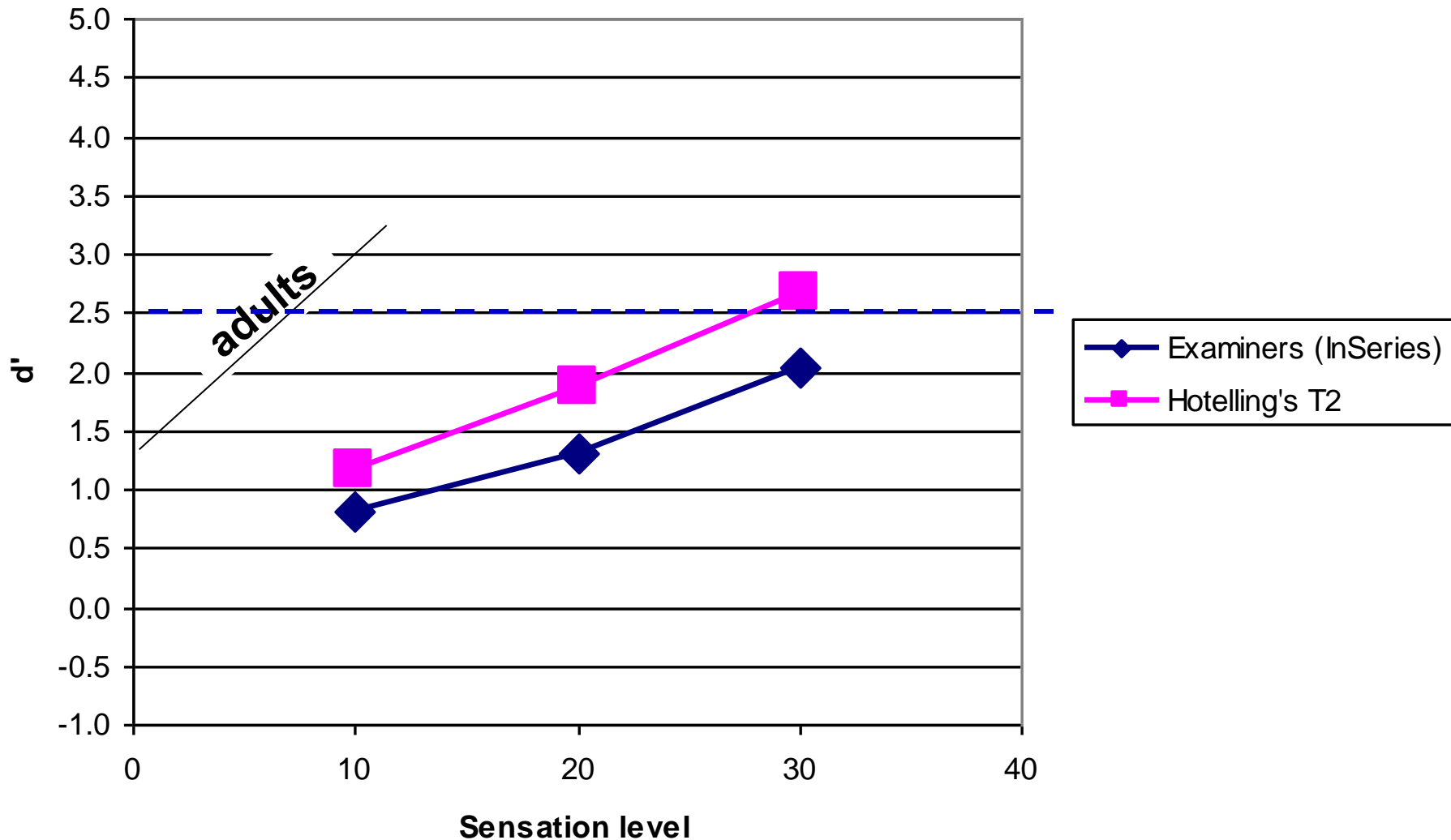


d' results - for 200 stimuli



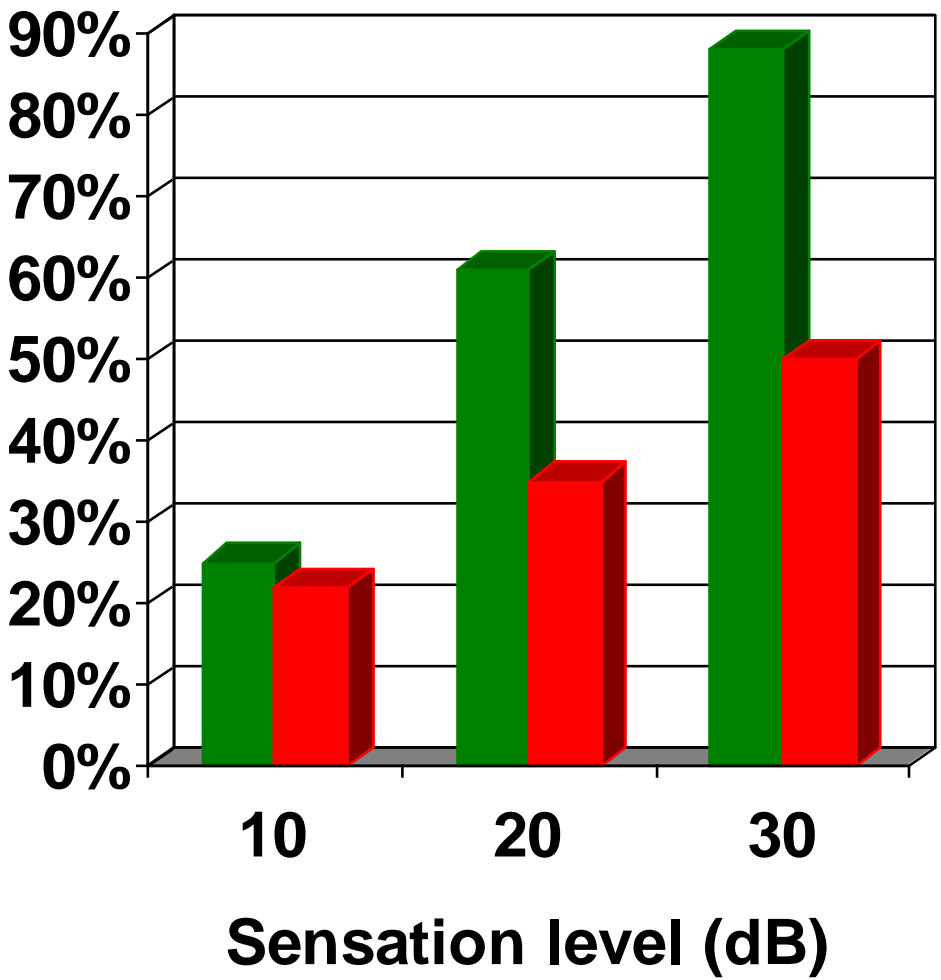
Infants: Hotellings versus experts

Normal hearing infants aged 7 to 16 months

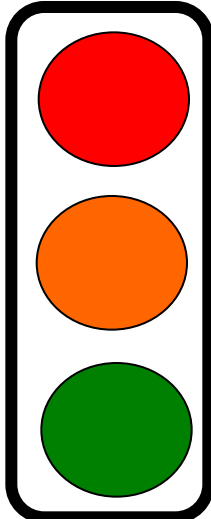


Proportion with responses present ($p < 0.05$)

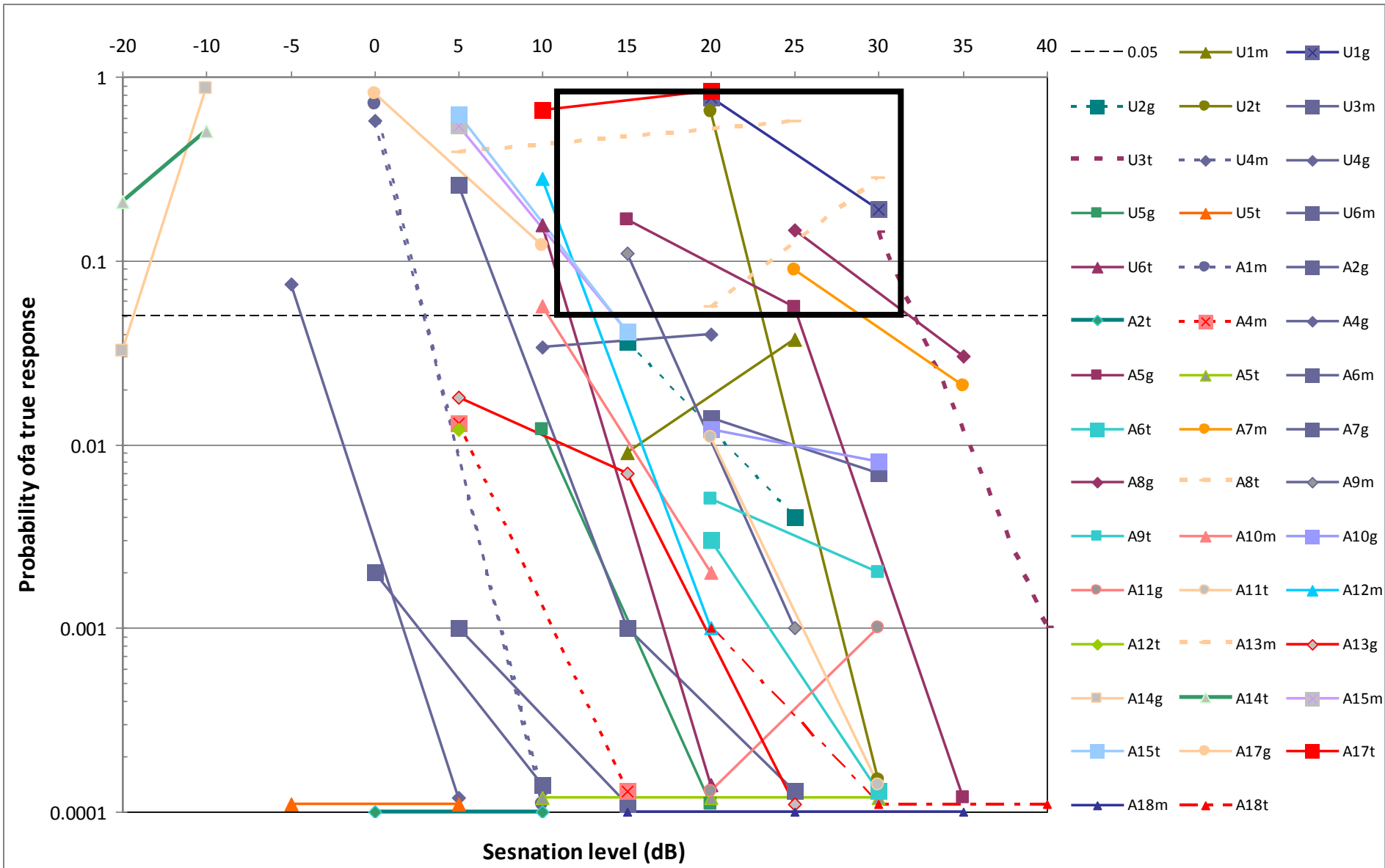
– normal hearing infants; 100 epochs



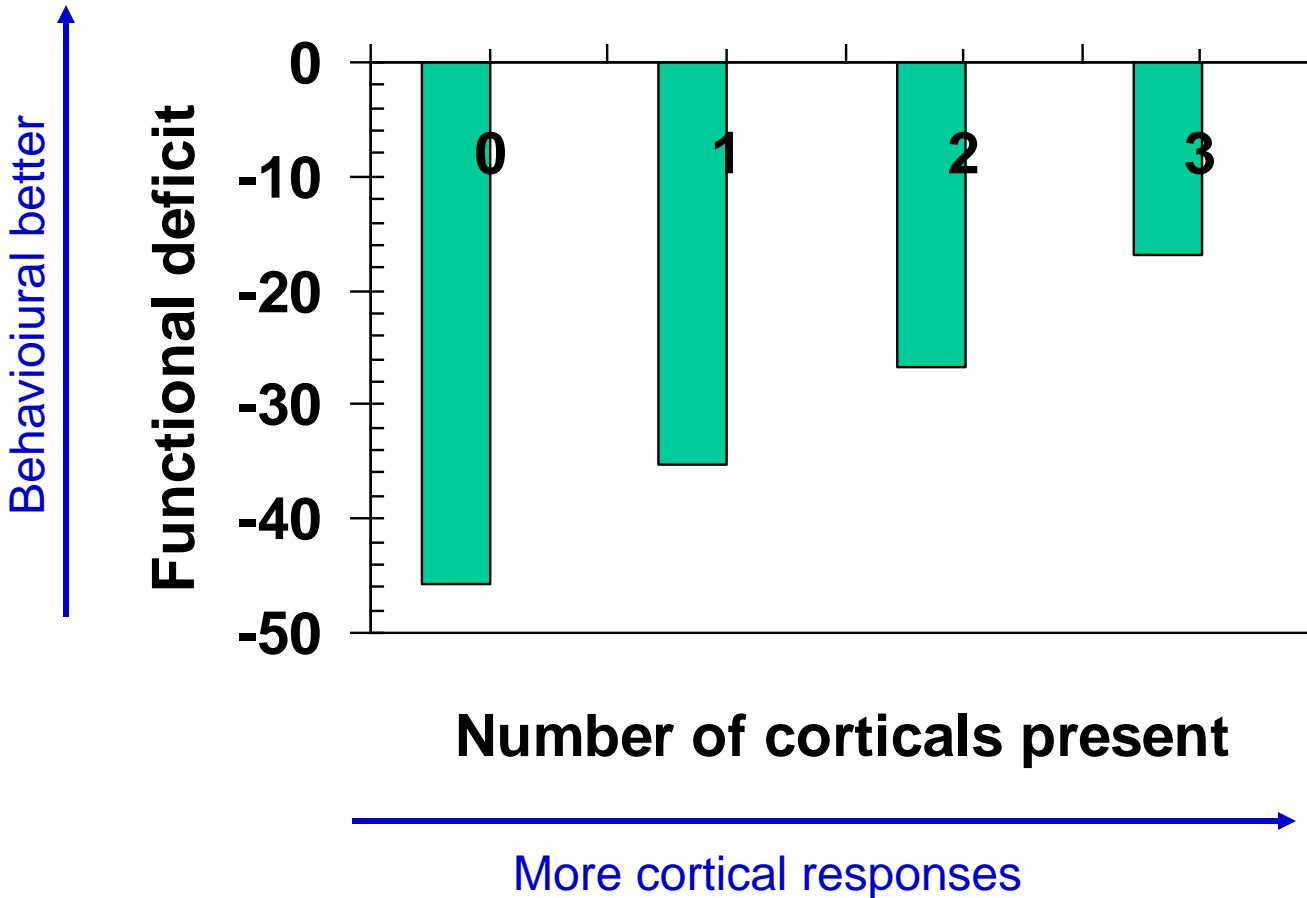
■ Noise < 3.4 uV
■ Noise > 3.4 uV



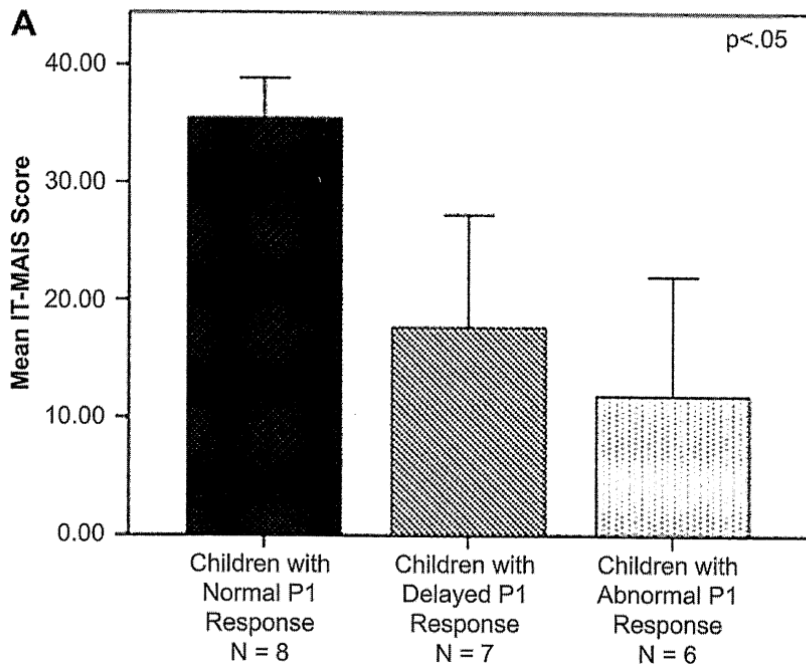
Detection of speech sounds



Functional deficit vs number of cortical responses present



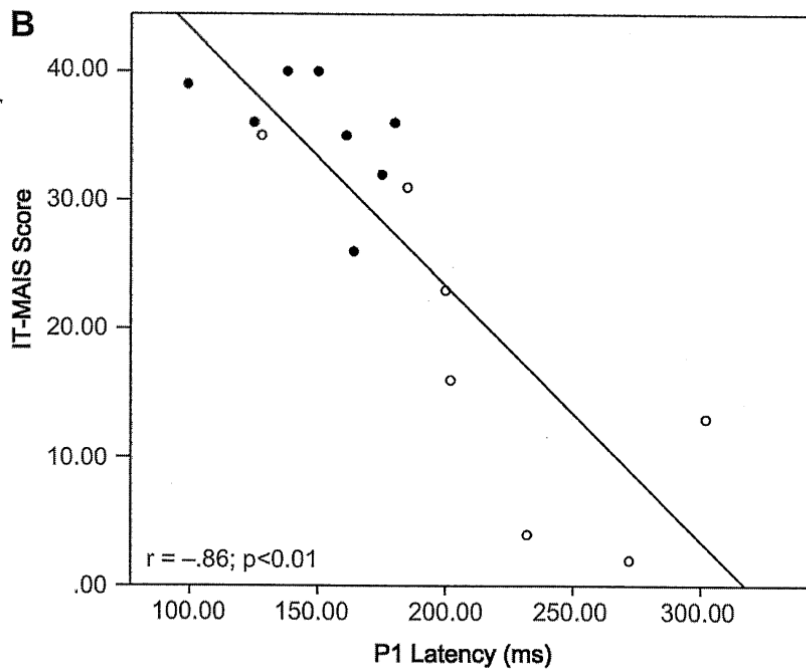
N = 24; p = 0.001
12 sensorineural
7 auditory neuropathy
5 multiply disabled



Children with auditory neuropathy

Sharma et al. (2011)
Int J Audiol

Figure 5. A: Mean IT-MAIS scores for children with normal, delayed, and abnormal P1 responses. B: IT-MAIS scores vs. P1 latency for children with normal (filled circles) and delayed (unfilled circles) P1 responses.



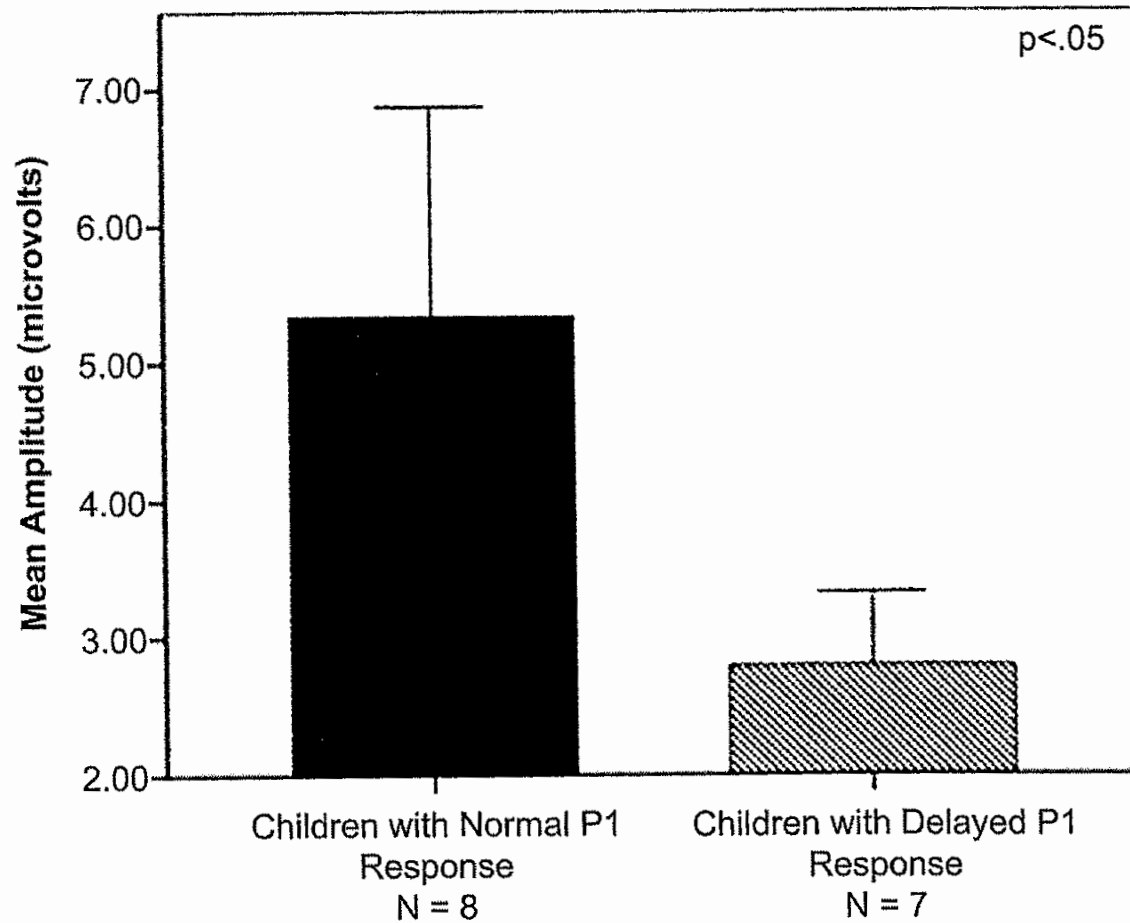


Figure 3. Mean P1 response amplitudes for children with normal P1 latency and delayed P1 latencies.

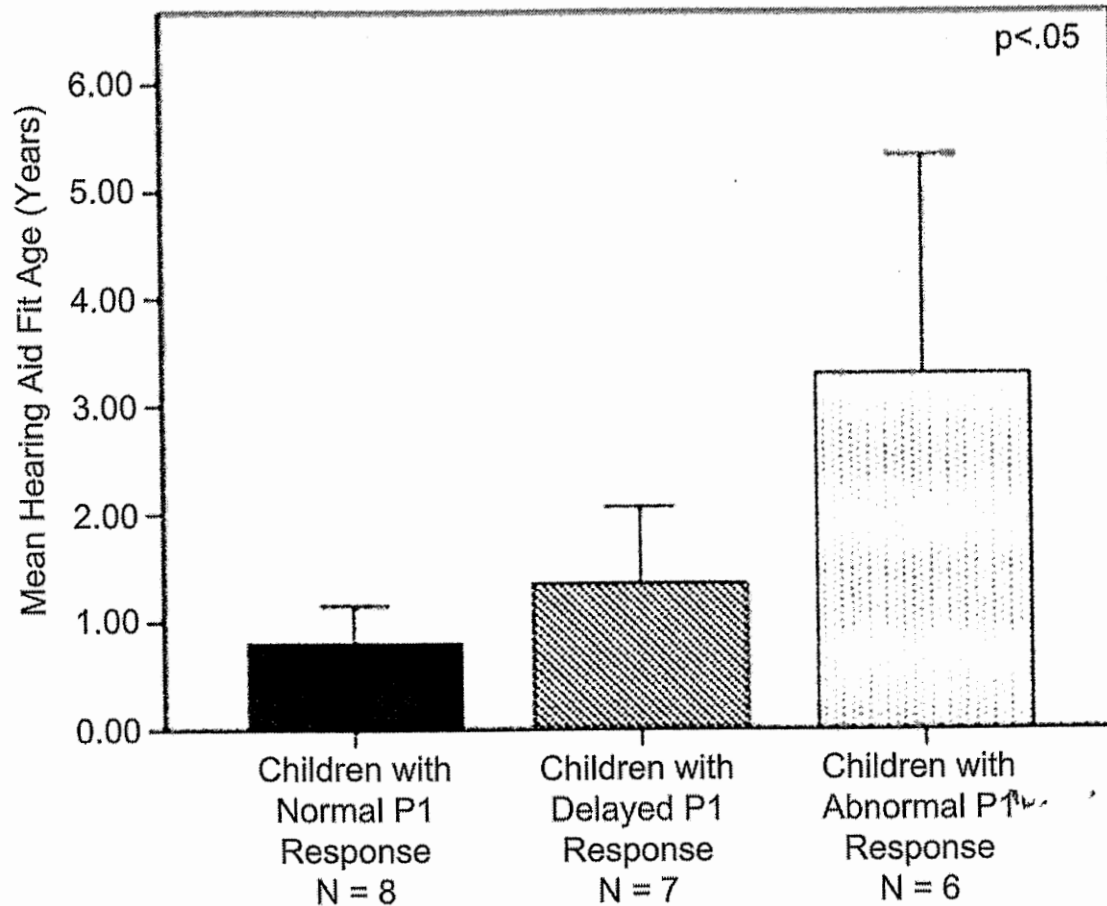


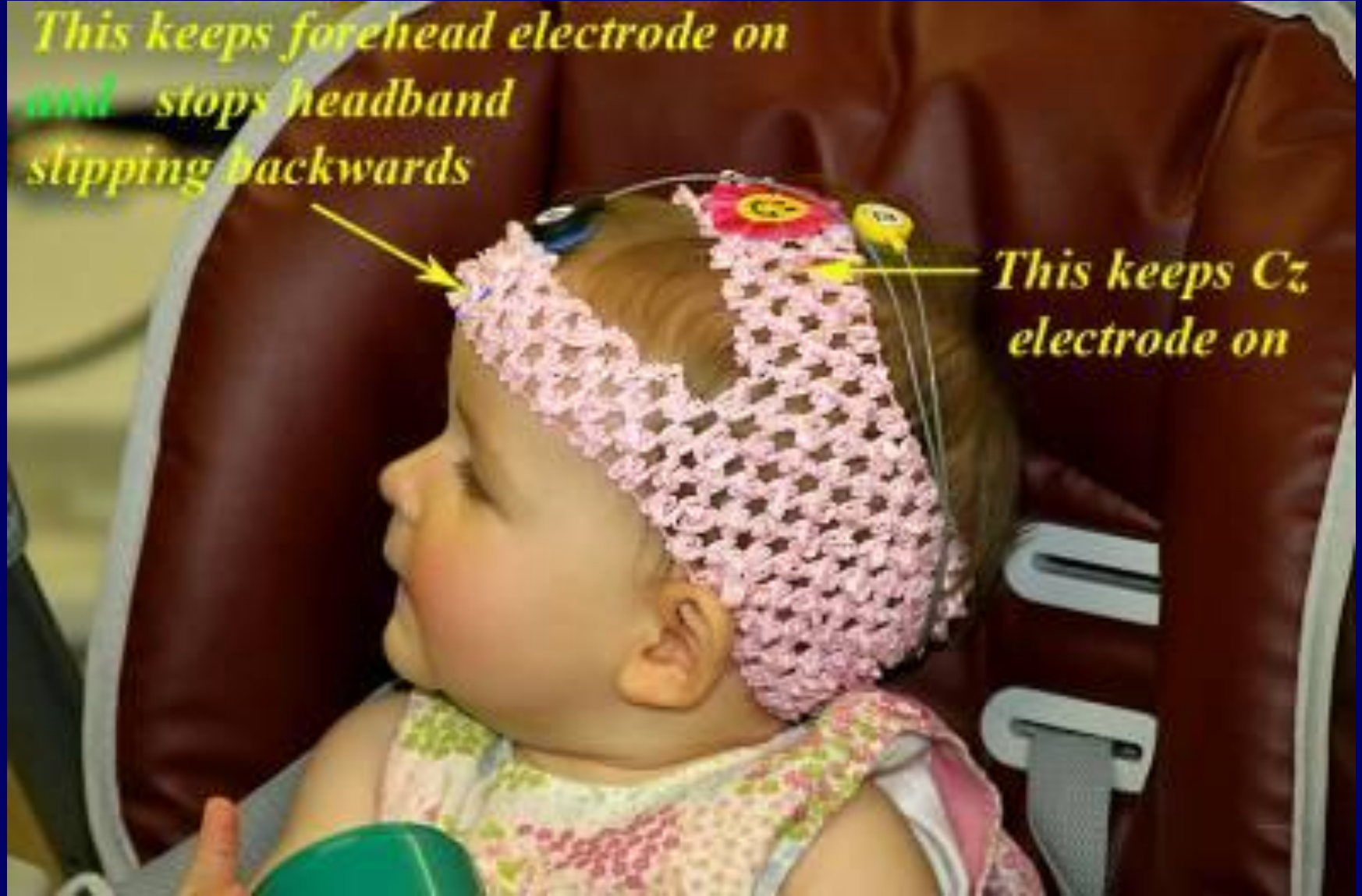
Figure 4. Mean ages of hearing-aid fittings for children with normal, delayed, and abnormal P1 responses.

Modes of operation

- Speech stimuli /m/, /g/, /t/ delivered in the sound field
- Tonal stimuli (50 ms long) delivered over insert earphones or bone-conductors

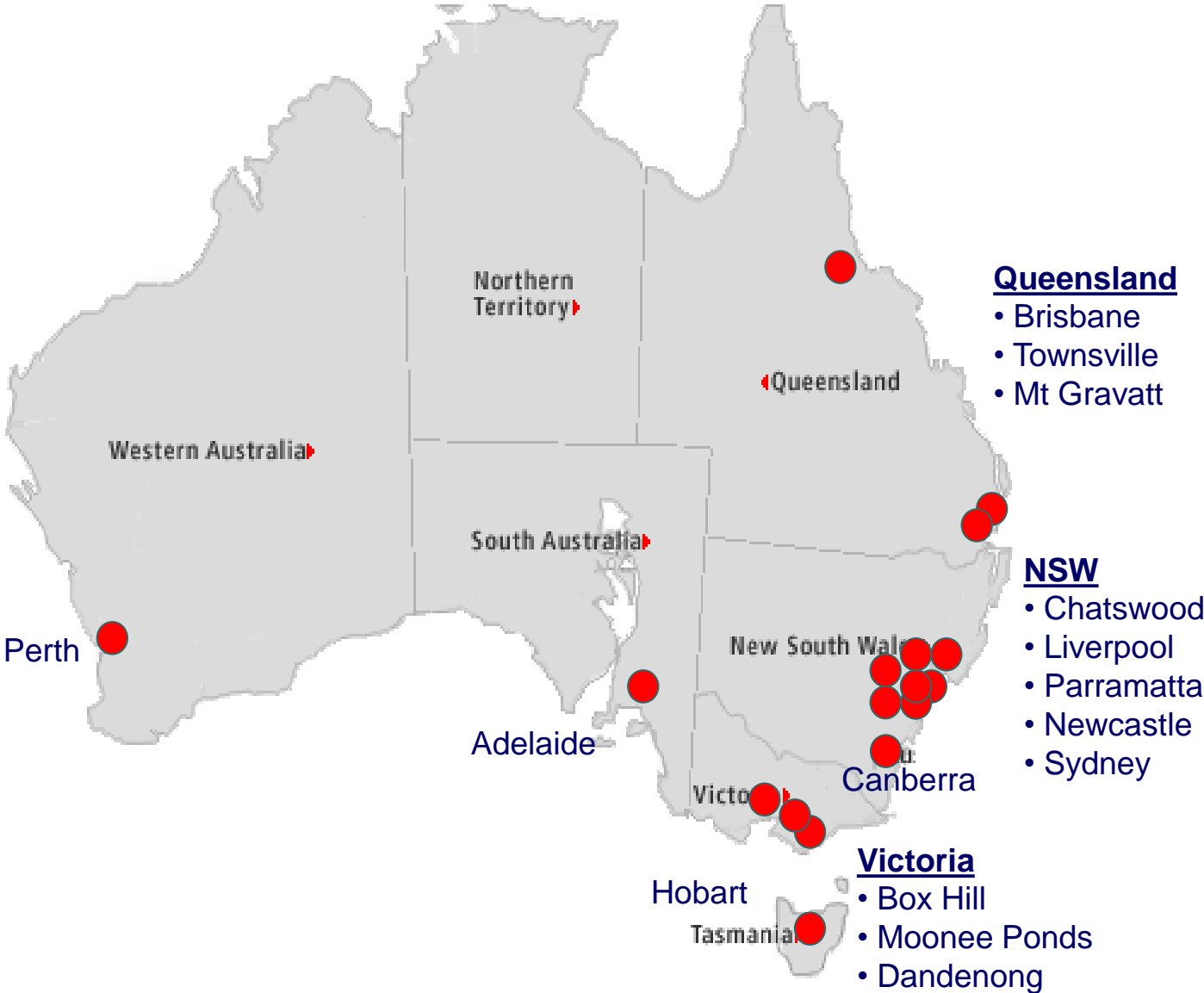


Keeping electrodes on the baby using a headband



Australian Hearing Centers with HearLab

(Sep 2011)



CASE STUDIES

Case 1

No cortical responses, and the results helped the parents accept the need for cochlear implants

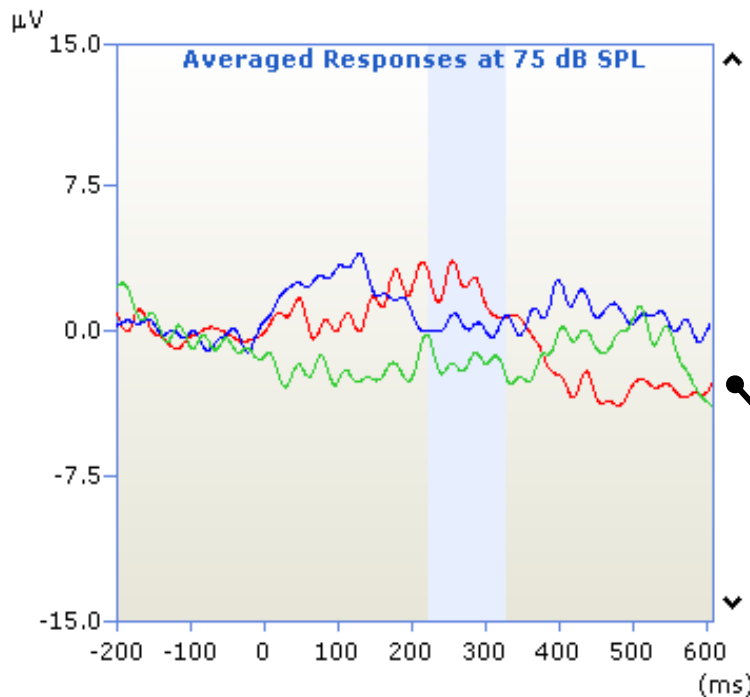
- Age at aided cortical testing
 - Visit 1
 - 6 weeks old (Initial hearing aid fitting day)
 - Visit 2
 - 3 months old

Tone-burst ABR (Estimated levels in dB nHL)				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	>95	>95	>95	>95
Left	>95	>95	>95	>95

Estimated Audiogram (dB HL) at Visit 1				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	85	90	95	95
Left	85	90	95	95

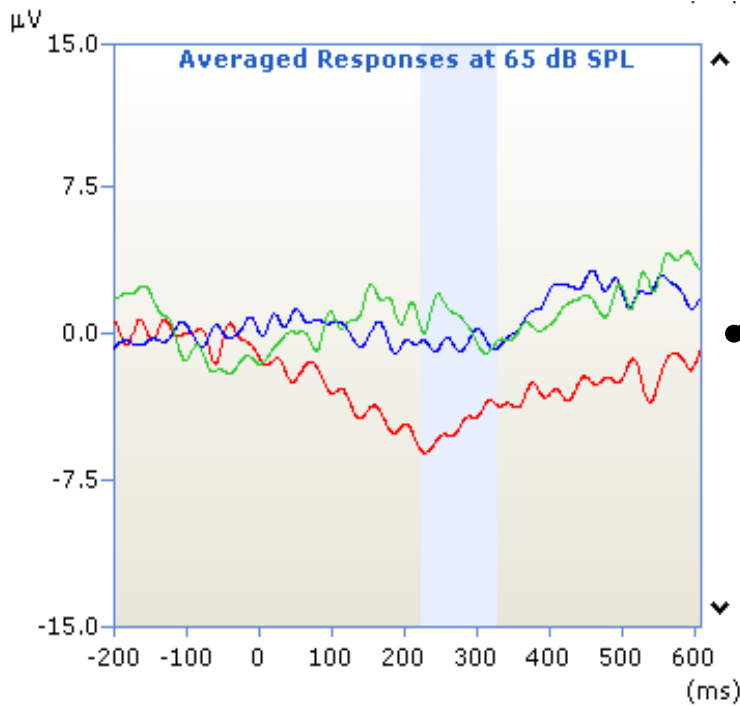
Estimated Audiogram (dB HL) at Visit 2				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	90	100	105	105
Left	90	100	105	105

Visit 1



Were responses detected?

	/m/	/t/	/g/
75 dB SPL	0.268	0.360	0.779
65 dB SPL	0.609	0.704	0.687



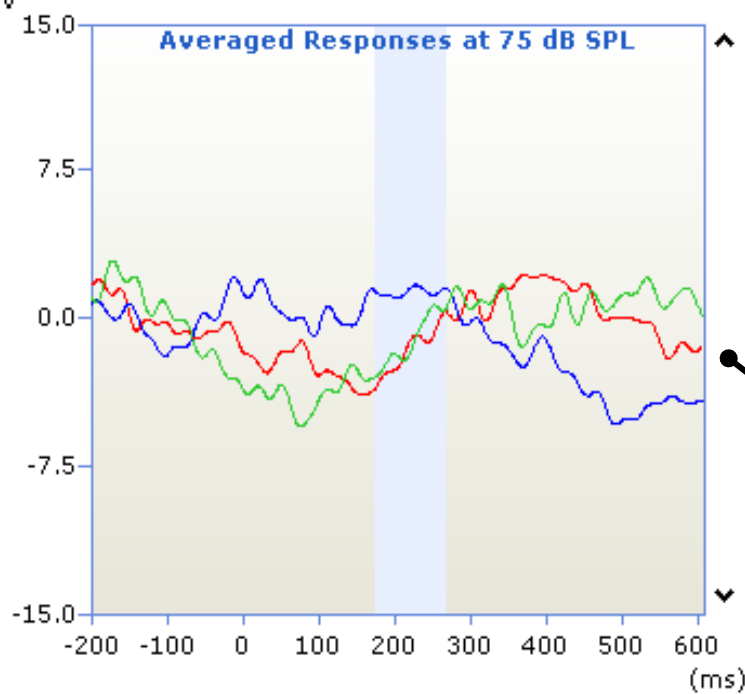
$P < 0.05$?

.... No



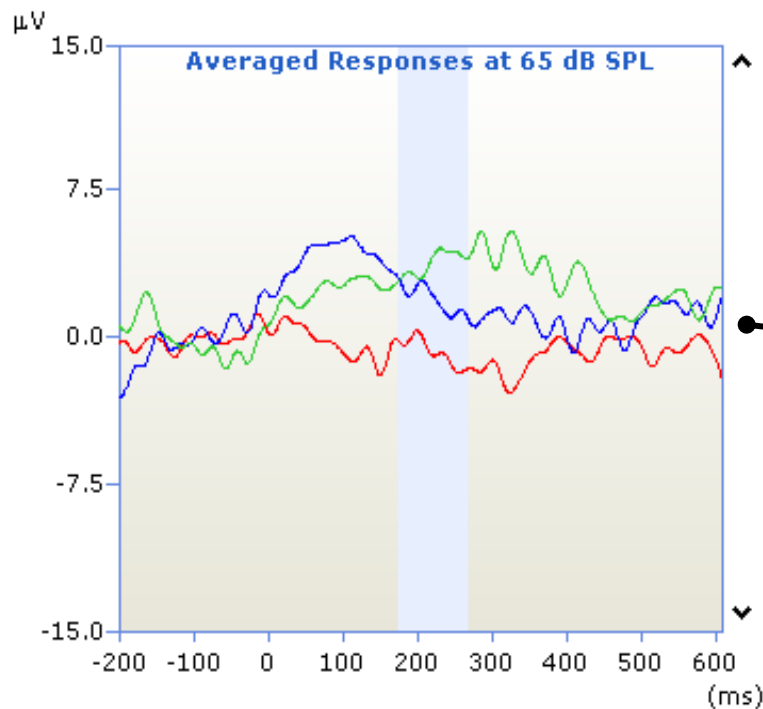
Increase gain at all frequencies

Visit 2



Were responses detected?

	/m/	/t/	/g/
75 dB SPL	0.617	0.705	0.418



Were responses detected?

	/m/	/t/	/g/
65 dB SPL	0.639	0.505	0.318

- The infant received bilateral cochlear implants at 5 months of age.
- Email from the baby's parents ~
“Thank you so much for the information you gave us on the previous testing as it helped us with our decision to proceed with the implants.”

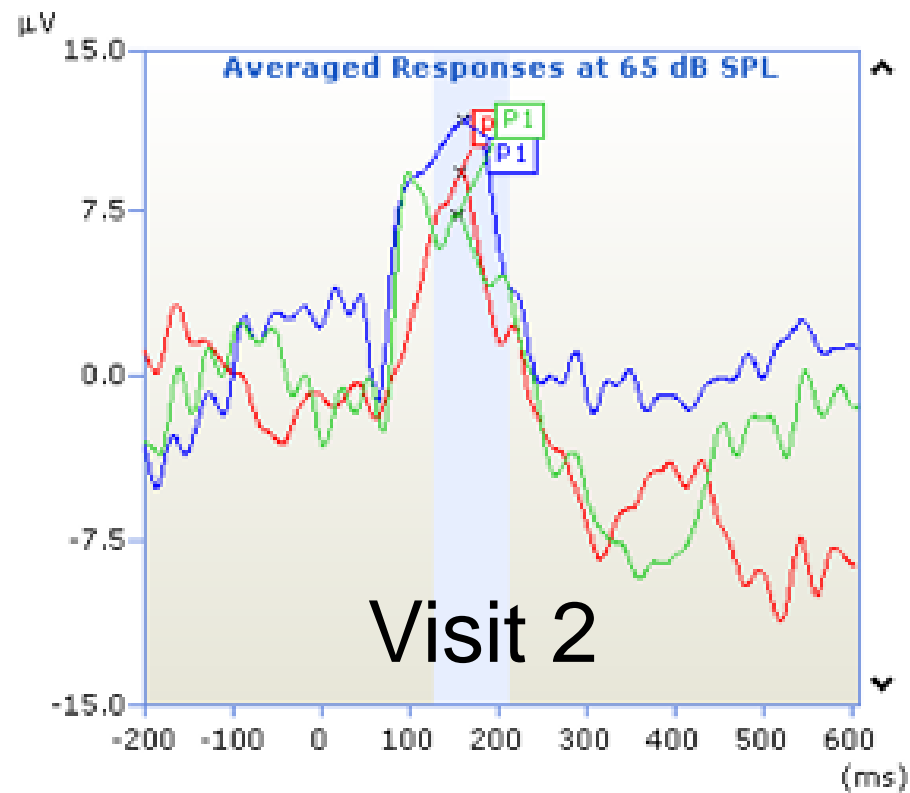
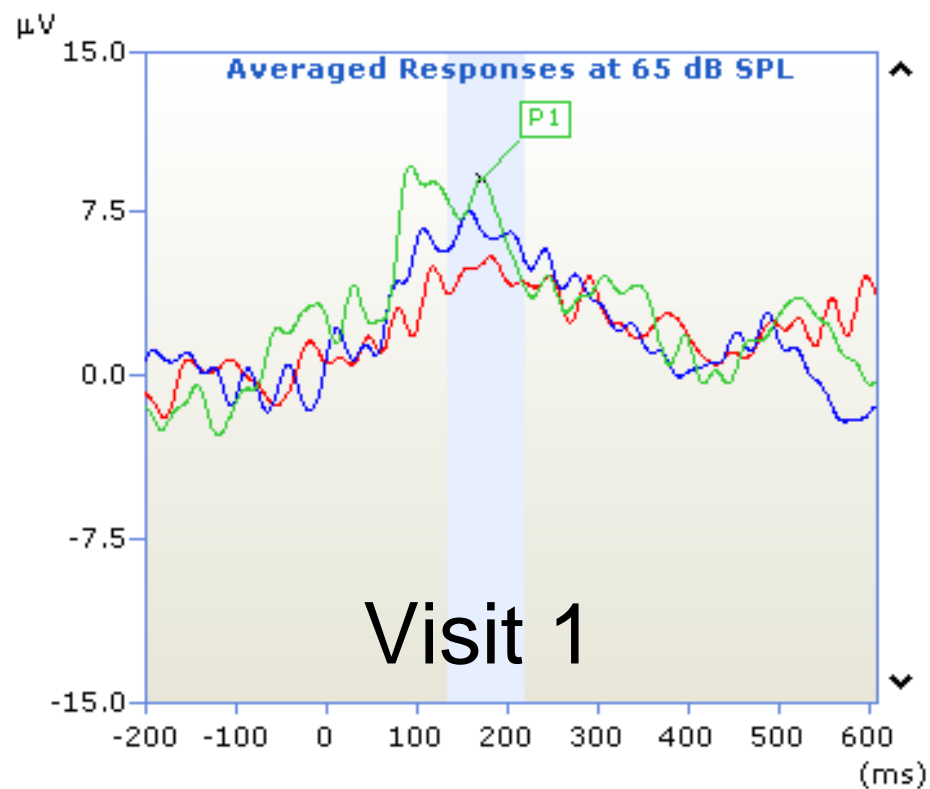
Case 4

Too few significant cortical responses, and the aid gain was increased, resulting in more cortical responses

- Hearing aid fitting at 9 weeks of age
- Age at aided cortical testing
 - Visit 1
8 months old
 - Visit 2
9 months old
- Hearing aids have been increased in gain two weeks before the second visit.

Estimated Audiogram (dB HL) at Visit 1				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	45	50	55	55
Left	45	55	65	55

Estimated Audiogram (dB HL) at Visit 2				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	55	50	55	55
Left	55	55	65	55



	/m/	/n/	/g/
65 dB SPL	0.326	0.184	0.043

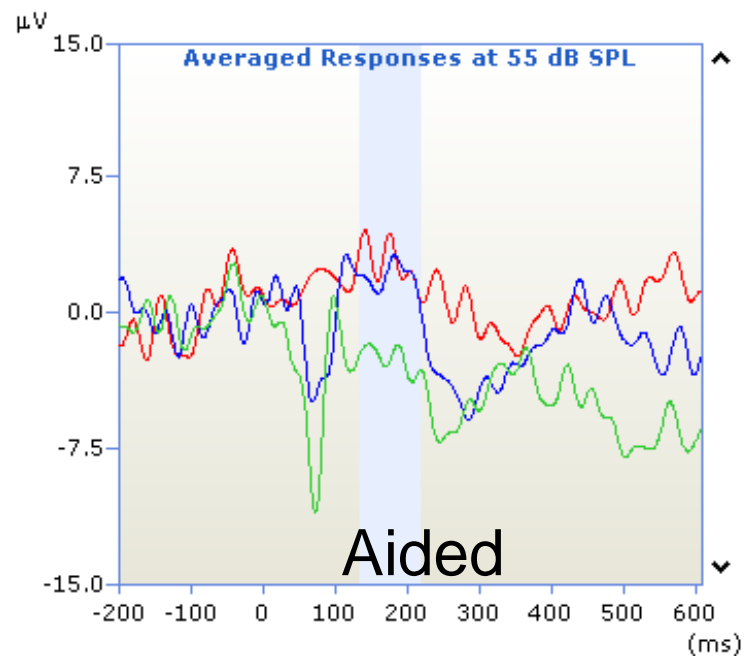
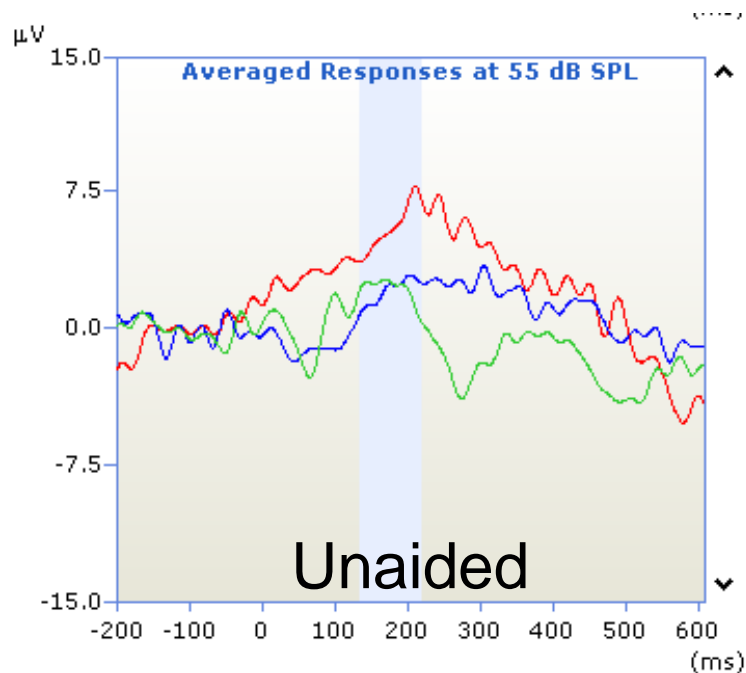
	/m/	/n/	/g/
65 dB SPL	0.043	0.007	0.015
55 dB SPL	0.000	0.103	0.104

Case 6

A case where the unaided /m/ was present but the aided /m/ was absent.

- Cortical testing at 8 months of age, nine days after the initial hearing aid fitting

Estimated Audiogram				
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Right	40	35	40	45
Left	40	35	40	45



Were responses detected?

	/m/	/t/	/g/
65 dB SPL	0.001	0.000	0.000
55 dB SPL	0.046	0.424	0.015

Were responses detected?

	/m/	/t/	/g/
65 dB SPL	0.066	0.000	0.000
55 dB SPL	0.528	0.004	0.092

Hearing Aid Coupler Gain at 65 dB SPL Input

250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
<0	0	7	15	20

* Both hearing aids are set the same.

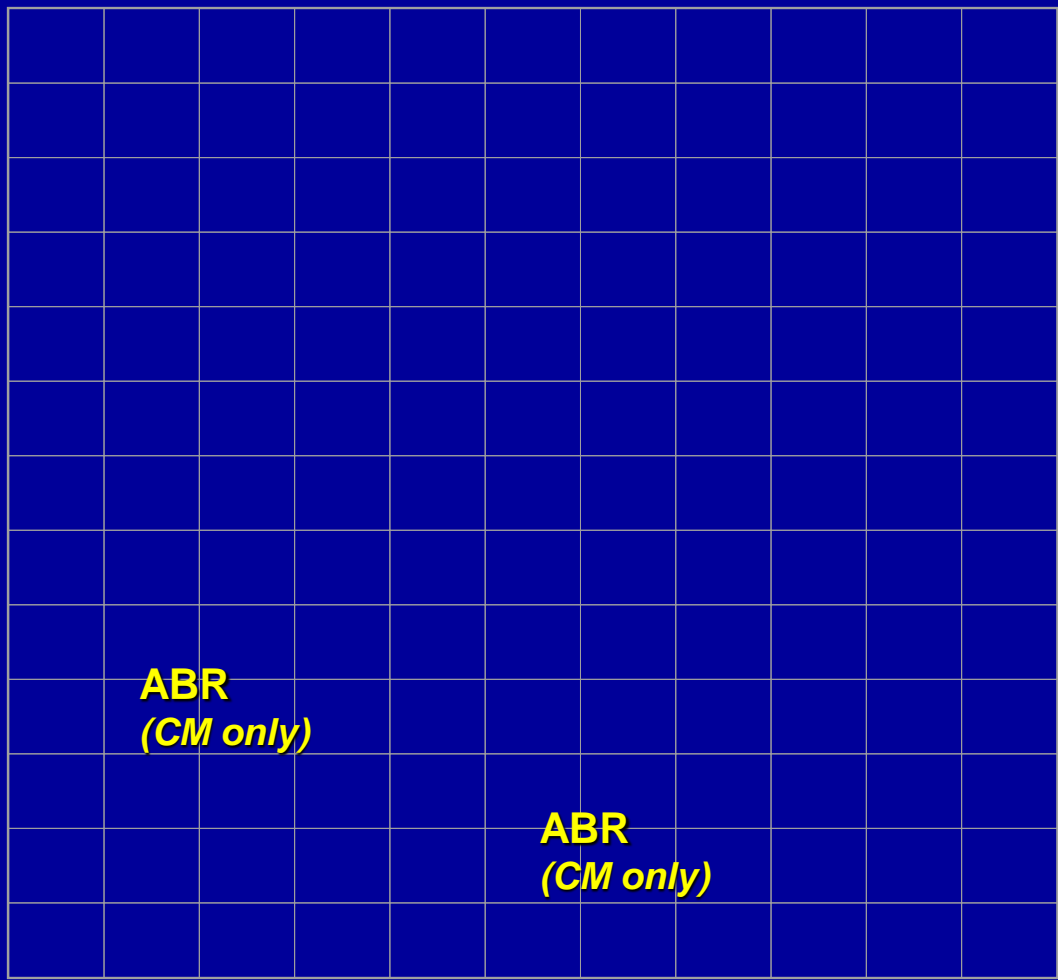
Case 7: ANSD

FREQUENCY (Hz)

250 500 750 1000 1500 2000 3000 4000 6000 8000

HEARING LEVELS IN DECIBELS

0
10
20
30
40
50
60
70
80
90
100
110



ABR
(CM only)

ABR
(CM only)

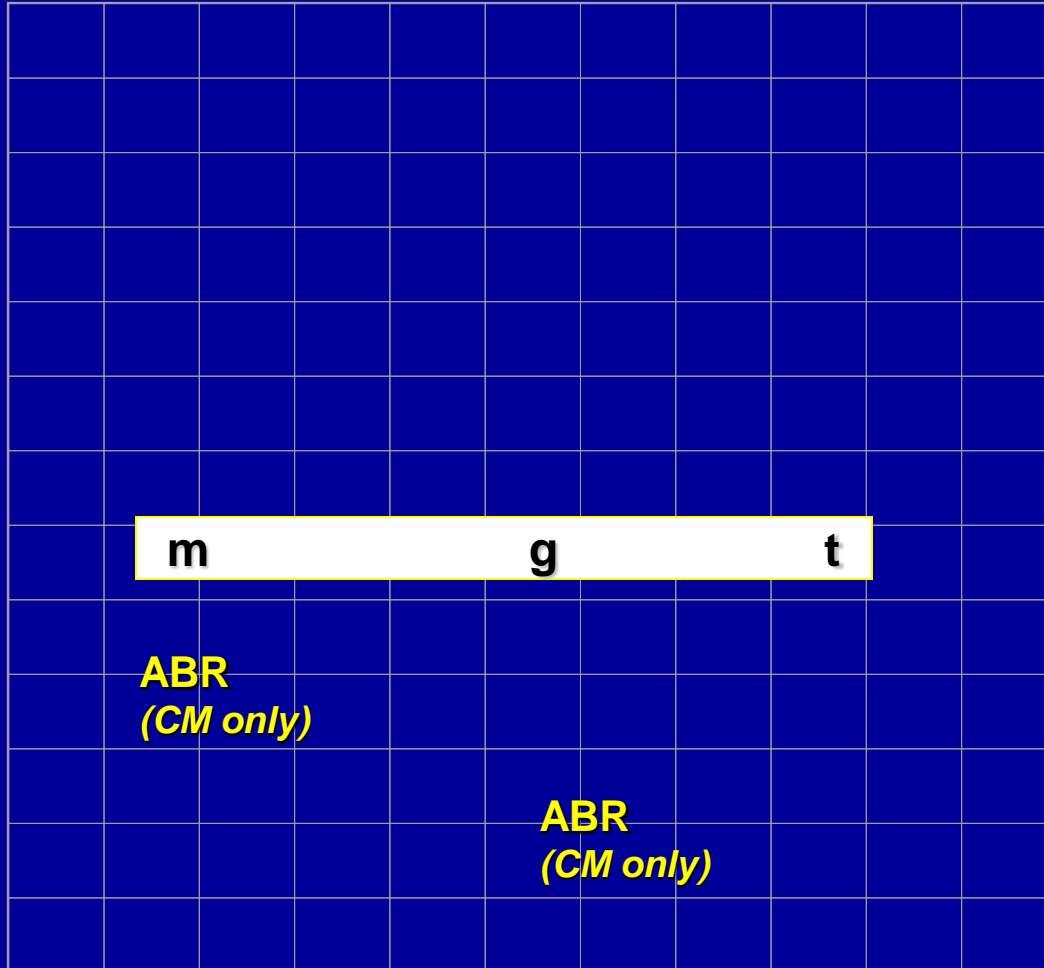
ABR
28/8/03 - NR

FREQUENCY (Hz)

250 500 750 1000 1500 2000 3000 4000 6000 8000

HEARING LEVELS IN DECIBELS

0
10
20
30
40
50
60
70
80
90
100
110



ABR

28/8/03 - NR

CAEP

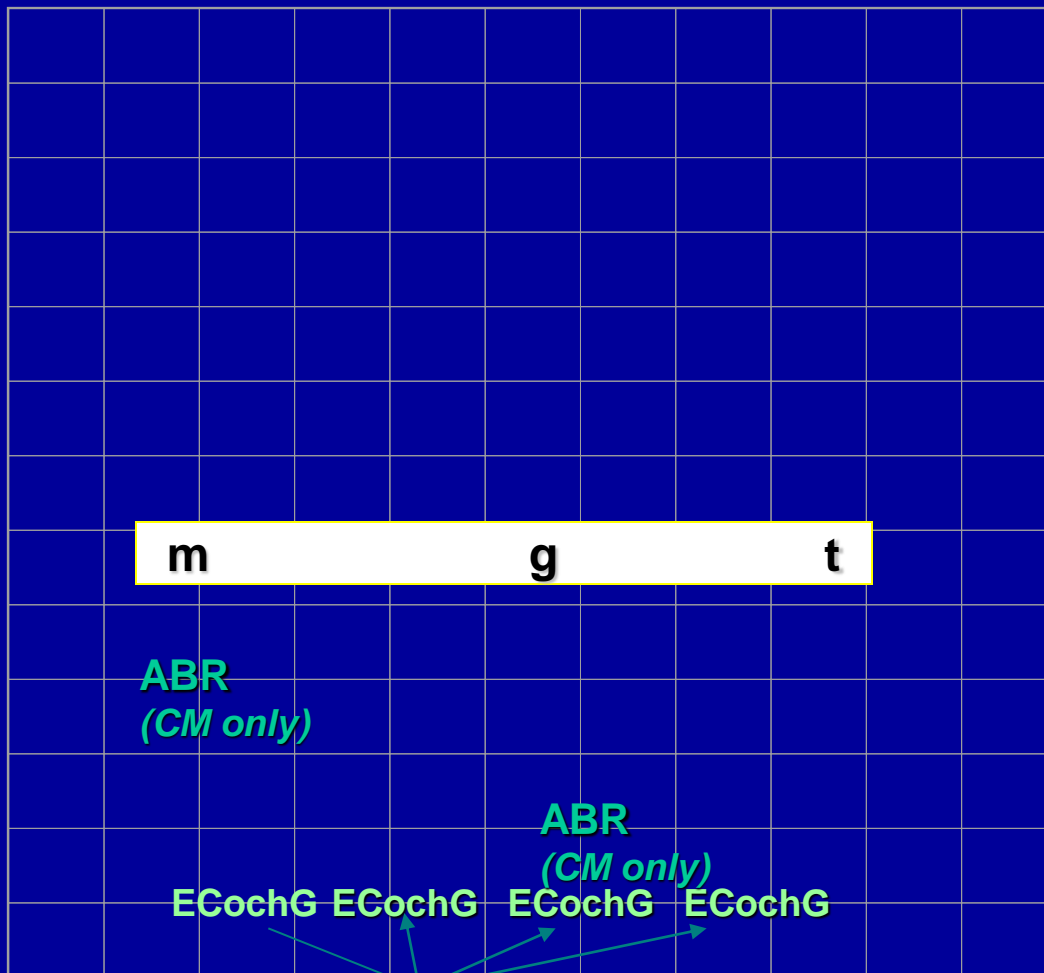
14/10/03

FREQUENCY (Hz)

250 500 750 1000 1500 2000 3000 4000 6000 8000

HEARING LEVELS IN DECIBELS

0
10
20
30
40
50
60
70
80
90
100
110



m g t

ABR
(CM only)

ABR
(CM only)

ECochG ECochG ECochG ECochG

(abnormal potentials only)

ABR

28/8/03 - NR

15/3/04 - NR

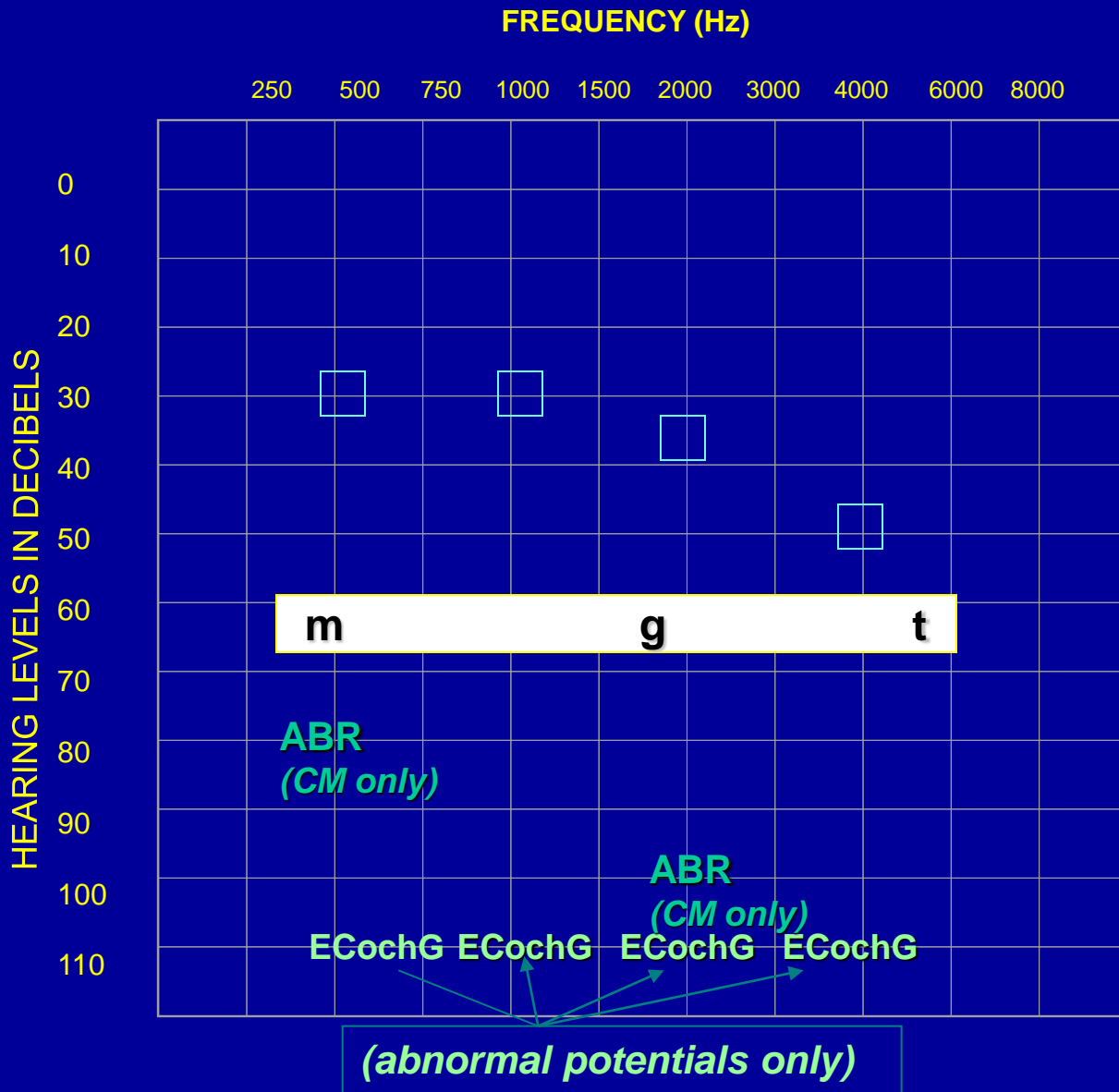
CAEP

14/10/03

30/3/04

ECochG

15/3/04



ABR

28/8/03 - NR

15/3/04 - NR

CAEP

14/10/03

30/3/04

ECochG

15/3/04

VROA

29/4/04

Case 11 - verifying speech audibility with a softband BAHA

- Child has a right sided cleft lip and palate and developmental delay.
- 8 weeks old – bilateral asymmetrical moderate to severe conductive hearing loss, confirmed using ABR.
- 9 weeks – fitted with softband BAHA
- 9 months old – unable to obtain reliable behavioural data due to developmental delay
- Child recently discovered BAHA as a new toy! Parents finding BAHA difficult to manage.
- Unable to verify benefit of BAHA

Case 11



Case 11 - unaided CAEP results

ACAModule

File Main Assessment Tools Help

Test Conditions

Both Unaided

Acq. Channel: Cz

Impedance: Good

Stimuli and Masking

Stimuli Type: Speech

Masking Type: None

Masking Lvl (dB):

Transducers Used

For Stimulus: Free Field

For Masking:

Test Duration

20 min

Additional Notes

Type in additional comments about the assessment here (max 500 chars):

Client Name: [redacted] Test Ear: Both Assessment Time: 18 Aug 2010 10:32 Current Time: 04 Oct 2010 15:02 Clinician Name: Electronics, Frye

Were responses detected?

	/m/	/t/	/g/
75 dB SPL			✓
65 dB SPL		✓	-

View history... View p values

Averaged Responses at 75 dB SPL

Averaged Responses at 65 dB SPL

Legend

- /g/
- /t/

Epoch Count...

Run Selection...

start ACAModule Document - WordPad 15:02

Case 11 - aided CAEP results

ACA 1.0

File Main Assessment Tools Help

Test Conditions

Both Aided

Acq. Channel Cz

Impedance Good

Stimuli and Masking

Stimuli Type Speech

Masking Type None

Masking Lvl (dB)

Transducers Used

For Stimulus Free Field

For Masking

Test Duration

3 min

Additional Notes

Type in additional comments about the assessment here (max 500 chars):

	/m/	/t/	/g/
65 dB SPL			✓

View history... View p values

Averaged Responses at 65 dB SPL

Legend

/g/

Epoch Count...

Run Selection...

Client Name [redacted] Test Ear: Both Assessment Time: 18 Aug 2010 11:35 Current Time: 11 Oct 2010 11:14 Clinician Name: Electronics, Frye

start ACA 1.0 Document - WordPad 11:14

Case 11 - outcome

- Without BAHA
 - CAEPs present for /t/ at 65 dB
 - CAEP was not present for /g/ at 65 dB but present at 75 dB.
- With BAHA
 - CAEP present for /g/ at 65 dB
- Conclusion
 - The BAHA provides significant benefit by making a wider range of speech sounds audible at average conversational level.
- Parents were reassured and encouraged by results -both unaided and aided.
- Subsequent VRA behavioural assessment confirmed a bilateral moderate upward sloping conductive hearing loss

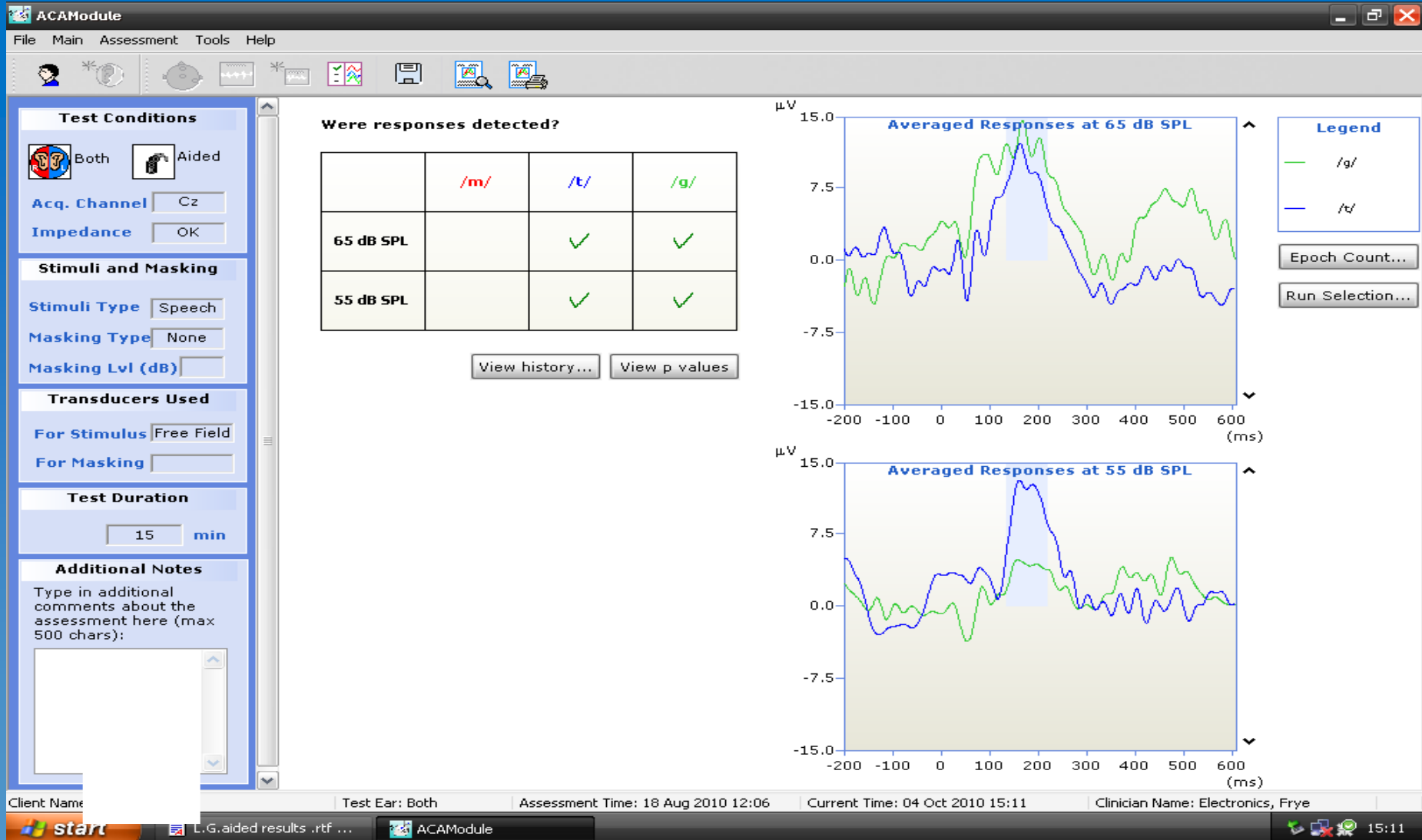
Case 12 - verifying speech audibility with hearing aids

- 7 weeks old- bilateral moderate to severe sloping sensorineural hearing loss confirmed using ABR
- 9 weeks – fitted with Nios Micro hearing aids using sound recover
- 8 months – reliable behavioural assessment confirmed ABR levels were accurate and stable
- Required confirmation that full range of speech sounds were audible

Case 12



Case 12 – Aided CAEP results



Case 12 – outcome

- CAEP was present for /g/ and /t/ at 65 and 55 dB with hearing aids in place.
- Conclusion – Hearing aids are maintaining the audibility of speech at soft and louder levels in both mid and high frequencies.
- Child 2's parents – 'we're pleased to know his hearing aids are doing their job. It's reassuring to see that he can hear speech'.

- Child has Downs syndrome
- 8 months - diagnosed with bilateral moderate mixed hearing loss using ABR and fitted with bilateral hearing aids
- 21 months - unable to obtain any reliable behavioural information.
- Child recently removing aids.
- No up to date behavioural information to verify hearing aid prescription

Case 14 – unaided CAEP results

ACA 1.0

File Main Assessment Tools Help

Test Conditions

Both Unaided

Acq. Channel: Cz

Impedance: OK

Stimuli and Masking

Stimuli Type: Speech

Masking Type: None

Masking Lvl (dB):

Transducers Used

For Stimulus: Free Field

For Masking:

Test Duration

13 min

Additional Notes

Type in additional comments about the assessment here (max 500 chars):

Were responses detected?

	/m/	/t/	/g/
65 dB SPL	-	-	-

View history... View p values

Averaged Responses at 65 dB SPL

Legend

- /m/
- /t/

Epoch Count...

Run Selection...

Client Name: [redacted] Test Ear: Both Assessment Time: 19 Aug 2010 14:37 Current Time: 11 Oct 2010 11:16 Clinician Name: Electronics, Frye

start ACA 1.0 L.P results aided.rtf -...

11:16

Case 14 – aided CAEP results (1)

ACA 1.0

File Main Assessment Tools Help

Test Conditions

Both Aided

Acq. Channel: Cz

Impedance: OK

Stimuli and Masking

Stimuli Type: Speech

Masking Type: None

Masking Lvl (dB):

Transducers Used

For Stimulus: Free Field

For Masking:

Test Duration

13 min

Additional Notes

Type in additional comments about the assessment here (max 500 chars):

Client Name: Test Ear: Both Assessment Time: 19 Aug 2010 14:55 Current Time: 11 Oct 2010 11:17 Clinician Name: Electronics, Frye

Were responses detected?

	/m/	/t/	/g/
75 dB SPL	-		
65 dB SPL	-	✓	

View history... View p values

Averaged Responses at 75 dB SPL

Averaged Responses at 65 dB SPL

Legend

- /m/
- /t/

Epoch Count... Run Selection...

Case 14 - outcome

- Unaided
 - CAEP absent using /t/ and /m/ 65 dB
- Aided 1
 - CAEP absent for /m/ at 65 dB and 75 dB,
 - Present for /t/ at 65dB
- Response seen only to high frequency stimulus with current hearing aid prescription.
- Changed hearing aid prescription to increase gain in low frequencies.
- Aided 2
 - CAEP present for /t/ at 65dB
 - CAEP absent for /m/ at 65dB
- ABR repeated and showed a deterioration in hearing thresholds particularly in low frequencies. Hearing aid prescription altered and CAEP now present for both low and high freq speech at quiet and conversation speech sounds.

Case 14 – Aided results (2)

ACAModule
_ □ ×

File Main Assessment Tools Help

Test Conditions

Both Aided

Acq. Channel

Impedance

Stimuli and Masking

Stimuli Type

Masking Type

Masking Lvl (dB)

Transducers Used

For Stimulus

For Masking

Test Duration

min

Additional Notes

Type in additional comments about the assessment here (max 500 chars):

Were responses detected?

	/m/	/t/	/g/
65 dB SPL		✓	✓
55 dB SPL		✓	✓

Legend

— /g/

— /t/

Averaged Responses at 65 dB SPL

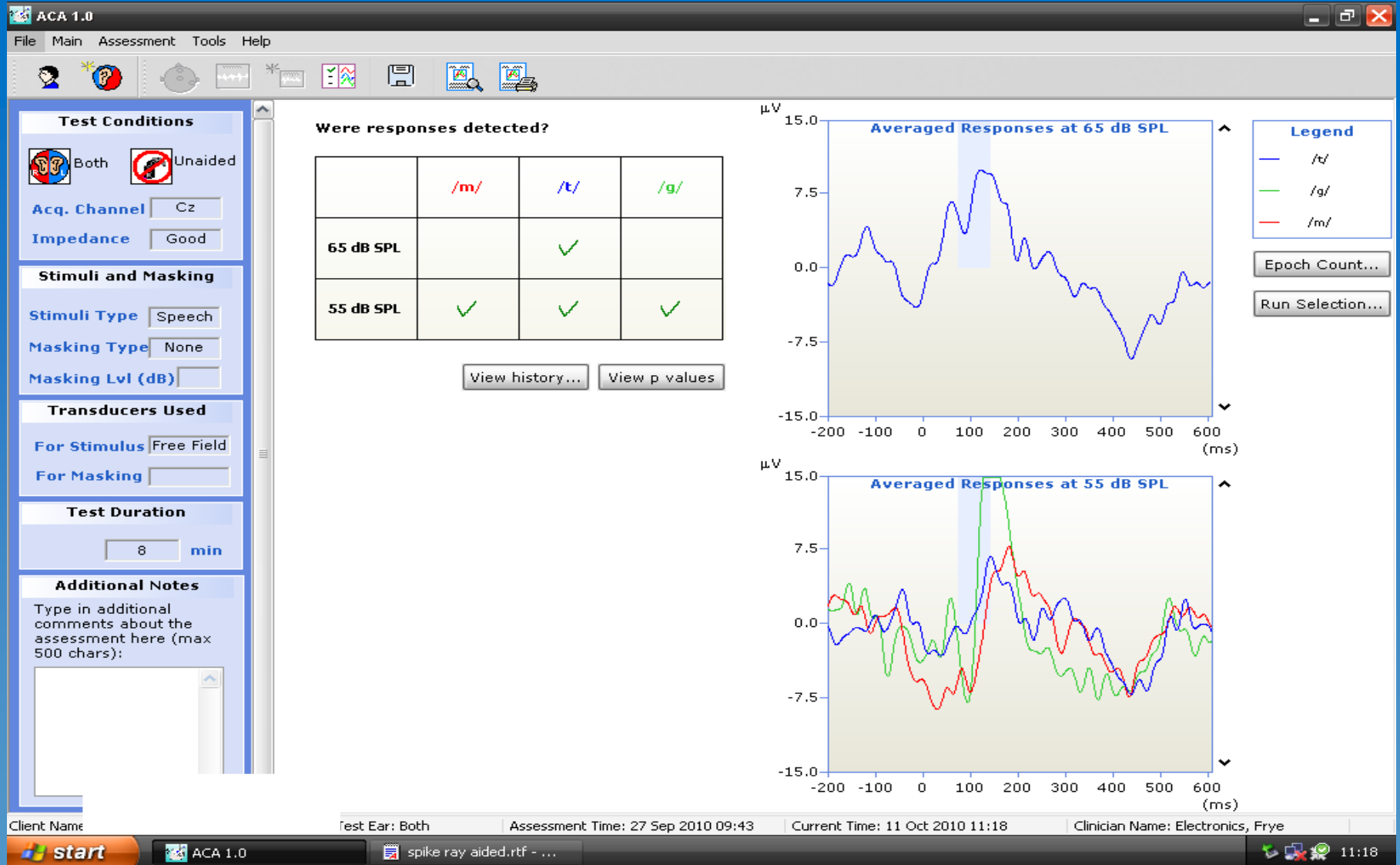
Averaged Responses at 55 dB SPL

Client Name: _____ ct 2010 15:11 Clinician Name: Electronics, Frye

Case 16 - Is speech audible?

- 3 years 9 months
- Developmental delay including delayed speech production
- Recent MRI confirmed brain damage
- Behavioural assessments inconsistent but indicate an overall high frequency severe sensorineural hearing loss.
- DPOAEs present bilaterally.
- Can she hear high frequency speech?
- Does she need a hearing aid?

Case 16 – Unaided CAEP results



Case 16 – conclusion

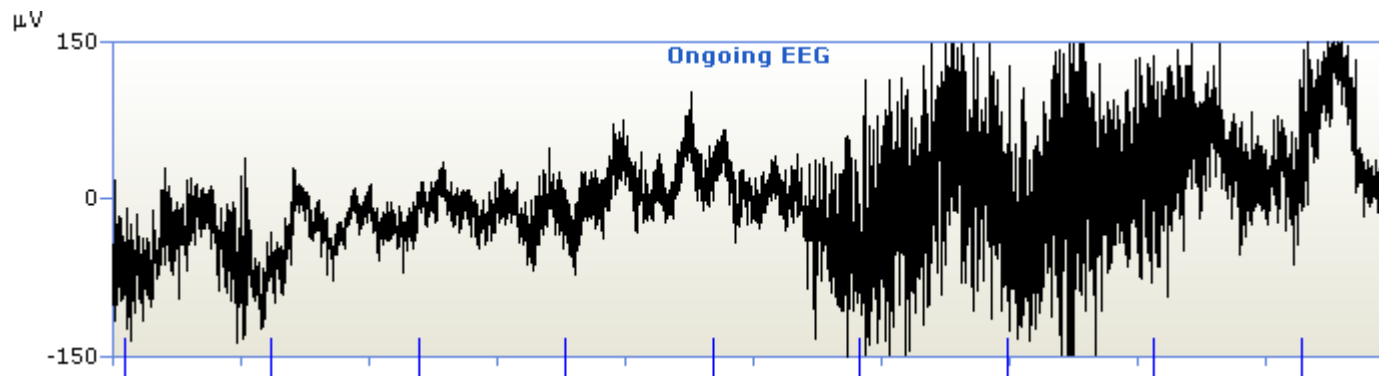
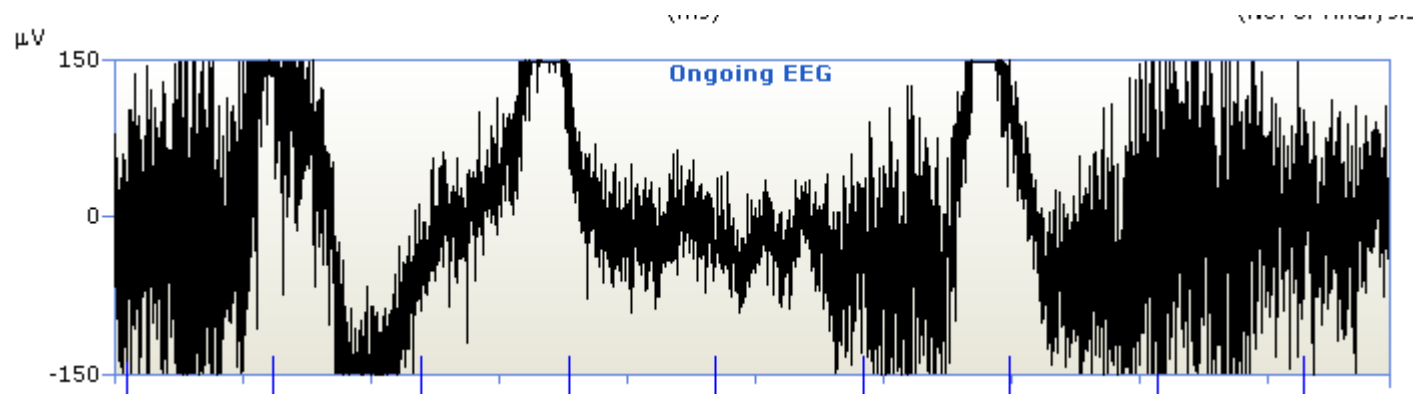
- CAEP present to /t/ and /m/ at 65 and /t/, /g/ and /m/ at 55 dB
- High frequency speech is audible at average and quiet conversational levels.
- Parents reassured
- Hearing aid not indicated
- ? Implications for neurologist re. cortical activation.

Case 5

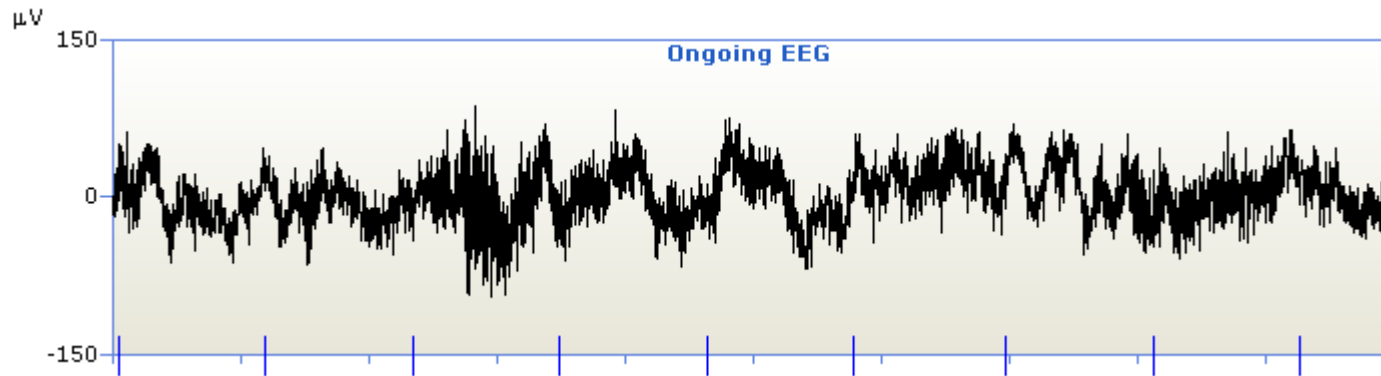
A case where cortical testing was not possible

- Age at testing: 4.5 years
- Multiple disabilities
- A reliable behavioural audiogram has not yet been obtained.

- She was moving all the time.



At her quietest state, but this only lasted for a few seconds.



Case 3

- 18 years old
- Hx of tuberous sclerosis and left temporal lobe removed several years ago
- Developmental delay and uncontrolled epilepsy
 - Family history of hearing loss
 - Under the care of specialist including neurologist
- Recent MRI – normal except for indications of earlier surgery

Case 3

- Presented with:
 - A virus (cough/cold) whilst o/seas and 2 weeks later suddenly complained she was unable to hear
 - Bilateral flat profound SNHL (3FAHL R=95 and L=100)
 - Normal ABR but large CM
 - Behaviourally not her usual sociable self, communicating visually but knows signs as well
 - Mother doubts it is non-organic as does not believe daughter could sustain this long.

Case 3

- Hearing aids recommended based on family concern of hearing and the client genuine distress of not being able to communicate
- At fitting appointment cortical threshold estimation (CTE) was arranged.
- 500, 1, 2 and 4 kHz were tested for the left and right ear via inserts.
 - Results: hearing within normal limits bilaterally

Non-organic Hearing Loss?

For more information

HearLab.NAL.gov.au