New Developments in Prescribing and Evaluating Children's Amplification

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National Acoustic Laboratories

Prescription of gain for children

A theoretical derivation, guided by:

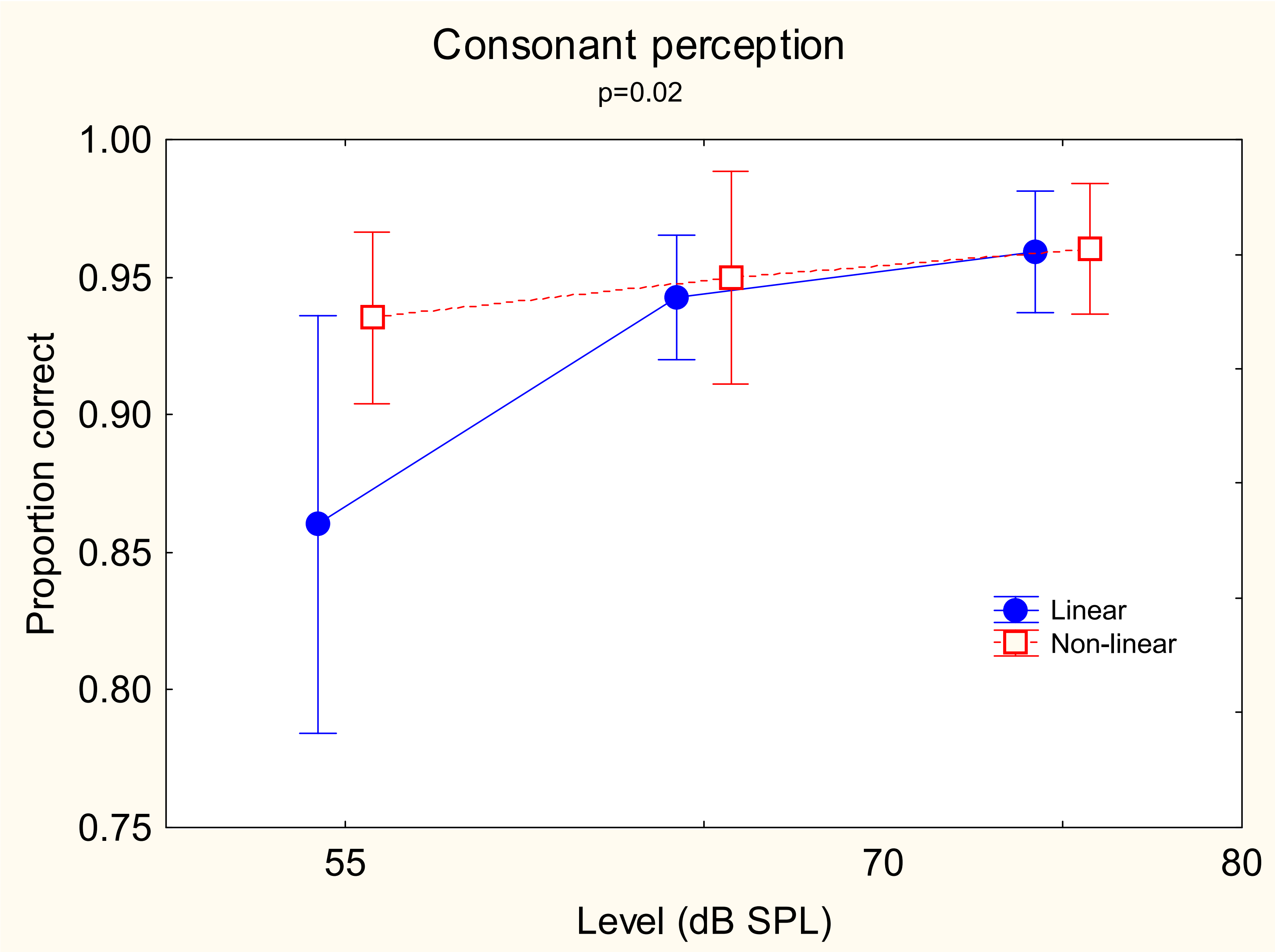
1. Linear versus non-linear
2. NAL-NL1 vs DSL[i/o] 4 (older children)
3. NAL-NL1 vs DSL[i/o] 4 (adults)
4. NAL-NL1 vs DSL[i/o] 4 (infants and toddlers)

Linear versus non-linear amplification

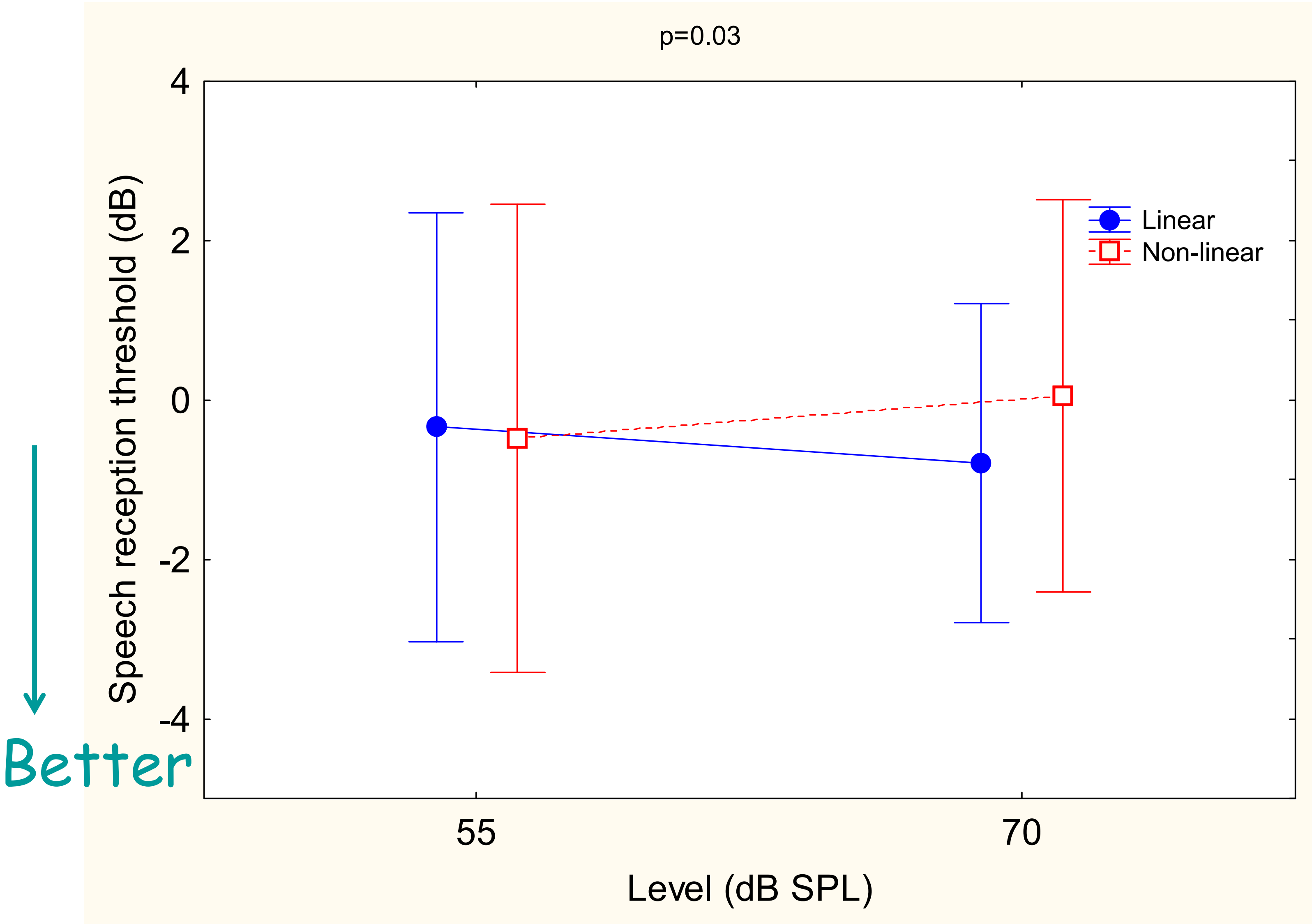
Older children

Teresa Ching, Mandy Hill

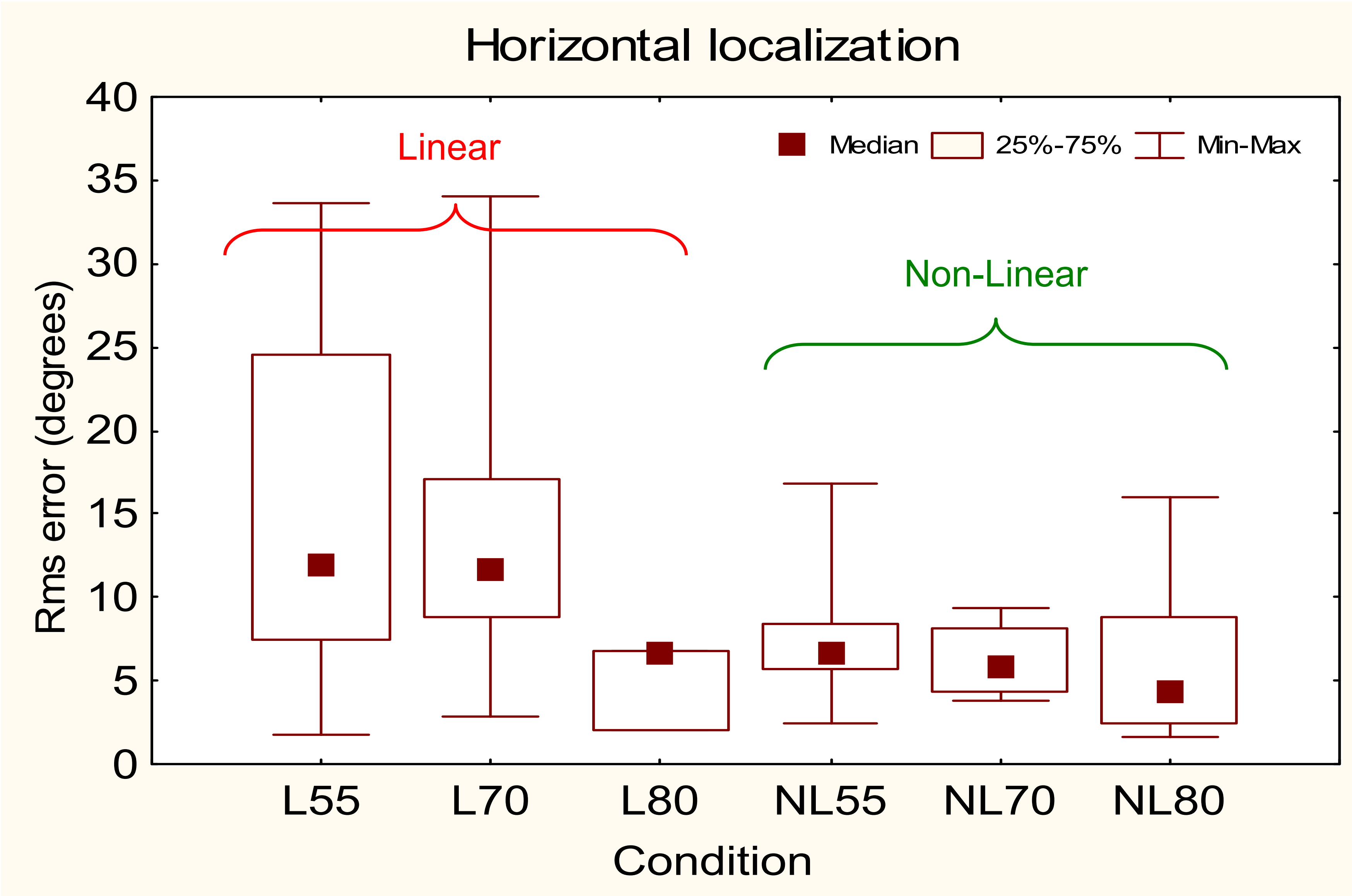
Non-linear → more intelligible



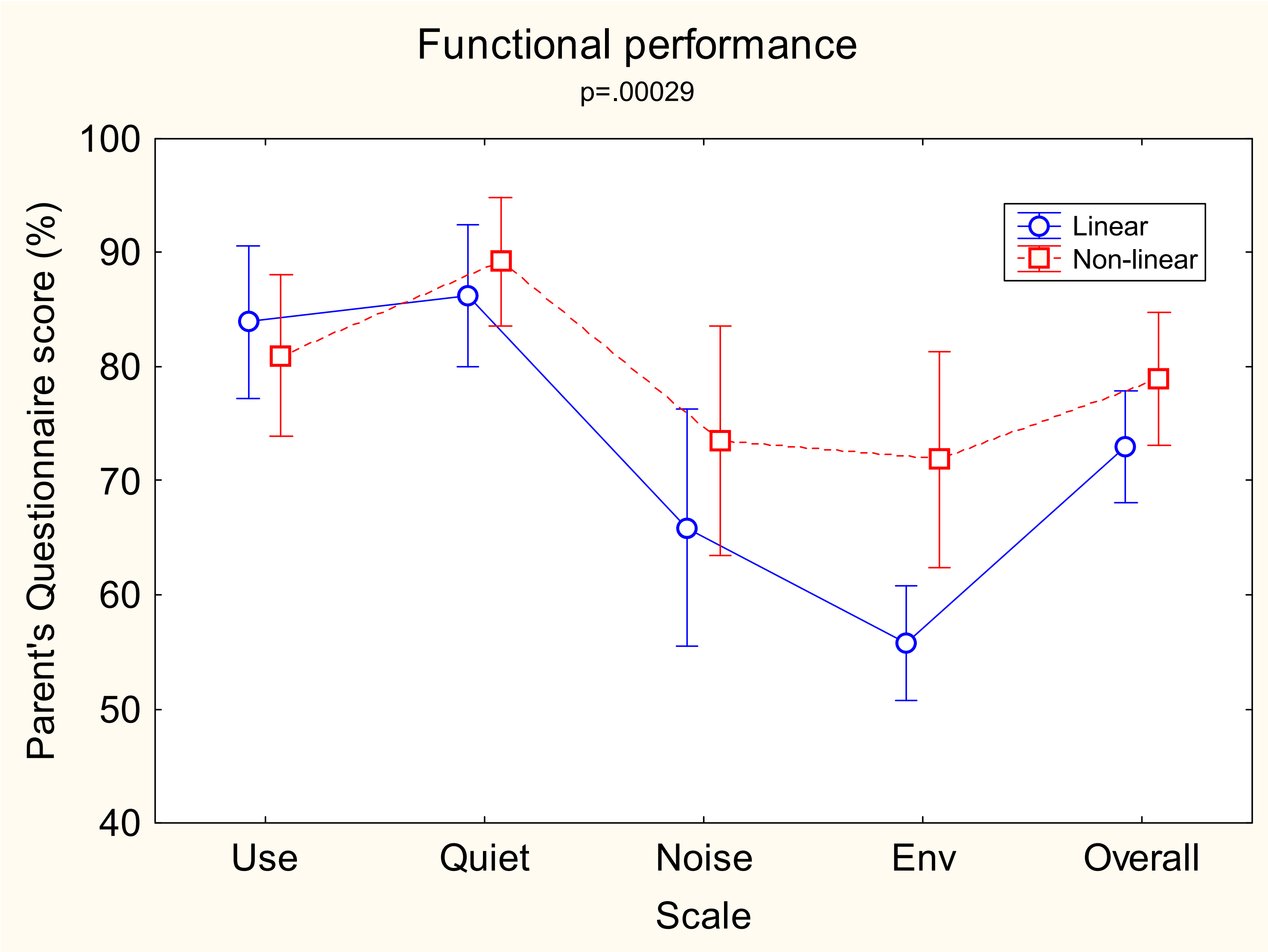
Sentence perception in noise



Non-linear → better localisation



Non-linear → better functional performance



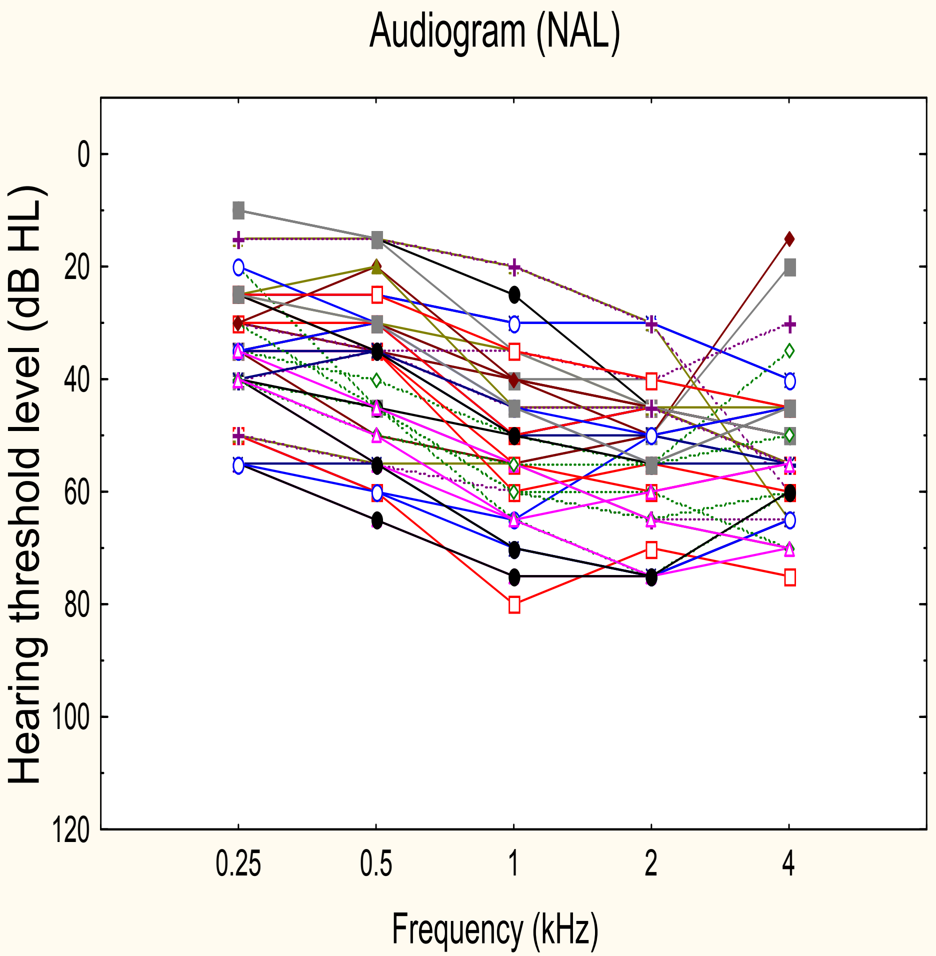
NAL-NL1 versus DSL[i/o] 4

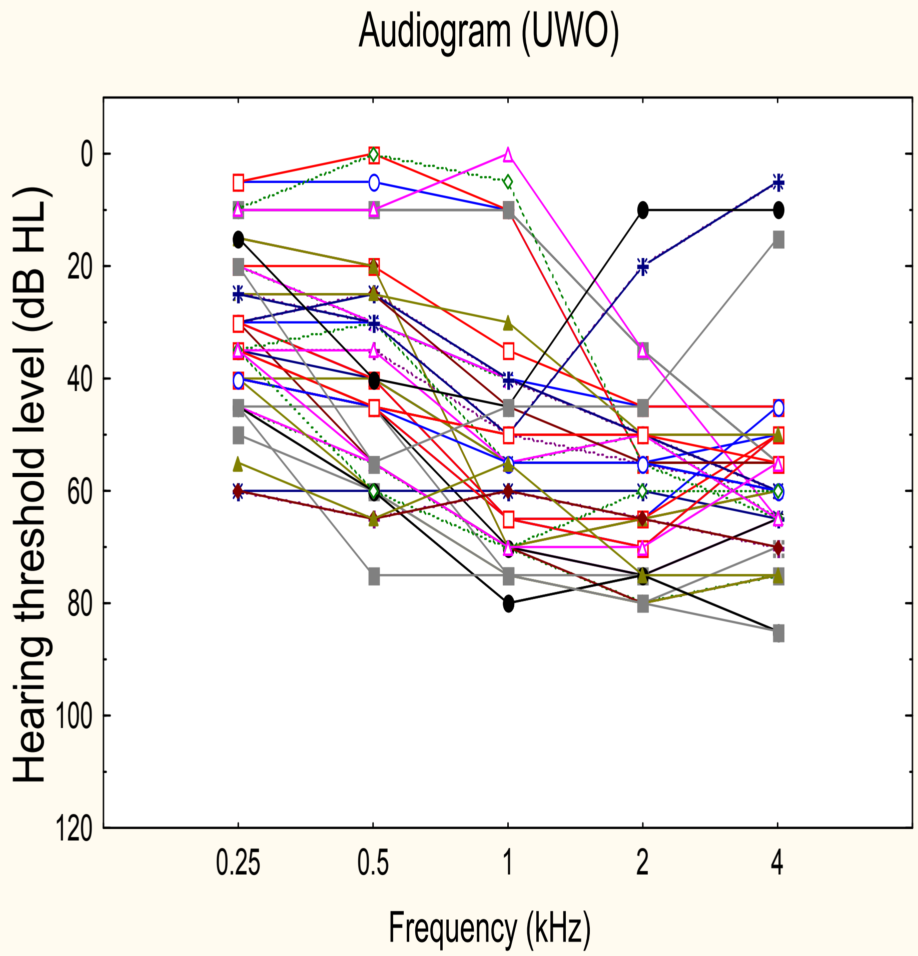
Older children

Teresa Ching, Susan Scollie, Richard Seewald, Louse Britton, Jayne Joyce,

Subjects:
48 children with sensorineural hearing loss

24 *24*

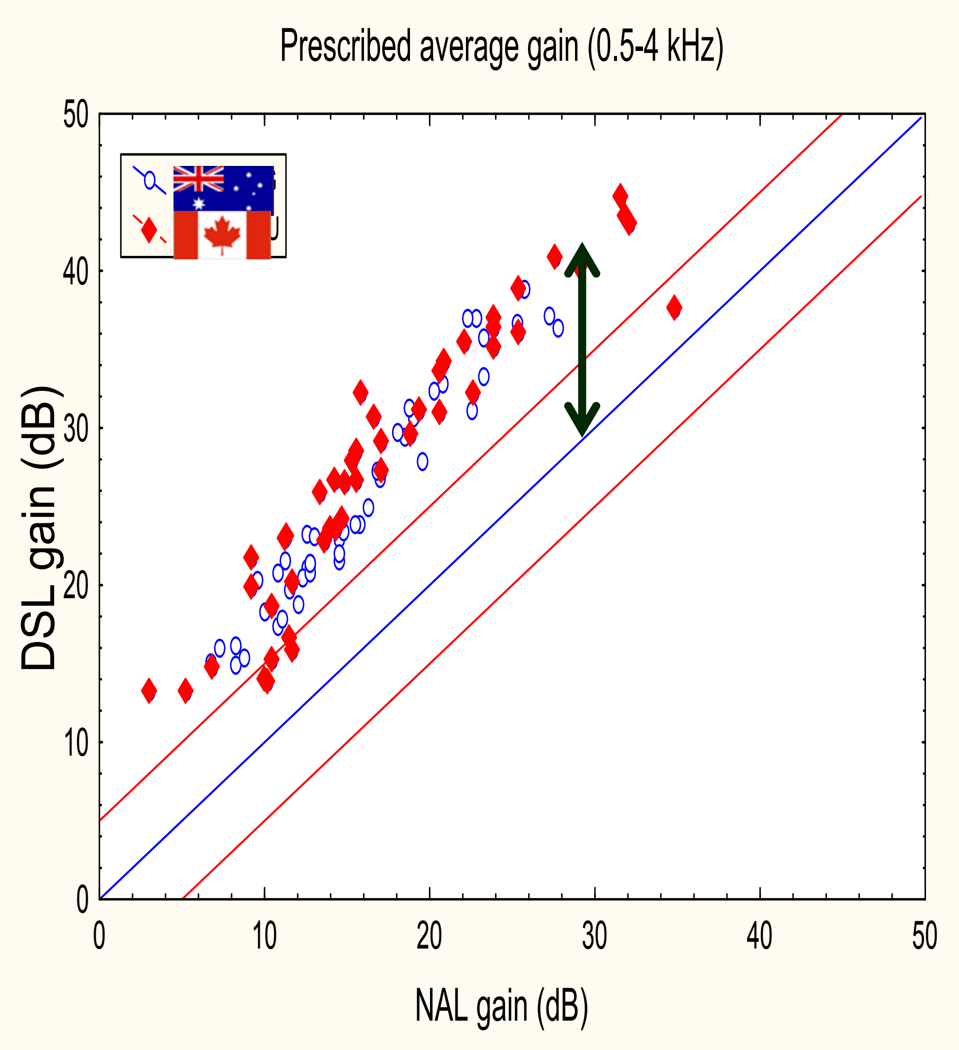


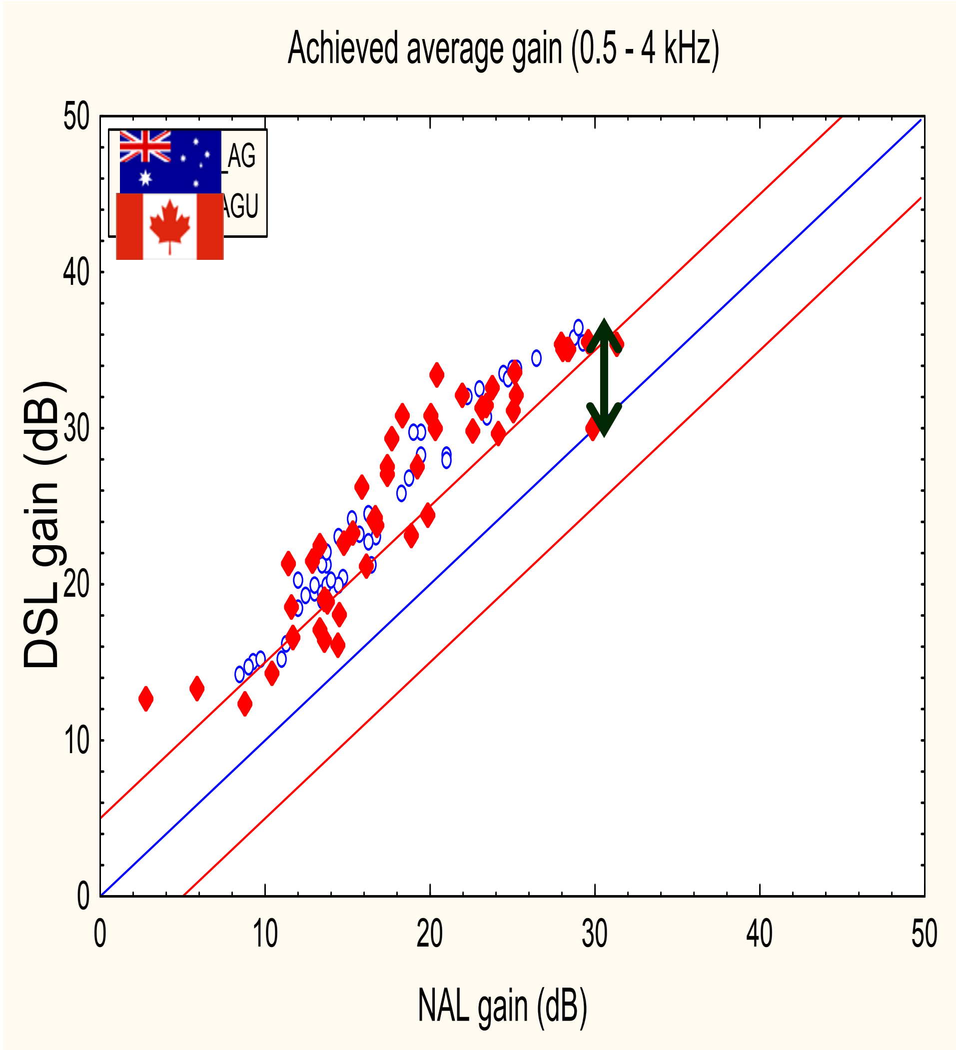


Gain: 4FA gain (0.5-4kHz) for 70 dB input: NAL and DSL

Prescribed

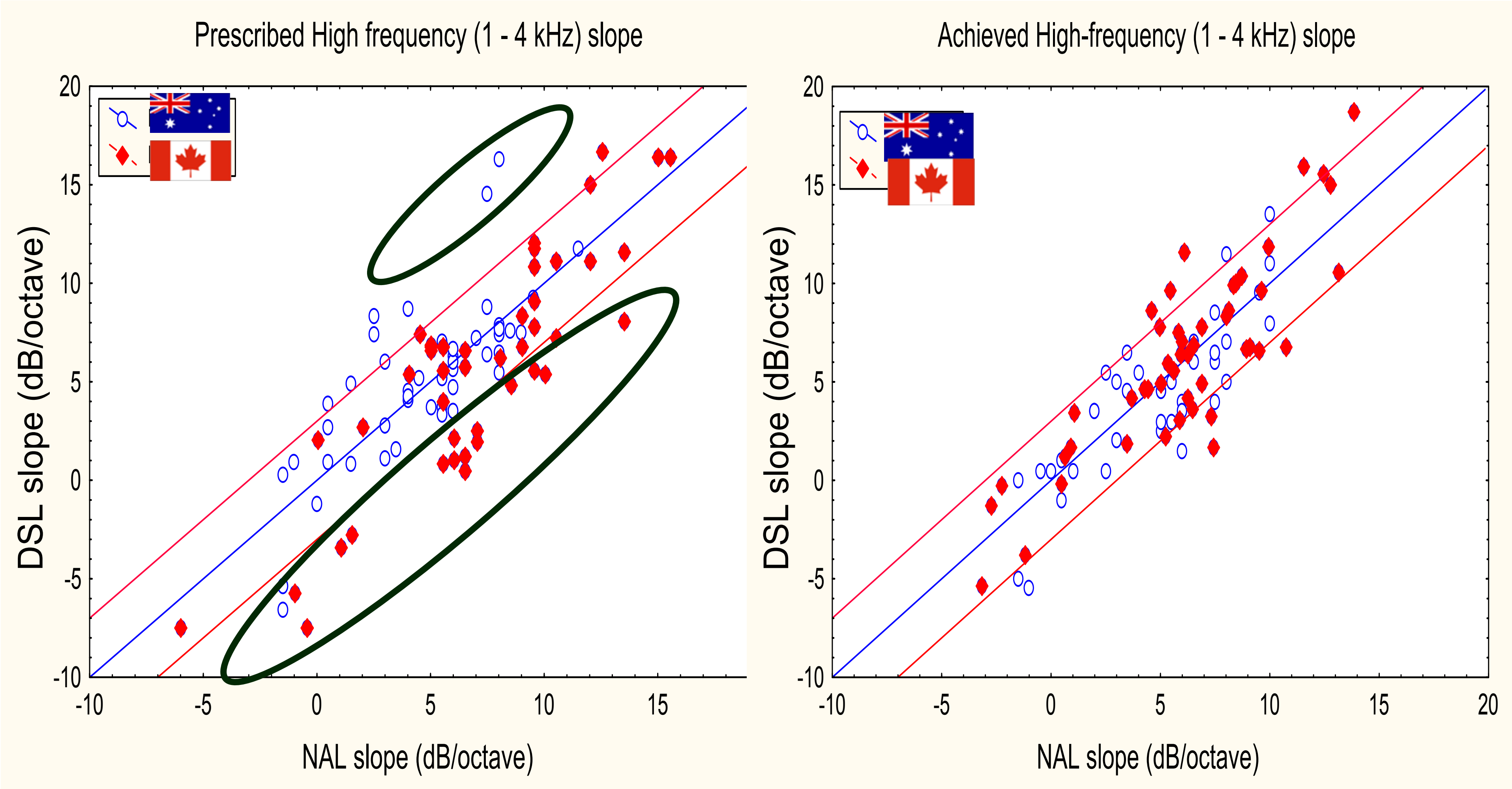
Achieved fitting



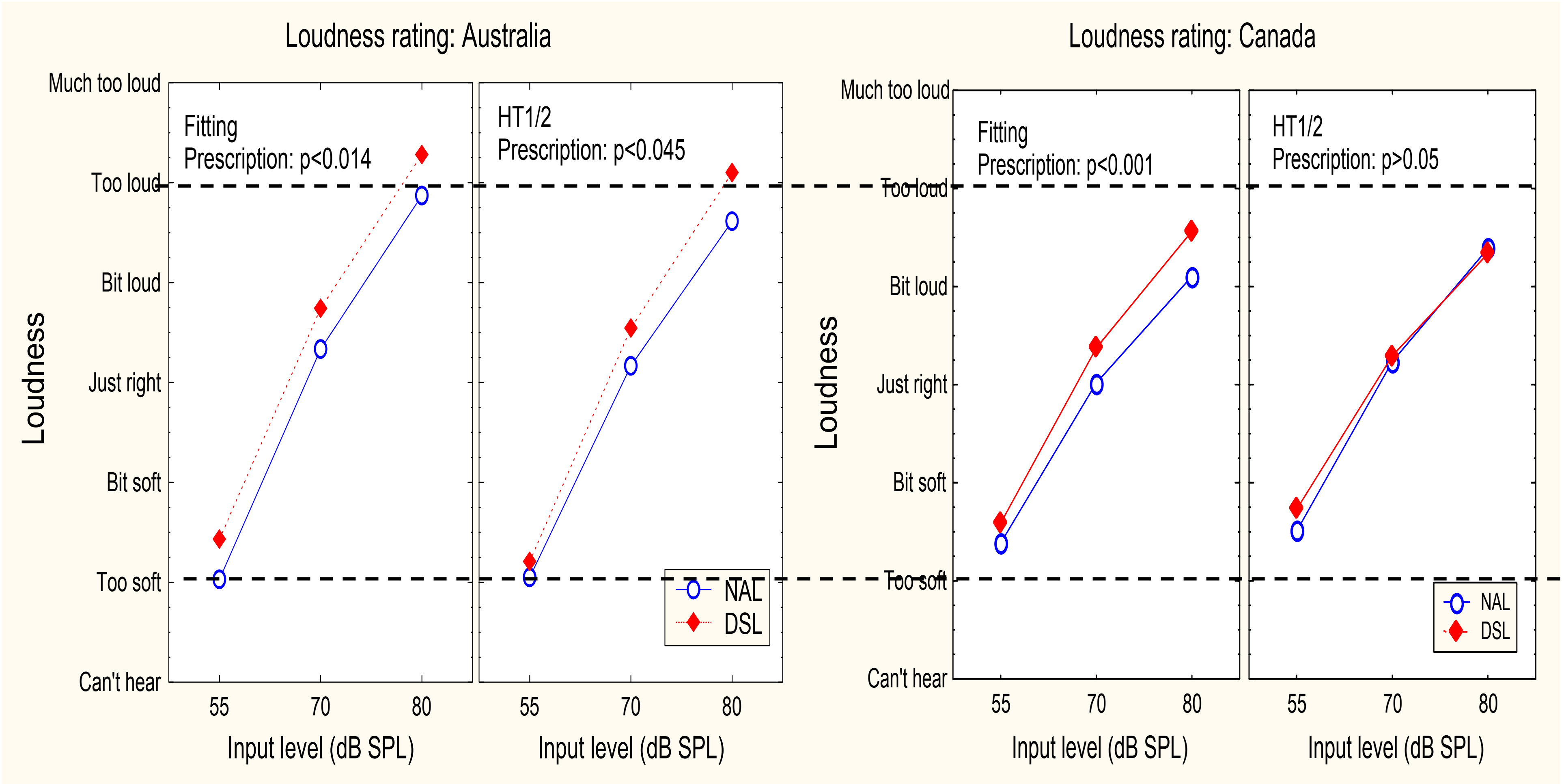


High frequency slope (1-4 kHz) for 70 dB input: NAL and DSL

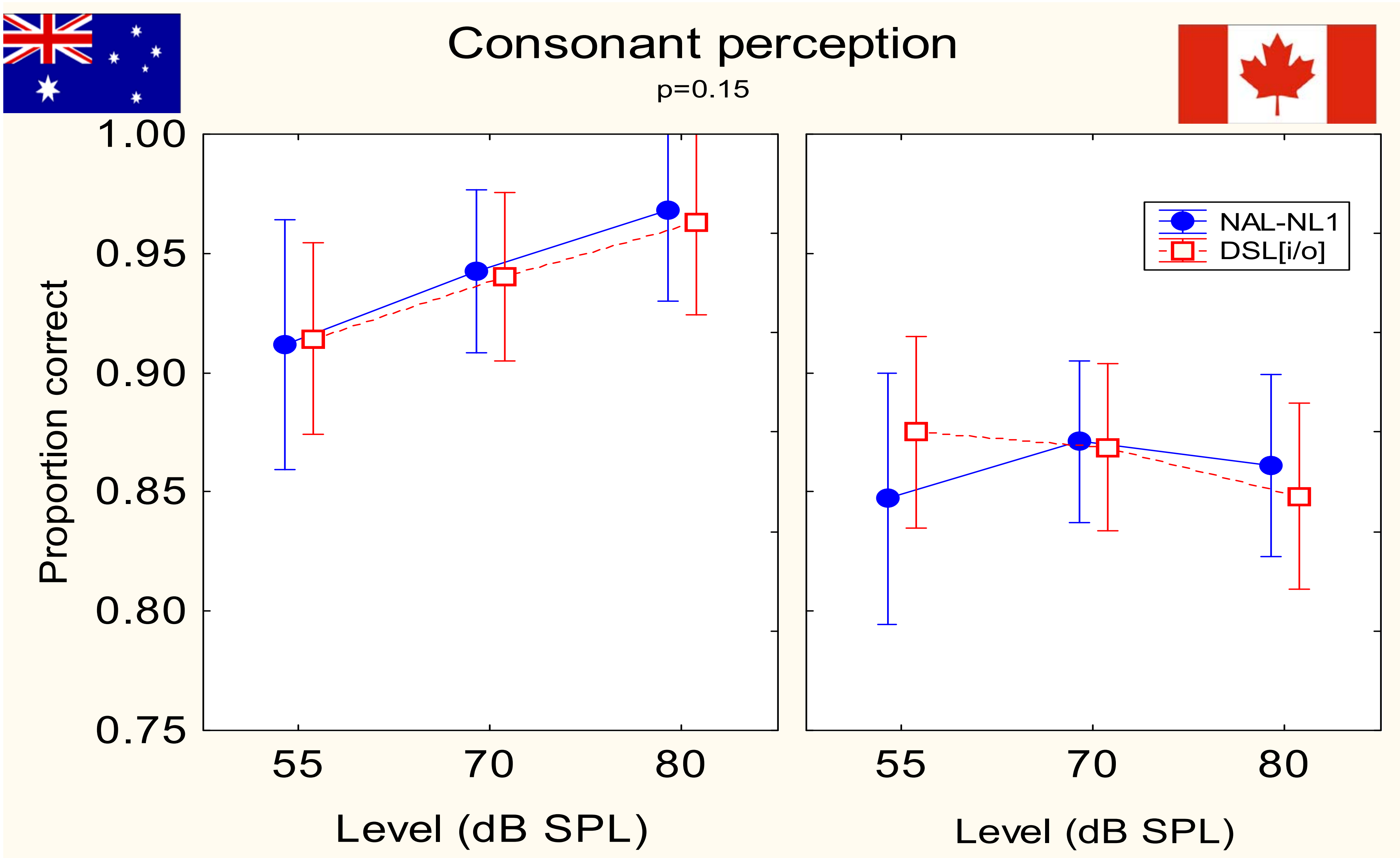
Prescribed *Achieved fitting*



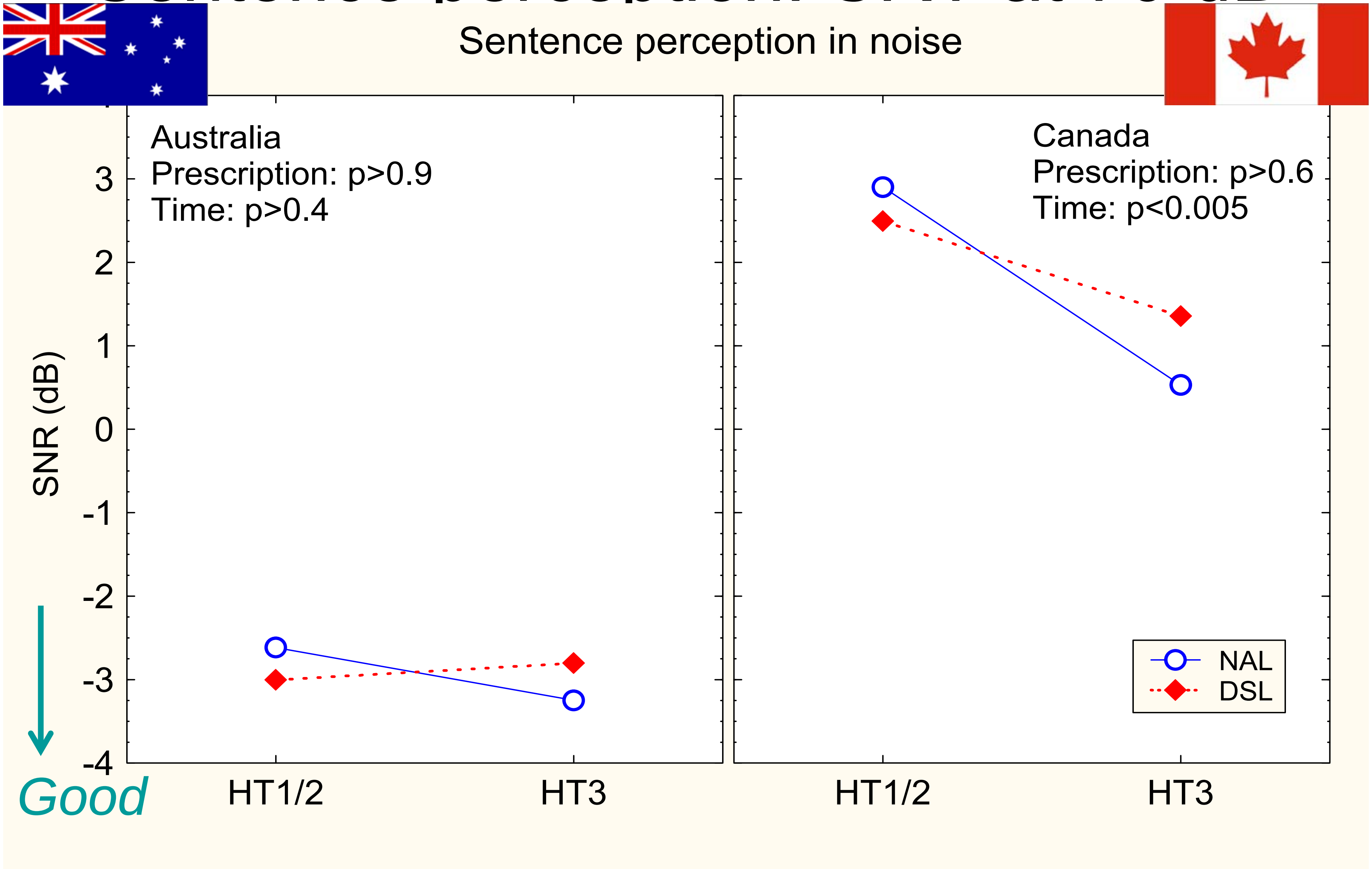
Loudness rating for speech



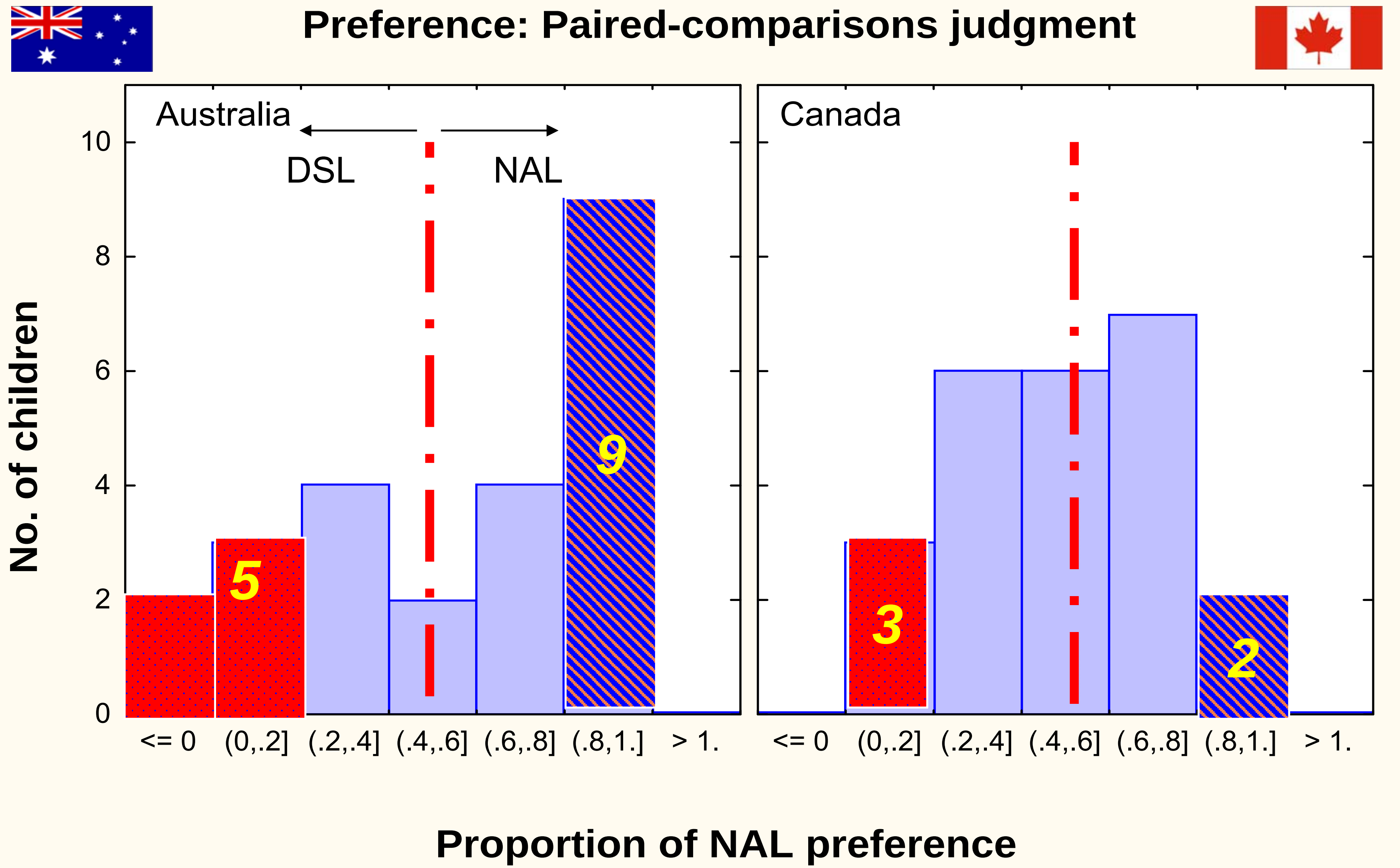
Consonant perception at 55, 70, 80 dB



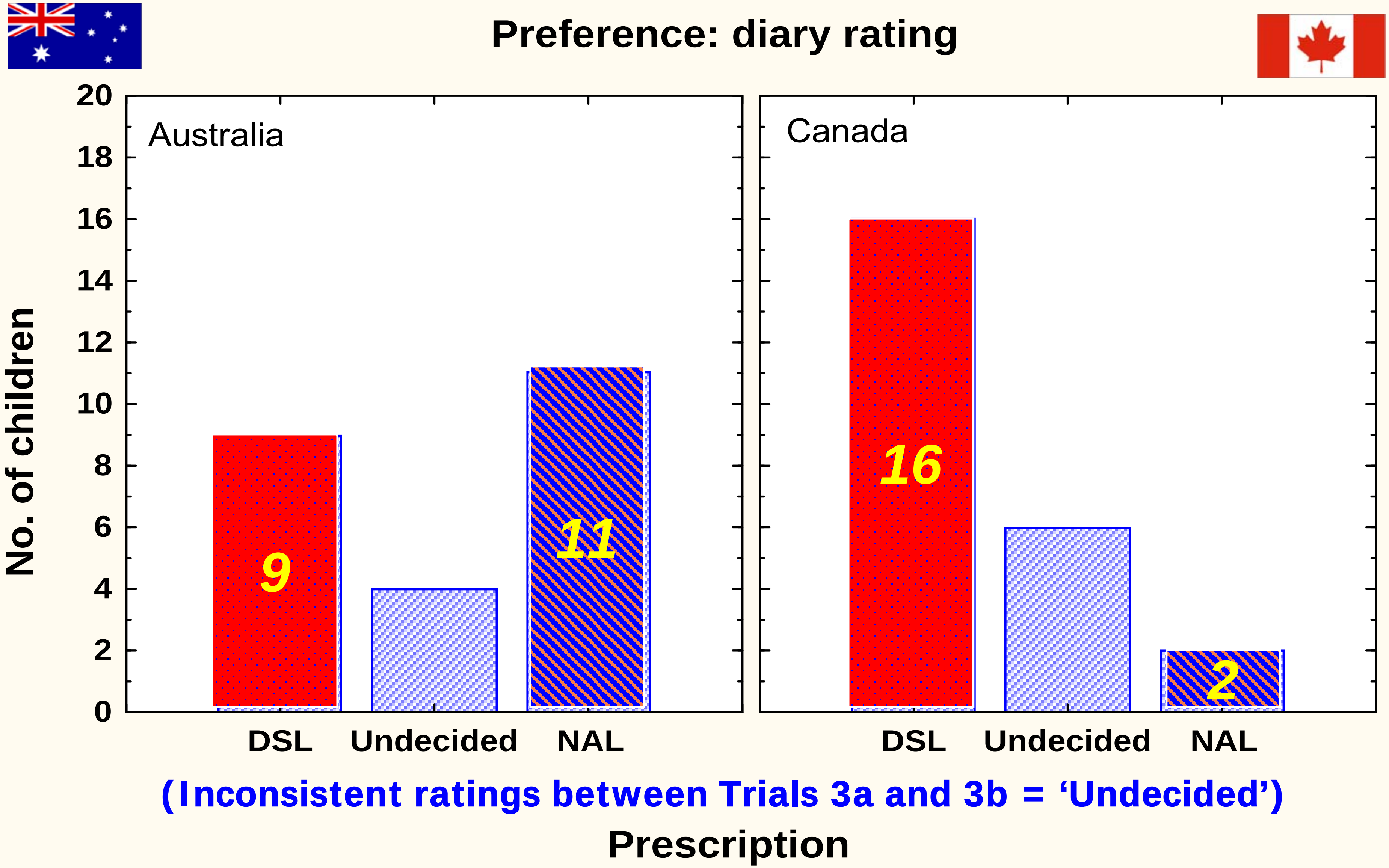
Sentence perception: SRT at 70 dB



Preference based on paired comparisons (mean of 50 comparisons per child)



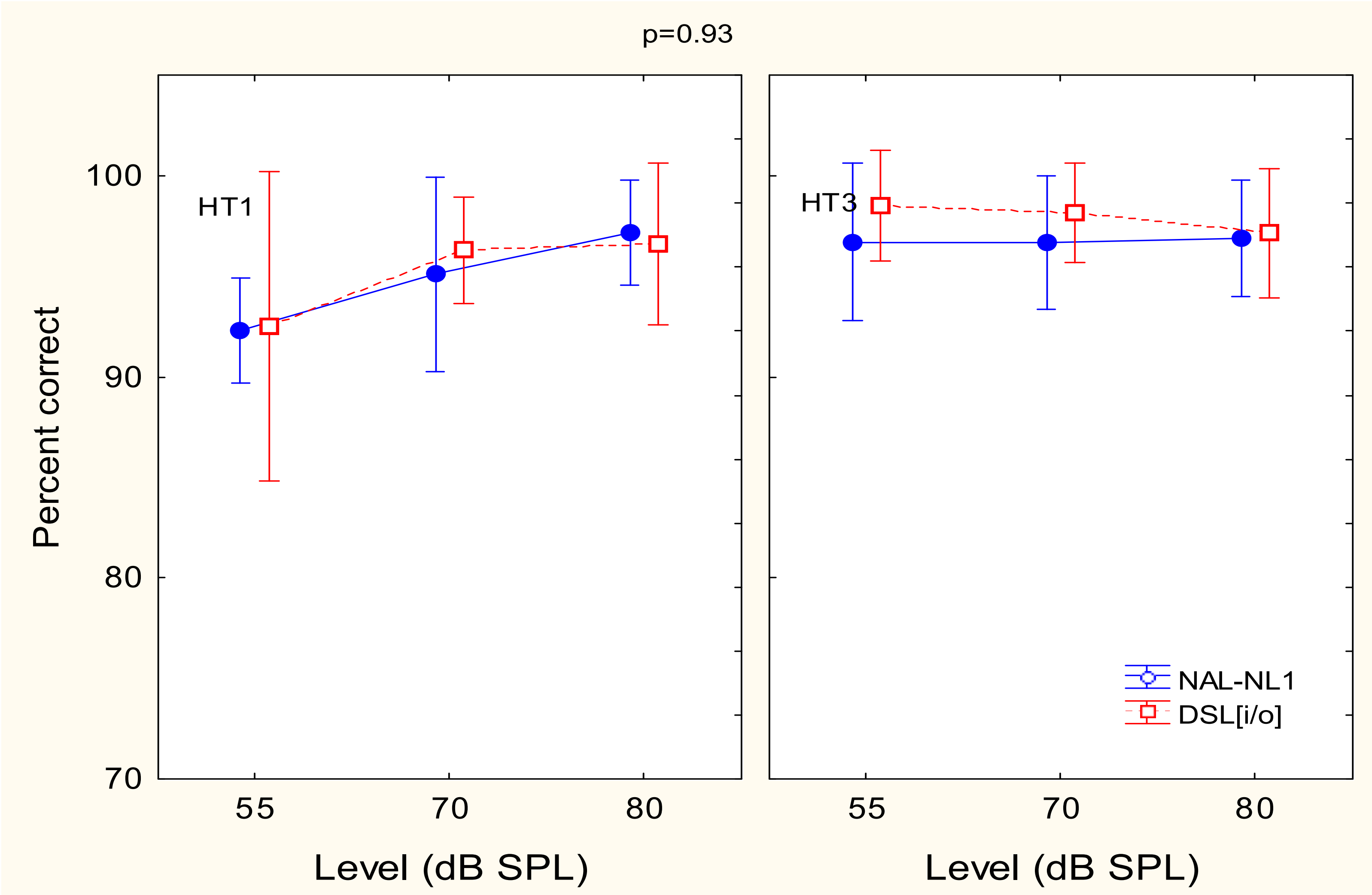
Preference based on diary preference ratings



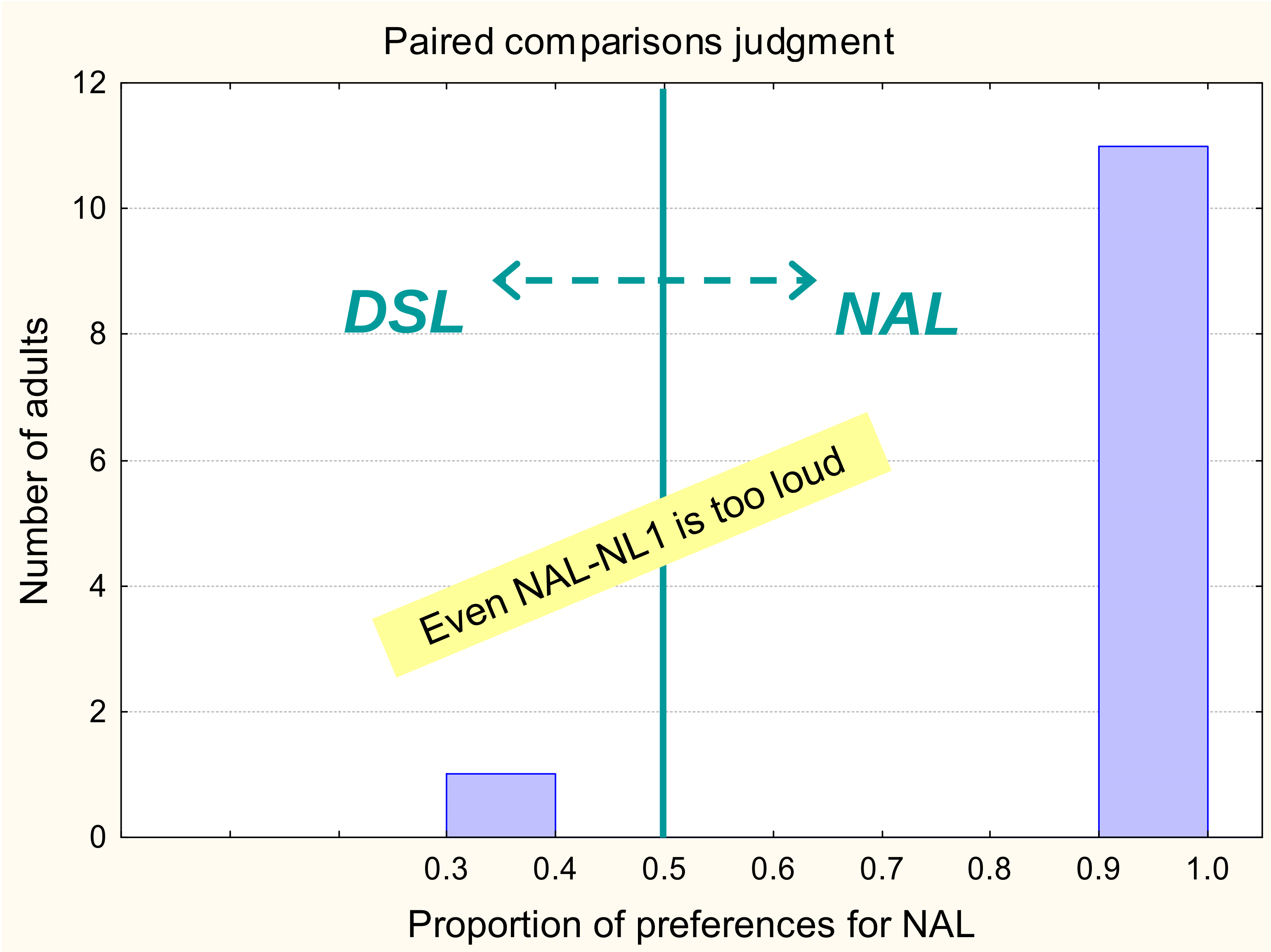
NAL-NL1 versus DSL[i/o] 4
adults

Teresa Ching, Mandy Hill

Adults: consonant perception



Adults: paired comparisons



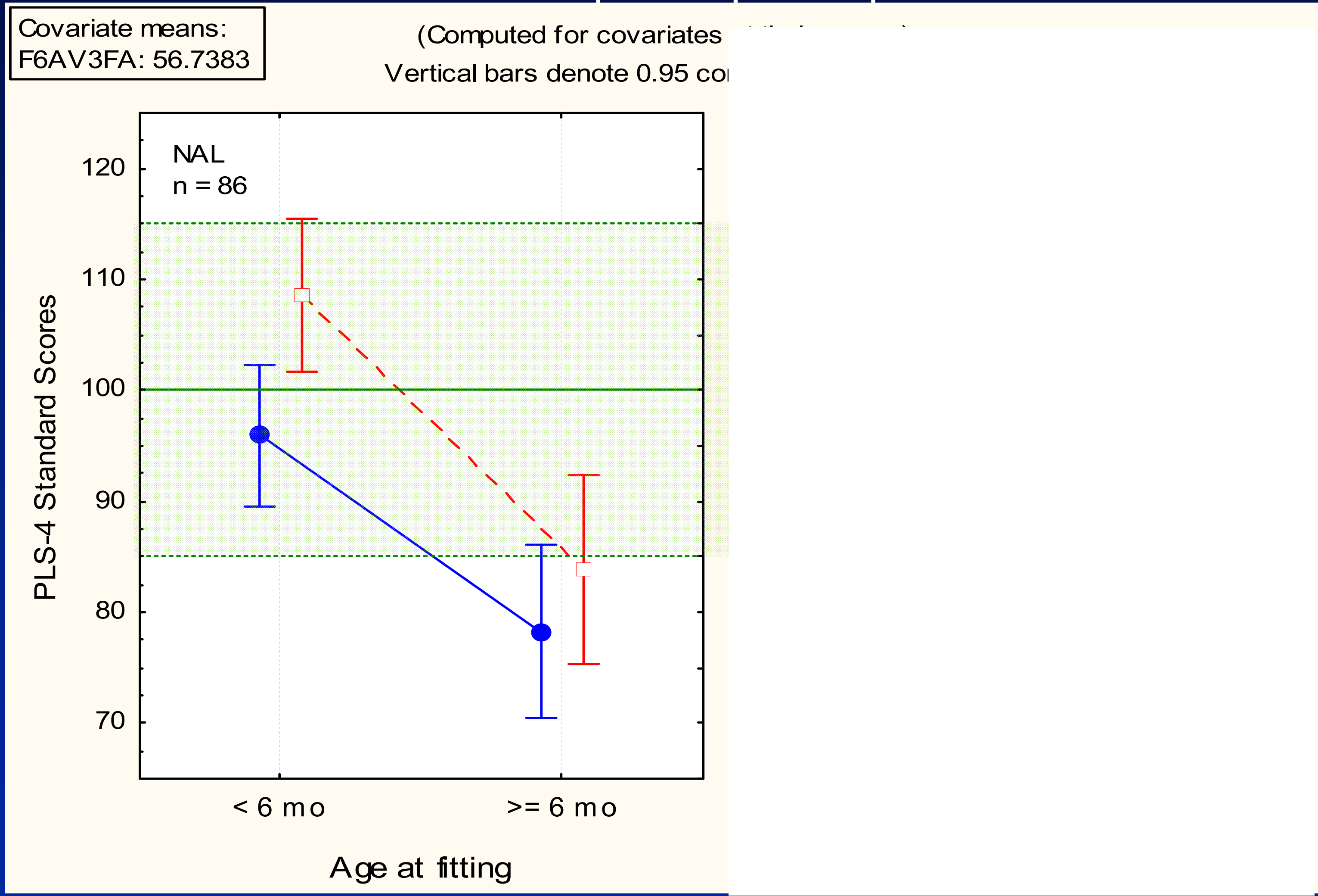
NAL-NL1 versus DSL[i/o] 4

Infants and toddlers

Teresa Ching + many others

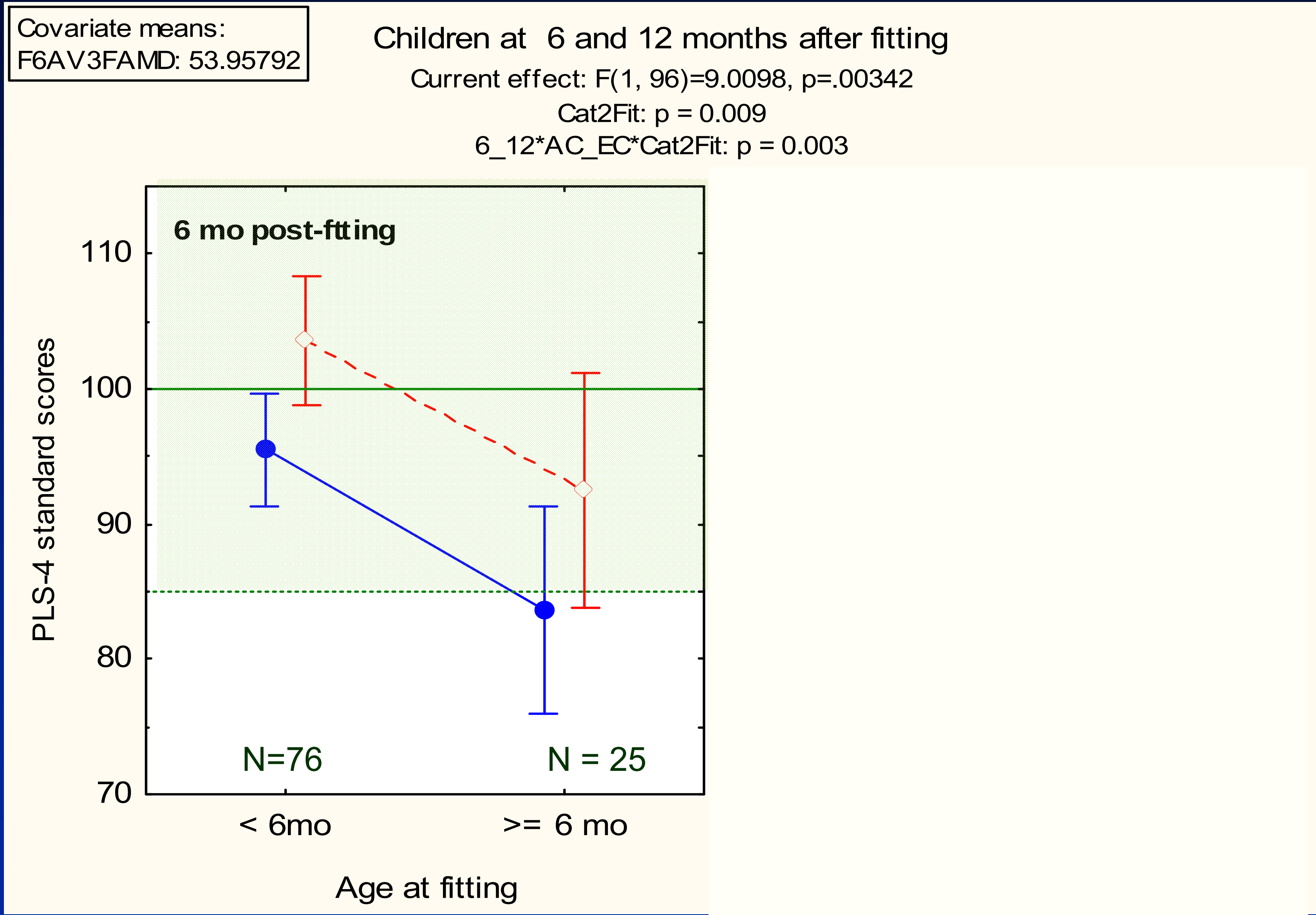
Age at fitting affects language at 6 m

- Effect of age of fitting: $p < 0.001$*
- Effect of hearing loss: $p = 0.002$*
- Effect of prescription: $p = 0.6$



T Ching, NAL, CRC Hear

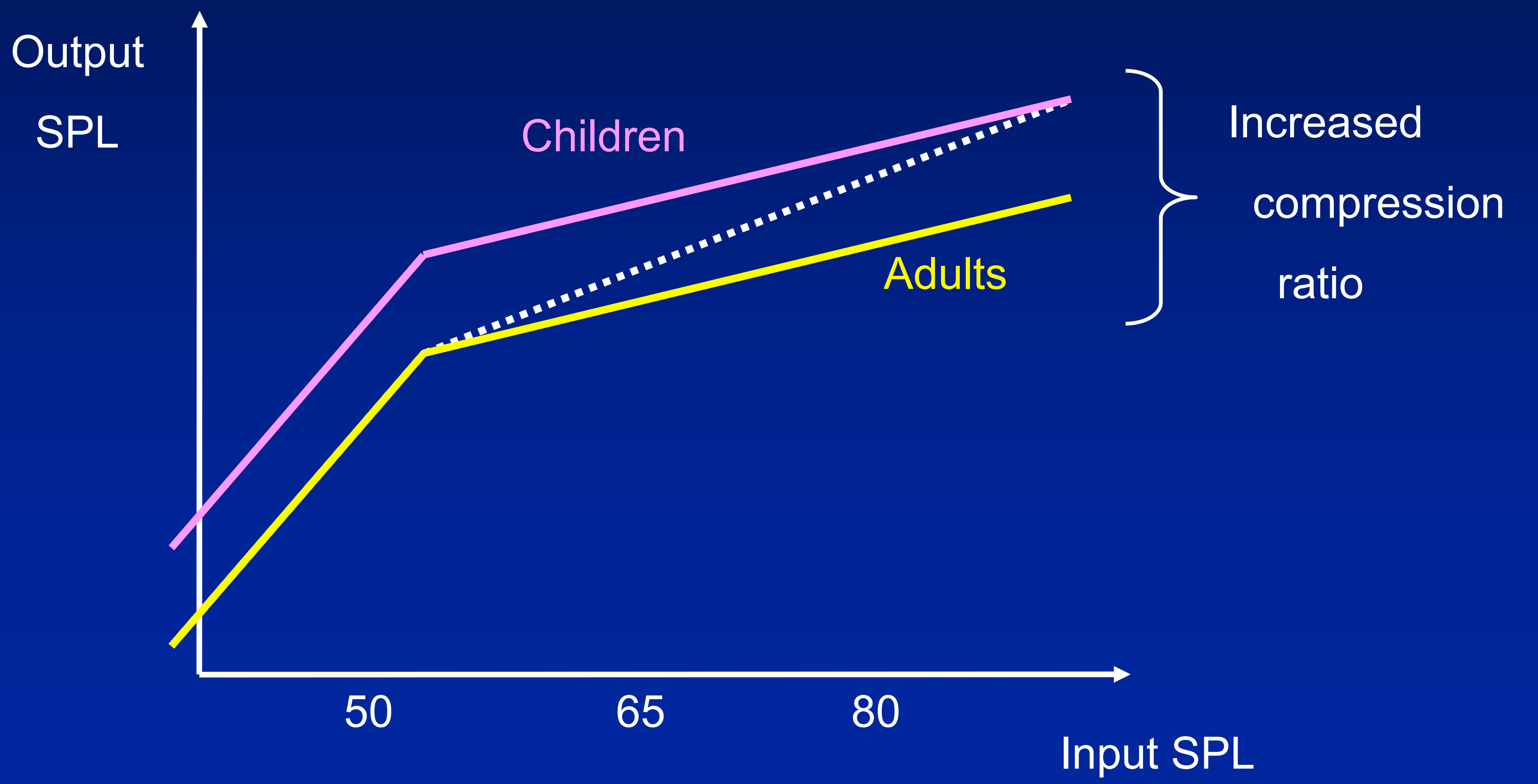
At 6 and 12 months after fitting



Summary: NAL-NL2 vs NAL-NL1 (overall gain)

Conclusions for NAL-NL2 re NAL-NL1

- turn down gain for high level sounds for adults
- Turn up gain for low level sounds for children



Directional microphones for children

Teresa YC Ching[1], Harvey Dillon[1], Anna O'Brien[1], Lisa Hartley[1], Josef Chalupper[2], Matthius Frohlich[2], David Hartley[1], George Raicevich[1], Catherine Morgan[1]

[1]National Acoustic Laboratories,

[2]Siemens Ltd.
CRC HEAR

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Survey

When do you fit directional microphones to children?

When they are infants ?

Above 3 years of age ?

When they are school age ?

When they are adolescents ?

When they are adults ?

Study design: participants

Subjects:

- 27 children
  - 11 normal hearing
  - 16 hearing-impaired
- 10 months to 6 years of age

- **Methodology:**
  - Listening behavior in everyday life situations
  - Directional benefit in these situations
  - Parents‘ diary

Study design: scenarios

Listening behavior

Video recordings in 4 scenarios:

child interacting with parent/caregiver in the child's home

child plays by him/herself with a parent elsewhere in the same room

child with a small number of children and adults around, and speech is not always directed to the child (e.g. mothers' group)

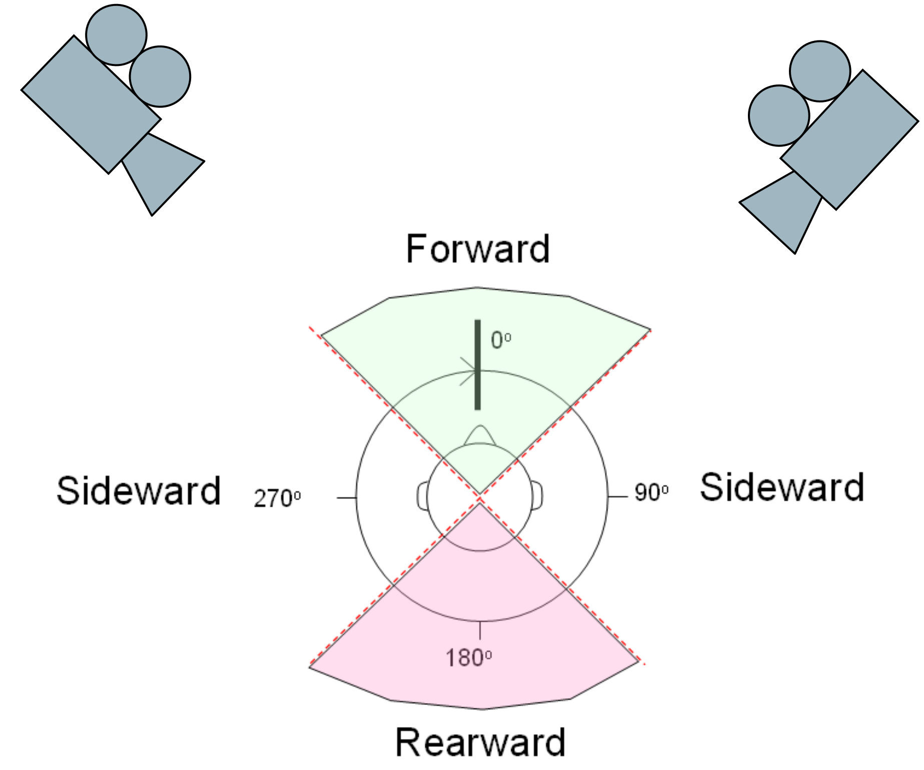
child playing outdoors with other children and adults

Study design: video analysis

Listening behavior

Videos “stitched” together and analyzed for:

- Time “target speech” present
- Proportion of time “target speech” is present that child is facing:
  - frontward
  - sideward
  - rearward



Study design – video recordings

Listening behavior: frontward

Study design – video recordings

Listening behavior: sideward

Study design – directional benefit

Directional Benefit

Speech Transmission Index (STI)

Talker's head substituted by loudspeaker

Child's head substituted by KEMAR's head

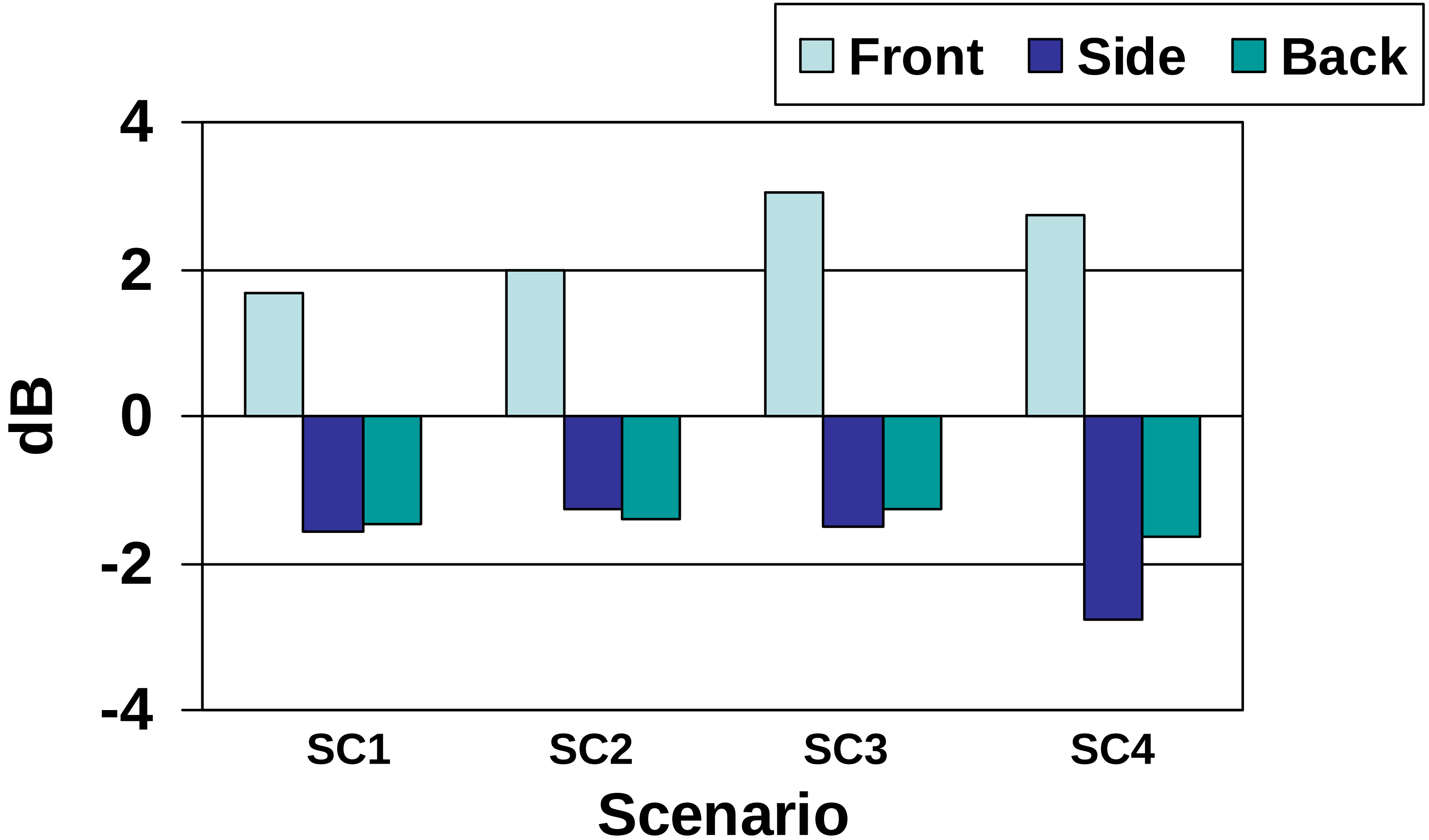
Hearing aid dummy behind KEMAR's right ear

Stereo recordings of STI stimulus at 0, 90, 180 and 270° KEMAR azimuth

Post-processing → omni and directional response

Benefit = $STI_{directional} - STI_{omni}$

Directional advantage



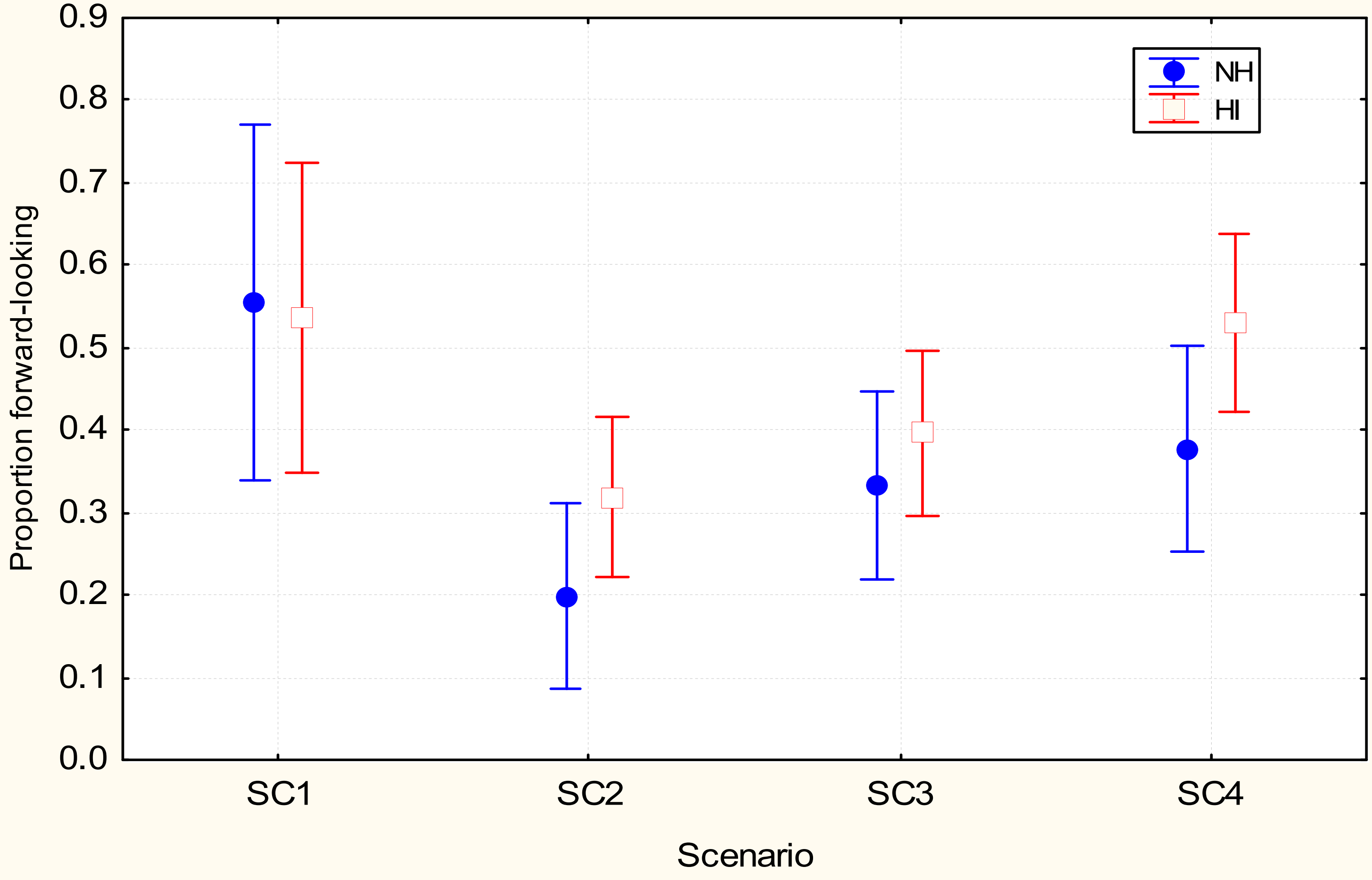
If the child looks ahead

→ directional microphones increase SNR

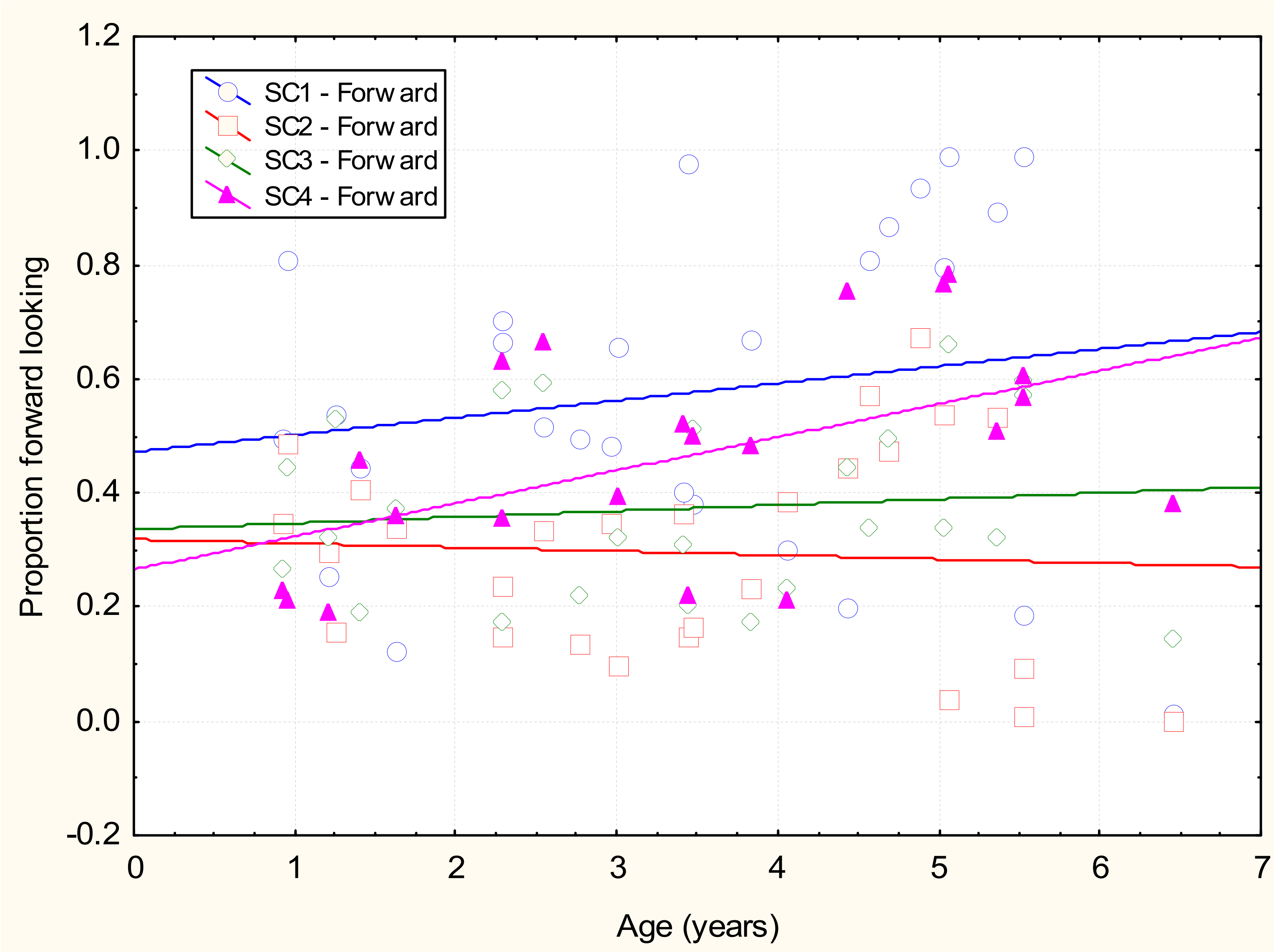
…. But how often does the child look ahead?

Forward looking in real life

Effect of age: p = 0.4
Effect of hearing: p = 0.09
Effect of scenario: p < 0.001**

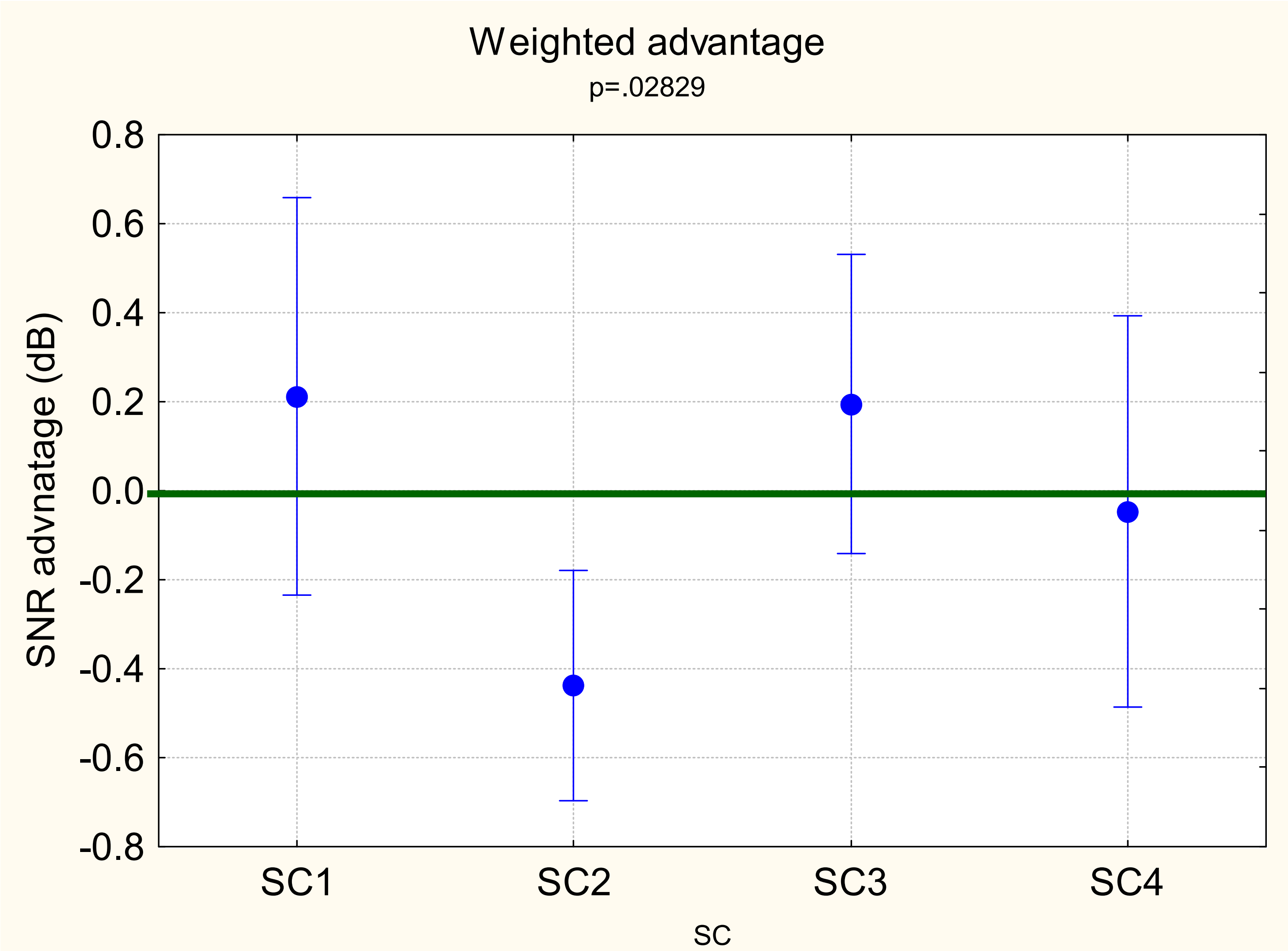


Proportion forward-looking vs age



Overall advantage in real life

Weighted advantage = dB front * %front + dB side * %side + dB back * % back



Summary

- Physical measurements of directional advantage up to 3 dB in different scenarios
- Age (10m – 6.5 yrs) does not affect proportion of time children look at the talker
- Both NH and HI children look at the talker >50% of the time with child-directed speech
- On average, weighted directional advantage varied between -0.4 dB to 0.2 dB across scenarios

Caveat – likely underestimate

- HI children in this study had no experience in directional mic technology
- Those with directional mics may look more at the talker
  - The talker attracts their attention
  - They are taught to look at the talker
  - They learn by themselves to look at the talker
- Hence potential for greater weighted advantage than we found

Message for clinicians

- Directional microphone technology does not significantly disadvantage children of any age
- Counsel caregivers and professionals on making the most of directional advantage
  - by facing the child when talking
  - by teaching the child to look at the talker

Message for hearing aid companies

Auto-selection of directional microphones should be dependent on the direction of the dominant speech signal.

The application of cortical auditory evoked potential recordings in infant hearing aid fitting

Maryanne Golding, Suzanne C Purdy,

John Seymour, Wendy Pearce, Lyndal Carter, Richard Katsch,

Mridula Sharma, Katrina Agung, Kirsty Gardner-Berry

Evaluation of aided functioning in infants

Universal new born screening

Early fitting of hearing aids

Need for an evaluation method

Confirmation of fitting

Fine-tuning needed

Cochlear implant needed

So baby, how does it sound?

Objective hearing aid evaluation for:

- young infants
- difficult-to-test people

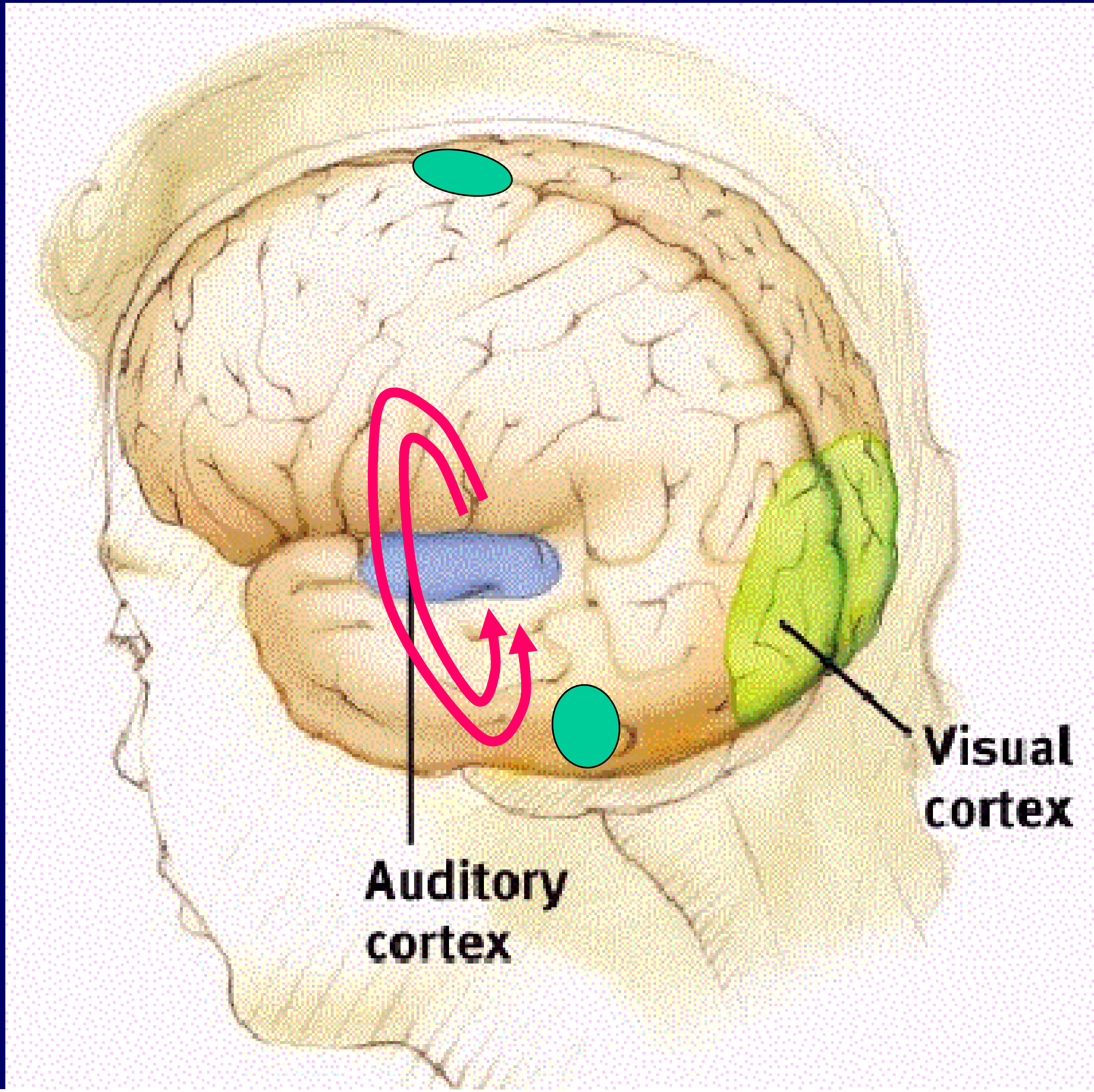
Why use *cortical* responses?

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

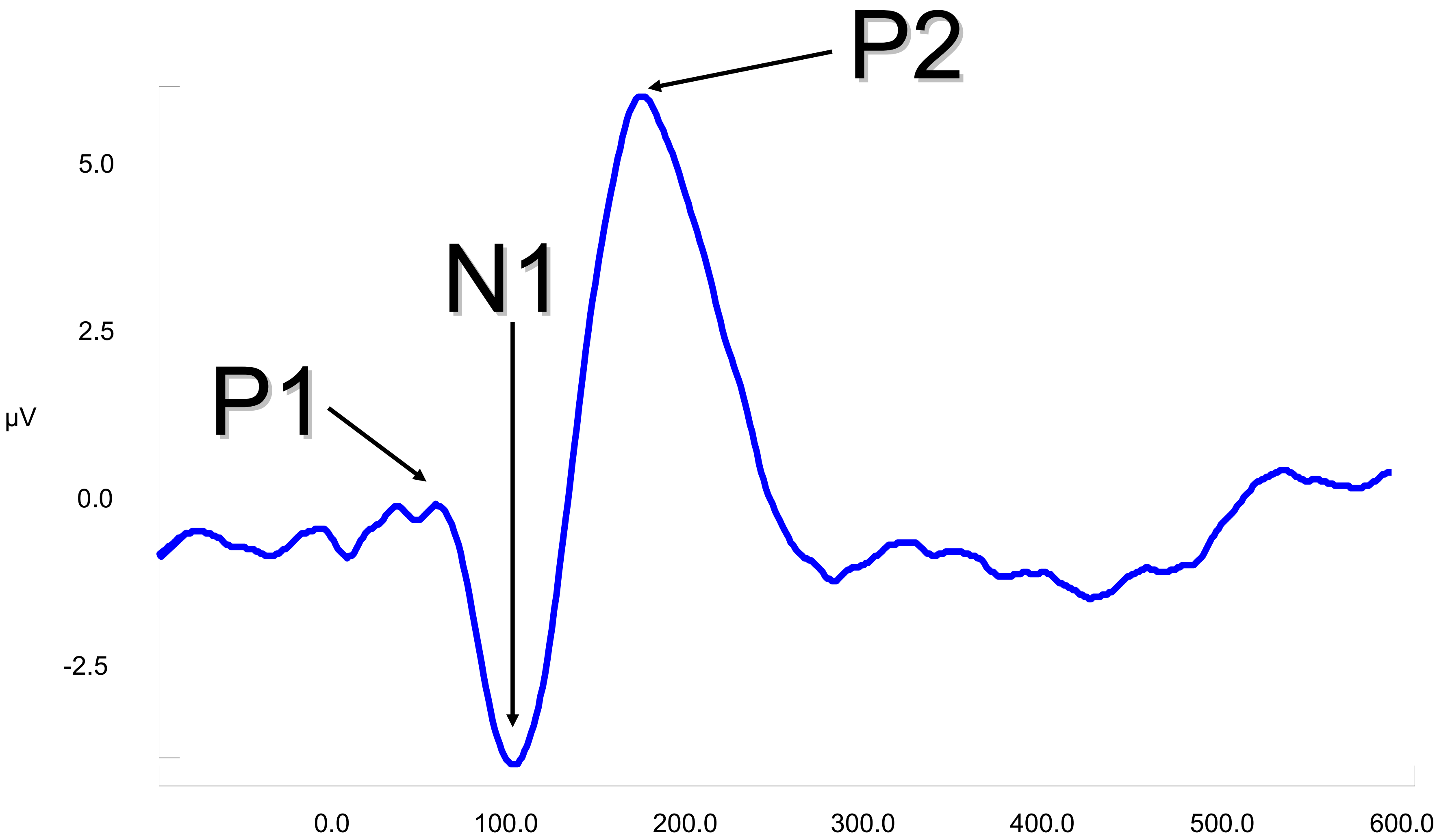
Where do cortical responses come from?

The end of the road



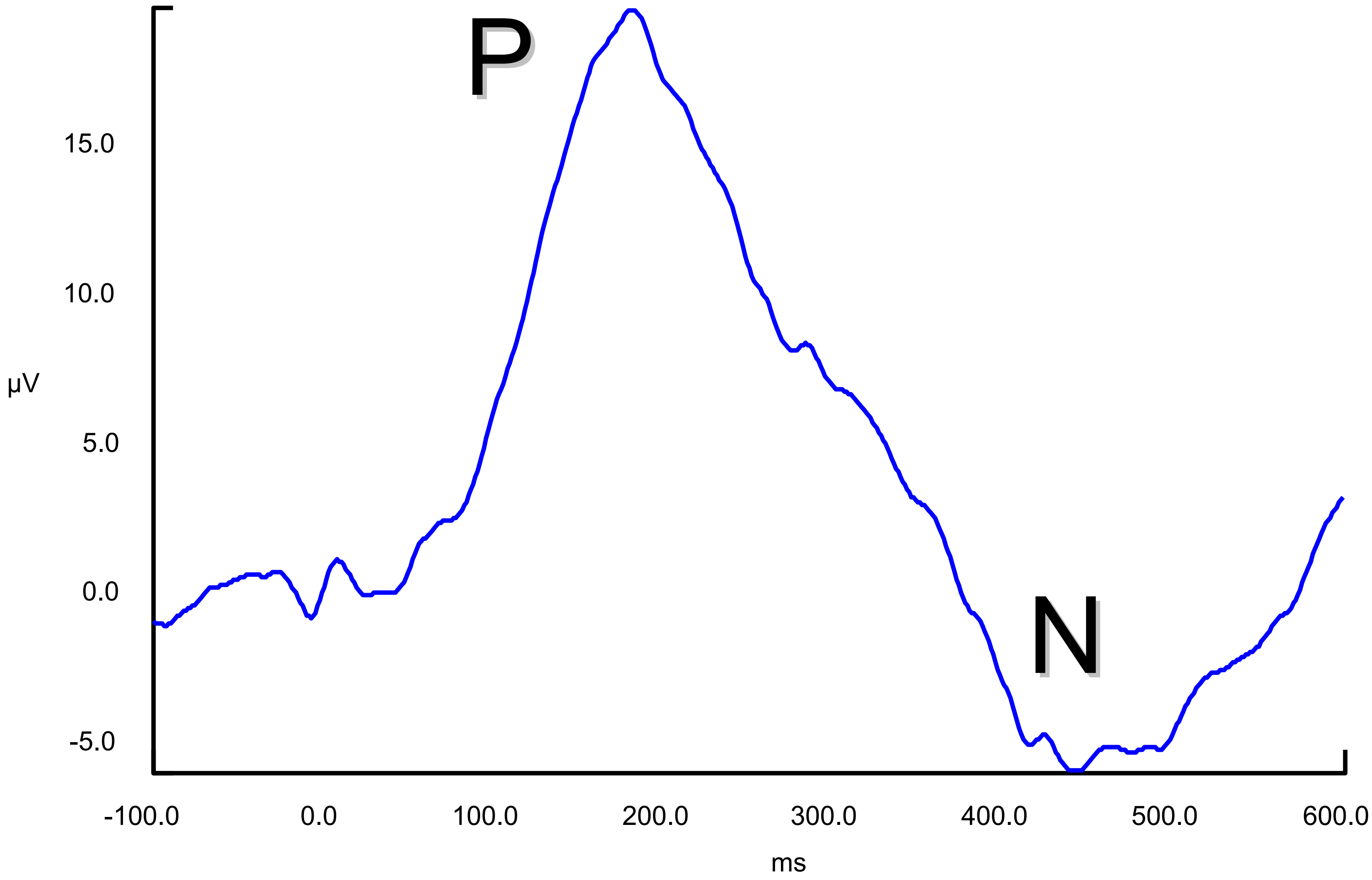
Cortical responses in adults with normal hearing

Adult

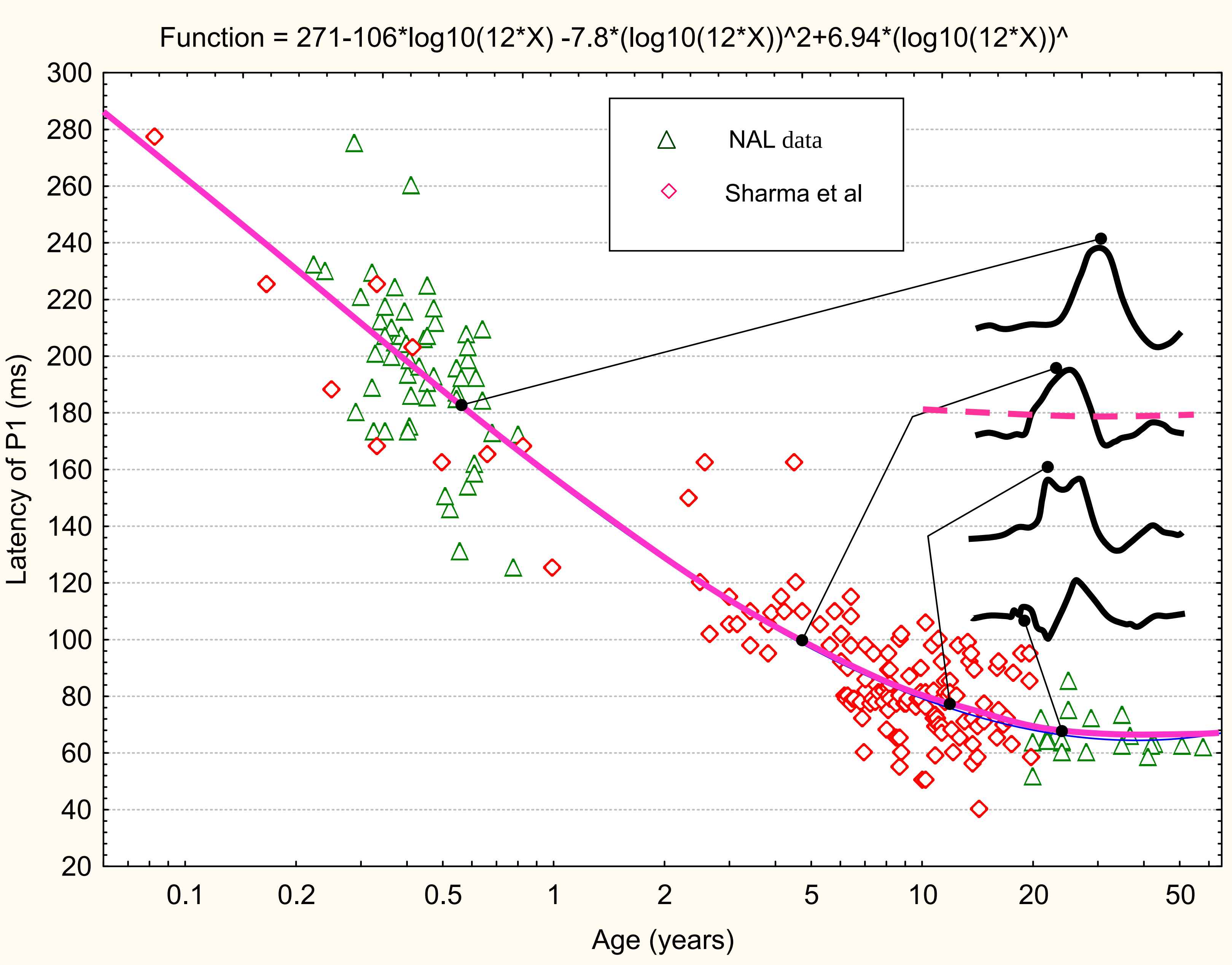


Cortical responses in infants

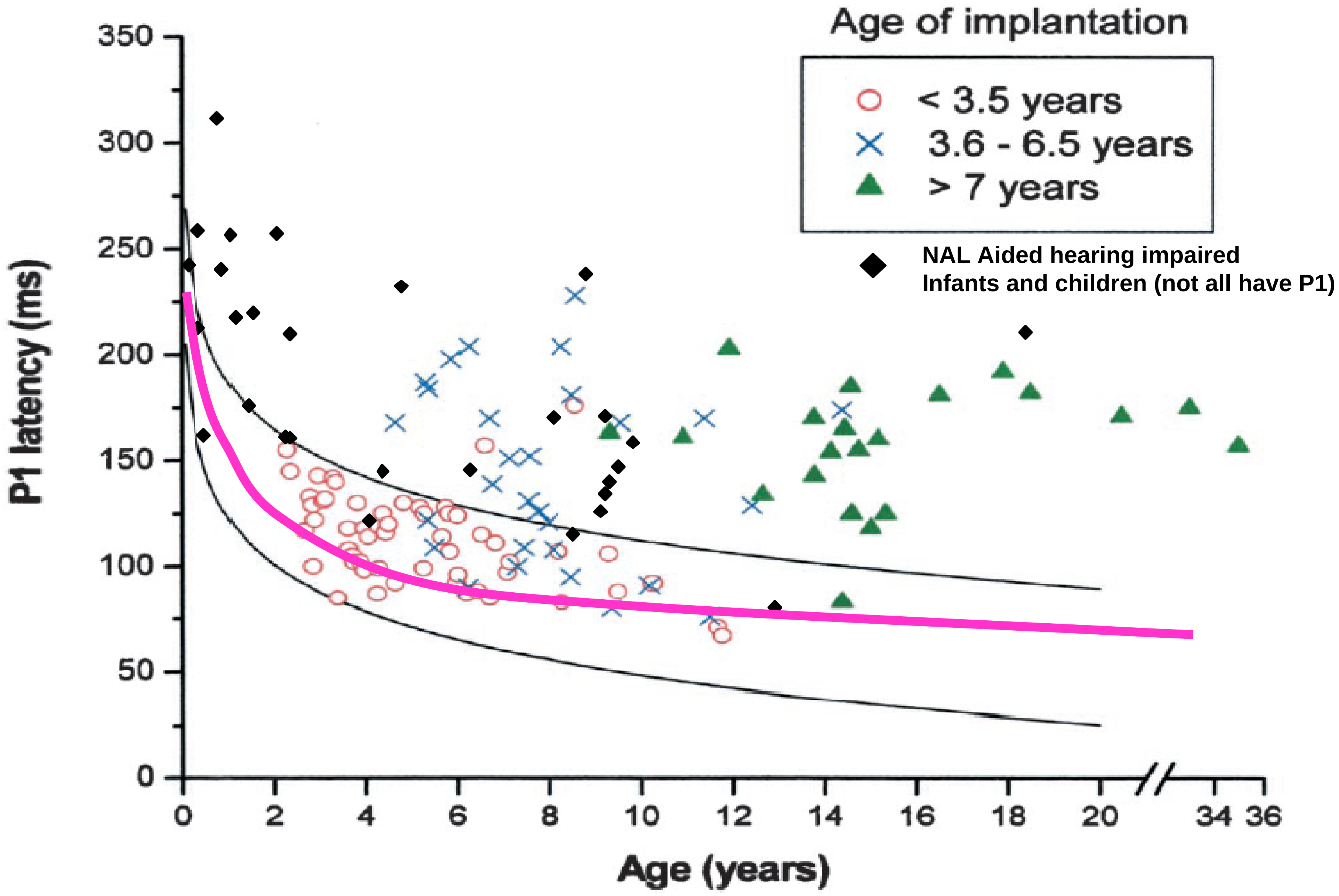
Infants



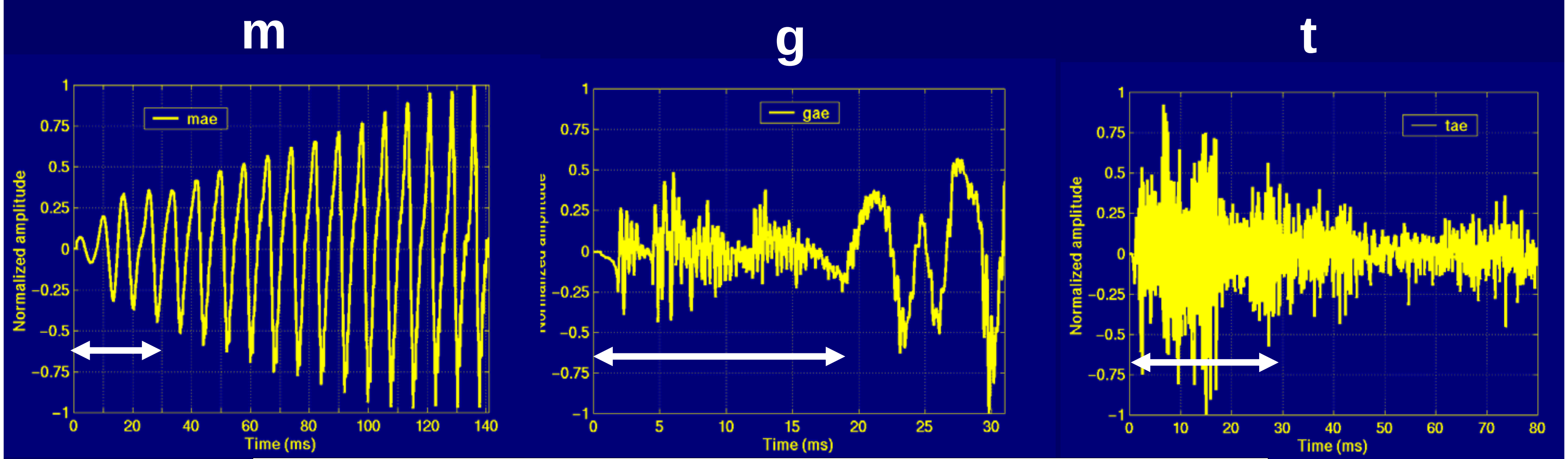
Latency versus age

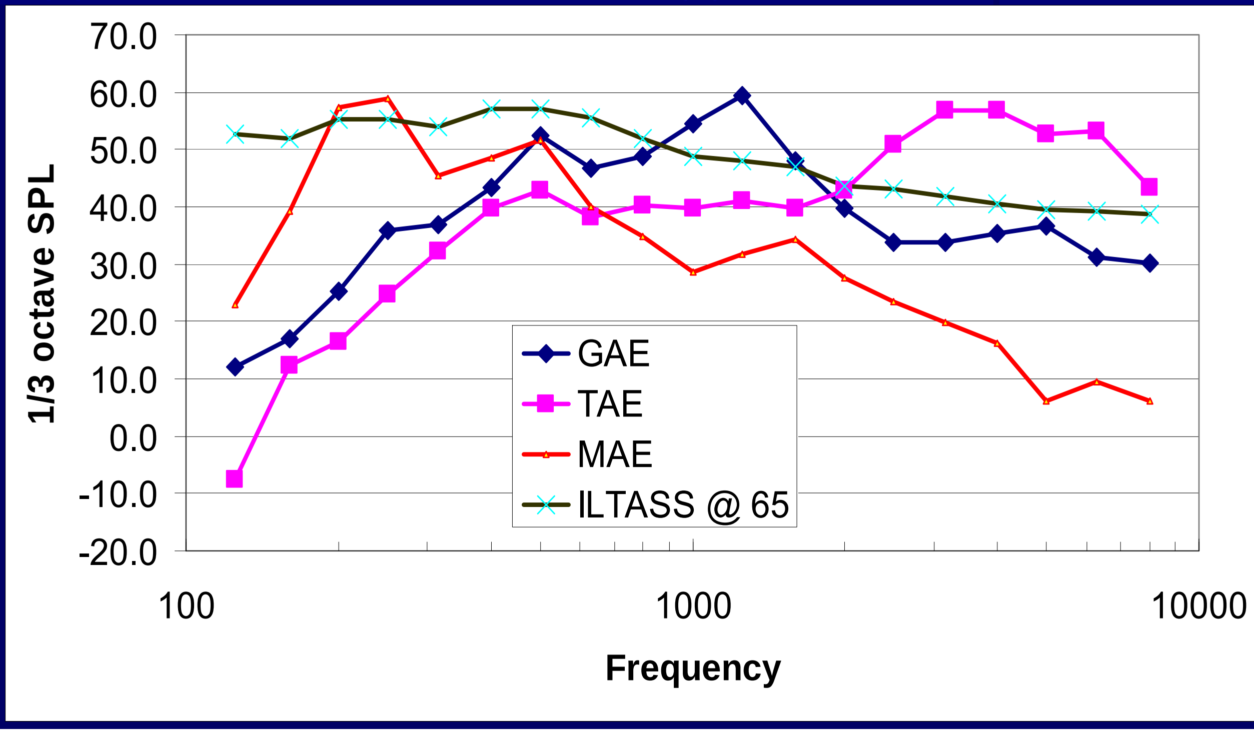


Children with CI (Sharma,2002) and NAL aided hearing impaired infants/children (N=40) using speech stimuli presented at 65 dB SPL.



Three stimuli





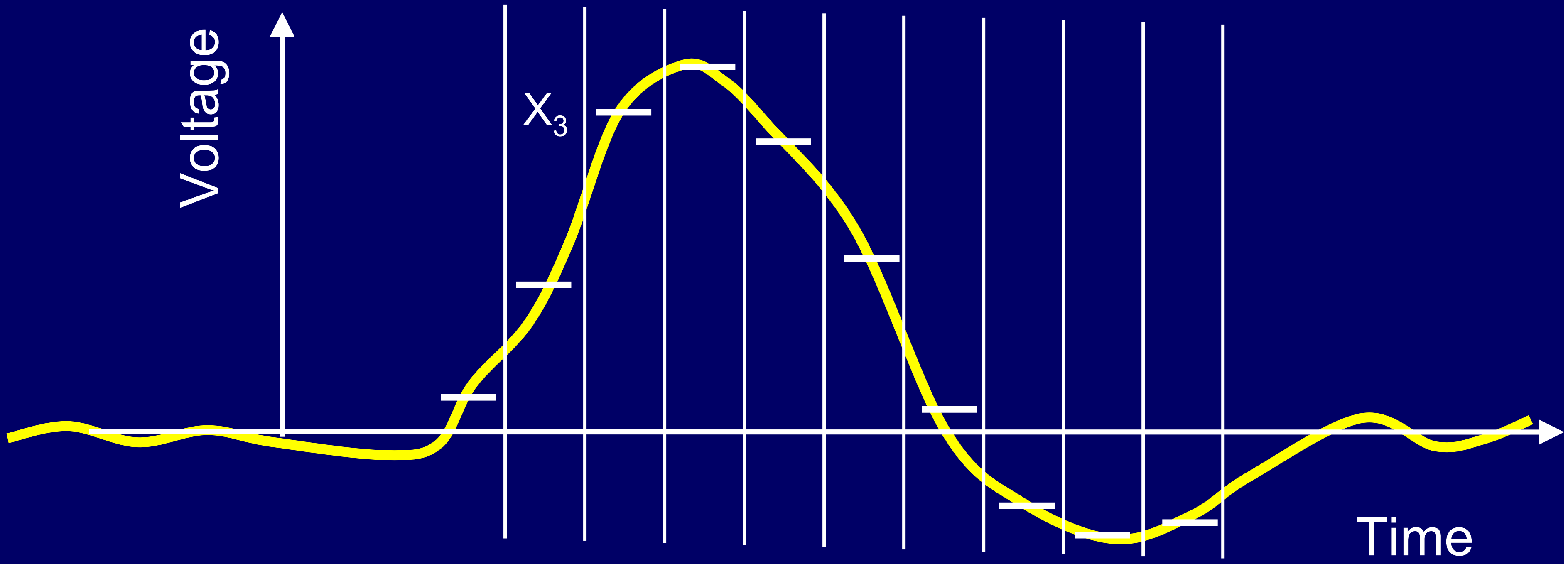
Why ***not*** obligatory cortical responses?

- variable shape across ages
- variable shape with auditory experience
- variable shape from person to perso
- variable shape from time to ti),
  especially sleepiness)
- stimulus
- Inter-stim

An automated method of response
detection and response differentiation

high skill level needed to read responses

Analysis using Hotellings t^2 statistic

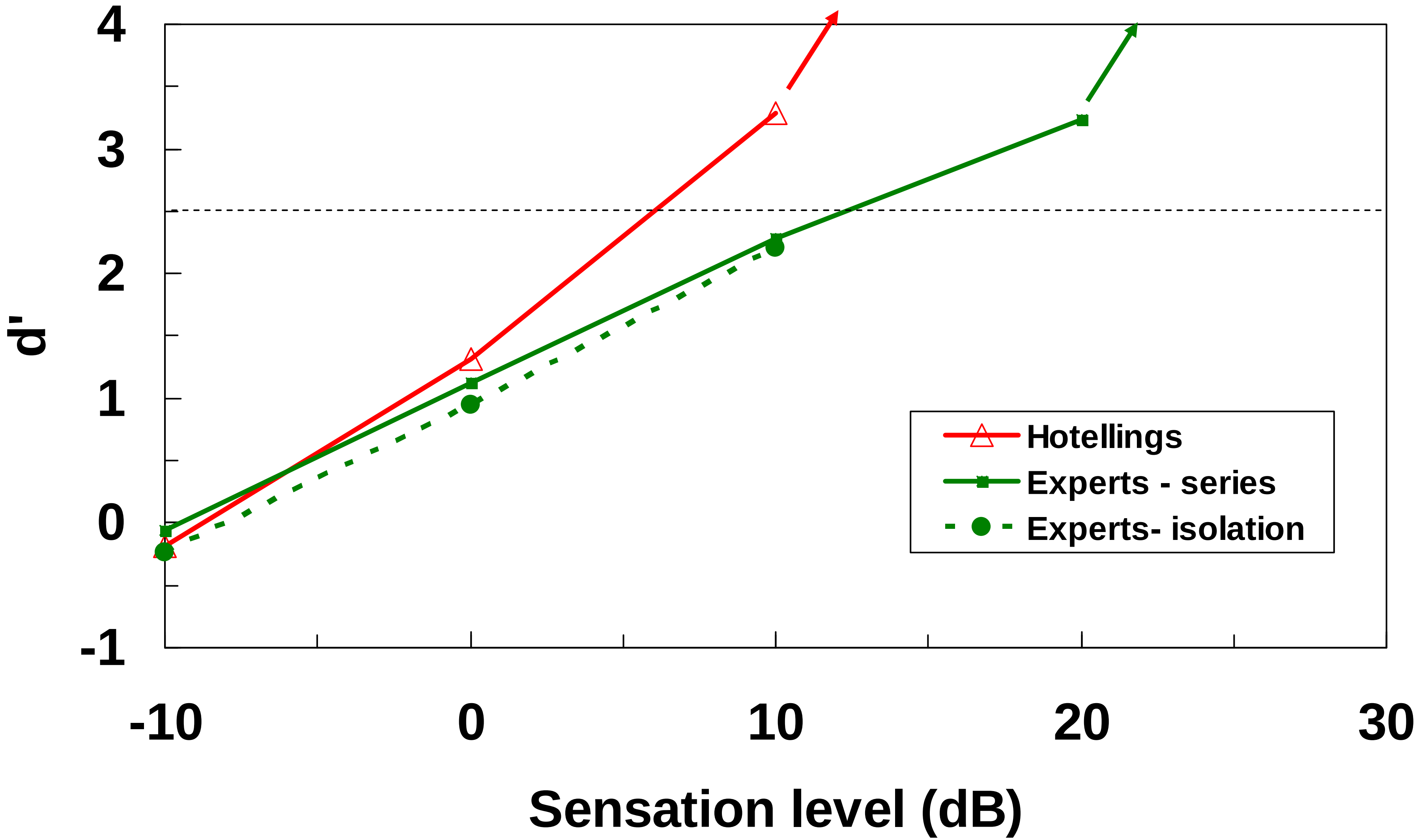


- Divide each record into 50 ms time bins
- Average data points within each time bin
- Use these averages as variables in Hotellings t^2 analysis
- Result is probability of the waveform being random noise

$$X = a_1X_1 + a_2X_2 + \ldots\ldots\ldots + a_9X_9$$

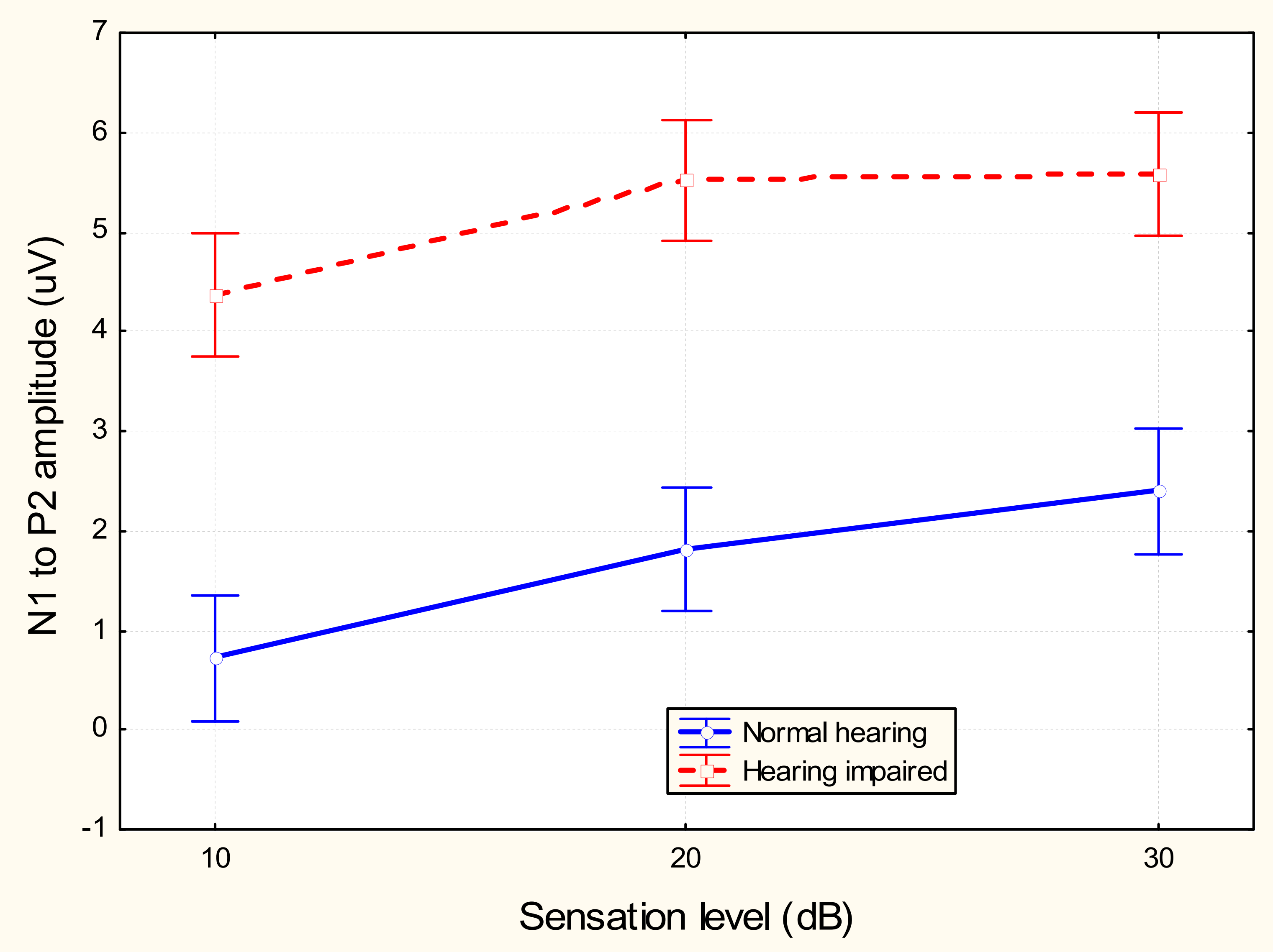
Test: is there any set of weighting coefficients for which $X \neq 0$?

d’ results - for 200 stimuli

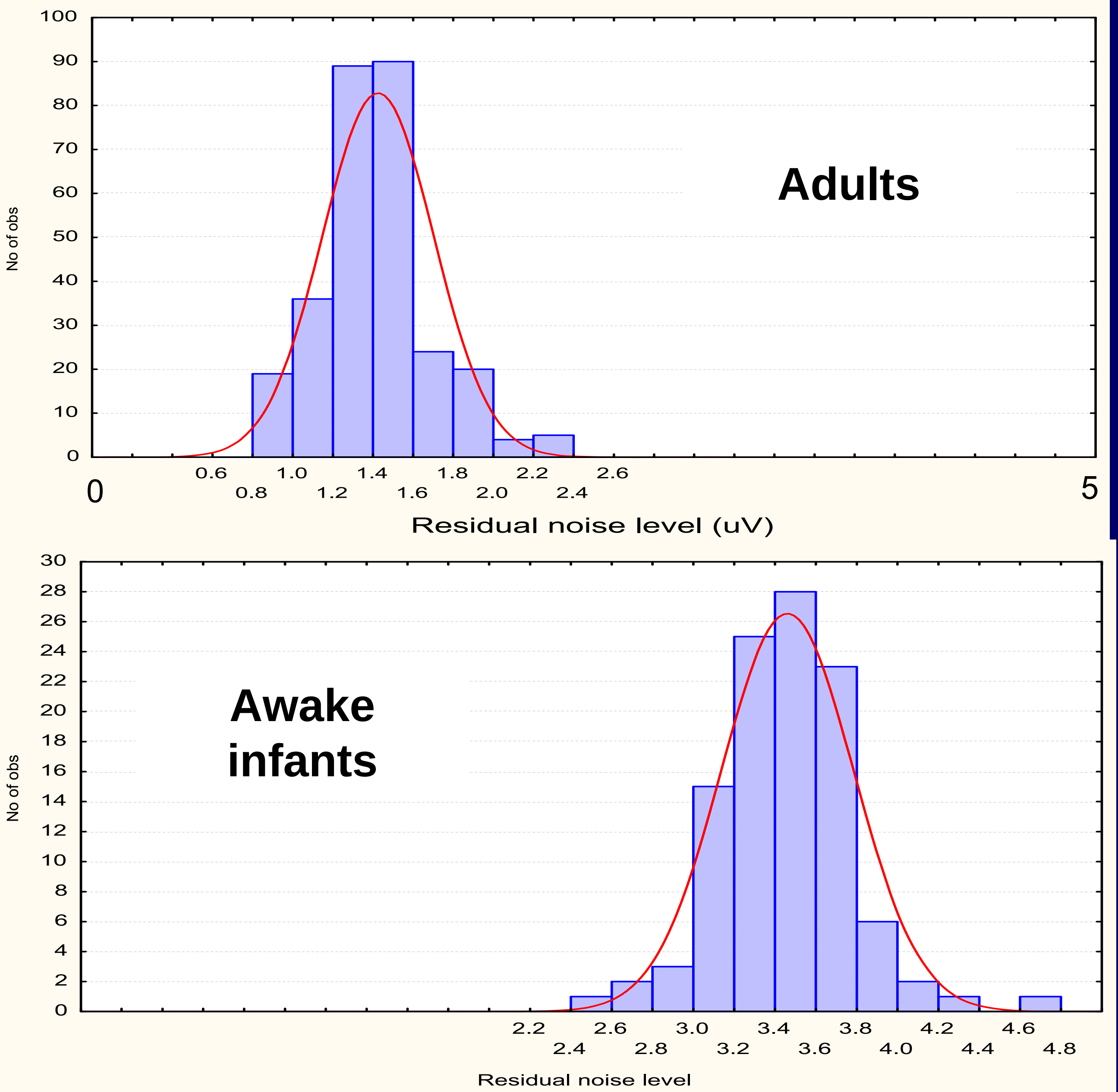


Growth of amplitude with SL

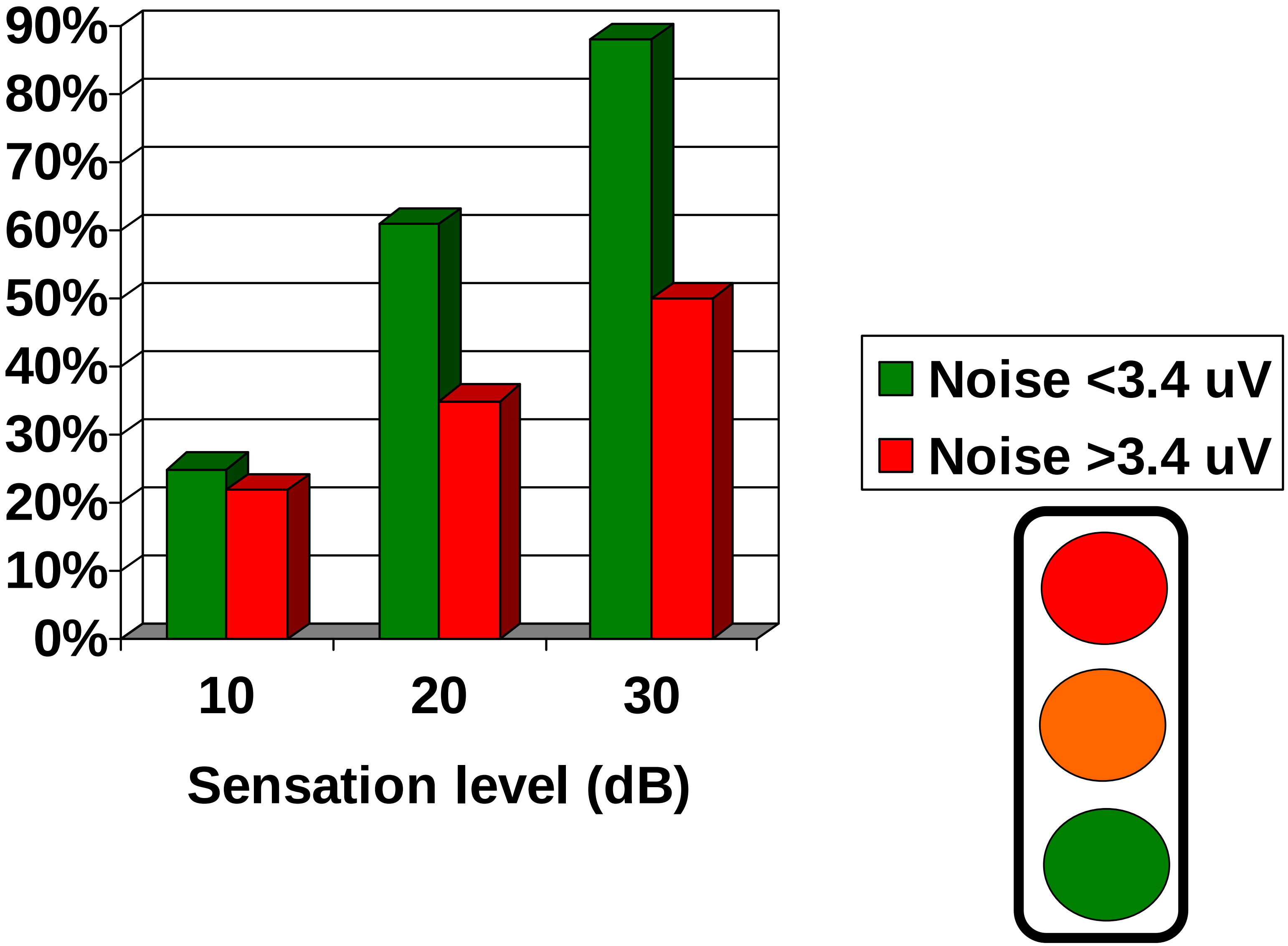
adults; tonal stimuli



Residual noise levels (for 100 epochs)



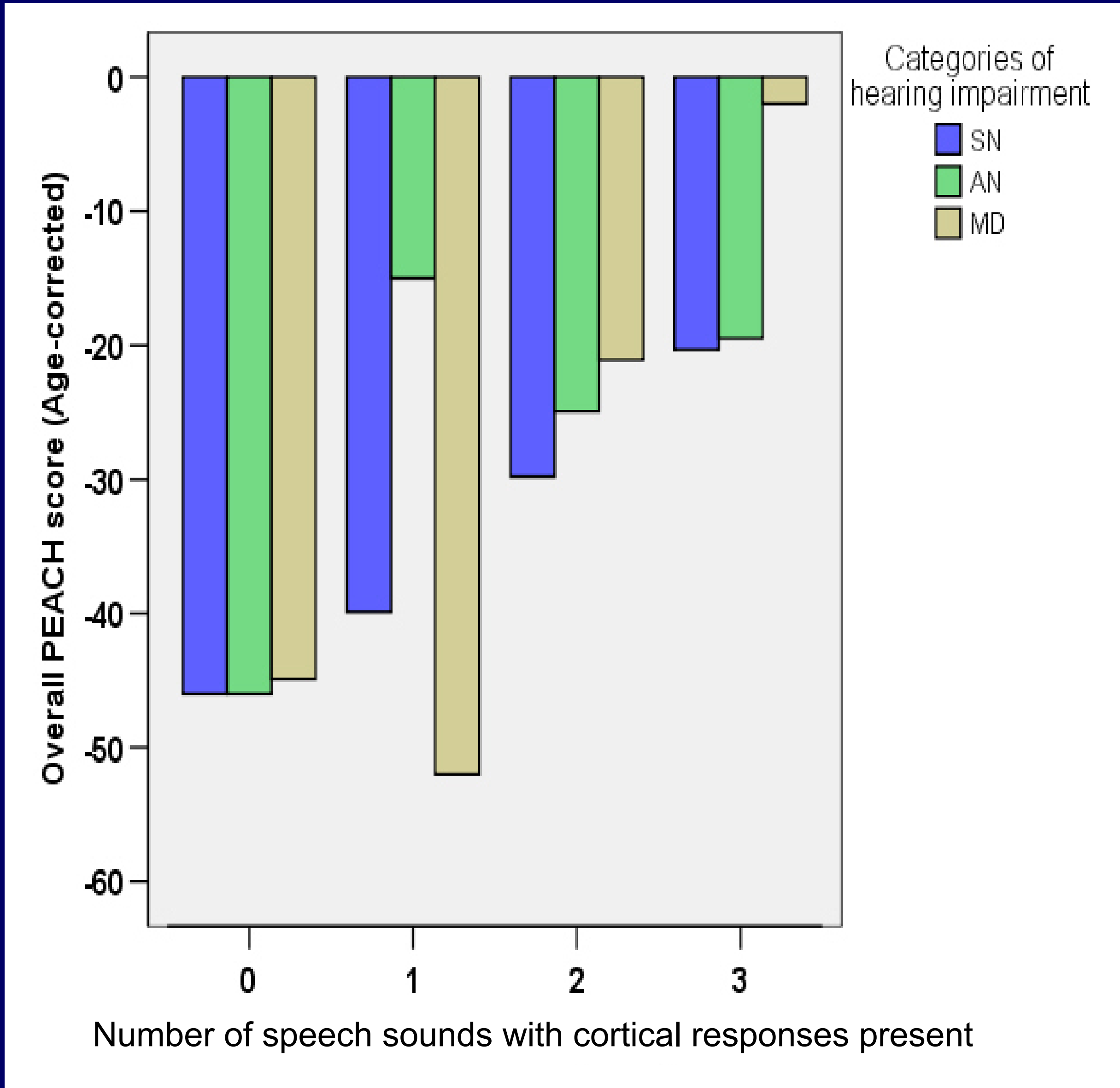
Proportion with responses present ($p<0.05$) – normal hearing infants; 100 epochs



Cortical responses and functional performance

Do cortical responses tell us about real-life auditory performance?

Functional deficit versus cortical score



* All aided children
r_s =0.60; n=24; p = 0.001

* SN only
r_s=0.61; n=12; p = 0.02

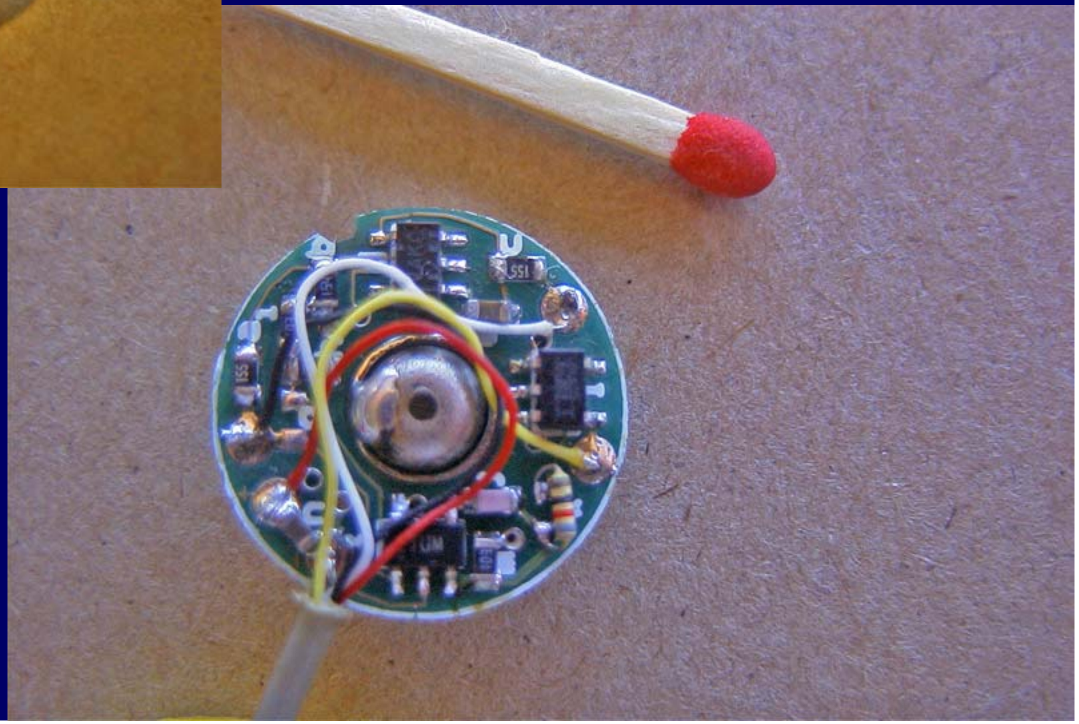
* MD only
r_s=0.82, n=5; p = 0.04

* AN only
r_s=0.36; N=7; p = 0.22

Reducing measurement variability (random electrical signals)

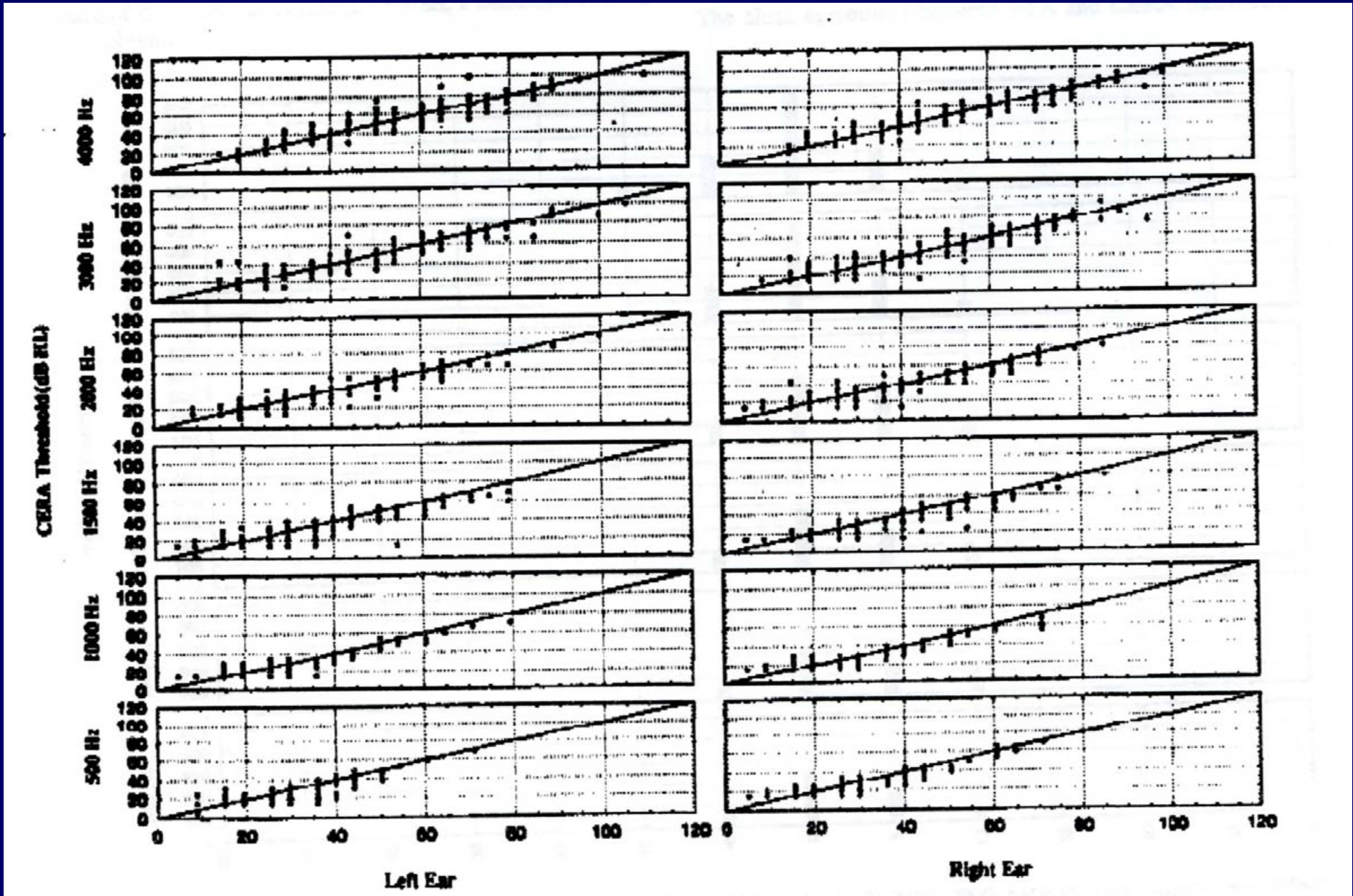
→ Speeding up measurements
→ Increasing validity of interpretation

Active electrodes



Finding thresholds with cortical responses

What does an absent cortical response mean?



From: Rickards, F. et al (1996) *Cortical Evoked Response Audiometry in noise induced hearing loss claims*. Aust. J. Otol. 2 (3)

Clinical applications and implications

Clinical applications of corticals

- For finding thresholds (when awake)
- Determining whether speech sounds are audible
  - aided or unaided
  - for patients who can't respond reliably by behavioral testing e.g., infants, multiply disabled people.

Clinical implications of corticals

Significant response is obtained to speech at 65 dB SPL

- Morphology normal for age → All is well
- Morphology abnormal for age → Repeat test

No significant response is obtained to speech at 65 dB SPL or to speech at 75 dB SPL

- Low residual noise → Re-check fitting; Consider all options
- High residual noise → Draw no conclusion !

Clinical implications of corticals (cont)

Mixed results (and noise is low)

- No /t/ response → Review HF gain or loss estimate
- No /g/ response → Review mid-freq gain or loss estimate
- No /m/ response → Review LF gain or loss estimate

Mixed results (and noise is high) → Draw no conclusions from missing response !

Thanks for listening

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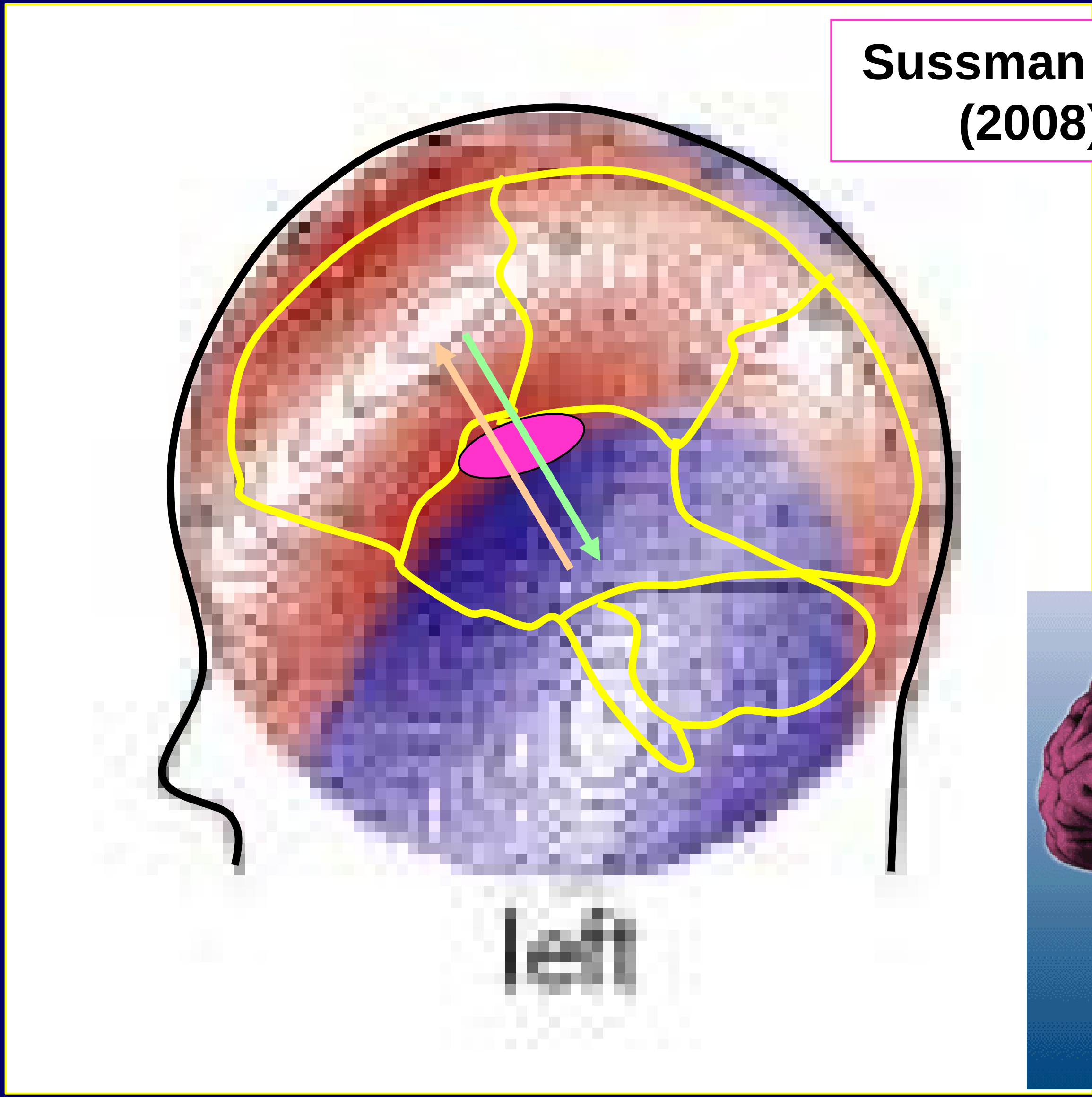
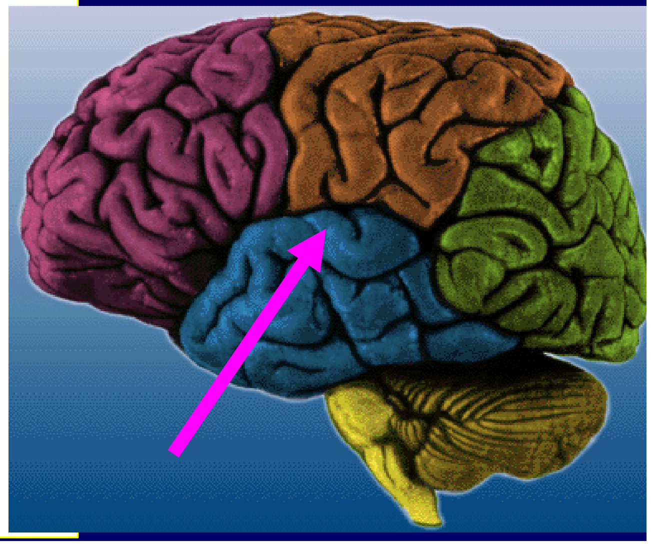
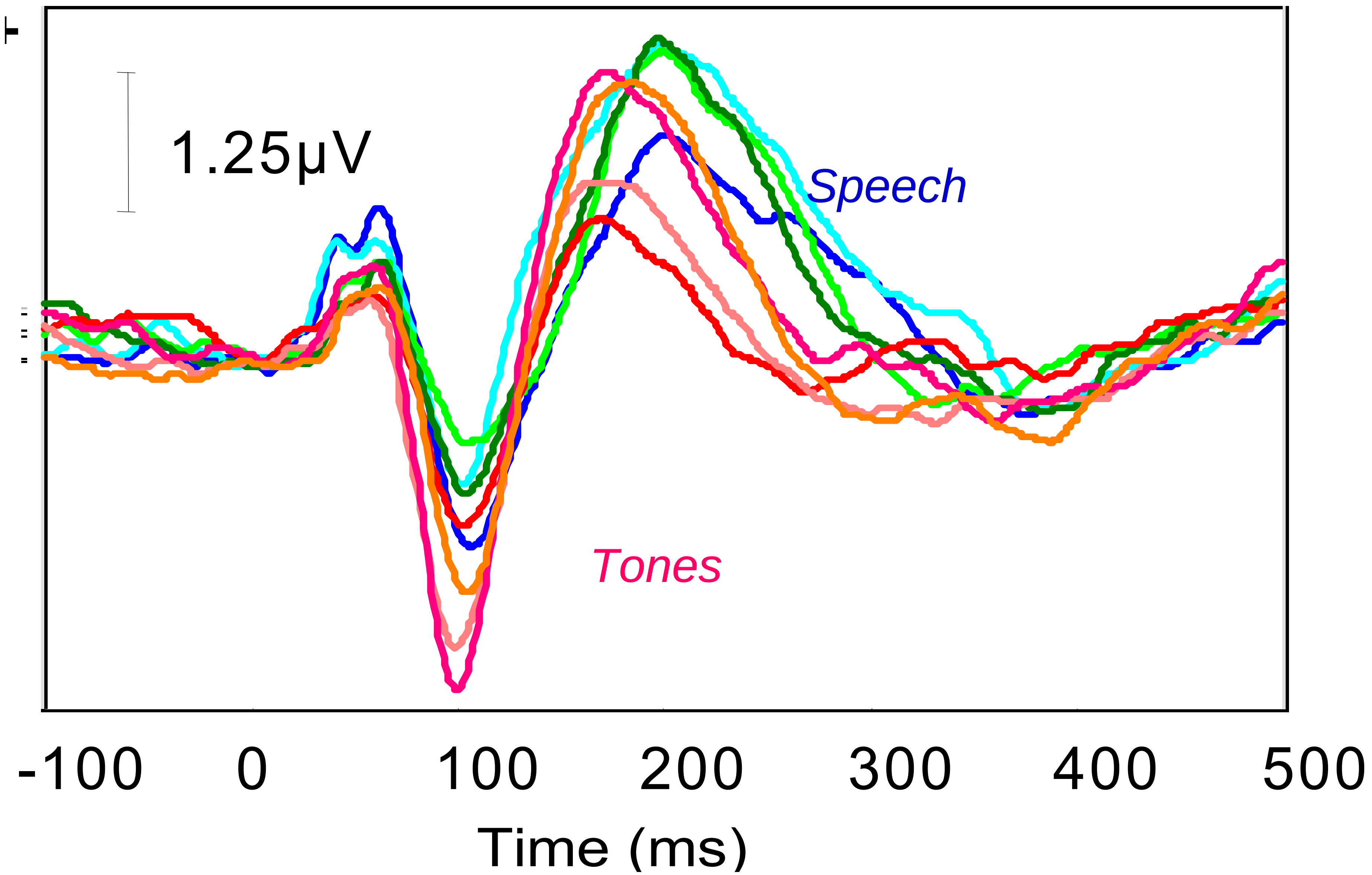
Auditory cortex and current sources



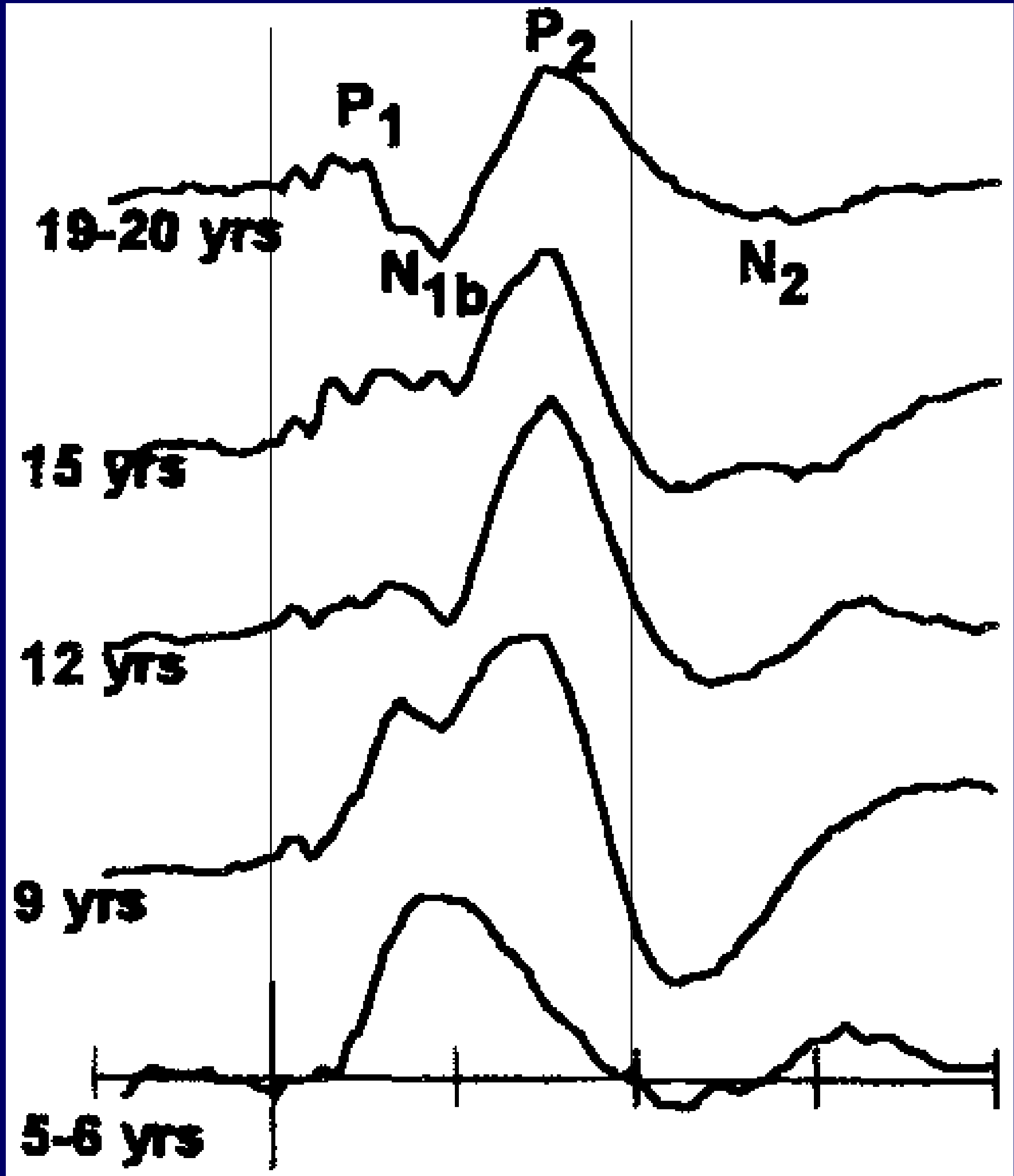
Sussman et al (2008)



Adult grand mean waveforms at Cz

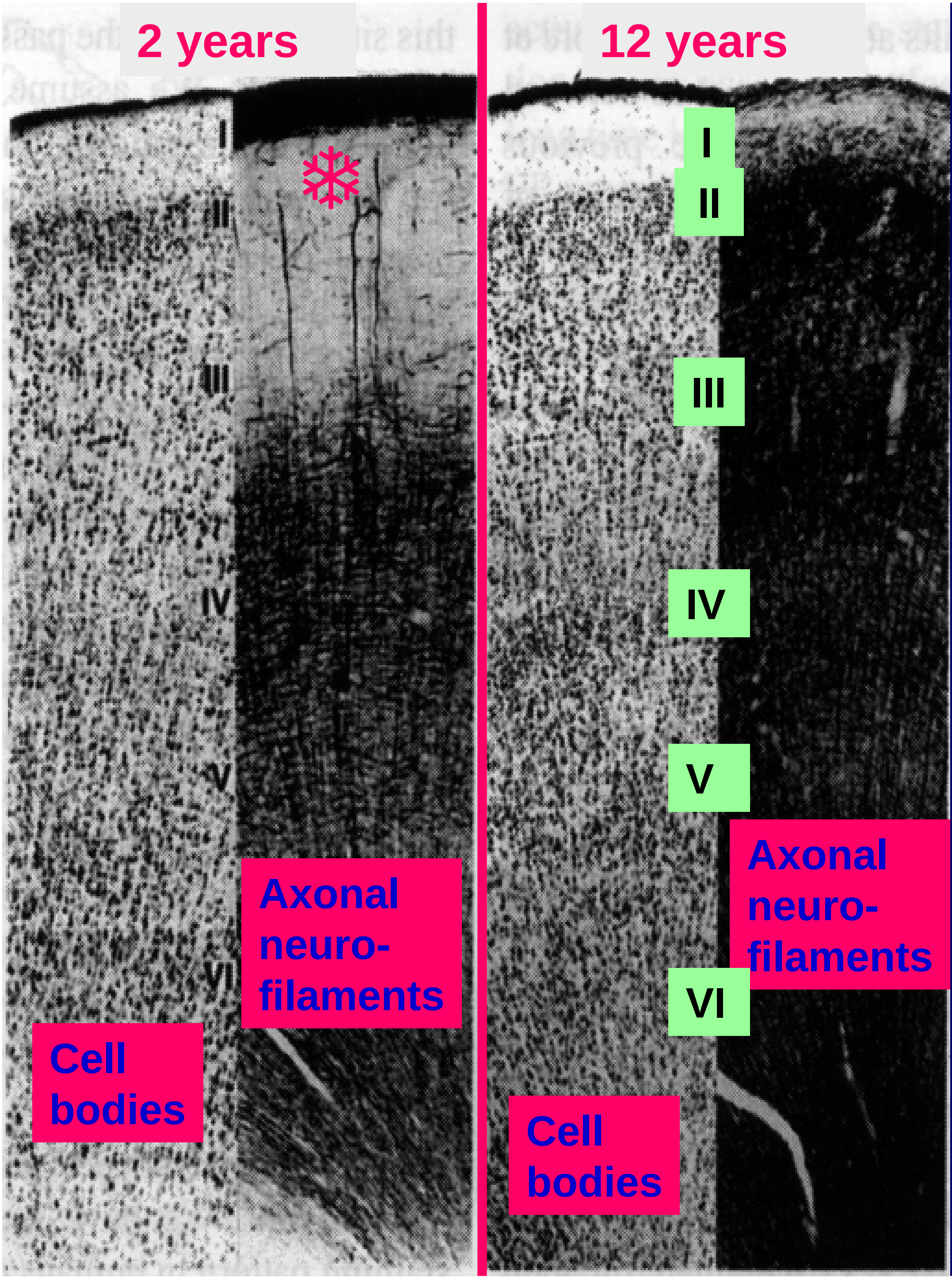


Maturational effects on cortical evoked response morphology



- N=8-16 per grand mean
- Cz site
- stimulus = 10 click train, 2 ms ISI @ 65 dB SL
- rate = 1.3/s

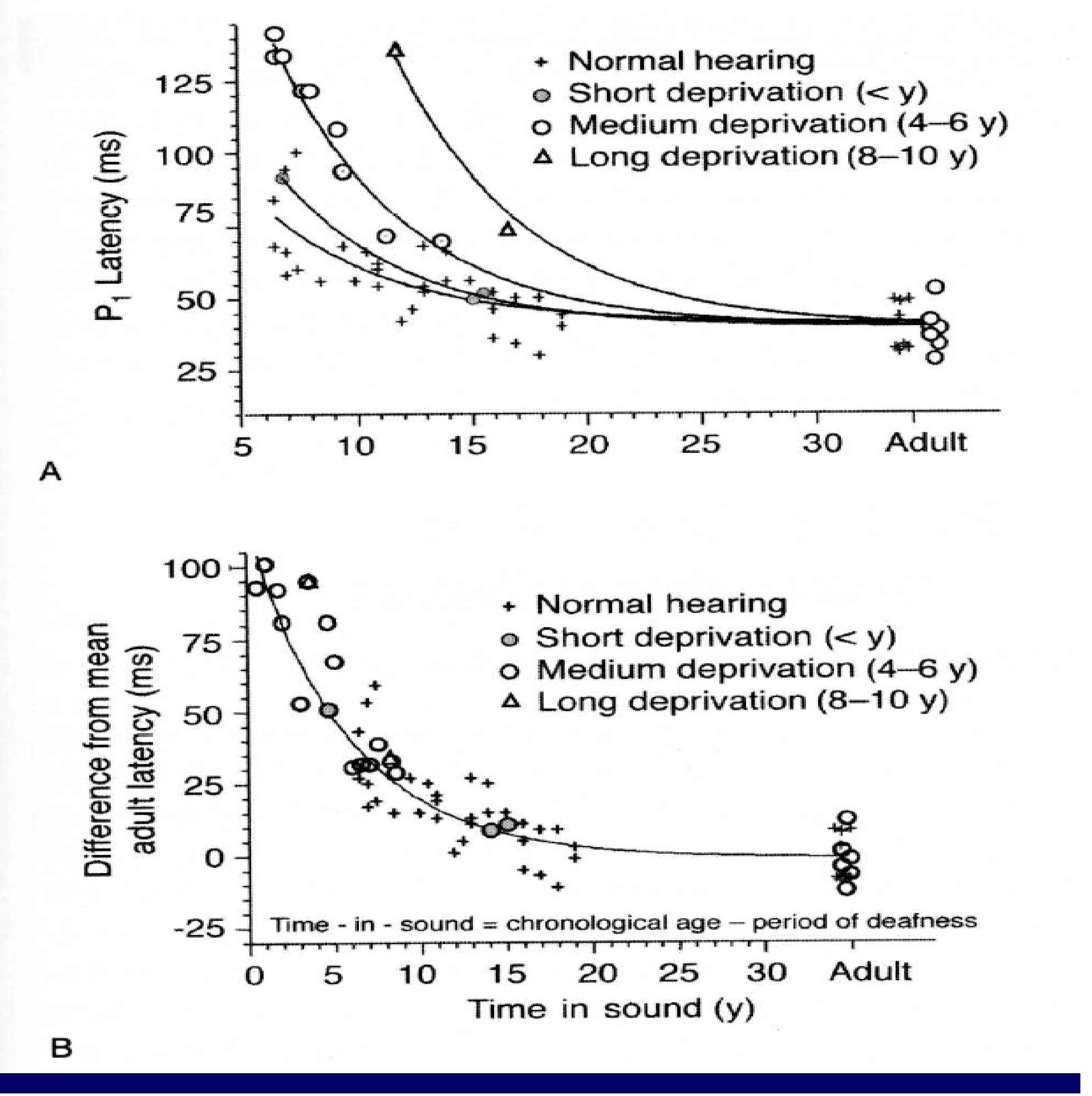
Ponton et al (2000)



❄ Fewer neuro-filaments in young children, especially in more superficial cortical layers thought to generate N1

(Ponton, Moore & Eggermont 1999)

Maturation with time “in sound”



Ponton and Eggermont 2007

Auditory system maturity

Ponton and Eggermont (2007):

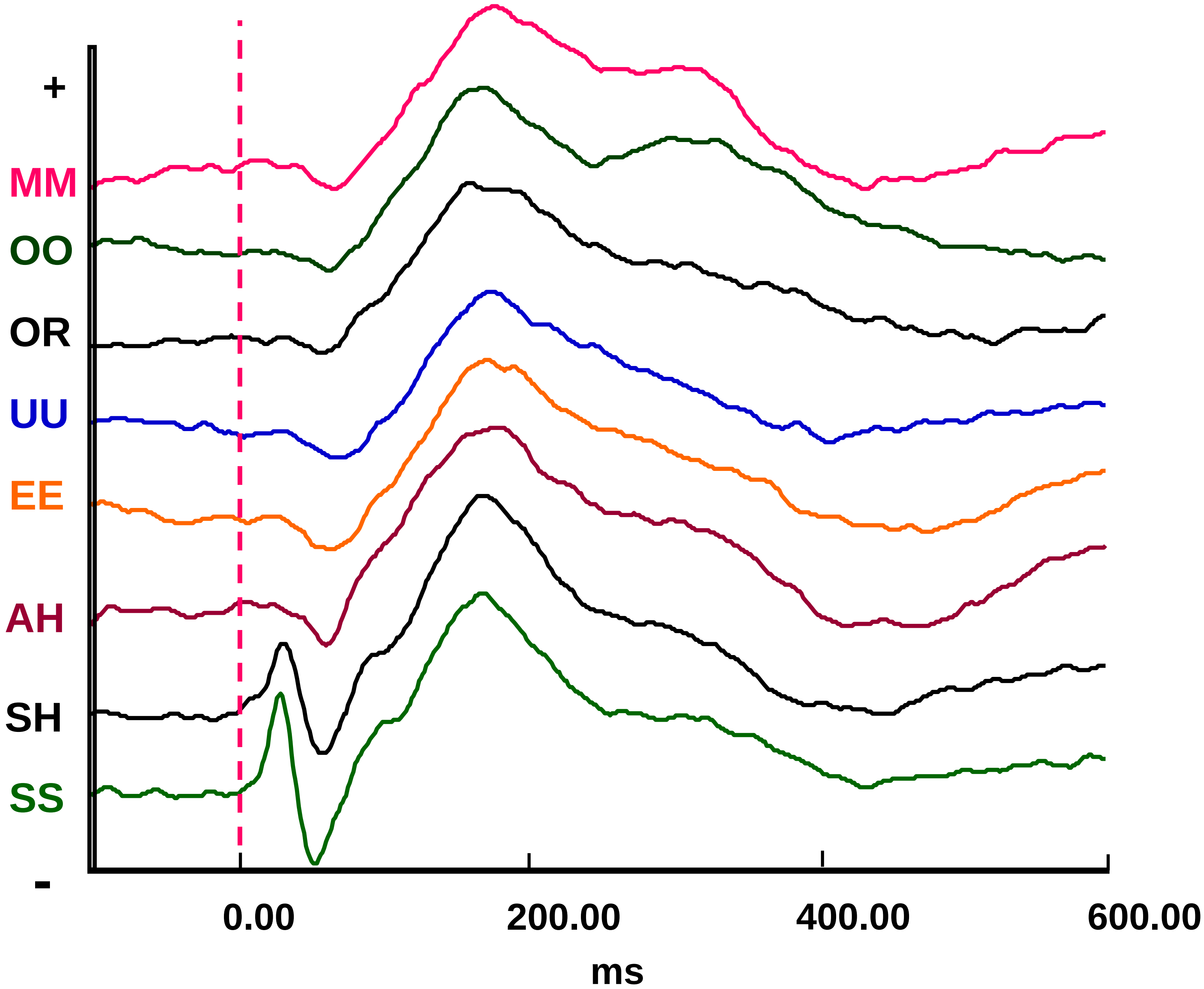
- Latency matures consistent with the time "in sound"

Sharma (2002):

- Provided implantation occurs by 4 years of age

Cortical responses in infants to different speech sounds

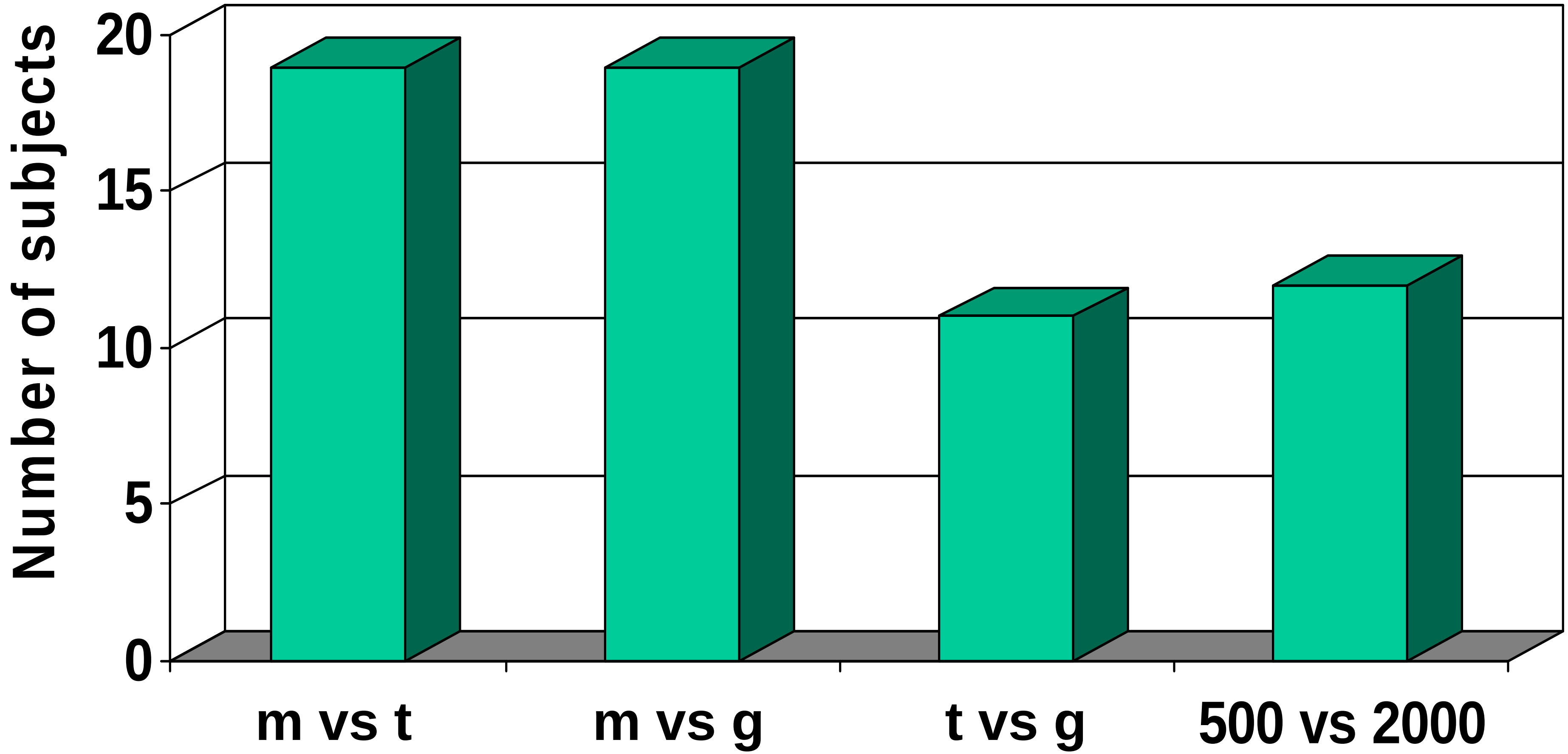
Grand Average n = 16 infants



Number of subjects (out of 20) with significant differences between responses

	ah	ee	mm	oo	or	sh	ss	uu
ah		7	4	7	7	12	12	13
ee	7		6	8	11	12	10	9
mm	4	6		8	8	10	10	7
oo	7	8	8		7	13	10	13
or	7	11	8	7		12	10	7
sh	12	12	10	13	12		3	14
ss	12	10	10	10	10	3		11
uu	13	9	7	13	7	14	11	

Number of infants (N=20) with significantly different cortical responses to pairs of stimuli



Based on MANOVA at Cz, 101 to 500 ms post-onset, in eight bins each 50 ms

Automatic detection of cortical responses

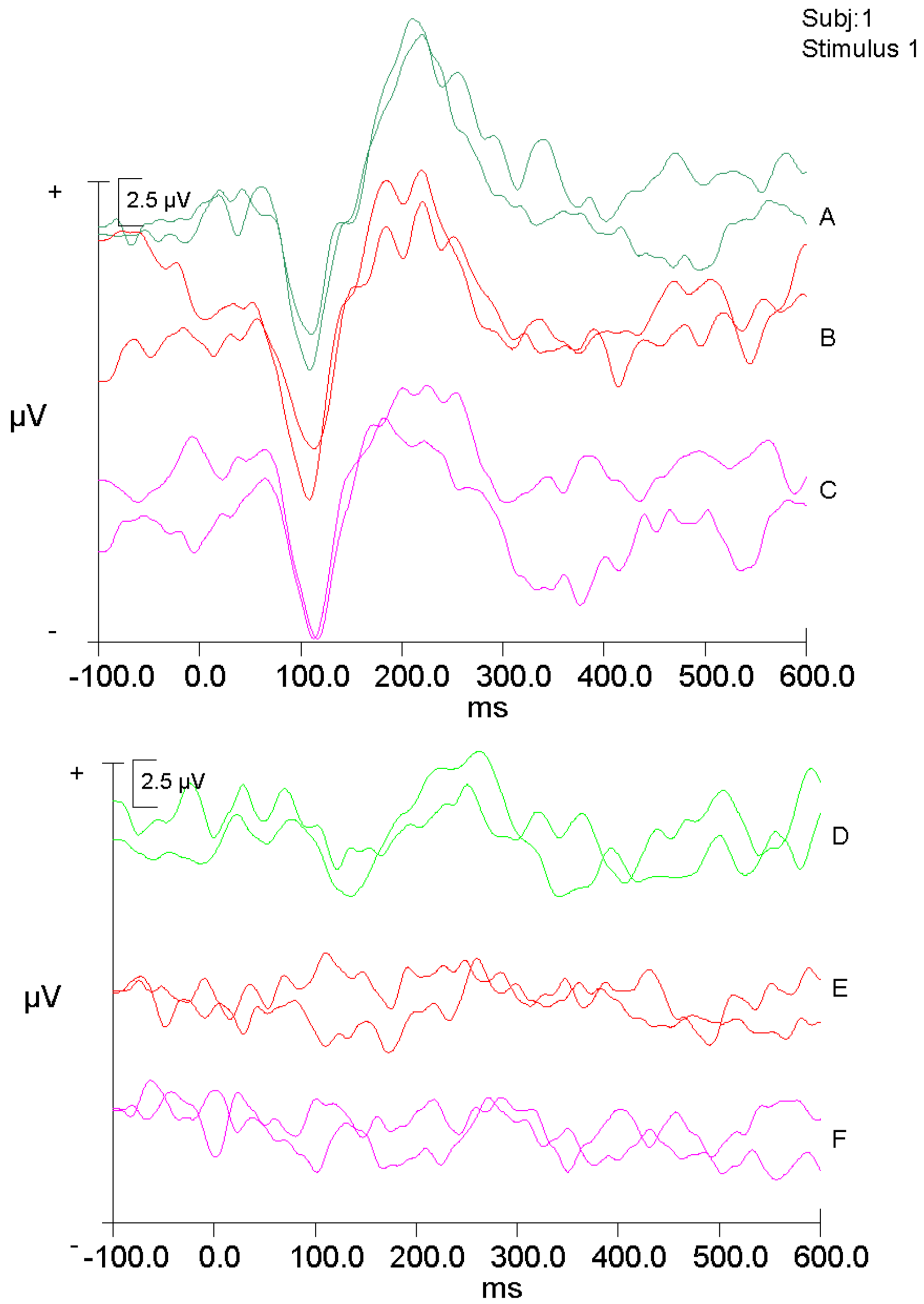
Desirable characteristics

- No reliance on a template
- Able to use information from contributing portions of waveform
- Able to discount non-contributing portions of waveform

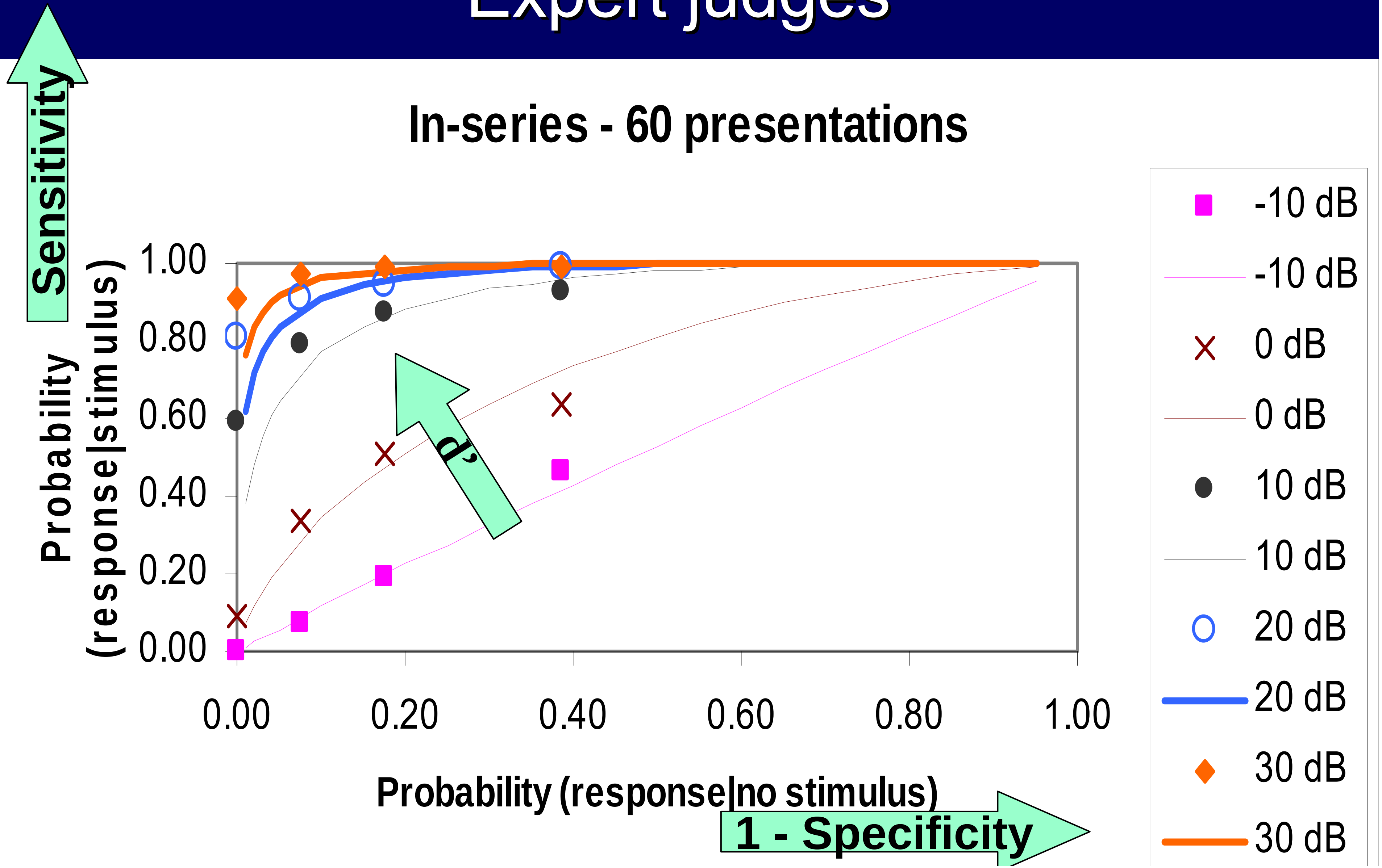
↓

Hotellings T^2

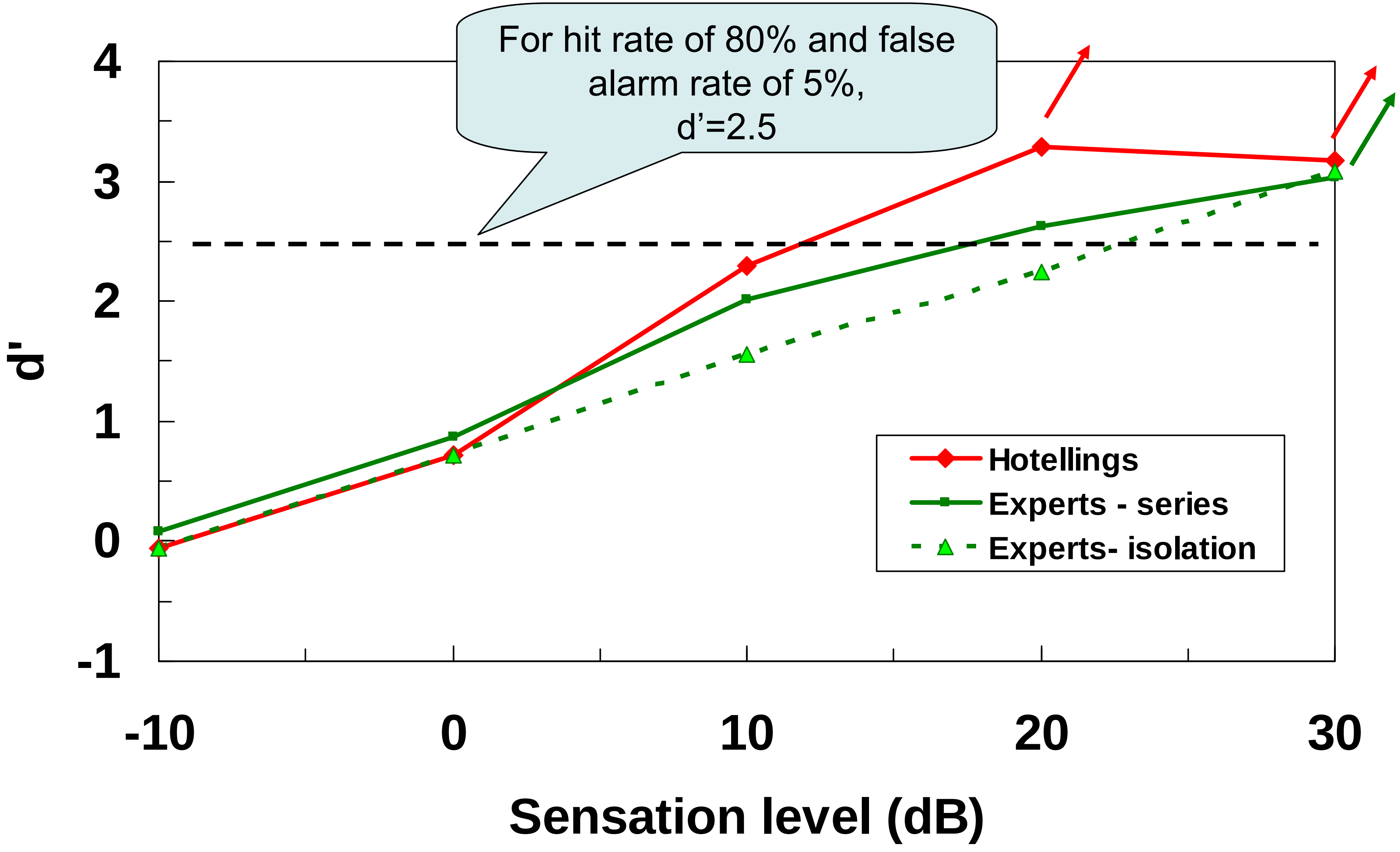
Presentation of average response in series



Receiver Operating Characteristics – Expert judges

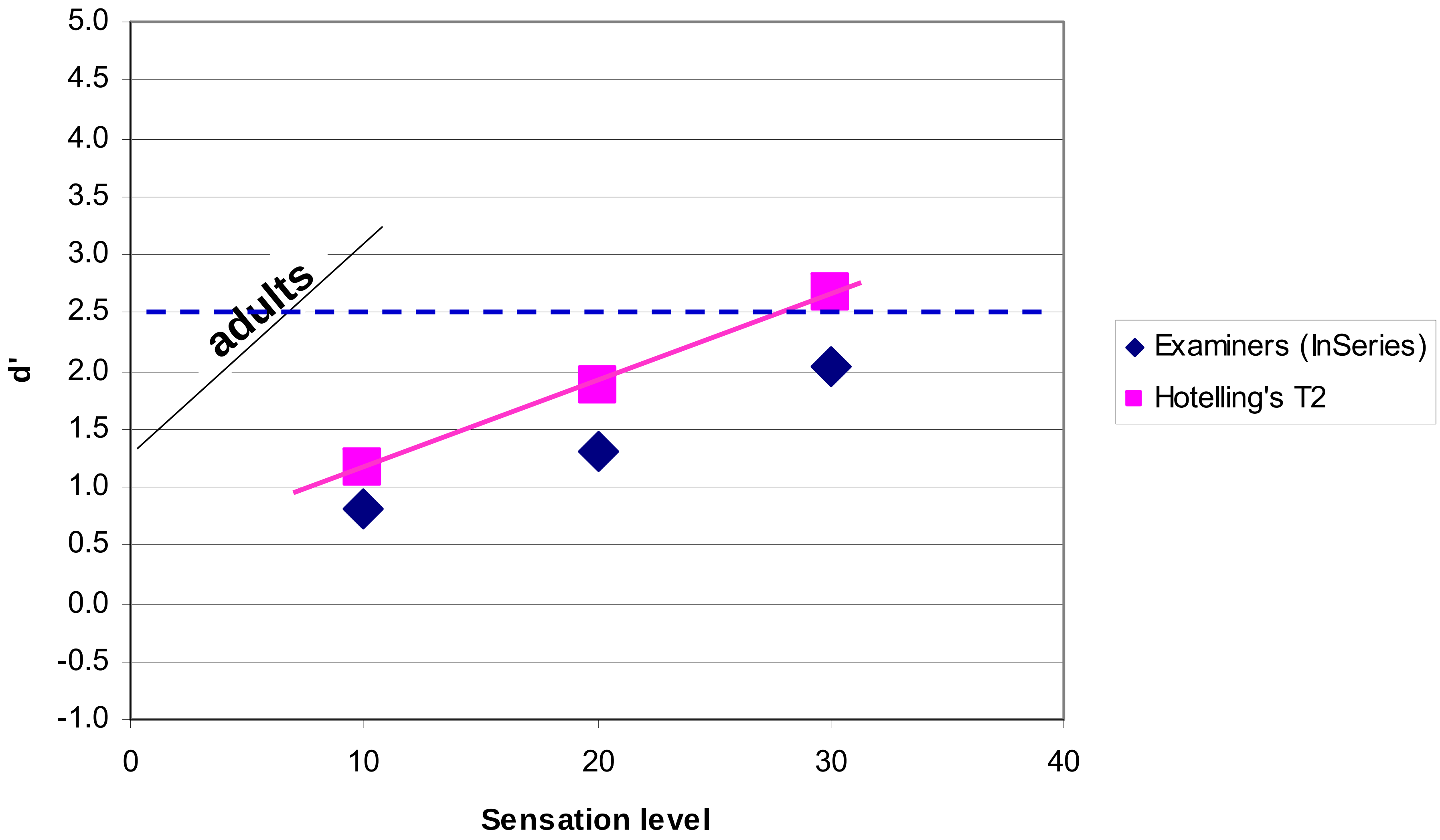


d’ results - for 60 stimuli

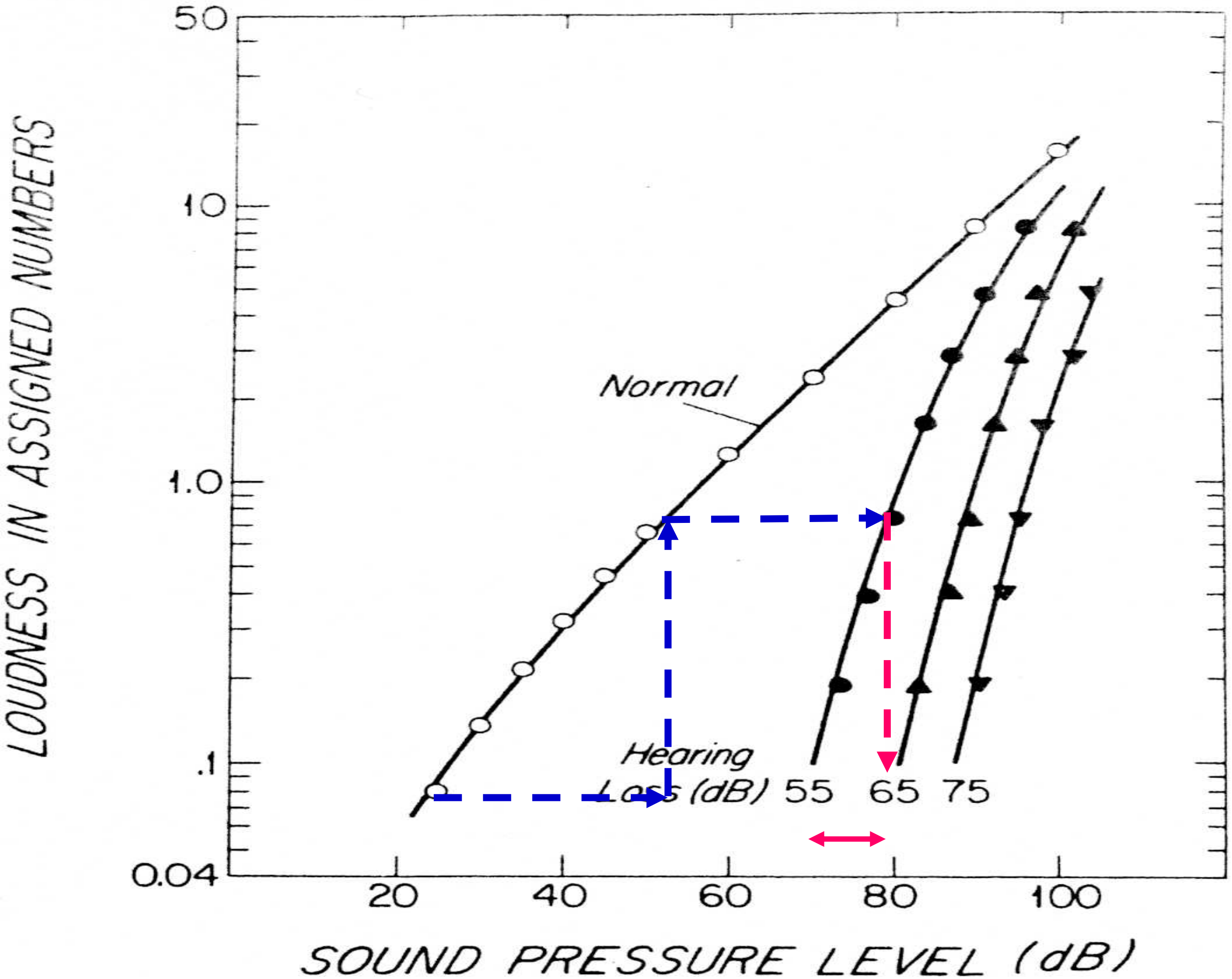


Infants: Hotellings versus experts

Normal hearing infants aged 7 to 16 months

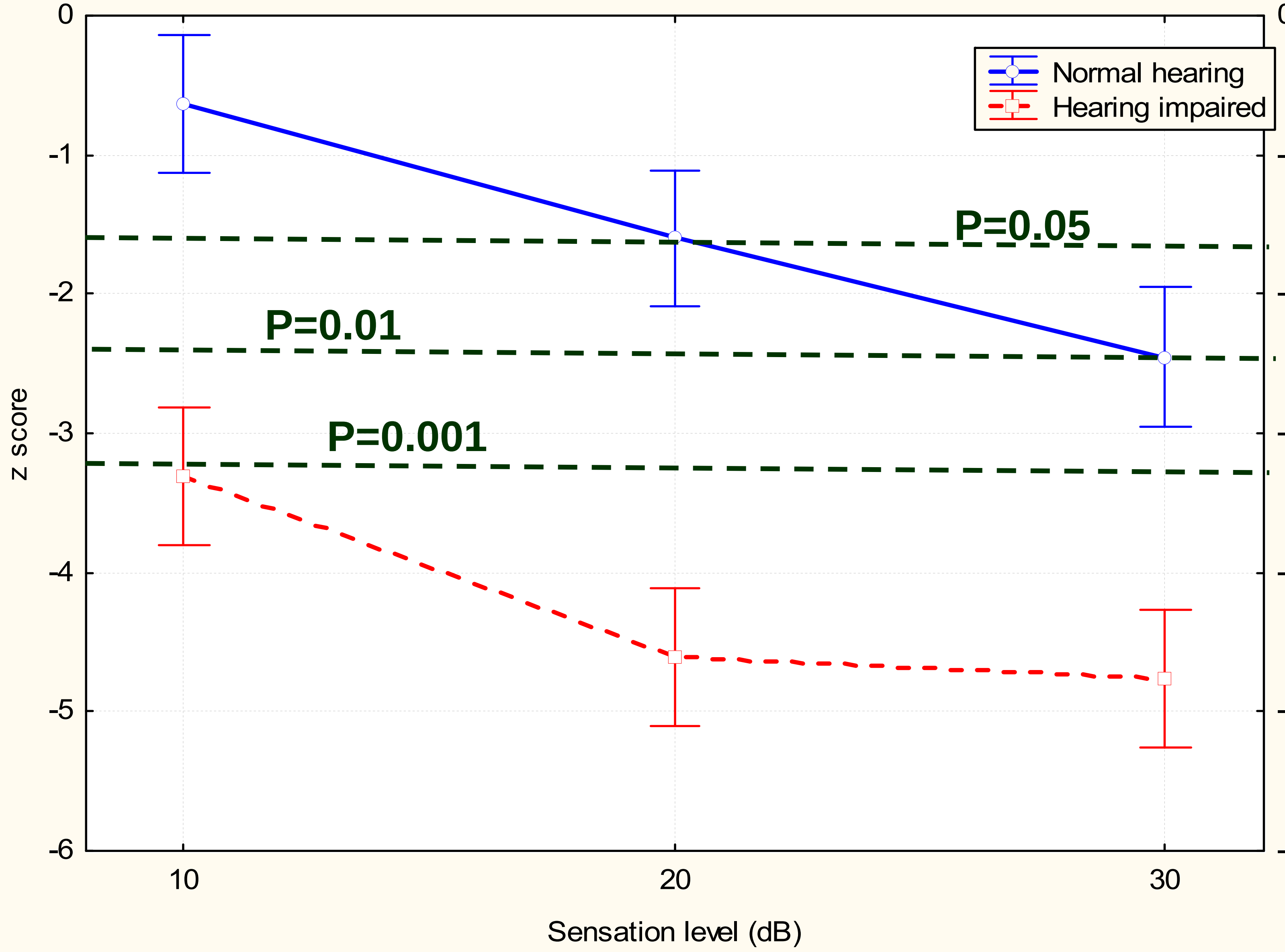


Loudness growth above threshold



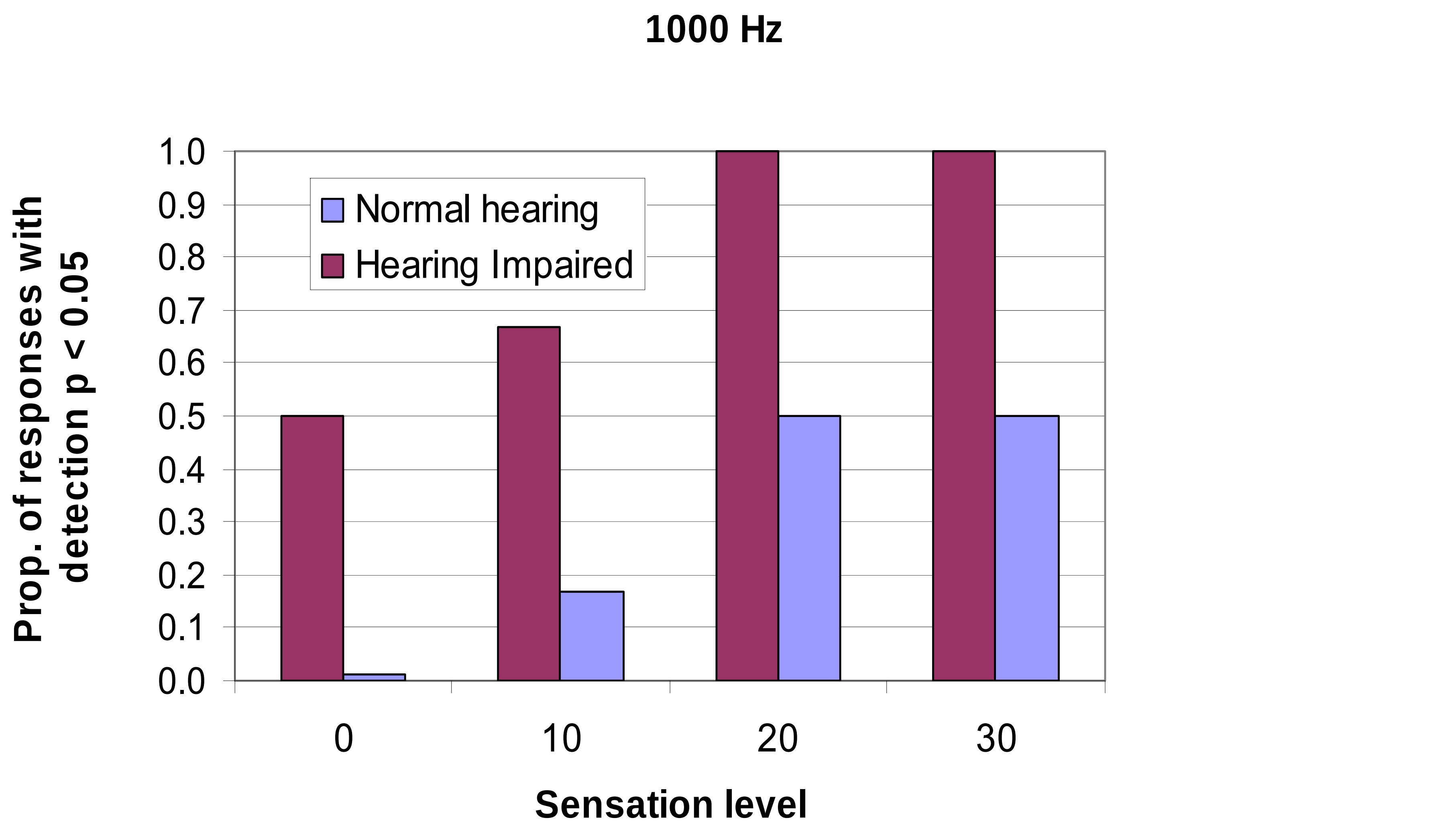
Hellman & Meiselman, 1990

Detectability (adults; tonal stimuli)

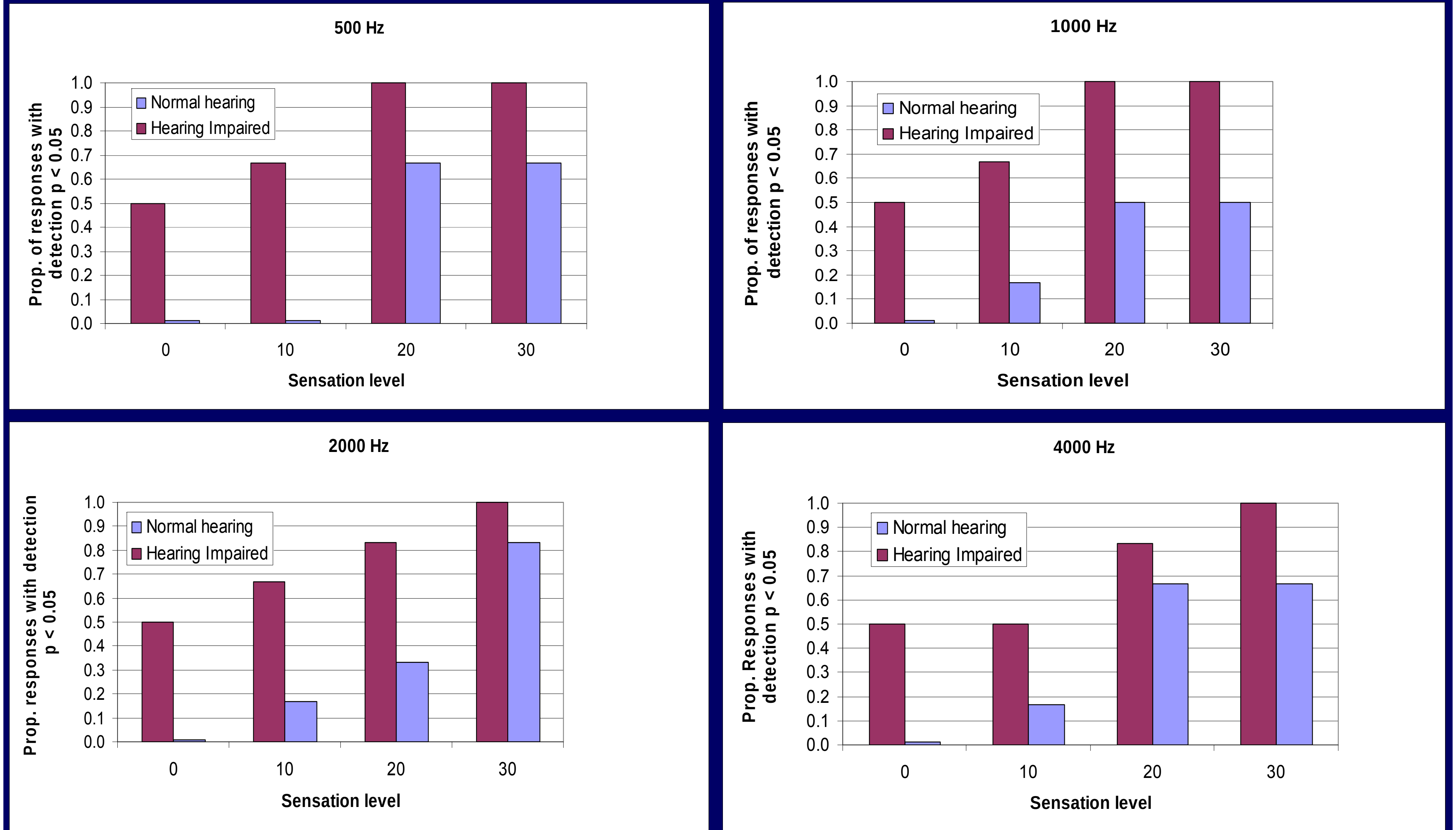


Significant responses – normal hearing and hearing impaired

Adults; tonal stimuli (n=100 or 200)

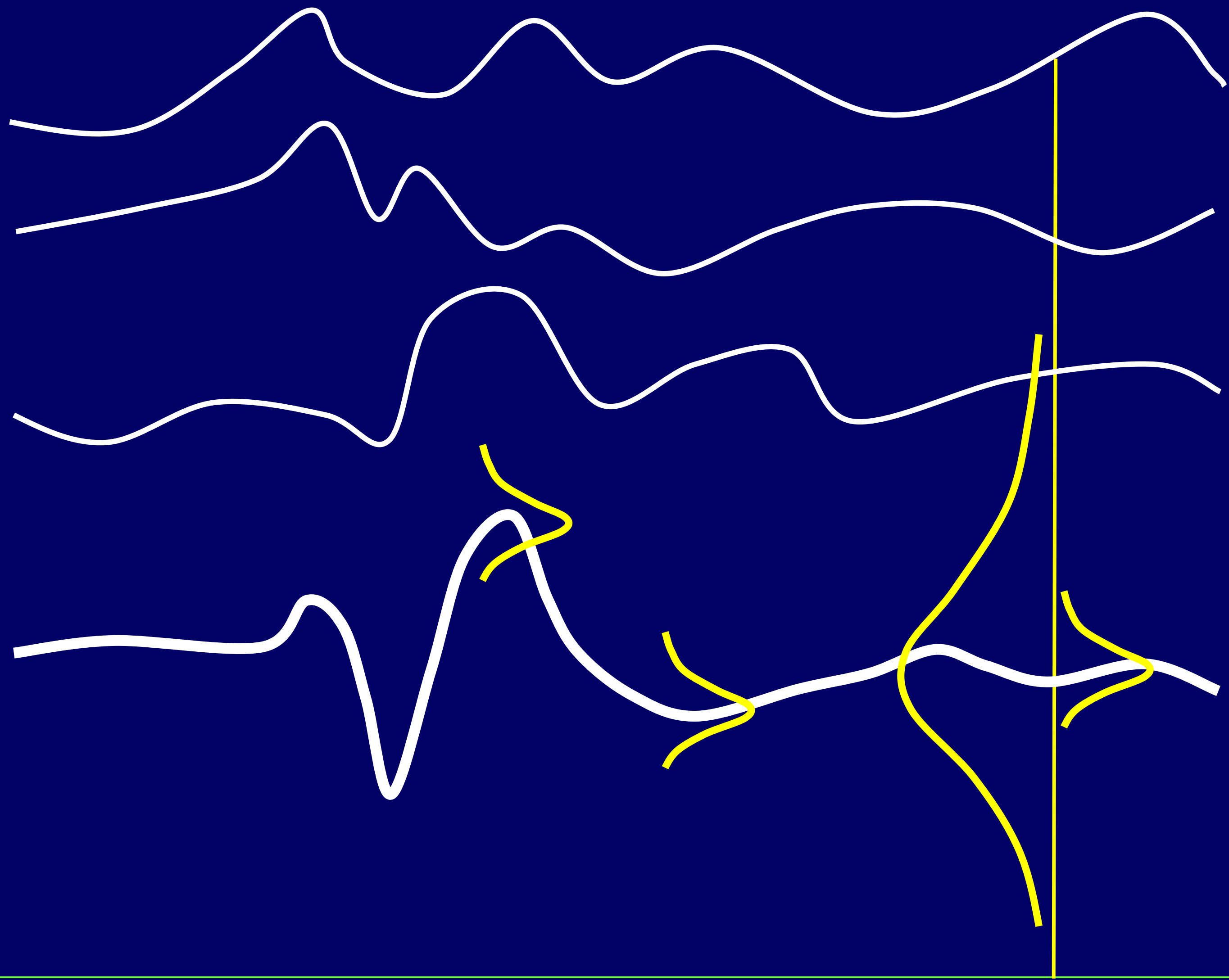


Proportion with responses present - adults



…….. but infants move around !

Residual noise level

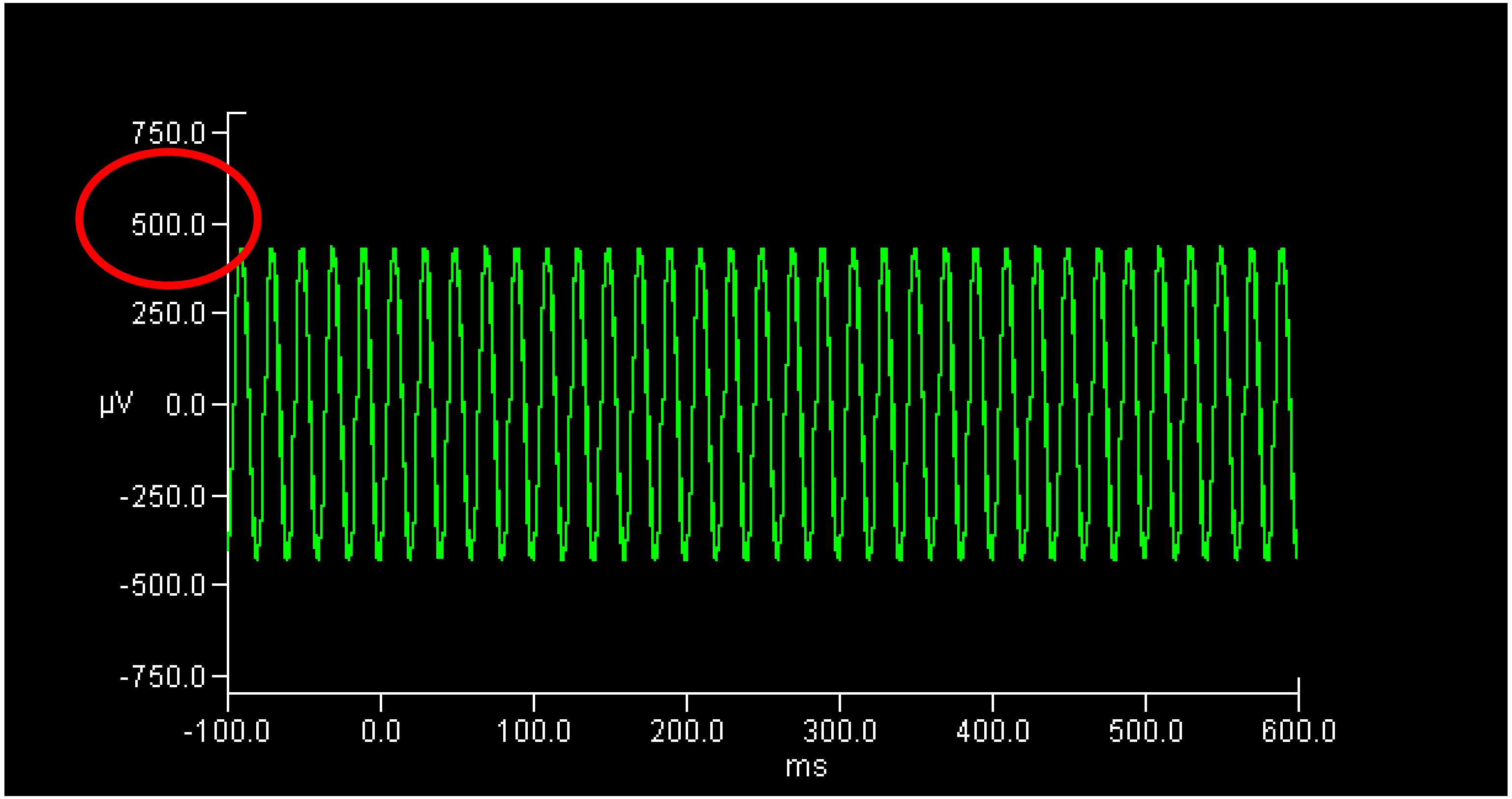


rms noise = standard deviation / √n

Reducing measurement variability
(random electrical signals)

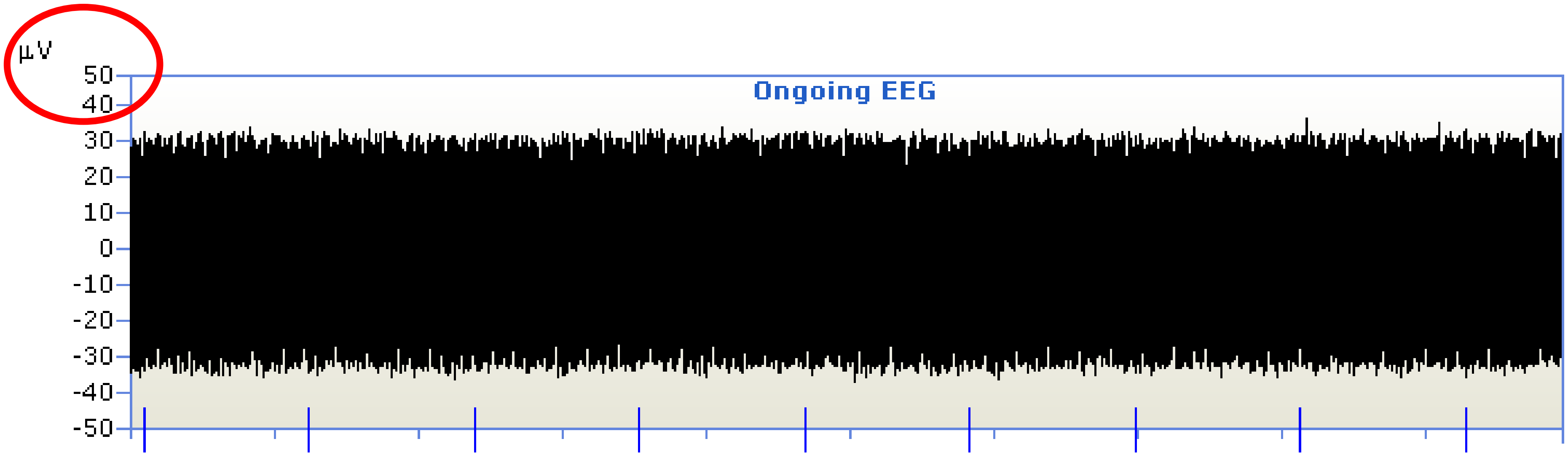
→ Speeding up measurements
→ Increasing validity of interpretation

Capacitive Coupling 50 Hz



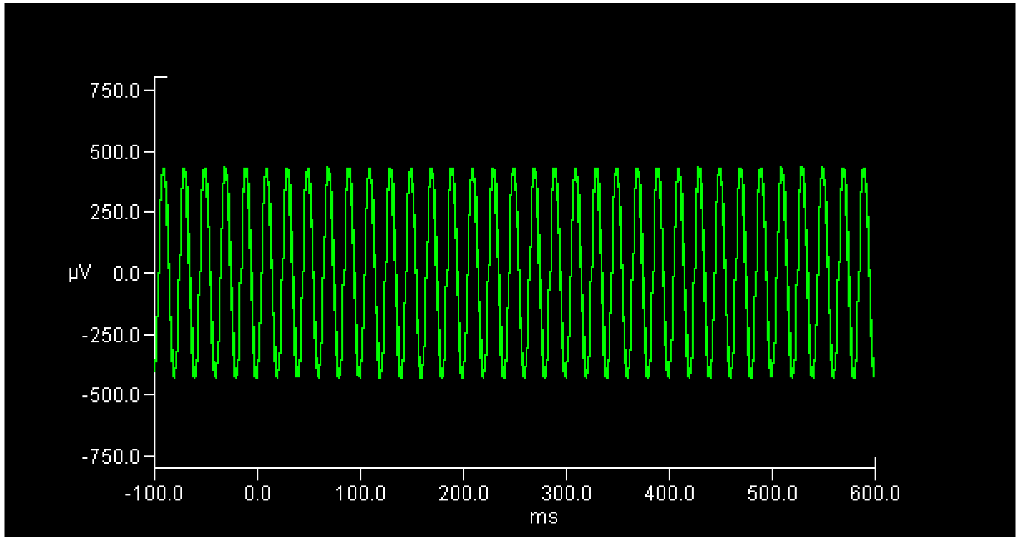
Passive Electrodes

Capacitive Coupling 50 Hz



Active Electrodes

Capacitive Coupling 50 Hz



Passive Electrodes

Active Electrodes

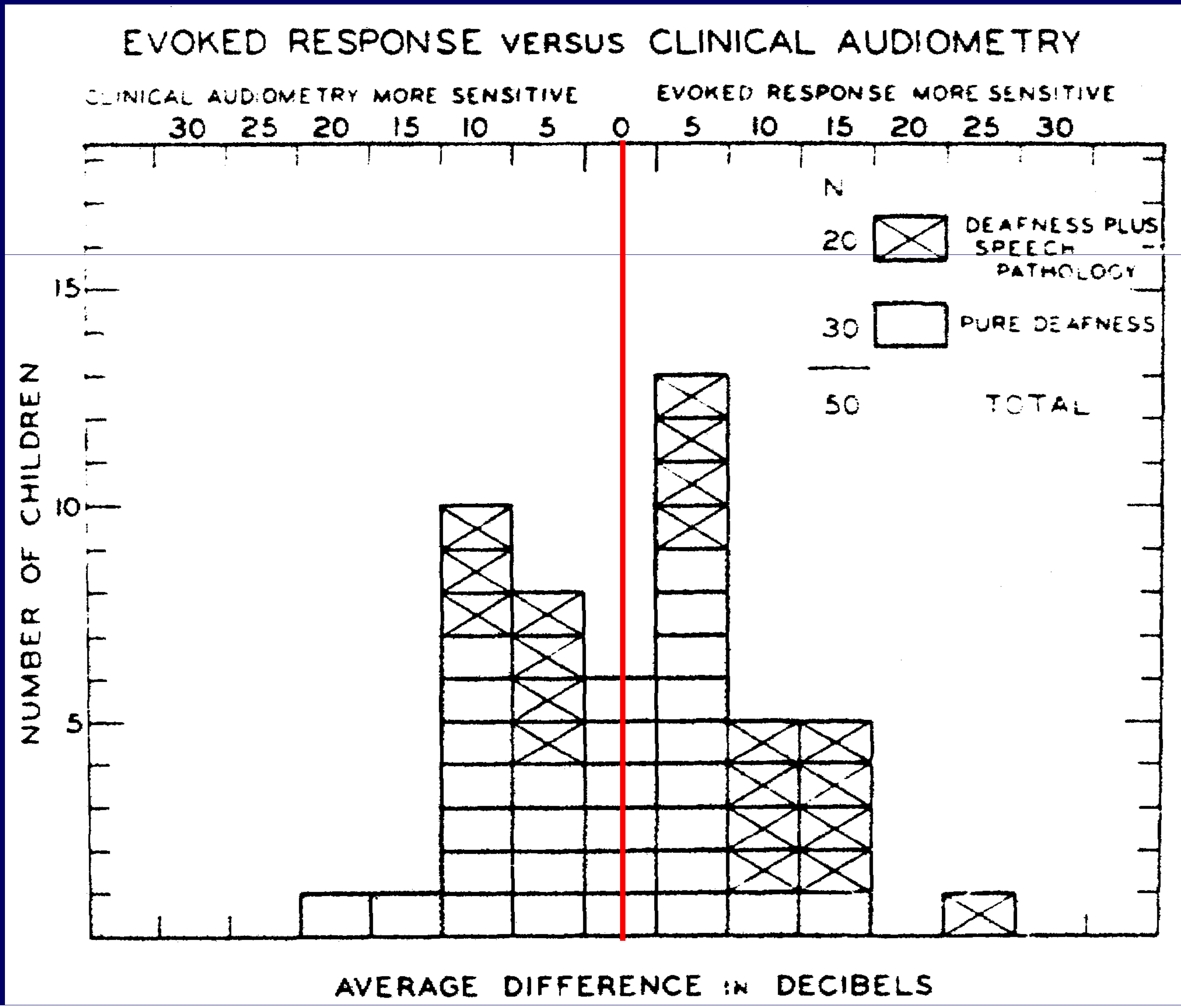
Finding thresholds with cortical responses

What does an absent cortical response mean?

Cortical auditory evoked responses traditionally used for objective assessment of hearing thresholds in adults

- In 1965 Hallowell Davis showed good agreement between cortical and pure tone thresholds in children
- For many years cortical response audiometry has been regarded as the “gold standard” for objective electrophysiological hearing assessment

Davis (1965) Cortical evoked potential versus behavioural thresholds

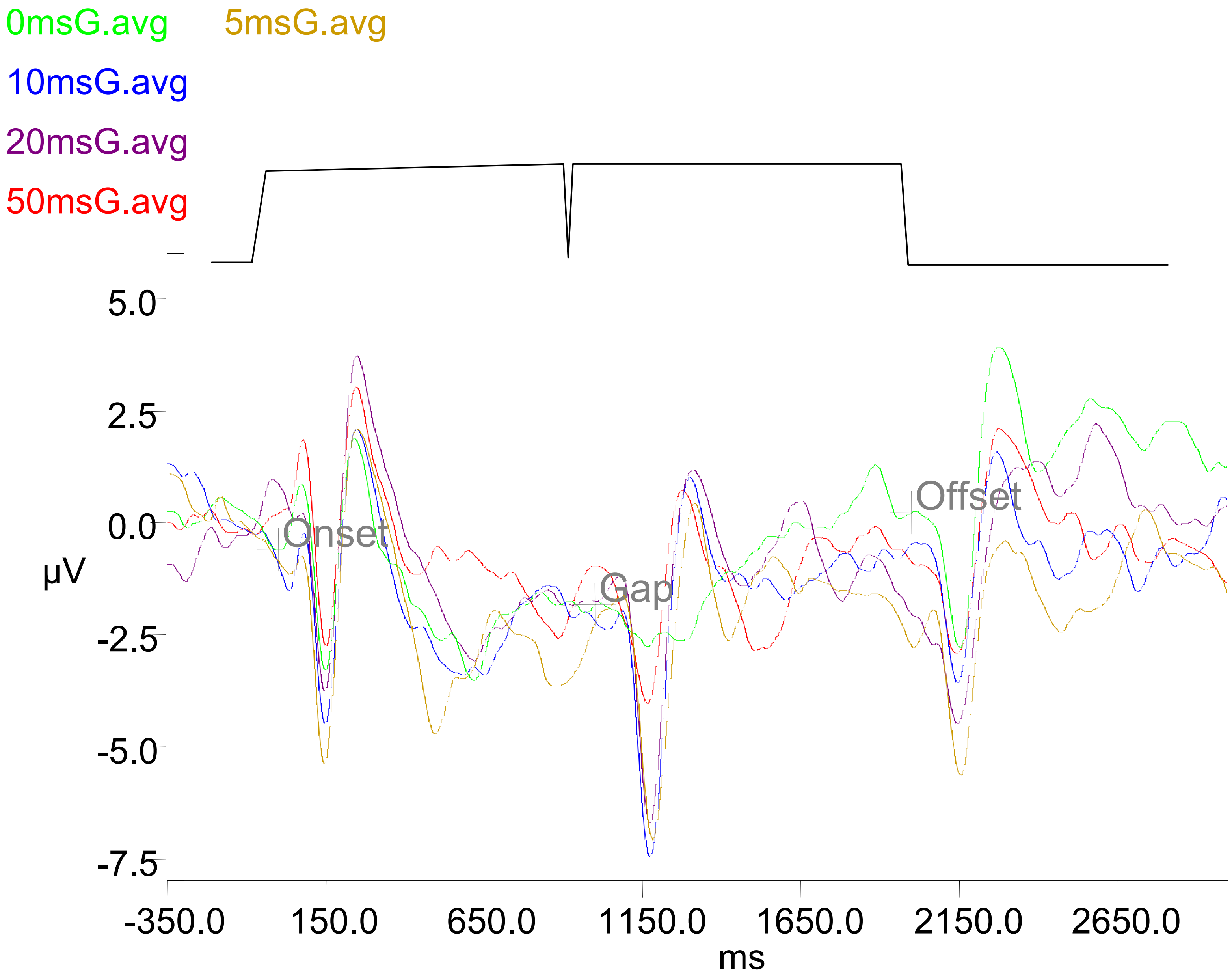


Corticals for more advanced measurements

Application for auditory neuropathy (AN)

- 15% of babies found to have hearing loss at birth in NSW have AN
- Management unclear (no device, hearing aid or cochlear implant)
- Rance showed close relationship between cortical response in older children and benefit from hearing aids
- Gap detection worse in people with AN
- Investigating gap detection by cortical responses

/Ah/ 2 second duration



Summary

Cortical responses

- For checking the audibility of speech sounds
- Indicate the maturity of the auditory system
- Automatic detection as good as experts
- Residual noise size critical
- For checking hearing thresholds when the patient is awake