SPAU332
Hearing Aids I

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Hearing aid prescription algorithms

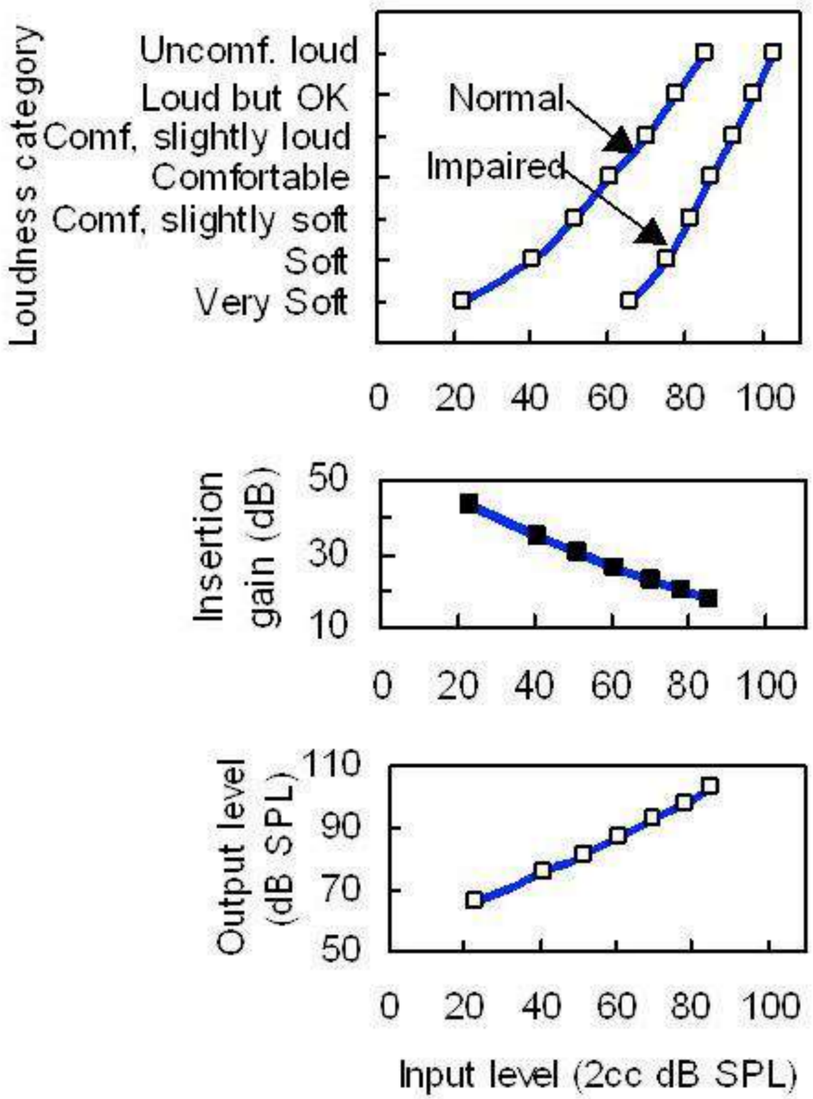
Aim of today's lecture: Understand the basic principles of prescription rules such as NAL-NL2 and DSL v5.

General concepts behind hearing aid prescriptions

- Hearing losses vary widely in their degree, configuration and type
- Amplification characteristics must be appropriate for individual
- Achieved using prescription procedure
- Prescription requires there to be some known (or assumed) relationship between a person's hearing characteristics and the required amplification characteristics

Mirroring of the audiogram

- Every 1 dB increase in hearing loss requires 1 dB of additional gain to compensate
- But for SNHL the gain needed to restore normal loudness perception is equal to the threshold loss only when the person is listening at threshold
- For all higher levels, this amount of gain would be excessive



Half-gain rule

- The next development was to base gain needed on the person's most comfortable level (MCL) rather than on thresholds
- It was observed that the amount of gain chosen by the most satisfied hearing aid users was approximately half the amount of threshold loss
- Did not take into account the variation of speech energy across frequency
- Cannot predict how much gain is needed at each frequency unless speech intensity taken into account
  - Low frequency components are more intense than high frequency components
  - Therefore half gain rule has to be modified (either a little less low-frequency gain or a little more high frequency

Current prescriptive approaches

Loudness normalisation

- Restore loudness perception to same loudness perceived a listener with normal hearing
- Usually for certain frequency bands
- Soft, medium, and loud speech sounds as heard by a normal hearer are appropriately amplified to the categorical rating descriptor of "soft" "average" and "loud" by an individual with hearing impairment.
- Strict loudness normalisation procedures did not account for the fact that all speech frequencies are not equally important
- Only so much loudness we can work with before patient finds amplified sounds too loud

Current prescriptive approaches

Loudness equalisation

- Equalise the perception of loudness over a range of frequencies
- Lower frequencies do not dominate loudness (as is the case for normally hearing listeners)
- E.g. frequency range of 500 to 4000 Hz can be amplified so that the loudness perception of 500 to 4000 Hz as well as narrow bands in between are

National acoustics laboratory prescription

- Original NAL method, 1976
- NAL-Revised (NAL-R), 1986
- NAL-Revised for severe and profound losses (NAL-RP), 1990
- NAL-Nonlinear 1 (NAL-NL1), 1998

National acoustics laboratory prescription

Loudness equalisation

- Does not try to preserve the normal loudness relationships among different frequency bands of speech.
- Tries to make all frequency elements of speech equally loud.

- Aims to make speech intelligible and overall loudness comfortable
- Concerned with **effective** audibility, not just audibility.

National acoustics laboratory prescription

Effective audibility

- For patients with severe or greater hearing loss, a small sensation level might give some amount of information, while a high sensation level will not necessarily add much more information for understanding speech.
- For those with profound hearing loss, audibility might be accompanied with virtually no added 'effective audibility'.

NAL-NL2

- Released in 2011
- Second generation of prescription procedures from NAL for fitting WDRC instruments
- Rationale
  - Maximise intelligibility by increased gain in the frequency response
  - Modify gain so that the loudness is not greater than that perceived by normal hearing listeners
  - Consistent with previous versions of NAL

NAL-NL2

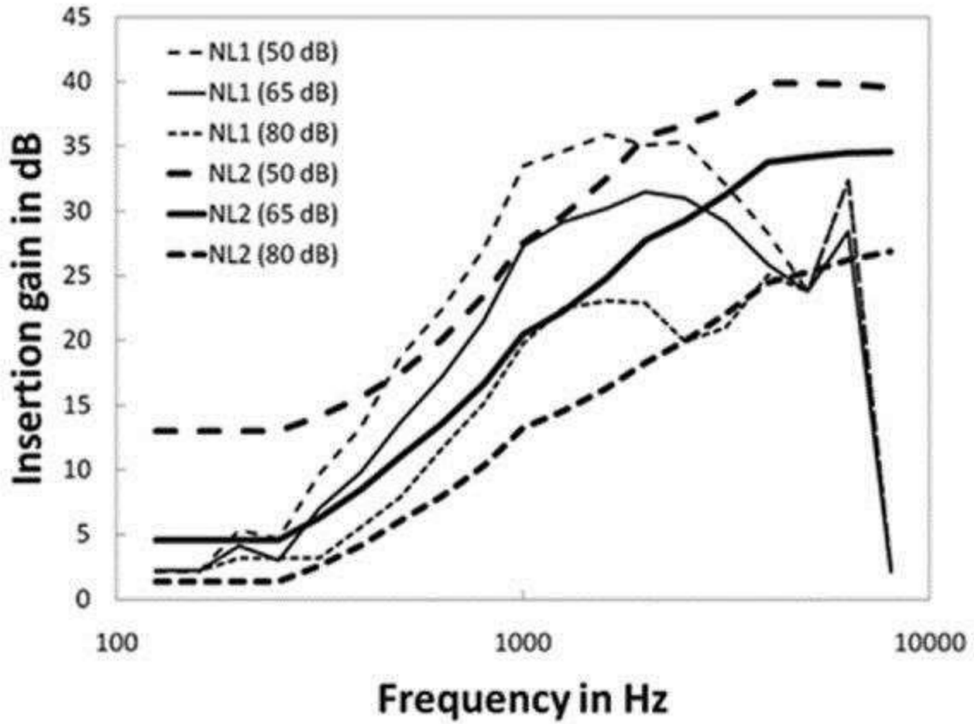
- Adaptive neural network to calculate gain based on audiogram
- Optimal gain-frequency responses derived for 240 audiograms
  - Wide range of severity and slopes
  - Seven speech input levels
- Optimised gain values from all audiograms and input levels drawn together into single composite

NAL-NL2

- Prescribe hearing aids to
  - Make speech intelligible
  - Make loudness comfortable
- Prescription also affected by
  - Localisation
  - Tonal quality
  - Detection of environmental sounds
  - Naturalness

Differences between NAL-NL1 and NAL-NL2

- NAL-NL2 prescribes relatively more gain across low and high frequencies and less gain across mid frequencies than NAL

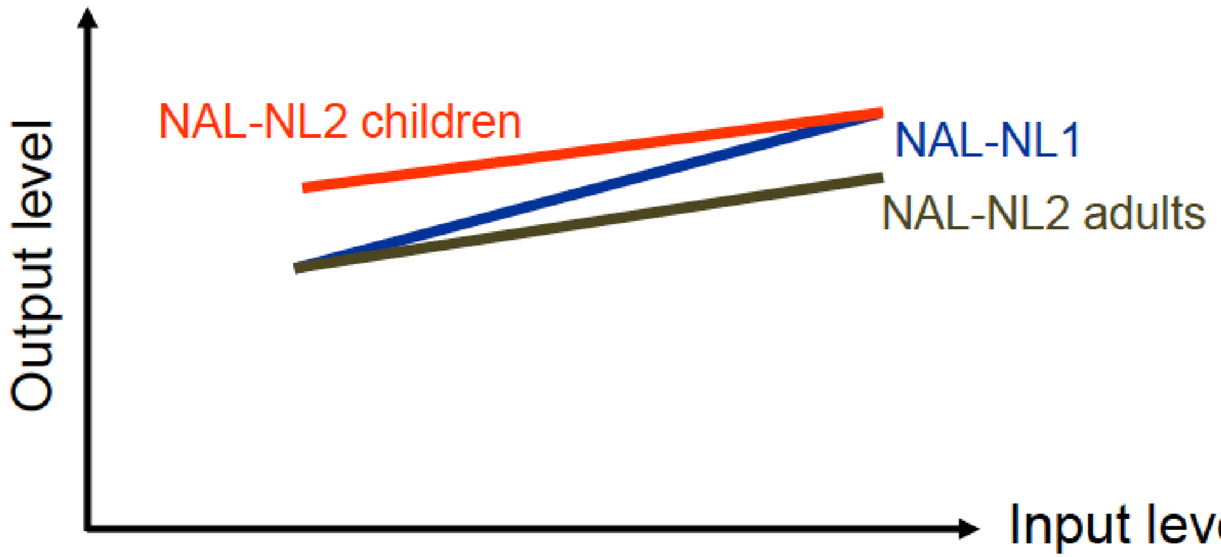


NAL-NL2

- Takes into account
  - Age
  - Gender
  - Language type
  - Binaural/monaural fitting
  - Hearing aid experience

NAL-NL2 - age

- Children tend to prefer more gain than adults



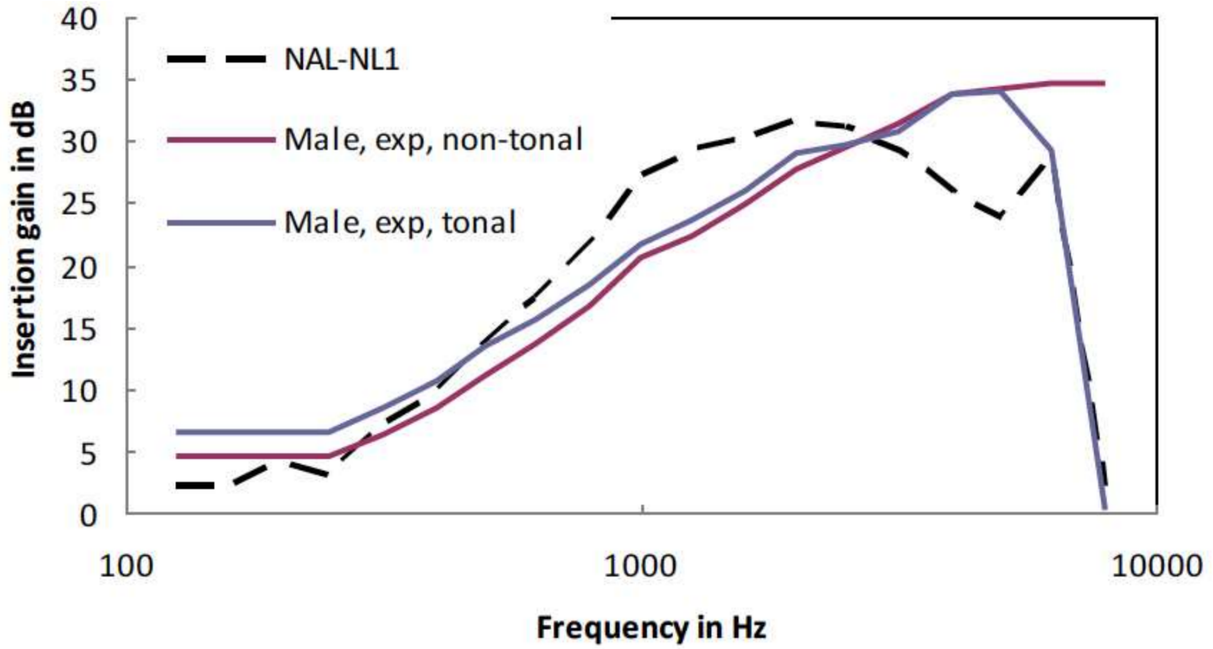
NAL-NL2 - gender

- Women prefer an average of 2 dB less gain than men
- Gender differences are therefore factored into the prescription formula
  - NAL-NL2 prescribes 2 dB higher gain for males than for females

Keidser G, Dillon H. What's new in prescriptive fittings down under? In: Palmer CV, Seewald R, eds. Hearing Care for Adults 2006. Stafa, Switzerland: Phonak AG; 2006:133-142.

NAL-NL2 – effect of language

- NAL-NL2 ensures that sufficient gain is applied at the frequencies that are most important for speech understanding.
- Low frequencies are more important in tonal languages, which are most common across Asia and Africa, than in non-tonal languages.
  - Slightly more gain is prescribed across the low frequencies for tonal than for non-tonal languages



NAL-NL2 – binaural fitting

- Listening with two ears provides more loudness than listening with one.
- Less gain is therefore used for bilateral fittings, especially at higher input levels.
- In NAL-NL2, the bilateral correction is 2 dB across the low input levels, increasing up to 6 dB for high input levels.

NAL-NL2 – hearing aid experience

- No difference in the gain preferences between new and experienced hearing aid users with a mild hearing loss.
- However, new hearing aid users with a *moderate* hearing loss did prefer significantly less gain than did experienced hearing aid users with a moderate hearing loss.
- Experience therefore taken into account for hearing aid users with moderate/severe hearing loss

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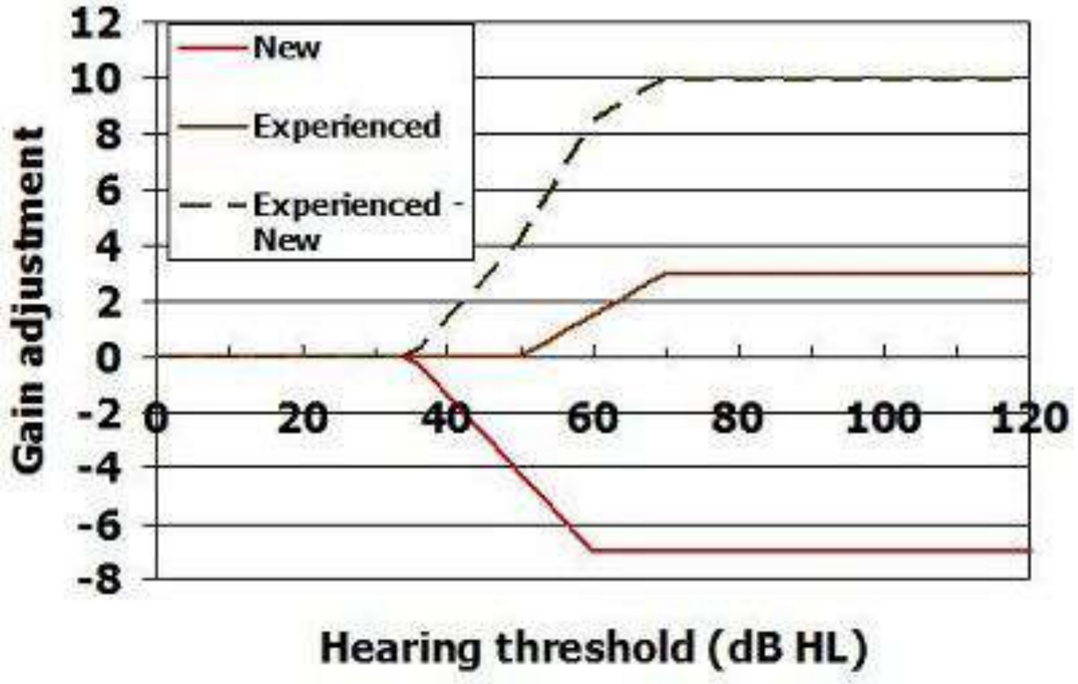


NAL-NL2 – compression speed

- Listeners with severe or profound hearing loss prefer lower compression ratios than those prescribed by NAL-NL1, when fitted with fast-acting compression.
- However, there is evidence to suggest that higher compression ratios could be used in this population with slow-acting compression.
- Therefore, in the case of severe or profound hearing losses, NAL-NL2 prescribes lower compression ratios for fittings with fast-acting compression than those with slow-acting compression.
- For mild and moderate losses, compression speed does not affect prescribed compression ratios.

Desired sensation level prescription formulae (University of Western Ontario)

- DSL (1985)
- DSL[i/o] (1995)

DSL[i/o]

- Main Goal: Audibility
  - Of vowel/consonant combinations
  - Especially important for children learning language.
- Secondary Goal: Comfort
  - Seeks to make speech comfortably loud in each frequency range, but **does not** attempt equal loudness in each frequency range.
- RECD is an integral portion of the formula.
- SPLO gram is the main feature.
- Everything is read in SPL
- Uses REAR only

DSL v.5.0

- Released in 2005
- More flexible fitting targets than previously
- Family of targets based on type of fitting
- Three target populations:
  - Infants
  - Children
  - Adults
- Takes into account:
  - Type of audiometric measurement including corrections for ABR and ASSR measurements
  - Type of fitting: binaural vs monaural
  - Type of hearing loss: corrections for mixed and conductive hearing losses
  - Enhanced normative data for RECDs with eartip / mould
  - Algorithm improved for more comfortable adult targets and targets for different listening environments.

Differences between NAL-NL2 and DSL v5.0

- Experience
  - DSL v5.0 does not incorporate a correction for gain based on experience with hearing aids
  - NAL-NL2 incorporates adjustments that differ as a function of hearing loss and include an increase for experienced hearing aid users and a decrease for new users

Differences between NAL-NL2 and DSL v5.0

- Gender
  - DSL v5.0 does not include an adjustment for gender
  - NAL-NL2 increases gain by 1 dB for male HA wearers and reduces gain by 1 dB for female wearers

Differences between NAL-NL2 and DSL v5.0

- Binaural fittings
  - DSL v5.0 targets for speech are reduced by 3 dB across input levels for bilateral fittings compared to unilateral fittings
  - NAL-NL2 has a correction for binaural summation of 2 dB at low input levels up to 6 dB at high levels

Differences between NAL-NL2 and DSL v5.0

- Listening in noise
  - DSL v5.0 targets are reduced by 3-5 dB for low-importance frequencies for listening in noise
  - NAL-NL2 does not have corrections for listening in noise

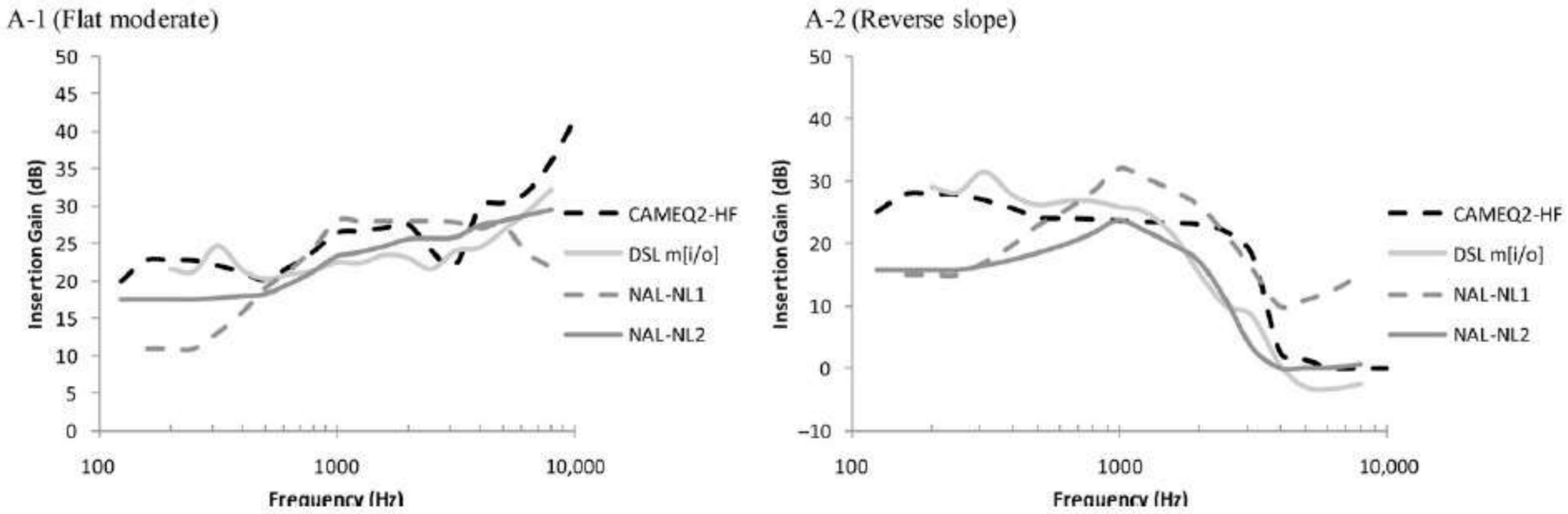
Differences between NAL-NL2 and DSL v5.0

- Correction for air-bone gap
  - DSL v5.0 correction adds 5-9 dB of gain depending on hearing level
  - NAL-NL2 applies prescribed gain for sensorineural component of the hearing loss and then adds 75% of the air-bone gap to this value

Differences between NAL-NL2 and DSL v5.0

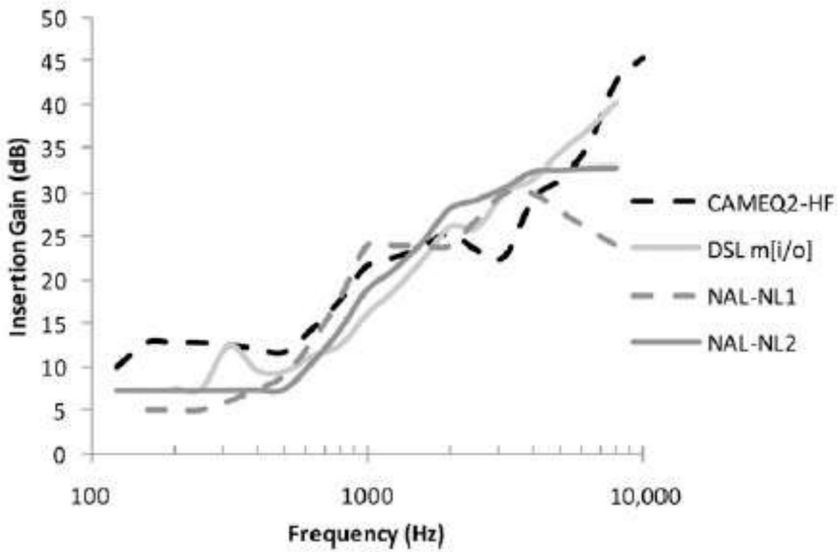
- Loudness discomfort
  - DSL v5.0 alters the prescription of gain and output for high input levels that approximate the loudness discomfort measure
  - NAL-NL2 does not alter gain or output based on patient-specific uncomfortable listening levels (ULLs)

Differences between NAL-NL2 and DSL v5.0

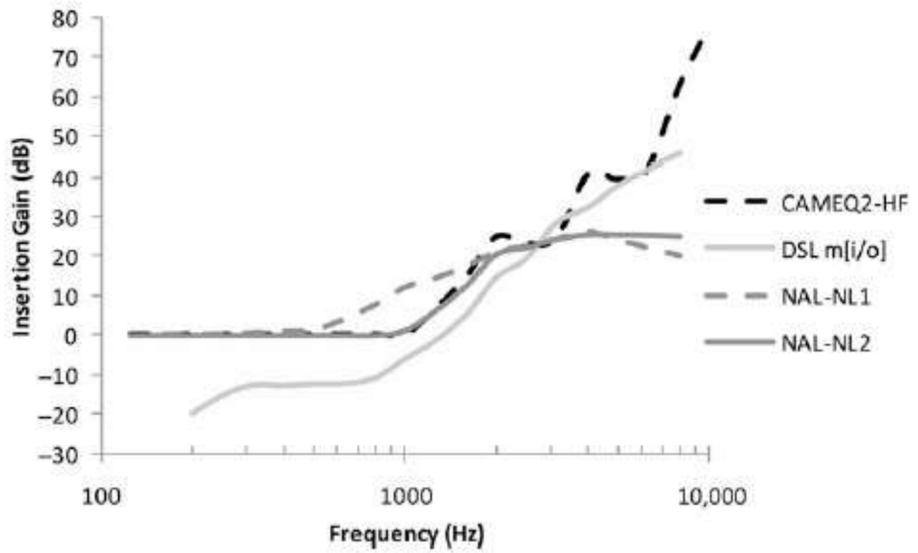


Differences between NAL-NL2 and DSL v5.0

A-3 (Moderately sloping)



A-4 (Steeply sloping)



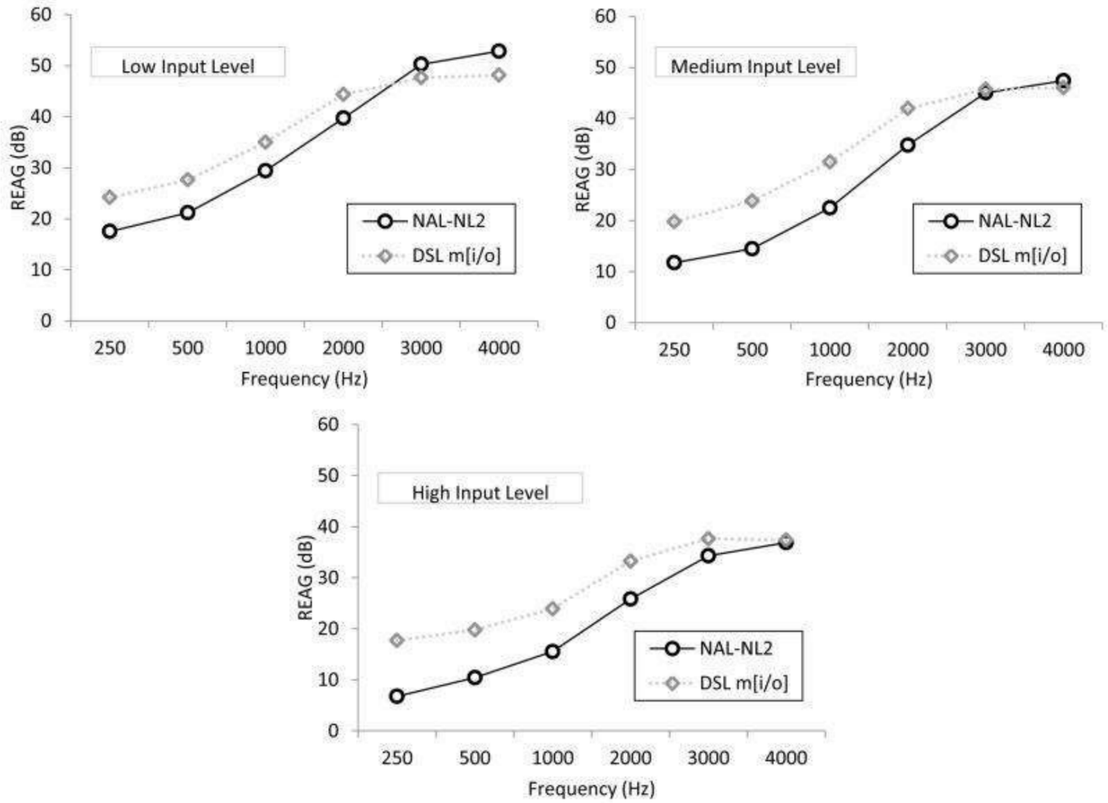
Clinical outcomes for DSL and NAL

- Outcomes from 48 children fitted with NAL-NL1 in Australia and DSL v4.1 in Canada
- Collaborative & double-blind study between NAL and UWO
- Speech perception were good for both prescriptions in quiet & in noise.
- SRTs and consonant scores were similar to normal hearing children
- Parents' and teachers' observations revealed no effect of prescription
- Children's own observations revealed strong preference for NAL-NL1 in real world noisy situations.

Clinical outcomes for DSL and NAL

- More negative comments about problems in noise for DSL 4.1
- More positive comments about loudness comfort for NAL-NL1
- More positive comments about listening to softly spoken speech or speech at a distance with DSL 4.1 than NAL-NL1
- To achieve optimum audibility of soft speech, children need more gain than is prescribed by NAL-NL1
- To achieve listening comfort in noisy places, children need less gain than DSL v4.1

Comparison of DSL and NAL formulae



Johnson, E. E., Hou, S., Dillon, H., Zhang, V., Burns, L., … Flynn, C. (2013). A comparison of NAL and DSL prescriptive methods for paediatric hearing-aid fitting: Predicted speech intelligibility and loudness. *International Journal of Audiology*, *52*(0).

Device-independent fitting strategies

- NAL
- DSL
- Fig-6
- VIOLA
- Camfit

Proprietary fitting strategies

- Found in individual manufacturers’ fitting software

Device-independent vs proprietary fitting strategies

Device independent fitting strategies

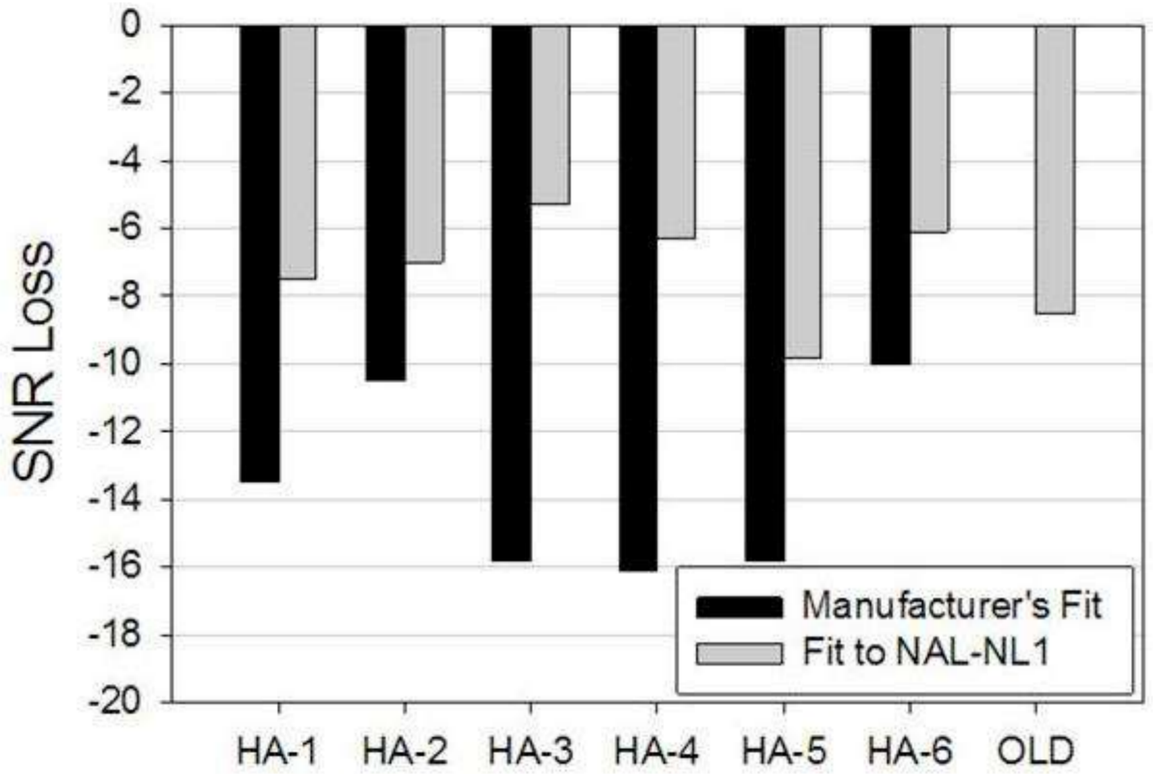
- Prescription formula is not hearing aid dependent
- When entering the audiometric data, the generated target can be applied to any hearing aid
- Usually published by non commercial research groups
- Supported by a stronger evidence base
- Information is out in public domain

Device-independent vs proprietary fitting strategies

Proprietary fitting strategies

- Related to particular circuitry/technology
- After entering the individual patient data, the algorithm prescribes all the signal processing features of the HA
- All hearing aid manufacturers have their own proprietary fitting rules
- Information about these rules are usually protected

Device-independent vs proprietary fitting strategies



http://www.audiologyonline.com/articles/20q-probe-mic-measures-12410