

Derivation of the NAL-NL2 prescription procedure

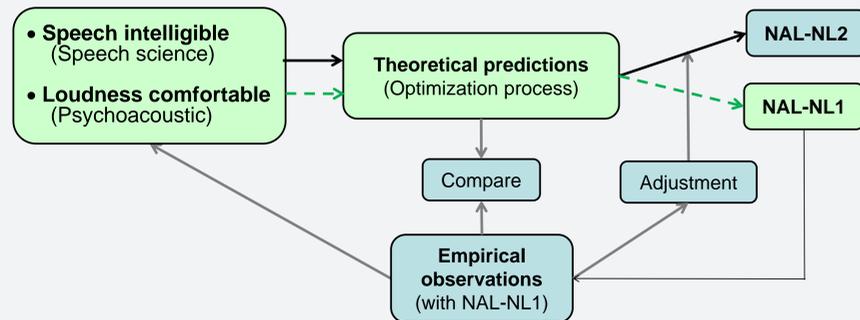
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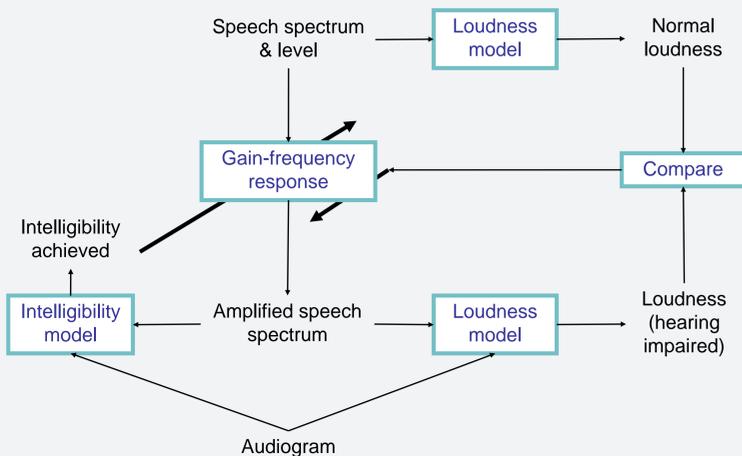
Background

The first procedure from NAL for prescribing nonlinear gain (NAL-NL1) was introduced in 1999. Recently, NAL-NL2 was introduced. NAL-NL2 maintains the same aim as NAL-NL1, which is to make speech intelligible and overall loudness comfortable. The theoretical component of NAL-NL2 is further derived using the same adaptive process that was used to derive NAL-NL1. The revisions leading to NAL-NL2 were largely directed by empirical data collected during the past decade with NAL-NL1 (see full line path below).

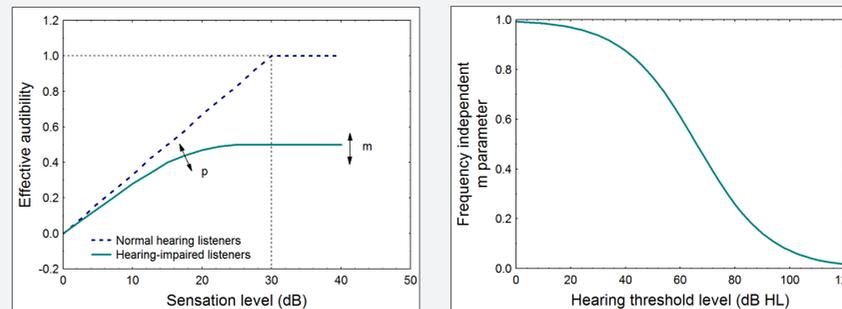


Optimization procedure

The adaptive process used to determine the optimum gain-frequency response for different audiograms and speech input is outlined below. Two modifications were made to this process before deriving NAL-NL2.

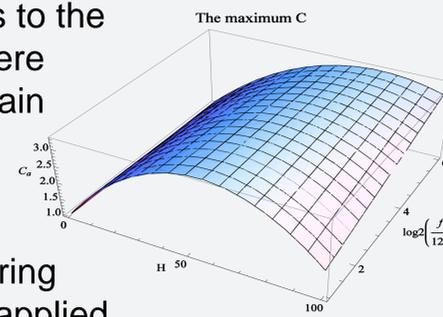


1) New models were introduced; A more recent loudness model¹ was used, and a new effective audibility factor (see below) was introduced in the speech intelligibility model.



2) Constraints to the selected gain were applied; No compression for speech < 50 dB SPL, and no gain at very low (<50 Hz) or at very high (>16 kHz) frequencies.

The optimization procedure was run twice using different important functions in the intelligibility model to derive gain for tonal vs non-tonal languages. Subsequently, constraints to the compression ratio (CR) were applied to the optimized gain values. The limit on the CR depended on frequency, compression speed, and degree of hearing loss². The maximum CR applied in the case of fast compression is shown here.



Multi-dimensional equation

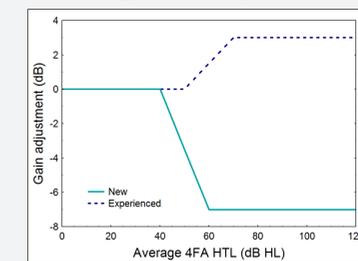
A neural network, with one hidden layer, used HTLs and speech level as input and the optimized gain values as output to derive the theoretical NAL-NL2 formula.

1. Moore BC, Glasberg BR. (2004) A revised model of loudness perception applied to cochlear hearing loss. *Hear Res*, 188:70-88.
 2. Keidser G, Dillon H, Dyrland O, Carter L, Hartley D. (2007) Preferred low- and high-frequency compression ratios among hearing aid users with moderately severe to profound hearing loss. *JAAA*, 18:17-33.

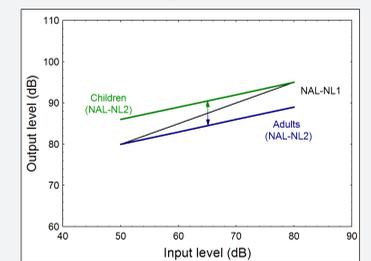
Adjustments

Empirical data suggested that different populations preferred different amount of gain. Consequently, the NAL-NL2 formula was adjusted to prescribe gain dependent on:

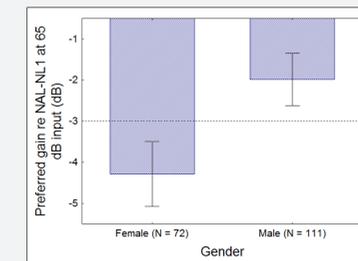
Hearing aid experience³



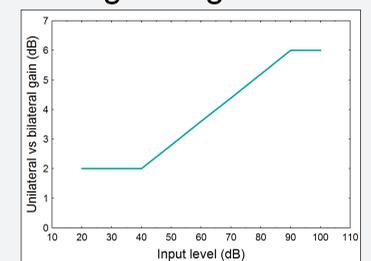
Age^{3,4,5}



Gender⁶

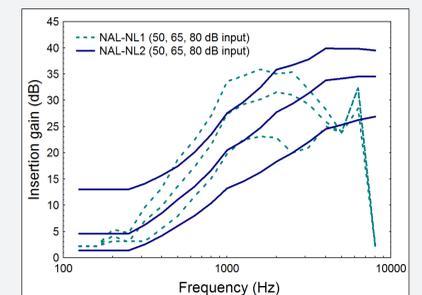


Fitting configuration



Resulting prescription

Supported by empirical data, NAL-NL2 tends to prescribe relatively more gain across low and high frequencies and less gain across mid frequencies than NAL-NL1 (see example for a moderate, gently sloping hearing loss to the right). NAL-NL2 further takes the profile of the hearing aid user, language, and compressor speed into consideration.



3. Keidser G, O'Brien A, Carter L, McLelland M, Yeend I. (2008) Variation in preferred gain with experience for hearing aid users. *IJA*, 47:621-35.
 4. Scollie S, Ching T, Seewald R, Dillon H, Britton L et al. (2010) Evaluation of the NAL-NL1 and DSL v4.1 prescriptions for children: Preference in real world use. *IJA* 49:S49-S63.
 5. Smeds K, Keidser G, Zakis J, Dillon H, Leijon et al. (2006) Preferred overall loudness II: Listening through hearing aids in field and laboratory tests. *IJA* 45:12-25.
 6. Keidser G, Dillon H. (2006) What's new in prescriptive fittings Down Under? In Palmer CV, Seewald R (Eds) *Hearing Care for Adults*. Phonak AG, Stafa, Switzerland, pp 133-42.