Fitting rationales
– Advanced

When audiology first developed, clinicians relied on their own personal criteria, usually based on experience with a particular hearing instrument model, to fit hearing instruments. It was difficult to teach this method to new clinicians or to make this method applicable from one clinic to the next. Clinicians soon realised that there needed to be a systematic prescriptive approach that could be used across the field of audiology.

Linear fitting rationales

Ideally, a fitting method could simply mirror the audiogram. For example, if there is a hearing loss of 30dB in the low frequencies and 60dB in the high frequencies, the mirror image fitting method would provide 30dB of gain for the low frequencies and 60dB of gain for the high frequencies. In this way, all of the patient's thresholds could be made to equal 0dB (i.e. normal hearing).

However, while this might work for a conductive hearing loss, it is not recommended for a sensorineural hearing loss because the loudness tolerance does not grow with the hearing loss. For example, if there is a 70dB high-frequency input and the mirror image fitting method were to apply 60dB of gain, this would equate to 130dB of output (i.e. well beyond the patient's loudness tolerance level).

Lybarger's half gain rule

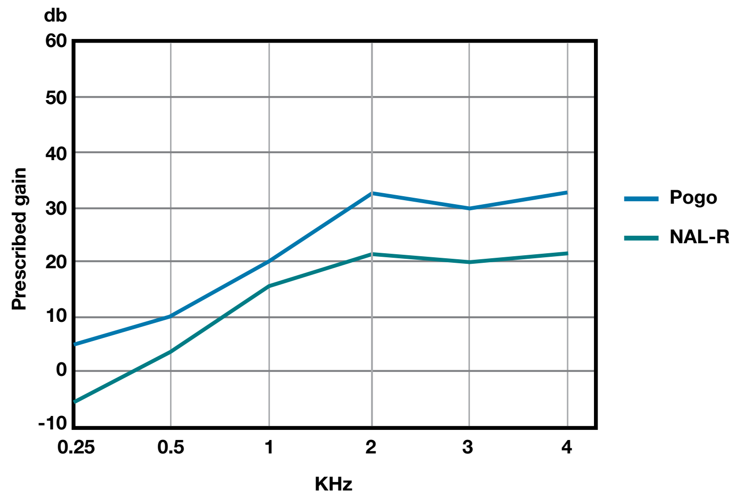
Lybarger fit patients with a sensorineural hearing loss with full gain hearing instruments. These instruments would apply the mirror image fitting method. So for a 40dB hearing loss, they would apply 40dB of gain. He then asked patients to set the volume control on these instruments where it sounded comfortable –they usually turned the volume halfway up. This meant having enough gain for both soft and loud sounds, while still being able to tolerate the output. So this method came to be known as the 'half gain rule'. The half gain method is the basis for subsequent linear fitting methods including POGO and NAL.

POGO

The prescription of gain and output (POGO) fitting rationale was developed by McCandless and Lyregaard in 1983. It calls for half gain at each audiometric frequency, 10dB less than half gain at 250Hz and 5dB less than half gain at 500Hz. More gain is given to the high frequencies because these contribute to speech intelligibility. Less gain is given to the low frequencies to reduce the risk of an upwards spread of masking.

POGO also recommends 10dB of reserve gain and that the maximum power output (MPO) of the hearing instrument is set to the patient's uncomfortable listening level (UCL). One limitation of POGO is that it is for sensorineural hearing loss only and does not provide appropriate targets for conductive hearing loss.

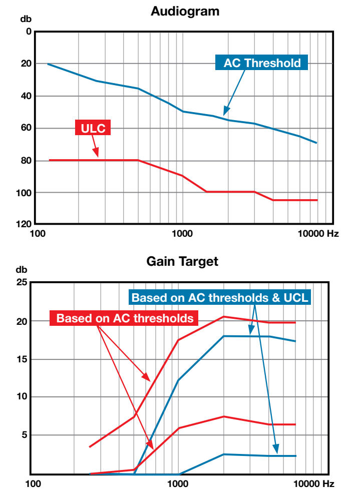
Comparison of POGO and NAL-R



Audiogram+ continued

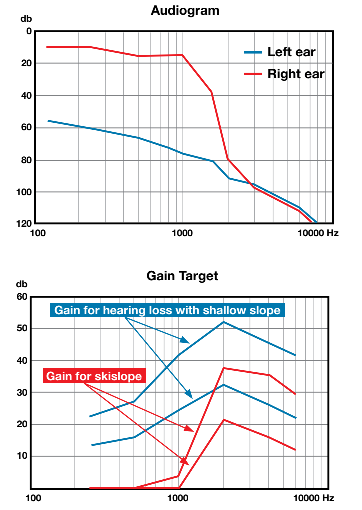
Uncomfortable listening levels (UCLs) are used to calculate targets in order to avoid **excessive gain**.

Uncomfortable listening levels



For **ski-slope hearing loss**, generally less amplification is prescribed in the high frequencies than with NAL-NL1. This is done in order to avoid over-stimulation of a cochlear dead region (a region in the cochlea where there are not enough undamaged hair cells to respond to a signal) and having upwards spread of stimulation interfere with discrimination.

Ski-slope hearing loss



Related information

Also refer to the section in this manual on **Psychoacoustics**, **Pure tone audiometry**, **Anatomy and physiology**, **Hearing instruments and hearing loss**, **Compression**, **Pediatric hearing aid fitting**.

Linear fitting rationales continued

NAL

Today, NAL-R is one of the most popular linear fitting methods. It can be used for both conductive and sensorineural hearing loss. NAL is named after its creators at the National Acoustics Laboratories in Australia. The goal of the NAL fitting rationale (and all NAL fitting rationales since) is to amplify unaided adjacent speech frequencies so that they sound equally loud at a comfortable listening level. This is known as loudness normalisation. The original NAL formula did not accomplish this and has since been revised to NAL-R.

NAL-R provides about 10dB more gain at 500Hz and 3-4dB more gain at 3000Hz and 4000Hz than the original NAL. NAL-R has taken over popularity from POGO as it prescribes less high-frequency gain than POGO for steeply sloping hearing losses. In general NAL-R provides slightly less than half gain.

The calculation for NAL-R is complex and based on three elements:

- A constant value based on half gain of the pure tone average (PTA). This is the average of the thresholds at 500Hz, 1000Hz and 2000Hz.
- Thresholds at each audiometric frequency multiplied by 0.31.
- Different gain values at each frequency required to make various speech frequency regions sound equally loud. Low and high frequencies are given slightly less gain than the mid frequencies.

NAL-RP is based on NAL-R but has special considerations for those with severe-profound hearing loss. Research has shown that when the PTA is greater than 60dB, patients prefer 10dB more than half gain. If the hearing thresholds at 200Hz are more than 90dB, patients prefer more low-frequency gain and less high-frequency gain than those with a flat hearing loss. These considerations are included in the NAL-RP fitting rationale. This means that hearing instruments programmed with NAL-RP amplify less at frequencies with severe-profound hearing loss and more at frequencies with better hearing.

Non-linear fitting rationales

NAL-NL1

There is a non-linear version of the NAL-R fitting rationale, called NAL-NL1 (i.e. non-linear version one). While the previous rules are designed for linear hearing instruments, or hearing instruments that provide linear gain, NAL-NL1 is designed for hearing instruments with non-linear gain, or hearing instruments with compression.

The goal with NAL-NL1 is to make various speech frequency regions sound equally loud. However, while the linear fitting rationales provide a target for just one input, non-linear fitting rationales provide targets for several inputs—soft sounds, medium sounds and loud sounds. NAL-NL1 includes the special considerations for severe-profound hearing loss from NAL-RP so the targets for NAL-RP and NAL-NL1 look similar for those with this degree of hearing loss.

DSL

NAL-NL1 and desired sensation level (DSL) are currently the two most popular fitting rationales available. The DSL method was developed by the University of Western Ontario in Canada, specifically for pediatric patients. The goal of the DSL fitting method is to make all sounds, not just speech sounds, contribute equally to loudness. This is known as loudness equalisation. The philosophy behind this approach is that children need to learn about their environment in addition to learning speech and so all sounds need to be accessible. Other differences between NAL-NL1 and DSL include the way that targets are reported. For example, with NAL-NL1, targets are given in terms of gain. With DSL, targets are presented in terms of output. Output at the level of the eardrum or the sound pressure level is seen as the important factor, while gain is seen as way of reaching the desired output.

Comparison of NAL and DAL

In terms of gain

- For a flat hearing loss, NAL-NL1 prescribes less gain than DSL across all the frequencies with the greatest difference occurring in the low frequencies.
- For a reverse hearing loss, NAL-NL1 prescribes less low-frequency gain than DSL and more high-frequency gain than DSL.

In terms of output

- For a flat hearing loss, DSL calls for more low-frequency output than NAL-NL1. The differences between the output for the two fitting formulas is most pronounced at 500Hz and 4000Hz, particularly for soft (50dB) input levels.
- For a sloping hearing loss, DSL calls for more output than NAL-NL1 with the most pronounced difference at 500Hz and 4000Hz.

Jargon Buster

Conductive hearing loss occurs when there is a problem transmitting sound waves through the middle ear or outer ear.

A **sloping hearing loss** is a hearing loss that becomes gradually worse moving from low frequencies to high frequencies.

A **flat hearing loss** refers to a hearing loss that is relatively stable across the frequencies 250-800Hz and does not vary more than 5-10dB from frequency to frequency.

A **reverse hearing loss** is a hearing loss where hearing thresholds are reduced in the low frequencies and improved in the high frequencies.

The **pure tone average (PTA)** is the average of hearing thresholds at 500, 1000 and 2000Hz.

Loudness normalisation is when all speech sounds are made to contribute equally to loudness.

Loudness equalisation is when all sounds, not just speech sounds, contribute equally to loudness.

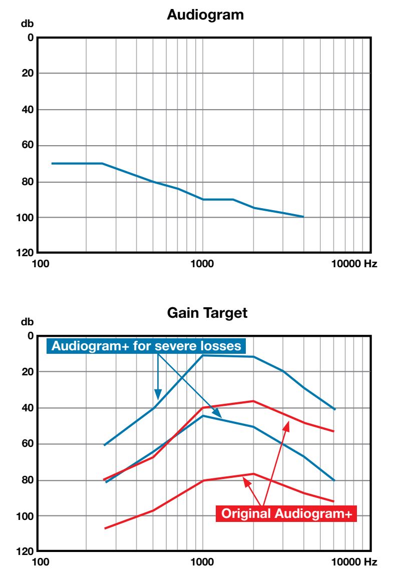
dB HL is the abbreviation for decibels hearing level. This is the decibel scale that allows the use of straight (linear) lines on the audiogram to represent the non-linear function of the cochlea.

Audiogram+

Audiogram+ is ReSound's own fitting rationale. Most hearing instrument manufacturers have their own fitting rationales, designed to work with their own products. Audiogram+ is a loudness normalisation formula similar to NAL-NL1 with a few adjustments.

For **severe hearing losses**, Audiogram+ increases the overall target gains for 50dB and 80dB inputs (particularly in the low frequencies) and the compression ratios are decreased for hearing losses above 50dB HL. This is similar to NAL-NL1.

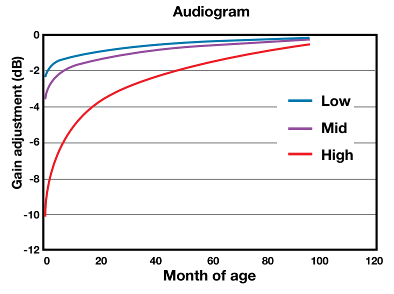
Severe hearing loss



For **age-related gain**, infants have smaller ears than adults. This means that less output is required from the hearing instrument to achieve a certain sound pressure level in the aided ear canal. DSL also features this consideration.

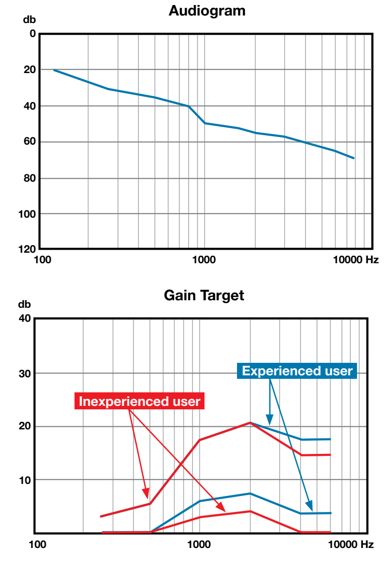
It is important to note that much larger adjustments are made for very young children, when the ears are smallest, than for older children.

Age related gain



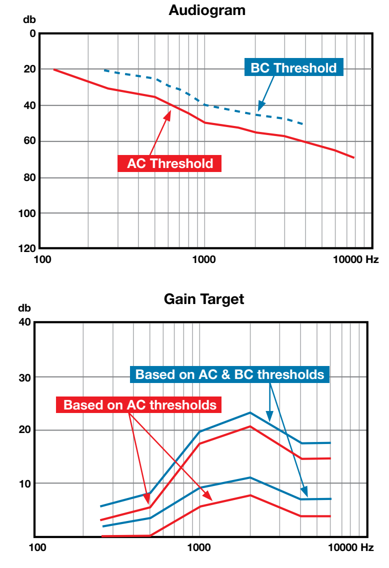
For **inexperienced hearing instrument patients**, Audiogram+ prescribes less gain for the 80dB input at mid and high frequencies and less gain for soft inputs at high frequencies. This results in more compression and maximises listening comfort for the patient.

For inexperienced hearing instrument patients



Conductive hearing loss often attenuates all sounds equally. However, research shows that patients with a conductive hearing loss do not want full compensation for the air-bone gap. Instead, they tend to prefer about a third to a quarter of the air-bone gap for loud inputs and less for soft inputs (Smeds & Leijon, 2000).

Conductive hearing loss



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