The Prescriptive Hearing Aid Fitting Formula Landscape

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Starkey

Hear better. Live better.

The Prescriptive Hearing Aid Fitting Formula Landscape

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Learning Outcomes

As a result of this course, participants will be able to:

List at least three different goals of hearing aid fitting formulas.

Identify the differences between generic and proprietary hearing aid fitting rationales.

Describe the features of at least three hearing aid fitting formulas and the patient populations for whom they are intended.

Agenda

History of Fitting Formulas

Independent/Generic Formulas

Proprietary Formulas

Clinical Considerations

“The goal in hearing aid selection and fitting is to provide comfortable hearing instruments that will meet the lifestyle needs of the patient while easing the patient’s communication difficulties and maximizing performance in different listening environments.”

J. L Northern, 2011

Hearing Aid Selection & Fitting

Product Family

Technology Tier

Style

Matrix

Coupling

Venting

Advanced Features

Hearing Test Results
(AC, BC, MCL, UCL)

Preferences

Lifestyle

Unique Listening Needs & Goals

Expectations

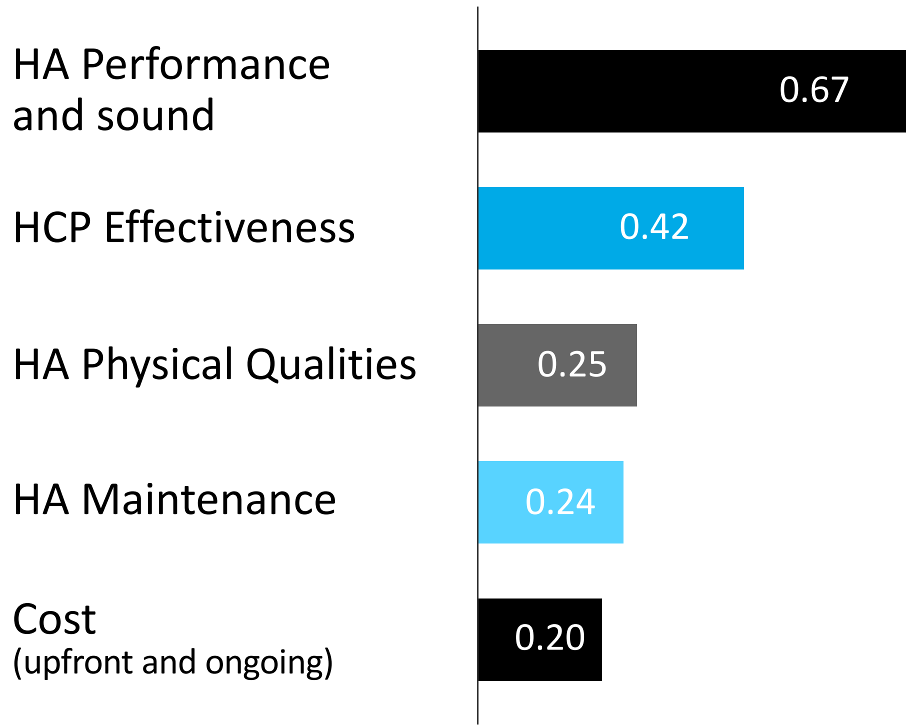
Performance in Quiet & Noise

Previous Experiences

Cognition/Memory Screening

Physical Dexterity

Hearing Aid Satisfaction



MarkeTrak 10 / Hearing Industries Association, 2019

Top Drivers of Hearing Aid Performance and Sound

Natural Sounding
Rich and Clear

Minimize background noise

Comfort for loud sounds

Ability to tell direction

MarkeTrak 10 / Hearing Industries Association, 2019

Goals of Hearing Aid Fitting Rationales

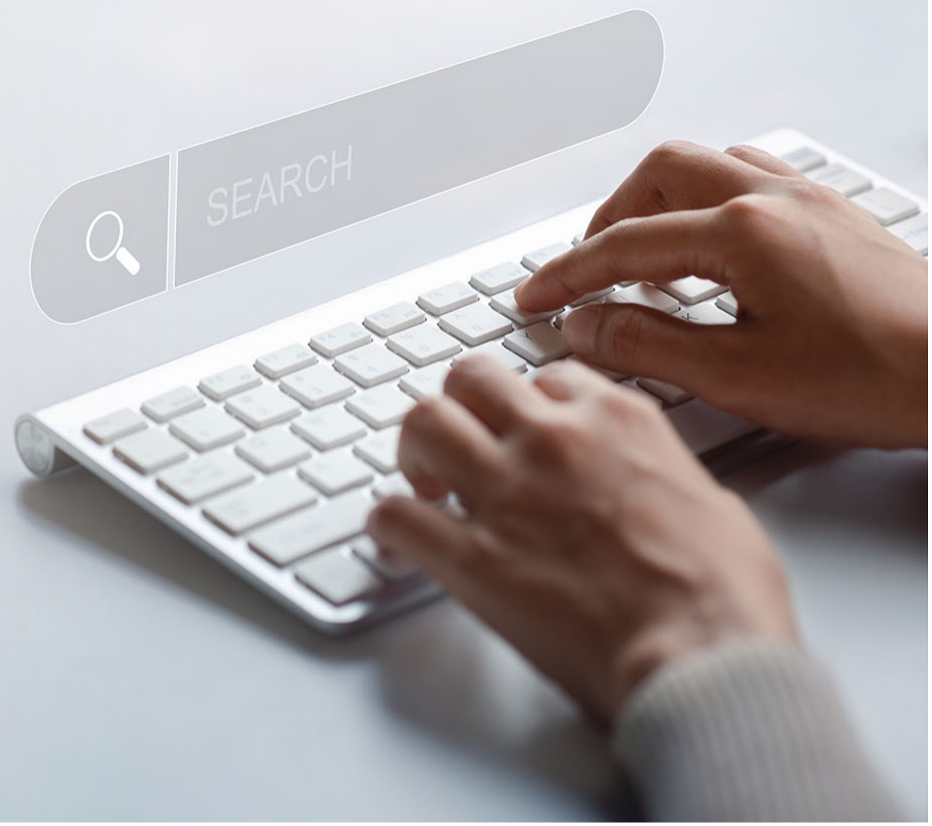
- Minimize initial **rejection**
- Maximize **speech intelligibility**
- Maximize usage of residual **dynamic range**
- Maximize **patient comfort**
- Maximize **sound quality**
- Maximize patient **satisfaction**

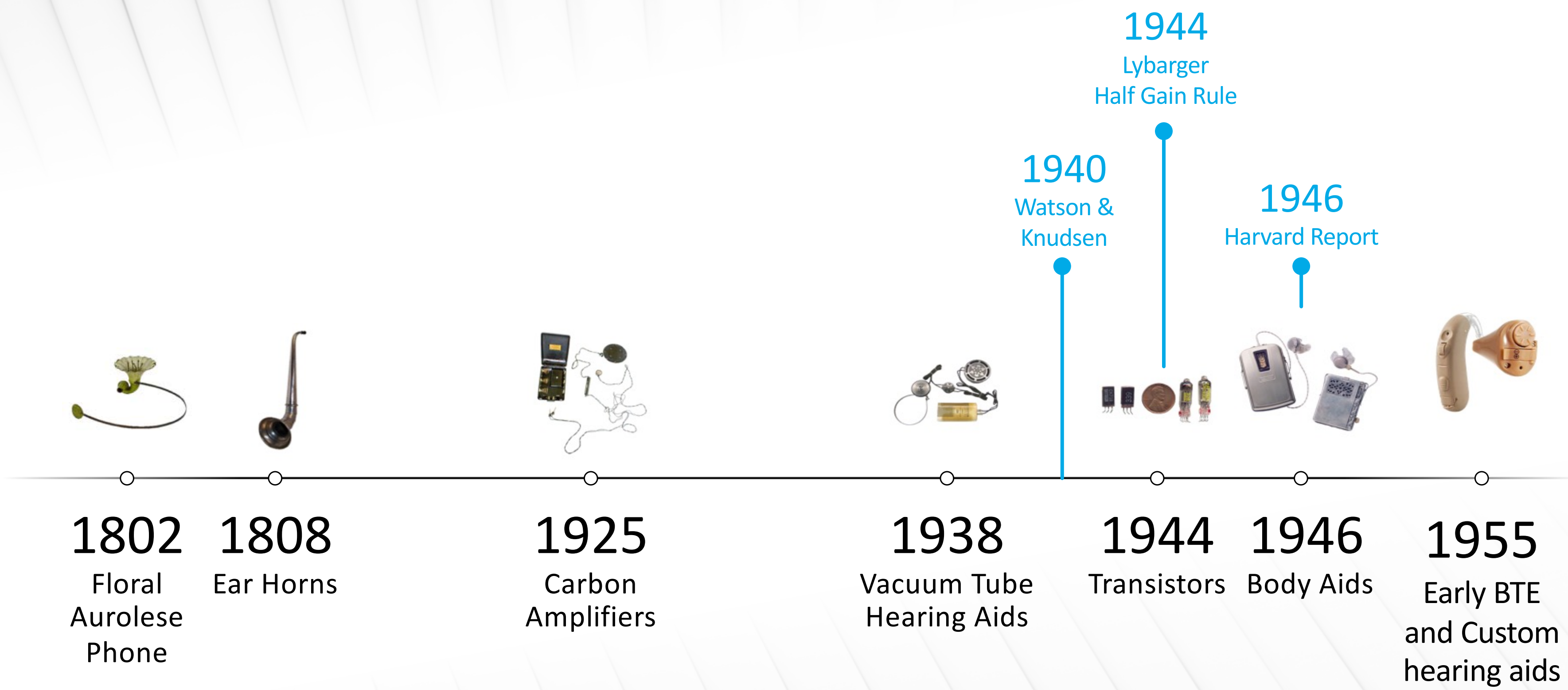
Fitting Formulas

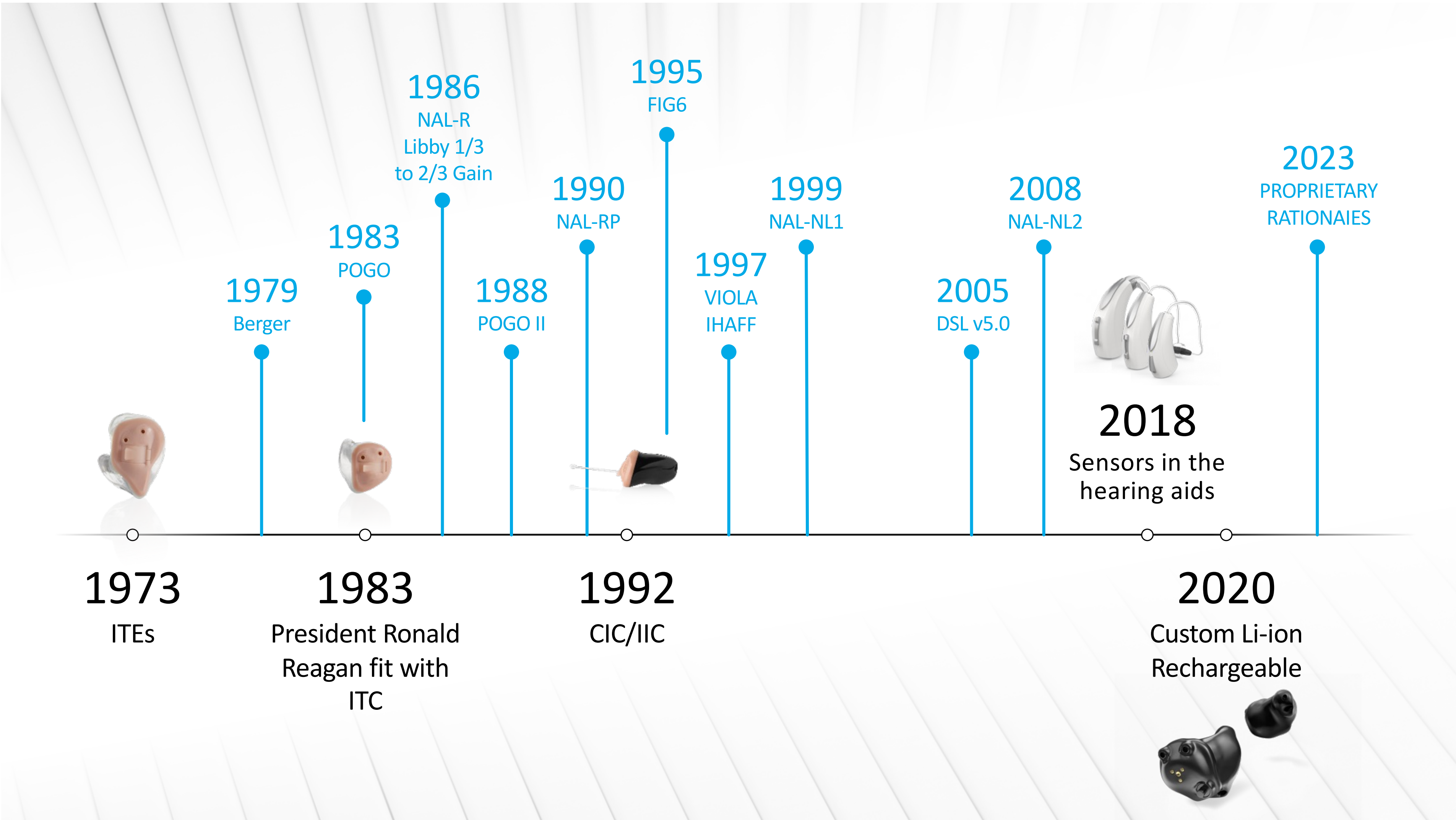
- POGO
- NAL-NL2 Tonal
- Manufacturer Proprietary
- Half Gain Rule
- DSL v5.0 Pediatric
- NAL-RP
- FIG6
- NAL-R
- BERGER
- VIOLA
- NAL-NL2 Pediatric
- DSL [i/o]
- Pascoe
- DSL v5.0 Adult
- LIBBY 1/3
- NAL-NL1
- NAL-NL2
- POGO II

Hearing Aid Fitting
"About 27,000,000"

Hearing Aid Fitting Formula
"About 5,740,000"




1944
Lybarger
Half Gain Rule
1940
Watson &
Knudsen
1946
Harvard Report
1802
Floral
Aurolese
Phone
1808
Ear Horns
1925
Carbon
Amplifiers
1938
Vacuum Tube
Hearing Aids
1944
Transistors
1946
Body Aids
1955
Early BTE
and Custom
hearing aids


1973
ITEs
1979
Berger
1983
POGO
1983
President Ronald Reagan fit with ITC
1986
NAL-R
Libby 1/3 to 2/3 Gain
1988
POGO II
1990
NAL-RP
1992
CIC/IIC
1995
FIG6
1997
VIOLA
IHAFF
1999
NAL-NL1
2005
DSL v5.0
2008
NAL-NL2
2018
Sensors in the hearing aids
2020
Custom Li-ion Rechargeable
2023
PROPRIETARY RATIONAIES

1
9
4
0

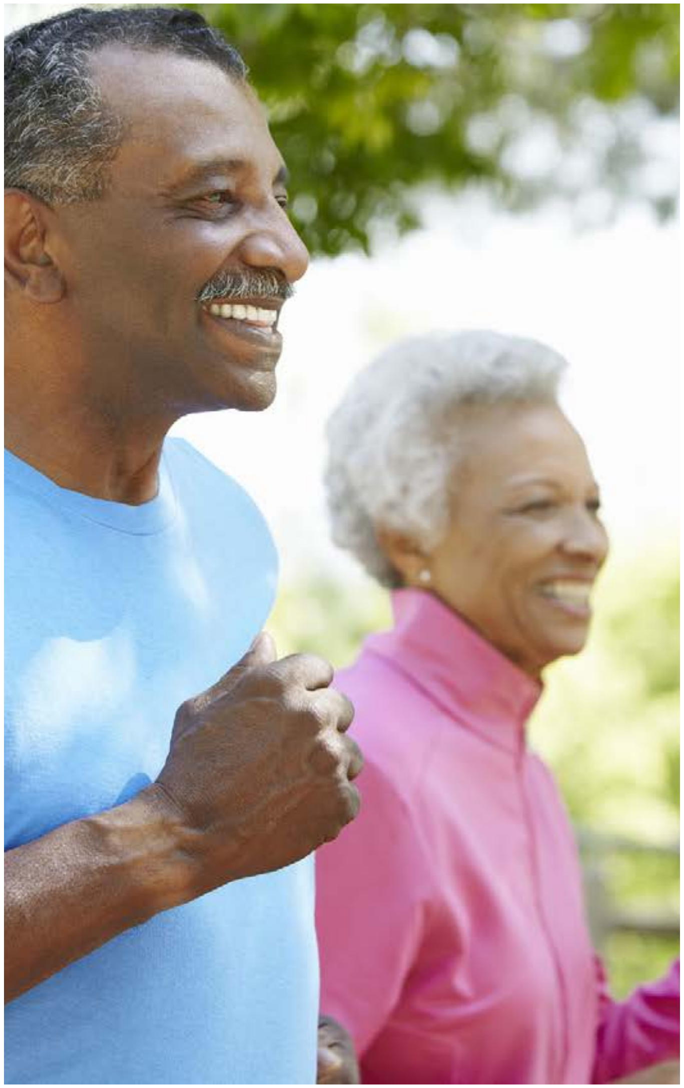
Watson and Knudsen

Selective amplification

Frequency response specific to degree of hearing loss and audiometric configuration

Suprathreshold method for determining required gain and frequency response based on the patient’s most comfortable loudness (MCL) levels across frequencies

First prescriptive fitting formula



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Harvard Report

Davis, et al.

Common frequency response

Most patients performed best with the same frequency response

Flat or 6dB/octave rising response between 300 and 4000 Hz

Primary objective of hearing aid evaluations was the “intelligibility of speech” using word tests

1
9
4
6

Comparative Approach

Patient is tested with several hearing aids using a variety of speech recognition tasks

Hearing aids could be differentiated from one another if the word recognition scores differed by 8% or more

Primary method for choosing hearing aids until the early 1980s

1975

Pascoe (1975)

Frequency-gain characteristics of hearing aids are important for optimizing speech intelligibility with sensorineural hearing loss

1978

Thornton & Raffin (1978)

Northwestern University (NU)-6 word recognition task had very poor **test-retest reliability which could impact the ability to identify differences between hearing aids**

1980

Studebaker & Hochberg (1980)

"Thirty years of **extensive research have failed to demonstrate that hearing aids can be chosen reliably or validly by [the comparative] method in a reasonable period of time.**"

1983

Walden, et al. (1983)

A **comparative procedure was not valuable unless hearing aids with very dissimilar frequency responses were being tested** - unlikely in clinical practice

"Real ear measures came on the scene and audiologists began to appreciate the difference between 2cc coupler output and measurements in the real ear along with the impact of earmolds on the hearing aid response" (Killion, 1981)

Today

DSL v5.0 Adult

NAL-RP

BERGER

NAL-NL2

DSL v5.0 Pediatric

Manufacturer Proprietary

NAL-R

NAL-NL1

NAL-NL2 Pediatric

Prescriptive Fitting Formulas

1

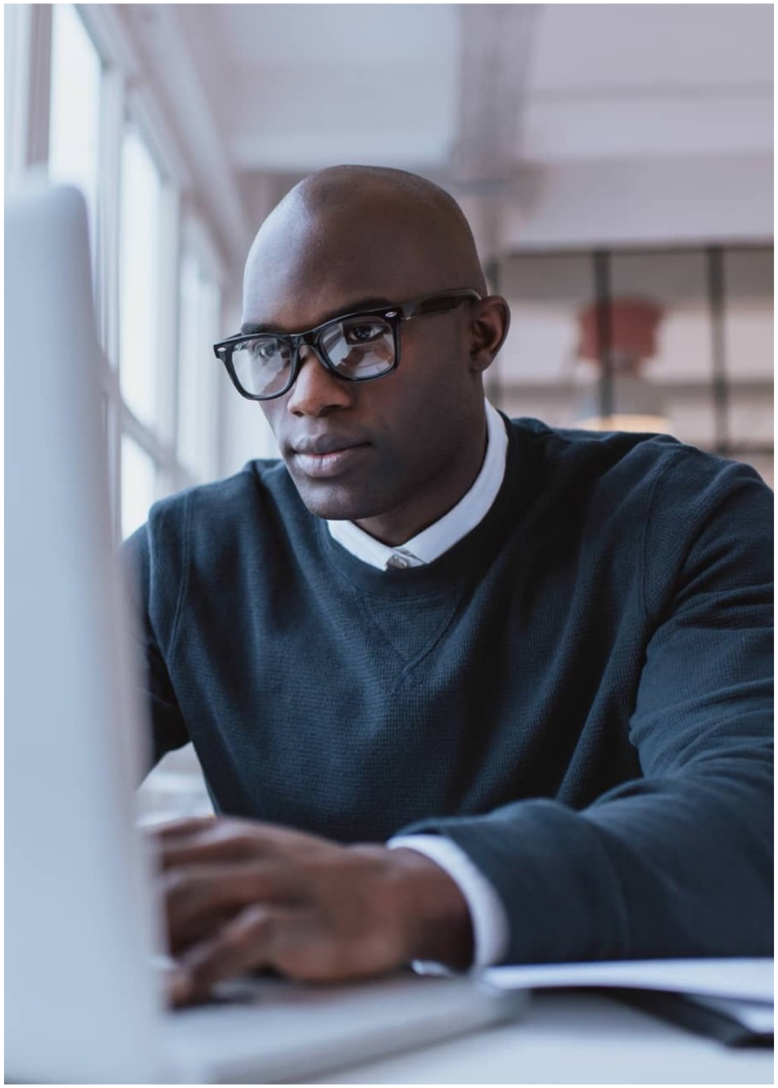
Theoretical Rationale

2

Amount and Type of Audiometric Information

3

Type of Signal Processing



Theoretical Rationales

LOUDNESS EQUALIZATION

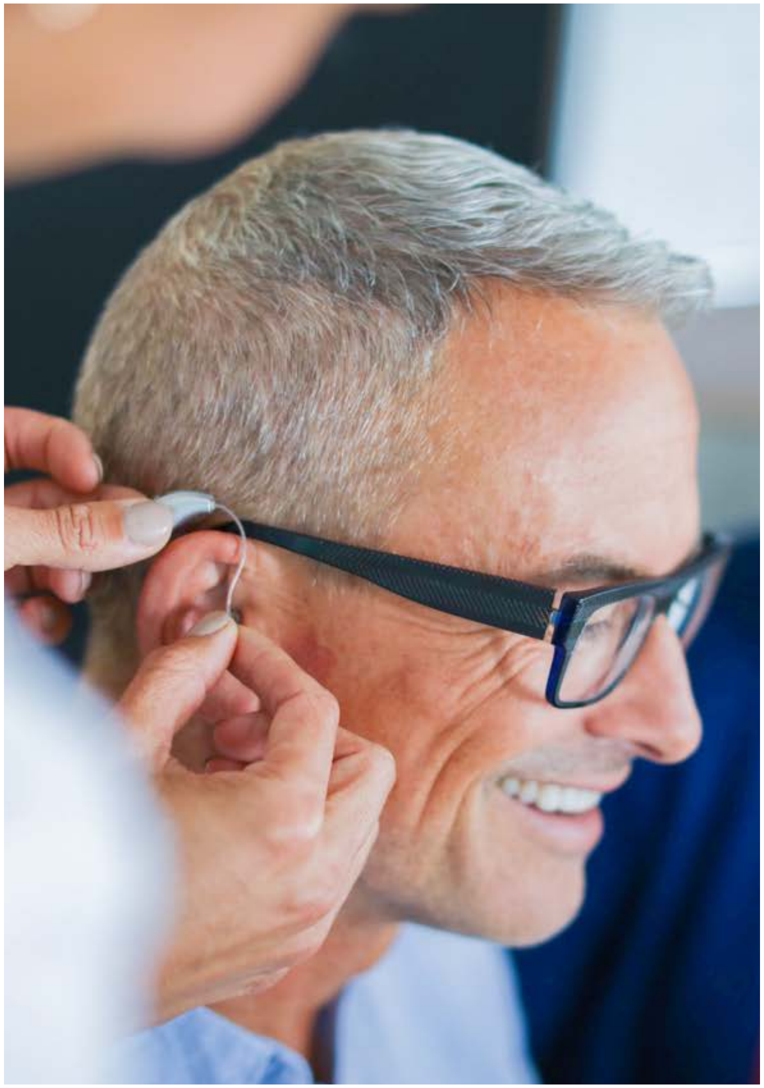
Loudness across frequency bands is equalized so all are perceived as equally loud

Patient should **perceive overall speech levels similarly to a person with normal hearing**

LOUDNESS NORMALIZATION

Patient should **judge soft, normal and loud sounds like someone with normal hearing**

Maintain normal relative loudness across frequency bands but with **lower frequencies perceived louder - vowels are more intense than consonants**



Amount and Type of Audiometric Information

AUDIOMETRIC INFORMATION

Hearing thresholds (AC, BC)

Transducer (Insert earphones, TDH, Sound field)

UCL / LDL

MCL

Hearing Loss Configuration

Type of
Signal Processing

LINEAR

Gain fixed across input levels

Gain varies as a function of frequency

A single gain target is produced

NON-LINEAR

Gain varies as a function of frequency and input level

Developed for use with compression hearing instruments to keep sounds within the user’s dynamic range

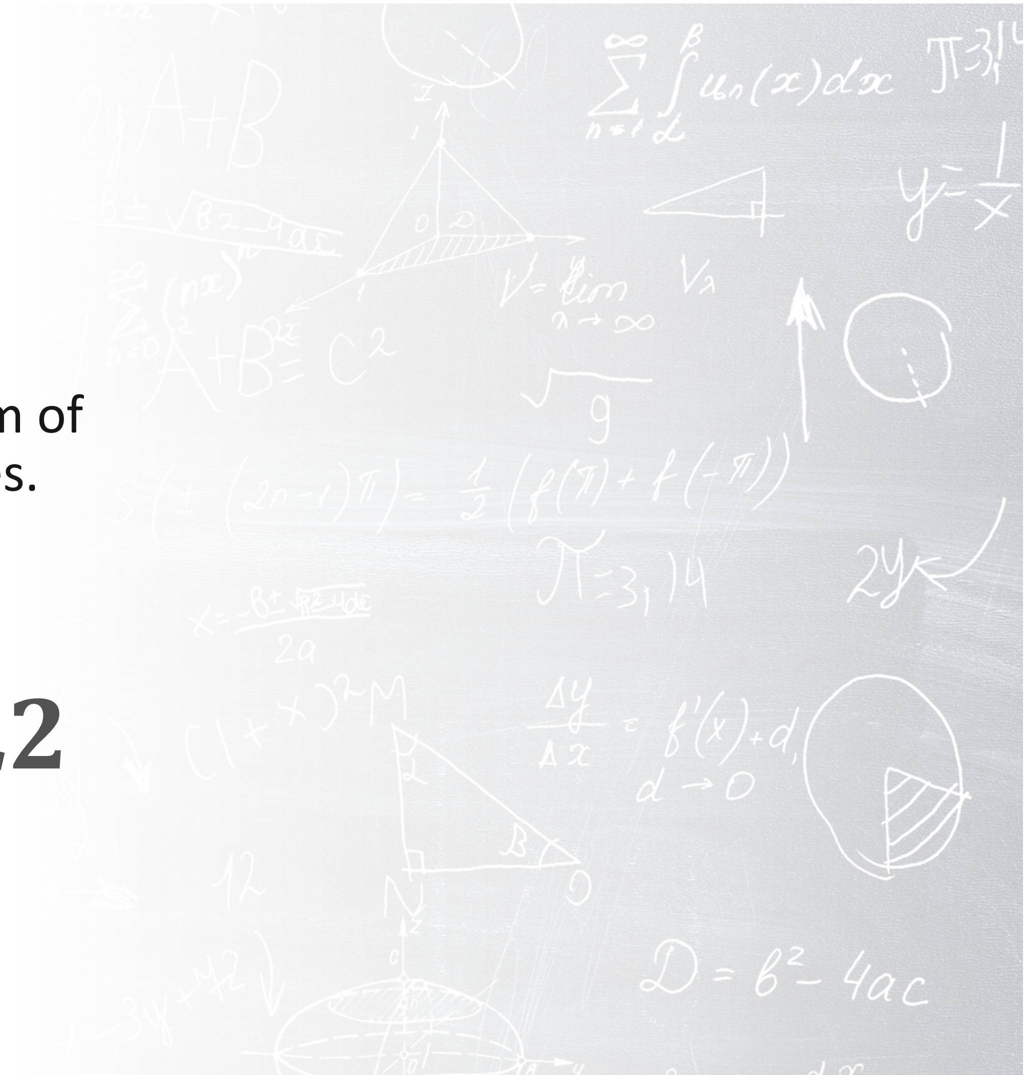
Multiple gain targets are produced

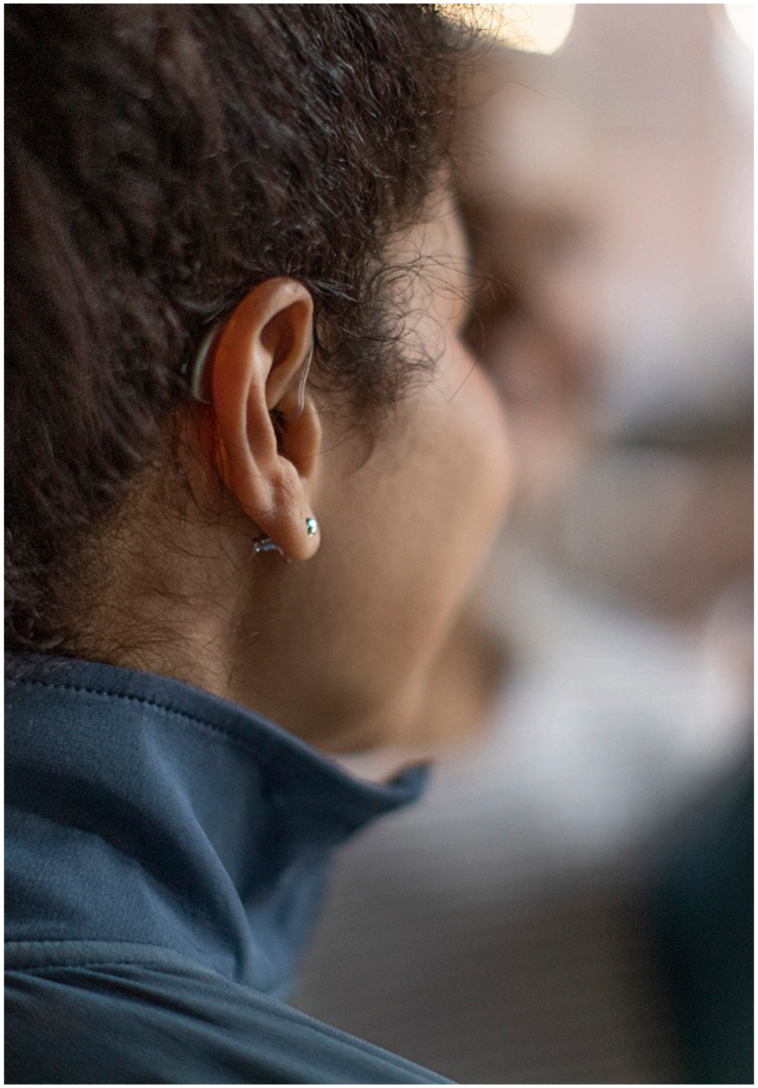
Formula Fun Fact

PYTHAGOREAN THEOREM

The square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides.

$$\boldsymbol{a^2 + b^2 = c^2}$$

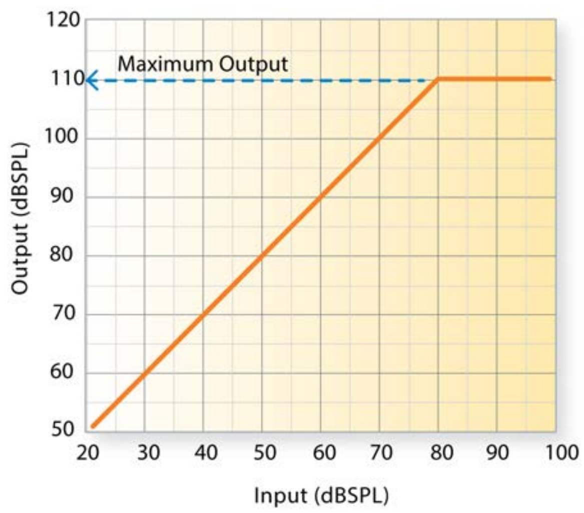




Independent/Generic Fitting Formulas

Linear Fitting Formulas

One frequency/gain target is produced



Half Gain Rule

Berger

POGO

Libby 1/3

NAL-R & NAL RP

DSL v5.0

1
9
4
4

Half Gain Rule

Lybarger

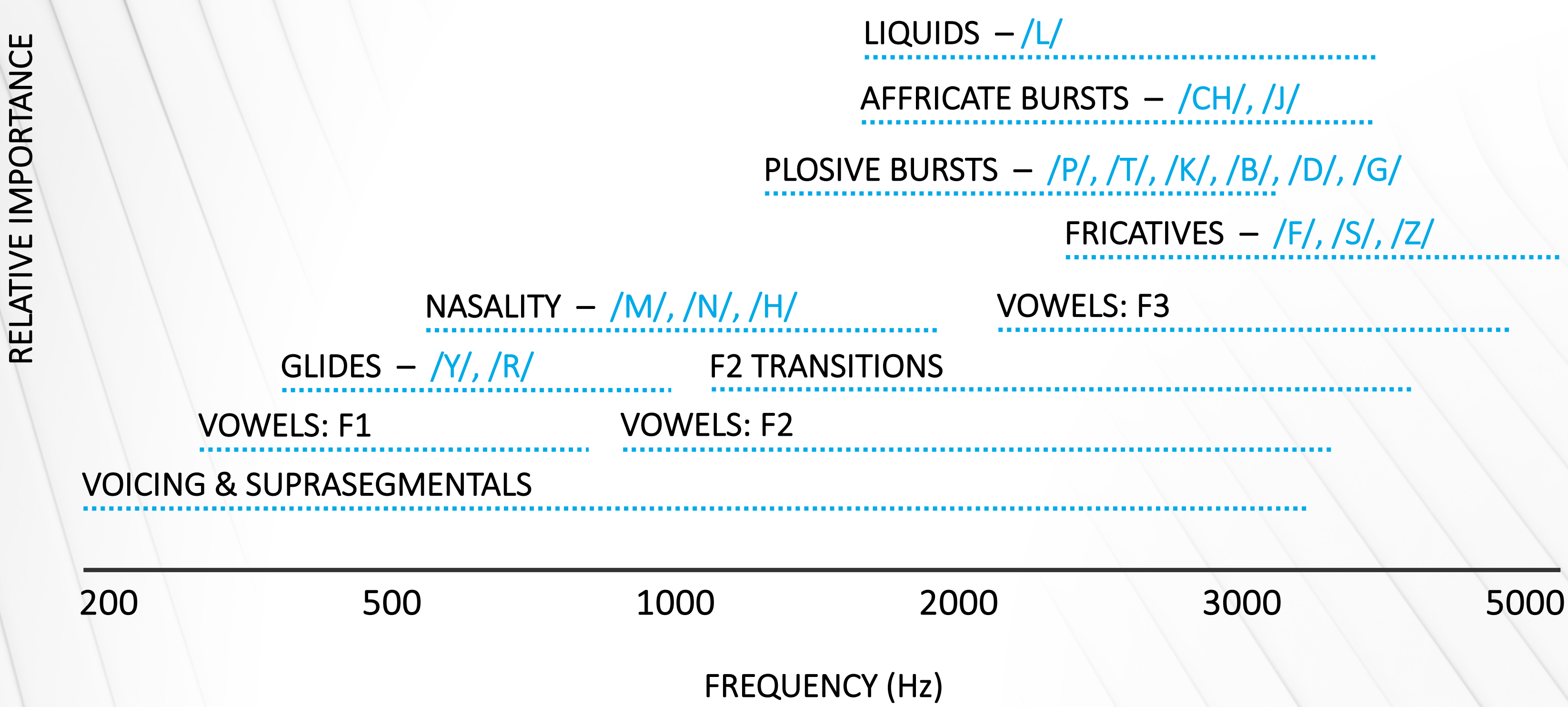
Aided thresholds improved by ***half the degree of hearing loss***

Average ***conversational speech will be amplified to the middle of the listener's dynamic range***

Less than half-gain is provided for the very lowest frequency to ***reduce the upward spread of masking***

Basis for subsequent linear fitting methods

Phonemic Classification



1
9
7
9

Berger et al.

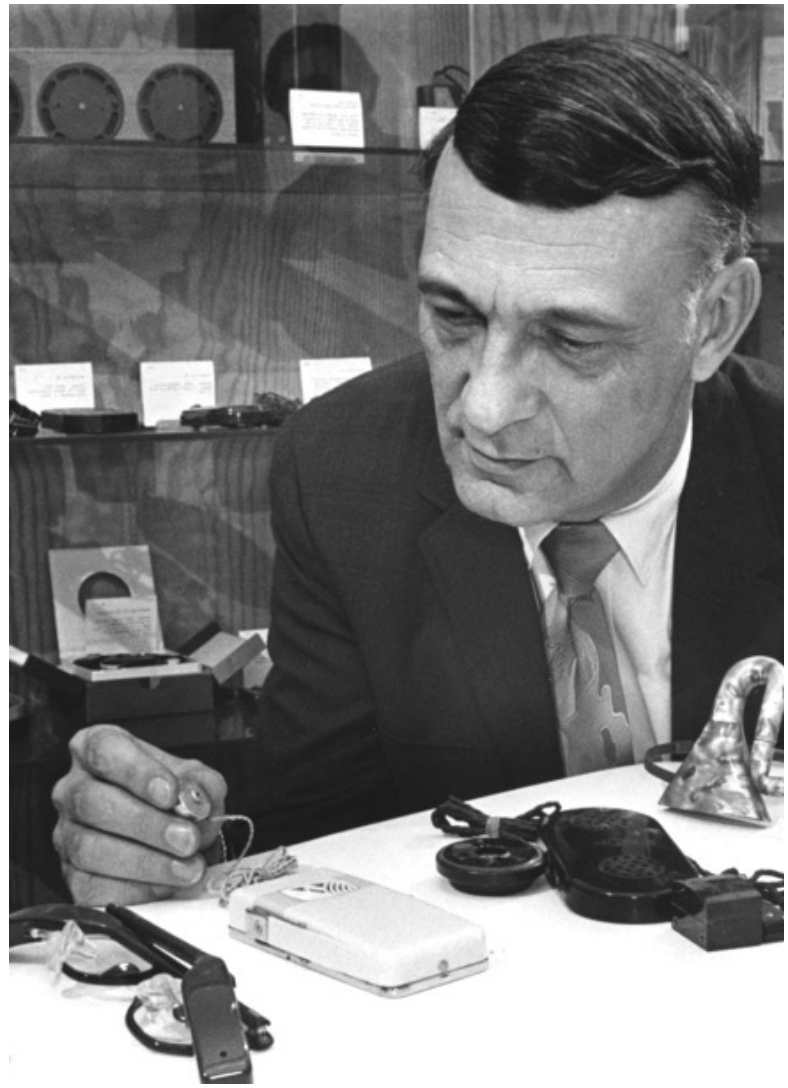
More than half gain provided at 1000 Hz and 2000 Hz *- the most important frequencies re: speech cues*

Keep less than half gain for the low frequencies to reduce the upward spread of masking and optimize speech intelligibility

Guidance for selecting maximum output (SSPL90) – listener's UCL minus 3 to 6 dB

10 dB of reserve gain

May be used with linear and non-linear hearing aids



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NAL-R

Byrne and Dillon

Adjacent ***speech frequencies should sound equally loud*** at a comfortable listening level

Reduce the intensity of louder speech sounds so ***all speech sounds are equally loud*** when aided

Less high frequency gain than Berger ***for steep, high frequency hearing losses***

Target gain looks ‘flatter’ than those prescribed by most other linear fitting methods

15 dB reserve gain

1
9
9
0

NAL-RP

Byrne, Parkinson, & Newall

Considerations for severe-to-profound hearing losses

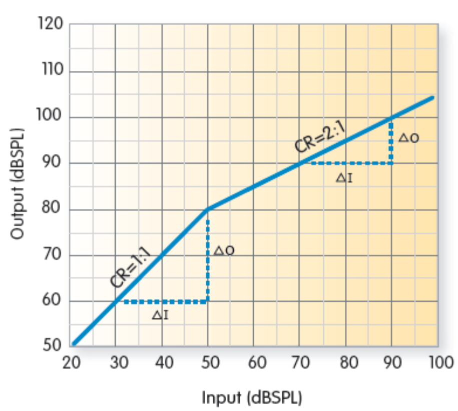
- Amplify less at frequencies where there is severe-to-profound loss
- Amplify more at frequencies where there is better hearing

Cochlear dead regions

Non-linear Fitting Formulas

Used with hearing aids offering compression so aided response is within the dynamic range

Gain varies as a function of frequency and input level - gain for soft input levels greater than gain for moderate or loud inputs levels



NAL-NL1 & NAL-NL2

DSL v5.0

FIG6

VIOLA/IHAFF

1
9
9
9

NAL-NL1

National Acoustic Laboratories' Nonlinear Fitting Procedure, Version 1

Compression-based method from the linear NAL-R method

Equalize loudness relationships among the speech frequencies

Gain for several input levels for maximal speech intelligibility

Overall loudness perception of aided speech is consistent with that experienced by those with normal hearing

Less prescribed gain in regions of severe hearing loss

Includes ***age-appropriate correction factors*** (e.g., for RECD)

Available for ***pediatric population***

NAL

2
0
0
5

DSL v5.0

Desired Sensation Level (DSL) Method
Scollie, et al.

Hearing aid prescription for ***infants, children and adults***

Higher listening level for ***pediatric patients*** than for ***adult patients***

Calculates a ***full range of targets for any audiogram of two or more thresholds***

Compression calculated with consideration for the ***channel architecture***

Targets for aided speech are limited so that ***speech peaks do not exceed the listener's UCL***

Full audibility of speech in quiet / less gain at speech frequencies of lower importance with a raised CT in noise

Binaural correction reduces speech targets by 3 dB

Higher targets for ***conductive and mixed hearing loss***

2008

NAL-NL2

NAL's second generation prescription for fitting WDRC instruments

Attributes of the hearing aid user are considered: ***gender, experience level, binaural listening, age, and language***

Female hearing aid users prefer lower overall gain than male users

New hearing aid users with more than a mild hearing loss prefer less gain with increasing degree of hearing loss than experienced hearing aid users

Unilaterally and bilaterally fitted hearing aid users prefer overall gain levels that vary less than estimated by the bilateral correction factor

2
0
0
8

NAL-NL2

Adults prefer lower overall gain than children

People with severe/profound hearing loss prefer lower compression ratios than predicted when fitted with ast-acting compression.

Slightly more low-frequency gain is prescribed for ***speakers of tonal languages*** (e.g. Mandarin)

Formula Fun Fact

FUNDAMENTAL THEOREM OF CALCULUS

Establishes the relationship between differentiation and integration and provides a way to evaluate definite integrals without using Riemann sums or calculating areas.

$$\frac{df}{dt} = \lim_{h \to 0} \frac{f(t+h) - f(t)}{h}$$

Proprietary Fitting Formulas

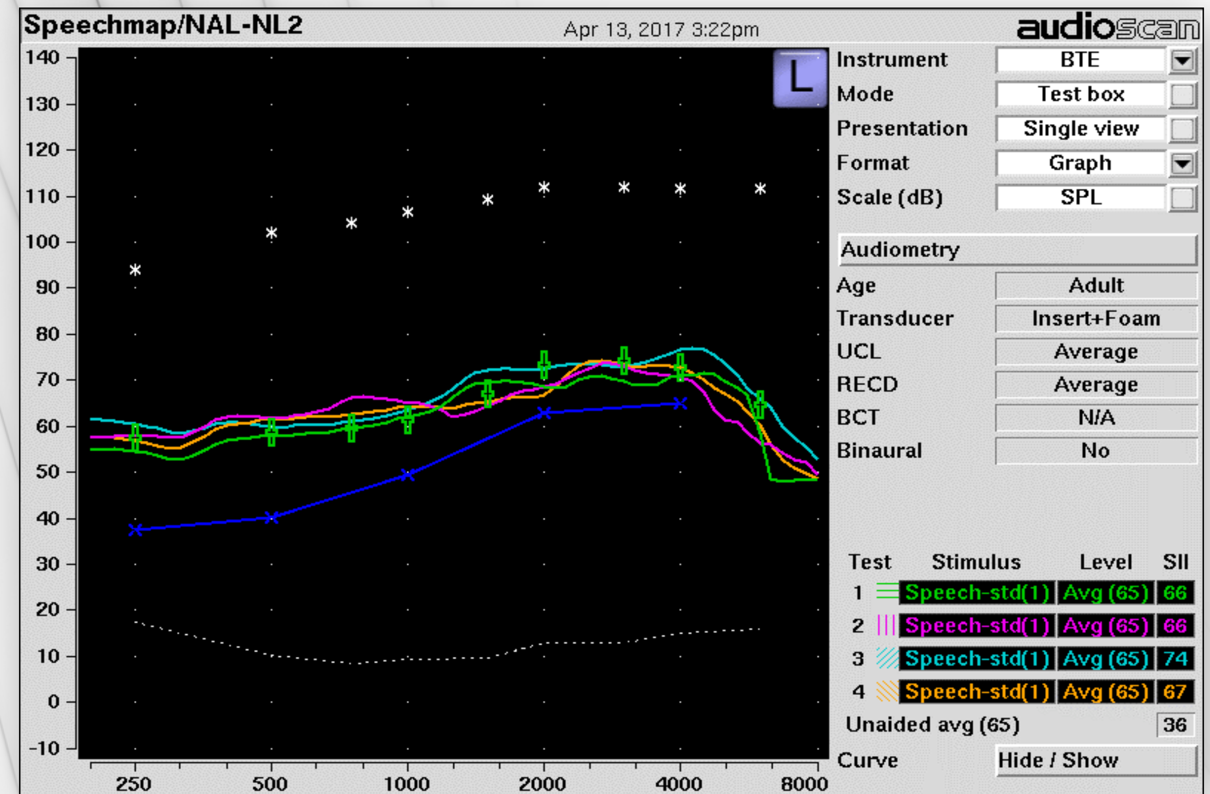
Developed by hearing aid manufacturers

Linear and non-Linear prescriptive approaches

Designed to optimize hearing aid performance based on the unique compression architecture and signal processing available

Manufacturer Proprietary Formulas

- Compression type
- Compression speed
- Compression attack and release times
- Number of channels
- Microphone location effects
- Acoustic effects of hearing aid style and coupling



Fitting Formulas

Generic Non-Linear

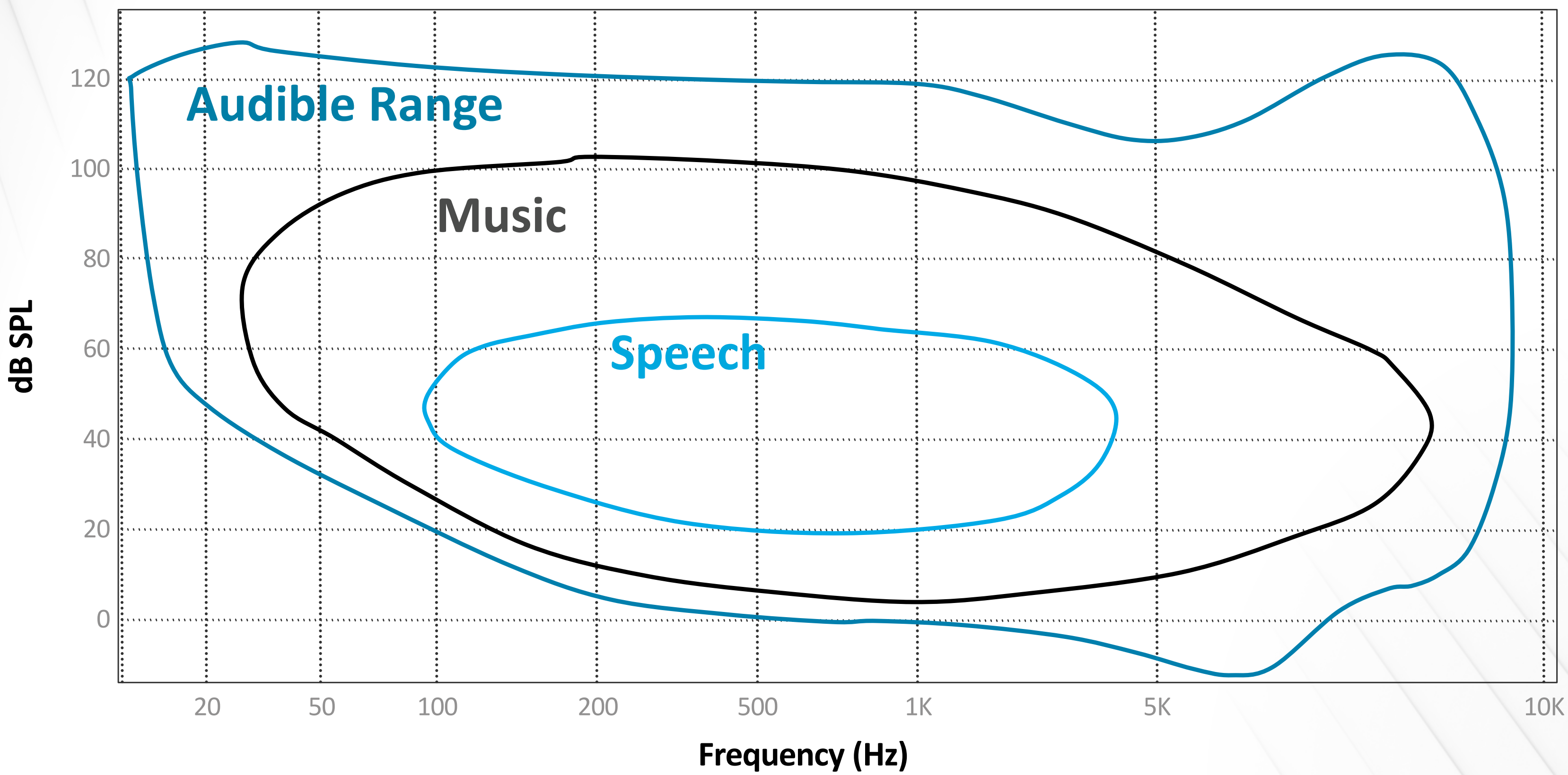
Music

Hearing loss impacts the enjoyment of music

Individual preferences for music exist

Music and speech are very different signals

Music vs Speech



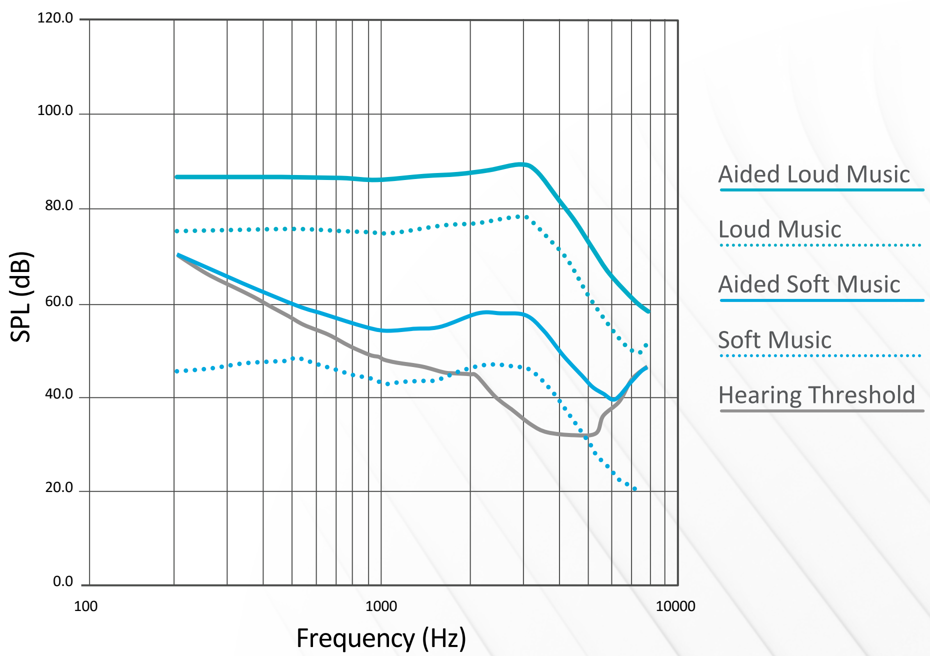
Music

Evidenced-based prescription optimized for music

Restores audibility for soft music

Restores desired loudness for loud music

Unique compression TKs & CRs

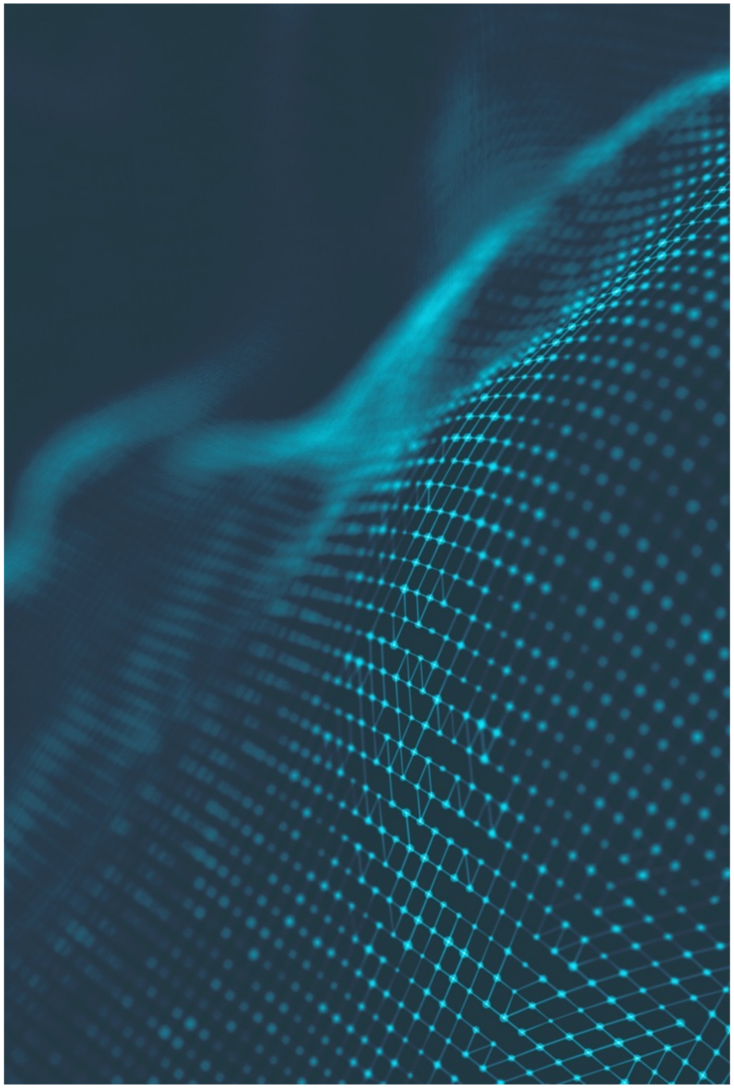


Dual Speed Compression

Uses both fast-acting and slow-acting compression

Two independent compressors active at the same time

Seamlessly adapts to dynamic situations



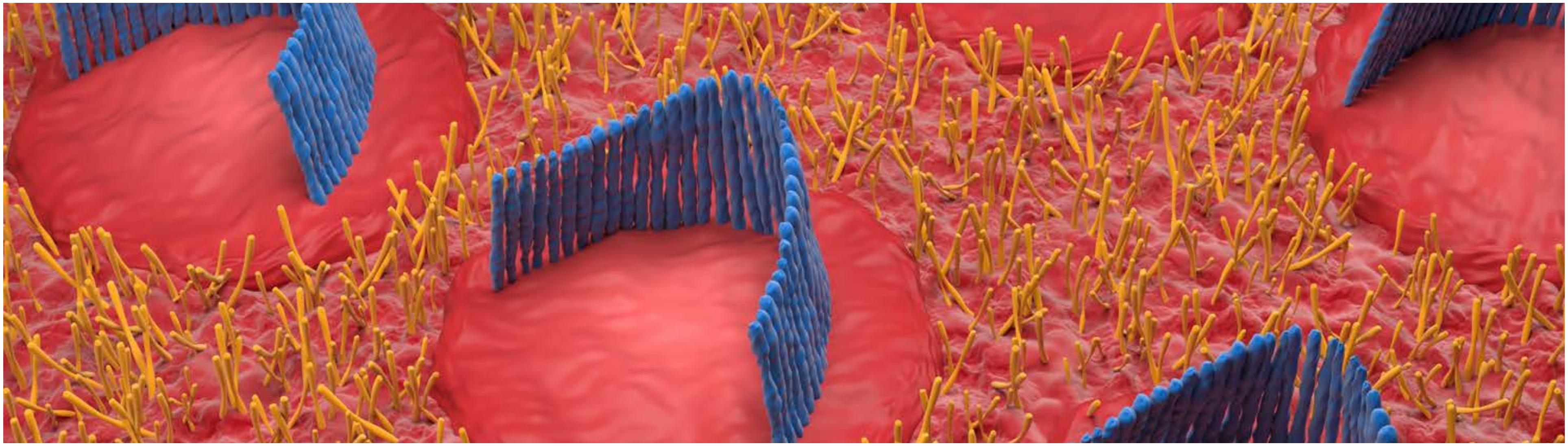
Compensating for Loss of Function

Outer Hair Cells

Fast Compression

Inner Hair Cells

Slow compression



2
0
2
3

e-STAT 2.0 Proprietary Fitting Formula

Designed to complement the Genesis AI compression architecture

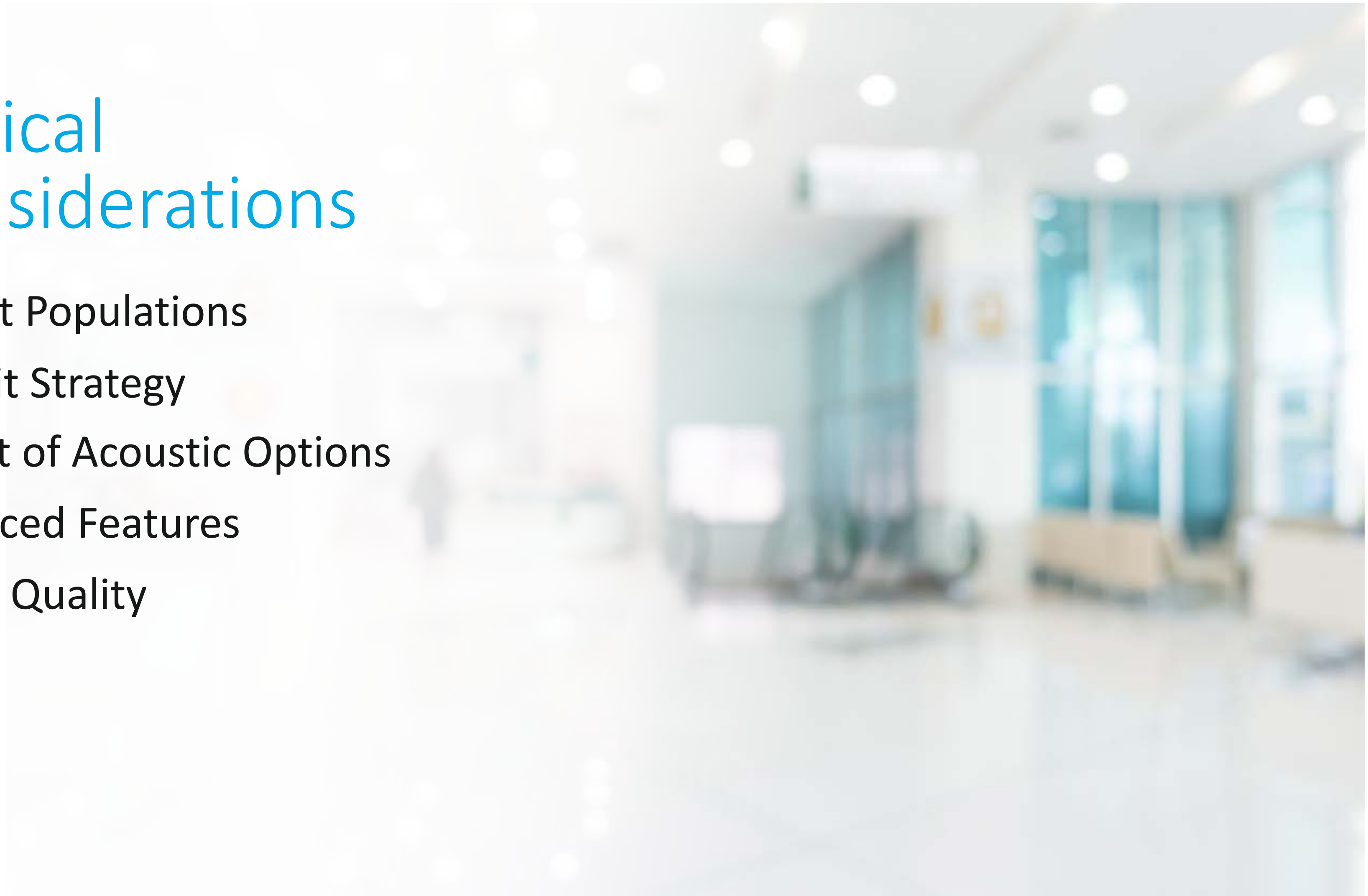
*Varies with the audiogram and acoustic stimuli
**Varies with audiogram and with frequency

~4-6 dB more gain for soft sounds*

10% higher speech intelligibility scores for soft speech vs. Evolv AI

More gain at higher frequencies** (> 3kHz)

Improved vent modeling



Clinical Considerations

Patient Populations

First Fit Strategy

Impact of Acoustic Options

Advanced Features

Sound Quality

Sensorineural Hearing Loss

Reduced dynamic range

Compression is usually necessary to fit signals into the patient's dynamic range

Non-linear fitting formula usually optimal

Proprietary / NAL-NL2 / DSL v5.0

Conductive/ Mixed Hearing Loss

Usually want more gain than someone with SNHL

No reduction in dynamic range

Linear processing may be more appropriate

Berger / NAL-R / DSL v5.0

Children

Size

Ear canal properties

Middle ear properties

Central auditory system

Test equipment / procedures

Audibility of speech is crucial – learning speech and language

DSL v5.0 or NAL-NL2

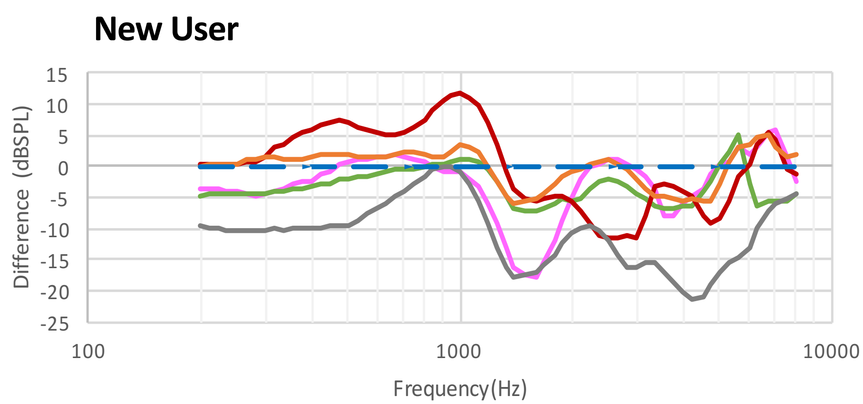
First Fit Strategy

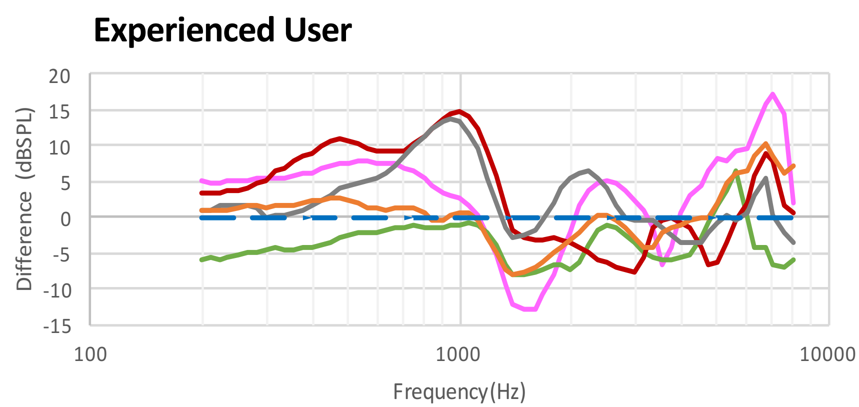
A B C

D E Baselined for Comparison

Audibility / Comfort

Impacts the frequency response





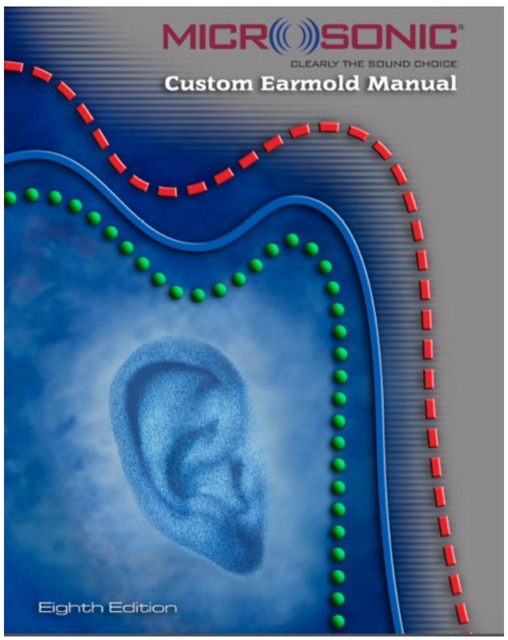
Real Ear Measurements

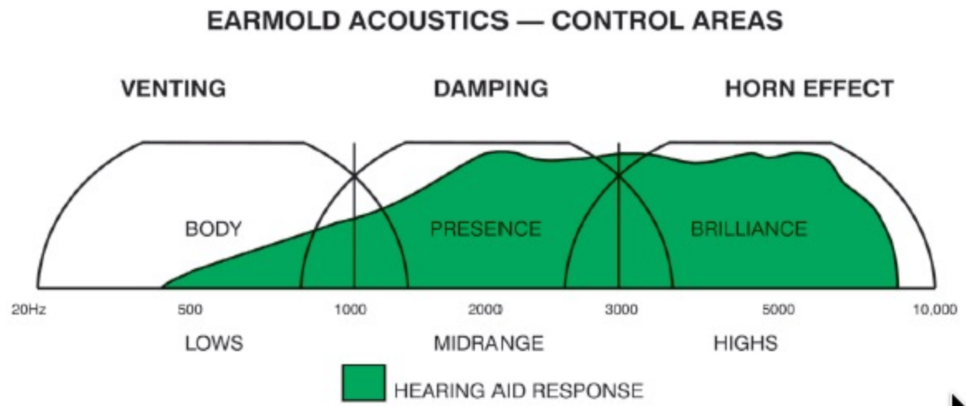
Best practice by the American Speech-Language-Hearing Association (ASHA) and the American Academy of Audiology (AAA)

Consumer Reports advocates for this practice in their “Hearing Aid Buying Guide”

Predicted real ear responses should not be considered a replacement for the real thing

Impact of Acoustic Options





CLASSICAL MODIFICATION AND EFFECT CHART

	Modification	Effect on Low Frequencies (Below 750 Hz)	Effect on Frequencies Between 750 and 1500 Hz	Effect on Frequencies Between 1500 and 3000 HZ	Effect on High Frequencies (Above 3000 Hz)
TUBING DIAMETER	Larger I.D. Tubing & Horn Tubing	Negligible	Moves peak to higher frequency	Increases height of peak and moves to higher frequency	Increases
	Smaller I.D. Tubing	May reduce below 1 KHz	Moves peak to lower frequency	Reduces height of peak and moves to lower frequency	Large reduction
TUBING LENGTH	Longer Tubing	Increases	Moves peak to lower frequency	Moves peak to lower frequency	Negligible
	Shorter Tubing	Slightly decreases	Moves peak to higher frequency	Moves peak to higher frequency	Negligible

Advanced Features

Feedback management
and initialization

Frequency Lowering

On Demand Adaptive Tuning

May impact the frequency response of the amplified signal

Ski Slope Hearing Loss

More complex than just restoring audibility – 'hearing' the high frequencies may not be useful

Focus is on the mid-frequency region that patients are relying on for speech understanding

Frequency lowering may be helpful for speech intelligibility

Sound Quality

Large individual differences

Frequency-gain responses for restoring audibility
may result in unacceptable sound quality perceptions

High frequency amplification may be detrimental
to speech intelligibility for some users

Sound quality and distortion must be considered

Fitting formulas provide a foundation

Response adjustments allow us to address
the unique needs and preferences of each listener

"Individualized adjustments may be needed to obtain a good fit. In this respect, the use of....prescriptive formulas....should probably be regarded as no more than a first estimate of the best frequency-gain characteristic for an individual patient."

Bratt & Sammeth, 1991

Validation Measures

Optimal performance and sound quality may require adjusting the response away from the prescriptive target

Noise reduction will impact gain at one or more target levels

Various subjective and objective outcome measures are available

Fitting Formula is the Foundation of the Hearing Aid Fitting

Consider type, degree, and configuration of hearing loss, experience, age, and other special considerations

Successful hearing aid fittings strike a balance among audibility, loudness, and sound quality

Both proprietary and generic fitting formulas are valuable

Real ear and outcome measures are important

Thank You.

Starkey

Hear better. Live better.