Hearing Aid Selection, Fitting, and Verification

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**LEARNING OBJECTIVES**

★ After this course participants should be able to:

1. Describe clinical verification of gain and output
2. Describe clinical verification of specific hearing aid features including directional microphones and feedback suppression
3. Describe how prescriptive gain methods are related to audibility
Setting The Stage...

More than half of Hearing Health Care Professionals do not fit to a verified prescriptive method.

What if anything, are we giving up?
A Few Questions to Get Us Started

- Are there differences between first fit and validated prescriptive methods?

- Should we fit a hearing aid using a validated prescriptive method?
  - Is there evidence to support doing so?

- Are we actually using a prescriptive method if we are not verifying?
Are There Differences between First Fit and Validated Prescriptive Methods?
LETS LOOK AT SOME OLD DATA FOR OPEN-CANAL FITTINGS (FROM BENTLER ET AL, 2006)

Hearing aids programmed
To default fitting; loss was normal in lows to 60 dB loss in highs.
These differences have been similar for more than two decades

- Sanders et al (2015) *Hear Rev, 21, 24-26, 28, 30, 32*
  
  - Evaluated difference between “first” fit and NAL-NL2 in 5 RICs from 5 manufacturers on 8 participants with high frequency sloping hearing losses
    - 74% of cases below NAL-NL2 at 55 dB SPL input
    - 55% of cases below NAL-NL2 at 65 dB SPL input
    - About 7-10 dB below

- Other similar studies
  
  - Aazh & Moore (2007) *J Am Acad Audiol, 18, 653 - 664*

It is important to know the audibility of soft speech too!
Gain is typically lower for first-fit than a validated methods—Does it matter?

Rhe importance of audibility in successful amplification of hearing loss Ron Leavitt and Carol Flexer

Hearing Review, December, 2013
WHAT THEY DID...

★ Selected the premier product from each of the “Big Six,” and programmed these hearing aids to each manufacturer's recommended fitting. Then reprogrammed them for NAL-NL2. All special features were activated.

★ For benchmarking purposes, they added a 7th hearing aid—a circa 2002 single-channel analog instrument, which they programmed to NAL-NL1.

★ Limitation? N=5, but still pretty compelling…
Performance for the aided QuickSIN presented in the soundfield at softer speech level. Bars indicate the average SNR disadvantage compared to individuals with normal hearing.
INITIAL-FIT APPROACH VERSUS VERIFIED PRESCRIPTION: COMPARING SELF-PERCEIVED HEARING AID BENEFIT

For the Ease of Communication, Reverberation, and Background Noise subscales, scores obtained with the verified prescription were significantly higher than those for the initial-fit approach, indicating greater benefit.

Of the 22 participants, 7 preferred their hearing aids programmed to initial-fit settings and 15 preferred their hearing aids programmed to the verified prescription.

Importantly, both groups went through fine tuning!
DIFFERENCES IN WORD AND PHONEME RECOGNITION IN QUIET, SENTENCE RECOGNITION IN NOISE, AND SUBJECTIVE OUTCOMES BETWEEN MANUFACTURER FIRST-FIT AND HEARING AIDS PROGRAMMED TO NAL-NL2 USING REAL-EAR MEASURES

Michael Valente
Kristi Oeding
Alison Brockmeyer
Steven Smith
Dorina Kallogjeri

J Am Acad Audiol, 2018, 29, 706–721
What they found...

★ 79% preferred programmed-fit, more than half of these elected to purchase the hearing aids.

★ APHAB: Problems in background noise 34% (first fit) versus 22.8% (programmed fit)
Why not just worry about audibility? Can't I just use a Live Speech Verification Method?
Remember – When we consider even average talkers, speech varies a lot in level!

- On average soft speech is about 52 dB SPL
- On average average speech is about 62 dB SPL
- On average shouted speech is about 82 dB SPL
- The dynamic range for one talker, at a single vocal effort is about 30 dB!
Live Speech Mapping: Can help us visualize audibility, but...

★ Level depends on talker, mood, etc. What do we want to make audible? How reliable is live speech testing?
  ★ It is not!

★ What is the patient outcome if we ensure all speech is audible?
  ★ Speech is too loud!

★ What can it be useful for?
  ★ After completing appropriate verification with a recorded signal it can be useful to demonstrate audibility for speech for counseling purposes. For example showing the patient that they will not hear everything so appropriate listening strategies should still be used.
What are the current validated prescriptive methods?

- National Acoustics Laboratory-Nonlinear (NAL-NL2) – version 1, 1976
- Desired Sensation Level (DSL V5) – version 1, 1984
- Cambridge fitting formula (CAMFIT2) – version 1, 1989
- Manufacturers Proprietary (although almost no-one really fits to these)
NOT SURPRISINGLY – THEY HAVE ENDED UP PRETTY SIMILAR (DIFFERENCE BETWEEN NL2 VERSUS DSL5.0 FOR 5 DIFFERENT ADULT AUDIOGRAMS). (EARL JOHNSON, 2012)

Differences are much larger in children – DSL places more importance on audibility.
They are also still much different in the extended high frequencies (Earl Johnson, 2015)
WHAT WOULD PATIENTS CHANGE FOR MUSIC?
D’ONFRIO, GIFFORD & RICKETTS, 2019

Gain Deviation from NAL-NL2 (dB)

Non-Musicians
Musicians

WFL SSS CST WFL SSS CST WFL SSS CST
LF MF HF
Empirically derived prescriptive fitting methods attempt to find the best starting balance by design – 40 years of refinement!

Mini-Summary

If there is not enough audibility – Speech recognition and self-report outcomes are poorer!

If there is too much audibility - Self-report outcomes are poorer and the instruments may even be rejected!
Prescriptive Targets are exactly that – Targets! Actually using a prescriptive method requires verification! (Probe microphone measures)

How do you know you hit the target?
So everyone is using Probe Mic, right? (From Mueller and Picou, 2010)

Figure 2. Percent of respondents who routinely use probe-microphone measures on the day of the fitting. The “Have Equipment” data include only respondents who own or have access to probe-mic equipment.
Knowing that people tend to inflate their use rate, Muller and Picou also asked the self-identified routine users how often they conducted different probe-mic procedures. One of the procedures was The Binaural Summation Index (BSI).

What percent of “routine users” said they conducted the BSI?

- All Respondents 21%

Sadly, the reported values are likely overestimated!
SIMPLY COMPLETING PROBE-MIC VERIFICATION CAN INCREASE PATIENT SATISFACTION! (AMLANI, PUMFORD, AND GESSLING, 2016)
... AND INCREASE WILLINGNESS TO PAY (AMLANI, PUMFORD, AND GESSLING, 2016):
... AND INCREASE PATIENT LOYALTY (Kochkin et al. 2014)

Was verification & validation used to fit hearing aid?
Is moving from 60% to 85% loyalty really that big of deal?
Remember probe-mic measurements are *NOT* a method of fitting hearing aids; they are simply a way to verify the prescriptive method used to fit hearing aids.

Plus a couple of others – Mostly Live Speech
**PROBE-MIC MEASURES HAVE BEEN AROUND FOR OVER 30 YEARS: WHAT’S CHANGED?**

- We tend to verify using “output” rather than “gain”
- We use test signals that include recorded speech or behave like speech.
  - We want to know the hearing aid output for speech inputs since that is the most common patient complaint.
- We verify at several different input levels
- The input signal is now speech (or speech-like); the process is sometimes referred to as “speechmapping.”
- Today’s hearing aids have more special features to verify
FOUR CONSIDERATIONS AS WE START TESTING:

★ Type of test signal

★ Calibration of the equipment/sound field
  ★ Probe tube itself (for most equipment)
  ★ Calibration/monitoring of the field

★ Positioning of the patient

★ Positioning of the probe tube
**Since prescriptive methods were designed to get the gain right for speech... Verification should be done with speech!**

- Equipment-specific real-speech signal (shaped to one of several different LTASS)
- International Speech Test Signal (ISTS); shaped to ILTASS
  - The North Wind and the Sun (500 ms), in six different languages (American English, Arabic, Chinese, French, German, and Spanish).
- **Special Features Testing**
  - Speech noise, pink noise or other “steady-state” noises (DNR)
  - Real world noises - e.g. air condition, vacuum (DNR)
  - Speech and noise from different speakers (directional microphone)
  - High frequency phonemes, Ling 6 and other specialty signals (frequency lowering).
In general, the purpose is to make the acoustic effects of the tube itself invisible.

This can be accomplished, in the calibration mode, by placing the tip of the tube next the opening port of the reference microphone, and then presenting a signal.

The machine will compare the two inputs (through the tube vs. direct to reference microphone), and automatically correct for the effects of the tube.
Typical calibration curve before effects of the tube have been equalized.

Manufacturer A

Manufacturer B
1. Can I reuse tubes on the same patient?
2. Can I reuse tubes on the same ear?
3. Can I reuse the tubes on different patients?
4. Can I use the tubes from one manufacturer on another manufacturer’s equipment?
5. When the tube is plugged, can I simply snip off the plugged end and use the tube?

No and Gross!
About the “reference mic.” Sometimes called the “monitoring mic” or “regulating mic.”

- Usually placed just below the earlobe.
- When enabled, monitors and controls the level of the signal from the loudspeaker, so that a valid and consistent signal is present at the ear.
- May be disabled for some types of measurements.
- Sometimes a two step calibration process (leveling then calibration)
WHERE DO I POSITION THE PROBE TUBE?

- The tip of the tube should be within 5mm of the eardrum
- The tip of the tube should be ~5mm beyond the tip of the hearing aid/earmold
- More important to get closer to TM as you fit “extended” high frequencies.
WHAT’S WRONG WITH THESE PICTURES?

Match to target with probe at correct depth

The “measured” high frequency output has dropped 5-8 dB because of probe tip placement.
Methods to assure good probe-tube placement:

★ Use marker as reference, positioned 28-30 mm from the tip of the probe, and then aligned with the inter-tragal notch.

★ Use anti-resonance notch in response as guide; if present, should be 6000 Hz or higher

★ Use earmold/earshell as a guide (mostly used in infants and children)
EXAMPLES OF MARKER AT INTER-TRAGAL NOTCH AND A MARKED PROBE TUBE WITH TUBE-HOLDER GUIDE
GETTING WITHIN 5 MM JUST GOT A LOT EASIER (AND FASTER), PARTICULARLY THOSE WITH LESS EXPERIENCE!
Before we get seriously started . . . A review of some terms:

- If the term ends in an “R,” it means that it is the absolute output in the real ear.
- If the term ends in a “G” it means that it is a difference value: The input subtracted from the output (e.g., REAG or REUG) or the reference REUR subtracted from the REAR (e.g., the REIG)
BEFORE WE GET SERIOUSLY STARTED . . . A REVIEW OF SOME TERMS:

★ REUR/REUG: The transfer function of sound from the free field to the eardrum.
   ★ The “open ear response”
   ★ Still useful to compare to REAR to visualize gain!

★ REOR/REOG: The effect that an earmold or hearing aid has on the REUG.
   ★ Not used much

★ REAR/REAG: The output/gain (output minus input) of the hearing aid in the real ear
   ★ REAR is by far the most common way to verify prescriptive targets!
BEFORE WE GET SERIOUSLY STARTED . . . A REVIEW OF SOME TERMS:

- **REIG**: The difference between the open ear response (REUR), and the output of the hearing aid (REAR).
  - How we used to verify prescriptive targets – not used as much now, but a good fit to REIG targets is a good fit to REAR targets

- **REAR85/REAR90 (formerly the RESR)**: The “MPO” of the hearing aid in the real ear.

- **RECD**: The difference between the output of the hearing aid in the real ear compared to a 2-cc coupler.
  - Used for “simulated REAR” in kids and hard to fit adults.
How do we typically verify a validated prescriptive target?

- The REAR (REAG)
  - The output of the hearing aid expressed in ear canal SPL (if the input is subtracted it’s the REAG).

- What are some other primary clinical applications?
  - To verify audibility
  - To assess special features
The term “speech mapping” simply means that you are using a speech signal (or speech-like signal) when you conduct your REAR measure.

Speech mapping IS real-ear testing, which IS a probe-microphone measure (term trademarked by Bill Cole back in 1992).
Typically, we would do REARs for three inputs: in this example, 55, 65, and 75 dB SPL
Verification of a Validated Prescriptive Method

Step-by-Step
Enter the Audiogram, TD and Select the Validated Prescriptive Method and Pertinent Information

Be sure to select the correct venting it affects calibration!
The system will convert everything to SPL in the ear canal and display Targets.
SEAT THE PATIENT IN THE CORRECT POSITION ACCORDING TO THE SPECIFIC PROBE MICROPHONE EQUIPMENT'S MANUAL (TYPICALLY HORIZONTAL AND VERTICAL AZIMUTH OF 0 DEGREE)
Place reference microphones on the ears, probe tube in the ears at the correct depth, mute the hearing aids and place them in the ears too. Then calibrate the reference mics if needed.
Adjust to match targets for “soft” (e.g. 55 dB SPL) then “loud” (e.g. 75 dB SPL) inputs.

- Within 3-4 dB is “close enough” remember, you may be adjusting anyway based on patient feedback.

- For new users it may be worthwhile to fit to target and then use the hearing aids Automatic Gain Increase (AGI, sometimes referred to as an acclimitization manager.
Typically, you will find that this leads to a good match for average (65 dB SPL) inputs – if not, adjust as necessary.

If you can only get one match to target “right” because of limited hearing aid adjustment, match for average speech is probably most important.
THE SHORTCUT!

★ Adjust overall gain to gain a match to target for 65 dB input
★ Run 55 and 75 dB input level curves
★ If your manufacturer gets the compression ratio right for NAL or DSL you may obtain a good match to the 55 and 75 dB SPL targets without further adjustments.
   ★ If this is the case, you can fit this way every time and it will be much faster than fitting soft, then loud, then average.
★ Consequently, it may be worthwhile to try different manufacturer settings to see if any of them get you close.
   ★ We know of at least one case in which the compression ratios were closer to NAL-NL2 for the manufacturers default than their version of “NAL-NL2”!
An REAR with a speech signals makes it easy to visualize audibility and counsel appropriately!

Easy to observe if audibility is present for high frequencies (Note: This is LTASS—peaks of speech will be 12-15 dB higher)
REMEMBER THE LINE IS ONLY THE MIDDLE SPEECH LEVEL!

99th
65th
30th

30 dB
"Percentile Analysis" helps you visualize audibility more accurately: but remember the goal is not 100%
**Reasons why the targets are below the thresholds in the high frequencies:**

- We only have so much loudness to use — validated prescriptive methods were designed to use it effectively.
- There is a point where extra audibility does not equate to increases speech understanding.
- The overall fitting must be reasonably “comfortable” for patients, or they will turn down gain and reduce audibility for ALL frequencies.
**The REAR85/REAR90 (formerly known as the RESR)**

- **What is it and how do we measure it?**
  - The MPO of the hearing aid measured in ear canal SPL. Input must be great enough to place output at max.
  - Usually conducted at high VC setting to predict worse case (unless fixed VC)

- **What are the primary clinical applications?**
  - Comfort (not too high or too low) and safety
Lastly, measure REAR85 or REAR90 and compare to patients' UCLs/TDs

- Patients still report being dissatisfied with loud sounds being too loud.
- Although many RIC instruments have a low enough output that you may not need to check routinely.
THINGS ARE JUST A LITTLE DIFFERENT FOR OPEN FITTINGS - IS IT REALLY A PROBLEM IF I FORGET TO SELECT “OPEN FITTING” DURING PROBE MIC?

“Get them, they used concurrent equalization for an open fit RIC!”
CONCURRENT EQUALIZATION: PROBLEM WITH OPEN FITTINGS

★ Sound leaking out of ear is picked up by reference mic
★ Sound leaking out of ear may be greater than the input to reference mic from loudspeaker
★ Reference mic thinks it is output from loudspeaker, and so loudspeaker output to ear is then turned down
★ The result will be less measured hearing aid output (and gain) than is actually present.
★ Complaint? When I match targets with OC using probe microphone, patients complain that is too sharp/harsh.
★ Solution? Disable the reference microphone (in most systems, select “open” and calibrate). This enables stored equalization
Concurrent vs. Stored equalization
(Input = real speech @ 65 dB SPL; hearing aid gain ~26 dB)
**NOTE WHAT HAPPENS WHEN YOU INCREASE GAIN IN THE HIGHS!**

*(INPUT = REAL SPEECH @ 65 dB SPL; HEARING AID GAIN ~34 dB)*
DISABLE REFERENCE MICROPHONE (MedRx)

Click Open Fit and Select Calibrate
DISABLE REFERENCE MICROPHONE (AUDIOSCAN)
DISABLE REFERENCE MICROPHONE (AURICAL)

Select the correct venting and check the box.
After Equalization the reference mic is disabled
CLINICAL TIP TO REMEMBER - AFTER EQUALIZATION / CALIBRATION THE PATIENT CANNOT MOVE!

★ The Curious Engineer  ★ The Slacker
How Much of a Problem Is Movement?
Can we make verification faster without losing accuracy? Folkeard et al., (2019)

- Bilateral autoREMfit took about 4 1/2 minutes with little variation.
- Clinician fit took about 2 1/2 - 3 minutes longer, but with much more variability (in some cases nearly 10 minutes with an experienced clinician).
...AND IT IS JUST AS ACCURATE, MAYBE MORE ACCURATE FOR INEXPERIENCED PROFESSIONALS

Although there are some manufacturer differences (Ricketts and Mueller, 2018)
Want to learn more about verification in a lot more detail including verification of special features? Or a lot more about hearing aids in general?
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