Hearing Aid Selection and Fitting: Clinical Tips from Recent Research

Presented by Gus Mueller, PhD

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Course Objectives

- After this course learners will be able to describe expected benefit from new fitting features and algorithms.
- After this course learners will be able to describe how prescriptive verification can alter hearing aid fitting outcomes.
- After this course learners will be able to describe clinical factors related to hearing aid acclimatization.

Hearing aid selection and fitting: Clinical tips from recent research

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Acknowledgement: A few slides that I’m using are taken from the talk I did with Catherine and Bob at the most recent AAA convention.

"The purpose of research is to give us a completely different idea of the things we know the best"

Paul Valery, 1908
“So much to read, so little time”

--Frank Zappa, 1976

My literature review will be categorized according to:

- Pre-fitting Assessment
- Signal Processing and Features
- Selection and Fitting
- Verification
- Outcome Measures
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General areas of pre-fitting testing

- Self-assessment scales
- Speech recognition measures (in particular, speech-in-noise tests)
- Loudness discomfort testing
- Acceptance of background noise
The Acceptable Noise Level (ANL) Test

Note: Most any speech or noise signal can be used, but standard uses R-SPIN babble as noise.

- What is it and how is the ANL measured?
  - **MCL** – find the patient’s preferred listening level to on-going conversation
  - **BNL** (Background Noise Level) – find the patient’s “acceptable” listening level to background noise when it is present simultaneously with conversational speech presented at their MCL
  - **ANL** = then, the BNL is subtracted from the MCL and you have the ANL

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**Table 1.** Fourteen studies published in peer-reviewed journals with information on language version, number of subjects, subjects’ hearing status, measurement, and presentation mode. 

<table>
<thead>
<tr>
<th>Study</th>
<th>Language</th>
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<th>Hearing Status</th>
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**Does the acceptable noise level (ANL) predict hearing-aid use?**

Olsen and Brännström, *IJA*, 2014

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45 peer-reviewed ANL papers published since 2004
Research with the ANL just keeps coming . . .

- Acceptable Noise Level Test: Bases and Theories
- Comparison of Acceptable Noise Level Generated Using Different Transducers and Response Modes
- Speech Intelligibility as a Cue for Acceptable Noise Levels.
- The Acceptable Noise Level and the Pure-Tone Audiogram
- Using QuickSIN Speech Material to Measure Acceptable Noise Level for Adults with Hearing Loss
- Development of the Visual Acceptable Noise Level Test
- Monotic and dichotic acceptable noise levels in typically developing children and adolescents

Gus’s thoughts on the routine use of the ANL test:

- Probably won’t help much for:
  - Programming gain and output
  - Selection of special features or strength of DNR features
- Might help for:
  - Identifying patients who need more hand-holding during initial fitting period
  - Providing realistic counseling
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A simplified model . . .

Cognition:
- Reacting: Storing in memory, reasoning and responding
- Comprehending: Interpreting contextual and grammatical information
- Listening: Selecting information—Attention and Effort
- Hearing: Acoustic speech signals to neural information

Working Memory:
We have all watched a duck glide smoothly across a lake

But 90% of what is happening is “below the surface”
When hearing loss is present . . .

Hearing loss makes auditory processing more difficult. The effort and stress leads to listening fatigue. Listening effort and stress is increased, as the task becomes more difficult. Hearing loss makes auditory processing more difficult.

Listening effort has become a very popular area to study the past few years

(Review of 2017 articles, courtesy of Catherine Palmer)

- Ohlenforst, B. et al, Effects of hearing impairment and hearing aid amplification on listening effort (E&H)
- Picou, E., Ricketts, T., How directional microphones affect speech recognition, listening effort and localization for listeners with moderate-to-severe hearing loss (IJA)
- Krueger, M., et al. Relation between listening effort and speech intelligibility in noise (AJA)
- Van den Tillart-Haverkate, M. et al. The influence of noise reduction on speech intelligibility, response times to speech, and perceived listening effort in normal-hearing listeners (Trends in Amp)
And there are more . . .

- Brennan, M. et al. Listening effort and speech recognition with frequency compression amplification for children and adults with hearing loss (JAAA)
- Alhanbali, S et al. Self-reported listening-related effort and fatigue in hearing-impaired adults (E&H)
- Bernarding, C, et al. Neurodynamic evaluation of hearing aid features using EEG correlates for listening effort (Cognitive Neurodynamics)

Ohlenforst et al Systematic Review

- Systematic Review
  - Does hearing impairment effect listening effort?
  - Can hearing aid amplification affect listening effort during speech comprehension?
- Concluded
  - Quality of studies was low
  - Listening effort was higher in people with hearing loss than normal hearing as measured by EEG
Other than behavioral measures, what are the objective methods to assess listening effort?

- **Objective**
  - Pupil diameter
  - Heart rate
  - Skin conductance
  - EEG activity
  - fMRI

- Various levels of sensitivity—some difficult to conduct in typical clinical research environments.

Somewhere in here we might have a measure of listening effort!
**Collection of the EEG samples:**

The EEG sample used for analysis was extracted to precisely coincide with the given task.

**Making sense of the EEG data:**

- For meaningful interpretation of the EEG activity, mathematical calculations of phase vectors were conducted for each sample (the Rayleigh Test).
- It’s a test for non-uniformity (as unimodal clustering) of a set of points on a circle (a lack of randomness).

\[
\bar{R} = \frac{1}{N} \left| \sum_{n=1}^{N} e^{\imath \phi_n} \right|
\]
A (very) simplified example of the scaled EEG activity (based on Rayleigh test)

Little Effort (random activity): Scaled score of ~0.3 or less

But what if . . . You start to hear a new sound . . . like you might have a flat tire?

High Effort (focused brain activity): Scaled score of ~0.5 or more
Research using the EEG for the assessment of listening effort:

Multi-center Evidence of Reduced Listening Effort Using New Hearing Aid Technology
Published on February 14, 2017

By Veronika Littmann, PhD; Yu-Hsiang Wu, PhD; Matthias Froehlich, PhD, and Thomas Powers, PhD

Narrow Directionality: We know it improves speech recognition, but does it reduce listening effort?
Does Narrow Directivity Reduce Listening Effort?
Objective Brain Behavior Findings

Listening Effort
(re: scaled EEG activity)

Site 1
Site 3

Narrow Directivity
“Off”
Narrow Directivity
“On”

Does Narrow Directivity Reduce Listening Effort?
Participants’ Subjective Rating

Participants’ Subjective Rating

Site 1
Site 3

Narrow Directivity
“Off”
Narrow Directivity
“On”
This course is presented in partnership with [Company].

### Aided Narrow Directivity vs. Normal Hearing

#### Brain Behavior Findings

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#### Participants’ Subjective Ratings

- **EXTREME**
- **VERY MUCH**
- **CONSIDERABLE**
- **MODERATE**
- **LITTLE**
- **VERY LITTLE**
- **NO EFFORT**

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How directional microphones affect speech recognition, listening effort and localization for listeners with moderate-to-severe hearing loss

Picou, E., Ricketts, T.

*International Journal of Audiology*

**What they asked?**

- What effect will a fixed directional microphone have on:
  - Sentence recognition in noise
  - Effort
  - Localization

Compared to an omni-directional microphone and an asymmetric directional set up
What they did?

- 18 adults with moderate-to-severe hearing loss
- NAL-NL2 with real ear verification of targets
- Dual task included pressing a button when the word could be used as a noun
- Could move head for the localization task.

Sentence recognition in noise
Findings for response time

So hopefully, with new technology, we can help our patients glide a little more smoothly through conversations.
And significantly reduce the effort that is going on “below the surface”

My literature review will be categorized according to:

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Audiogram that requires a little thinking . . .

Regarding a potential hearing aid fitting, you basically have three choices:

- Do nothing (assuming patient is okay with this)
- Fit hearing aid to bad ear
- CROS (or maybe BiCROS) fitting
Outcomes of Hearing Aid Use by Individuals with Unilateral Sensorineural Hearing Loss

Bishop C., Hamadain E, Galster J, Johnson M, Spankovich C, & Windmill I

*J. Am. Academy Audiology, 28(10)*

Participants

- 22 individuals with PTA (0.5, 1, 2 kHz)
  - ≤ 25 dB HL in better ear
  - ≥ 40 dB and ≤ 90 dB in worse ear
  - No prior experience with amplification
Procedures

- Word recognition in sound field
- Speech perception in noise: QuickSIN
  - Speech and noise at 0º
  - Speech better ear/Noise poorer ear
  - Speech poorer ear/Noise better ear
- Subjective benefit in real world trial
  - APHAB
  - SSQ

Findings for the QuickSin
SNR Loss (small numbers good)

A: Speech/noise = 0º
B: Speech to better ear
C: Speech to poorer ear
Findings for the SSQ (benefit also noted on the APHAB)

So after the study was completed, what percent chose to keep their hearing aid?

59% kept their hearing aid
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In 2017, there were several articles related to the fitting of hearing aids to prescriptive targets—we’ll review a few
An Unfortunate Truth . . .

In the U.S., the majority of individuals fitting hearing aids do not conduct real-ear verification of gain and output.

Somewhat Reasonable Question #1: “In the big picture of patient outcomes, does it really matter if real-ear verification is conducted?”

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 and Dorina Kallogjeri

Journal American Academy of Audiology, 2017
What they did . . .

- Double-blind randomized crossover design (24 participants)
- Mild-moderate downward-sloping bilateral hearing losses.
- All were new users.
- Initially fitted to either NAL-NL2 or manufacturer’s proprietary algorithm; cross-over after four months.
- Testing included speech recognition in quiet and in noise (HINT), subjective responses for the Abbreviated Profile of Hearing Aid Benefit (APHAB) and the Speech, Spatial and Qualities of Hearing (SSQ) questionnaire, and patient preference.

Mean audiogram
What they found . . .

- Laboratory performance for speech recognition significantly better for NAL-NL2 fitting (for soft and raised-speech levels).
- No difference for HINT performance.
- No difference for SSQ. BN scale of APHAB significantly better for NAL-NL2 fitting.
- After real-world trial with both fittings, 19 of 24 preferred the NAL-NL2 algorithm.
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8/9/18

Somewhere, someplace, this afternoon, there is a rep telling a naive dispensing audiologist: "Trust me, our hearing aids work the best when you use our proprietary fitting."
So clearly . . .

Using the proprietary fitting is a disservice to our patients.

Somewhat Reasonable Question #2:
“What if I simply click on the manufacturer’s NAL-NL2 fitting—is it then okay to skip verification?”

Real-Ear Measurement and Its Impact on Aided Audibility and Patient Loyalty

Amyn M. Amlani, John Pumford and Erich Gessling

What they did . . .

- Three groups, 20 in each group (mean age 67)
  - Group 1: Experienced hearing aid users
  - Group 2: Owners of hearing aids, but not using them—labeled “In the drawer.”
  - Group 3: New hearing aid users
- The same protocol was followed for each patient except:
  - ½ of each group had NL2 fitting targets verified with probe-microphone measures
  - The other ½ had hearing aids fitted using “Quick Fit’ (NAL-NL2); adjustments made based on user comments while listening to the CST passages.

What they did . . .

- Compared deviation from NAL-NL2 for the “fit to target” and “manufacturer’s NAL-NL2 fit” for 55, 65 and 75 dB inputs
- Calculated SII for the different fittings
- Conducted Connected Speech Test (CST; SNR= +4)
- Assessed consumer loyalty for advocacy, purchasing and retention.
What they found . . .

- Real ear output for the manufacturer’s NAL-NL2 fell an average of 7-10 dB below desired NAL-NL2 targets.
- SII values averaged 0.15 below targets for the manufacturer’s fit.
- The CST was significantly better for the “fit to target” for two of the three groups.

FLASHBACK 201
What they found: Speech recognition for the CST (SNR=4 dB)
So clearly . . .

Mindlessly clicking on the manufacturer’s NAL-NL2 seems to be about as bad as using proprietary fittings.

Somewhat Reasonable Question #3: “Are there really patients out there walking around with these crappy fittings?”

How many people in the U.S. are suffering from being fitted incorrectly?

Hearing aid programming practices in Oregon: Fitting errors and real ear measurements
Ron Leavitt, Ruth Bentler and Carol Flexer
Hearing Review, 2017
What they did . . .

- Conducted probe-mic measures on total of 97 patients (176 fittings).
- Experienced hearing aid users (mean age 75 years) who came to clinic, but had been fitted elsewhere (24 different clinics)
- Hearing aids from 16 different manufacturers
- Probe mic testing was conducted (60 dB SPL input), and the deviations from NAL-NL2 target were calculated

Mean audiogram of participants
What they found . . .

- Mismatch from target by 10 dB or more: 72%
- Mismatch from target by 5 dB or more: 98%

What they found . . .

- Fitting error the same for newer vs older hearing aids.
- Fitting error smaller for 5 of the Big 6 companies than the other 11 brands
- Fitting error no different for hearing aids fitted by audiologists vs. hearing instrument specialists
Why we should not be surprised?

So clearly . . .

All this certainly helps explain why hearing aid benefit and satisfaction is not as high as we would like.

Somewhat Reasonable Question #4: “Maybe it’s just not possible to fit to the NAL-NL2 (or DSL) and that is why most audiologists don’t even try?”
Matching real-ear targets for adult hearing aid fittings: NAL-NL1 and DSL v5.0 prescriptive formulae

Sandra Baker and Lorienne Jenstad

*Canadian Journal of Speech-Language Pathology and Audiology*. 41 (2). 2017

What they did . . .

- One hundred ears were assessed for DSL v5.0 and 134 ears were assessed for NAL-NL1 to determine how closely the fittings matched real-ear targets; testing conducted for inputs of 55, 65 and 75 dB SPL.
- Seven experienced clinicians at three different clinical sites submitted hearing aid real-ear measurements from sequential patients (all adults) who attended their scheduled appointment to be fitted with new hearing aids.
- For both prescriptive methods, data was subsequently divided into four groups based on degree of hearing loss.
- Analysis included frequency-specific calculations of critical differences, and determination of percent that real-ear output was within +/- 5dB of target.
This course is presented in partnership with

So clearly . . .

It’s possible to fit to both NAL and DSL prescriptive targets nearly 100% of the time, even for severe hearing losses.

Somewhat Reasonable Question #5:
“Why isn’t it done in many clinics?”

Results very similar for other inputs, and for the DSL v5.0

Percent fit to +/- 5 dB of NAL target (65 dB SPL input)
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BONUS CATEGORY

I don’t know that it’s a fact, I just know it’s true!
From the world of diagnostics:

“The most difficult word on the NU#6 List 1 is LAUD.”

Top 5 most difficult, from the research of Hurley and Sells (2003)

1. Death
2. Knock
3. Laud
4. Puff
5. Keen
I don’t know that it’s a fact, I just know it’s true!

One more from the world of diagnostics:

“When the hearing loss is 100% cochlear, air and bone conduction scores are the same.”
What is the probability of air and bone thresholds being the same for 500, 1000, 2000, and 4000 Hz for both ears?

1 in 250,000

This means that a clinical audiologist seeing 10 patients/day will observe an air-bone match in both ears every 104 years.

From Margolis (2008), Audiology's Dirty Little Secret. AudiologyOnline.
"The new-user’s performance using hearing aids, fitted bilaterally, improves after a few weeks of hearing aid use."


Habicht J, Finke M and Neher T.
Ear and Hearing
What they did...

- The processing speed for new hearing aid users and experienced users (matched for age and working memory) were compared.
- An eye-tracking paradigm was used for estimating how quickly the participants could grasp the meaning of sentences presented against background noise together with two similar pictures that either correctly or incorrectly depicted the meaning conveyed by the sentences.
- Testing was conducted at the start of the study, at 12 weeks and at 24 weeks.

Improvement in processing time for new hearing aid users

![Graph showing improvement in processing time for new hearing aid users over time.](image-url)

This course is presented in partnership with [Partner Logo]
“New hearing aid users tend to ‘get used to’ background noise, and are less bothered by it after a few weeks of hearing aid use.”

Auditory Distraction and Acclimatization to Hearing Aids

Piers Dawes and Kevin Munro

Ear and Hearing, 38(2): 174-183
What they did...

- New adult hearing aid users (n = 35) completed a test of aided speech recognition in noise and a test of auditory distraction by background sound amplified by hearing aids on the day of fitting and 1, 7, 14, and 30 days post fitting.
- At day 30, participants completed self-ratings of the annoyance of amplified sounds.
- A control group of experienced hearing aid users (n = 20) completed the tests over a similar time.

What they found . . .

- Analysis of a sub-group of the new users—those who used their hearing aids more regularly and had more hearing loss—found that speech-in-noise performance improved during the 30-day period (~3 dB SNR).
- Improvement in aided speech recognition was associated with self-reported reduction in the intrusiveness of background sound.

Interestingly, there were no associations between improvement in speech recognition and the ANL score or the distraction measure.
Nearly all patients discover their plugged RIC receivers around 4:00 on Friday afternoons!

“For the most part, the hearing aid’s signal classification system selects a program for a given listening situation equal to, or better than what the patients would select themselves.”
The performance of an automatic acoustic-based program classifier compared to hearing aid users’ manual selection of listening programs

Grant D. Searchfield, Tania Linford, Kei Kobayashi, David Crowhen & Matthias Latzel

International Journal of Audiology

What they did...

- Twenty-five participants with symmetrical moderate-severe sensorineural hearing loss were fitted bilaterally.
- Preferences for different listening programs were compared across four different sound scenarios (speech in: quiet, noise, loud noise and in a car).
- Following a 4-week trial, preferences were reassessed and the users preferred program was compared to the automatic classifier.
- Testing conducted for sound quality and speech recognition in noise (HINT).
Significant advantage for HINT noted for “automatic” for most listening situations (no significant difference for quality ratings)

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What they found . . . SSQ: Trend but not significant
What they found . . . APHAB

APHAB data (50th percentile) compared to older people with normal hearing
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H. Gustav Mueller

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2018 Signia Expert Series

Seamless Transitions from Pediatric to Adult Hearing Health Care (Recorded)
Catherine Palmer, PhD

OTC – Over The Counter or Over the Cliff? (Recorded)
Thomas A. Powers, Ph.D.

August 9, 2018 at 12:00 PM ET
Hearing aid selection and fitting: Clinical tips from recent research
H. Gustav Mueller, Ph.D.

August 28, 2018 at 5 PM ET
Perspectives on the diagnosis and remediation of Auditory Processing Disorders: some things we know and some things we still need to find out.
Harvey Dillon, Ph.D.
Thank you!!!