Hearing Instrument Verification and Validation: Practical Advice that will Improve Your Fittings

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- Verification techniques are primarily used to determine if the hearing aids meet a particular standard and are performing appropriately.
- Validation techniques use functional gain, speech perception, questionnaires, or interviewing to determine how much benefit one is receiving from the hearing aids.

- Performing only **verification** measures provides information regarding how much gain your patient is receiving, but little information about whether this amount of gain is actually benefiting your patient.
- Performing only **validation** measures provides benefit information, but does not provide any information regarding whether your patient is fit with the appropriate amount of gain.

Questions answered by V&V

- Verification: Do the hearing aids meet a particular standard and perform as expected?
  - Examples: Do gain settings match validated prescriptive targets? Are loud sounds tolerable?
- Validation: How effective are the hearing aids, or how much benefit does the patient receive from hearing aids in daily life?
  - Examples: COSI, APHAB, word recognition in noise tests

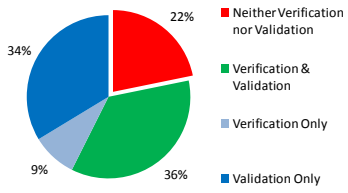
To do a fitting justice, we need both Verification and Validation

…And we will achieve greater user satisfaction

Benefits of V&V

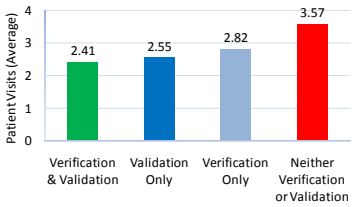
- MarkeTrak survey (Hearing Journal, June 2011) showed successfully fit patients required fewer office visits
- Fewer office visits were needed when Verification AND Validation procedures were completed
- This could potentially increase the amount of time you have to see new patients

Verification & Validation Stats



Kochkin, The Hearing Review June 2011

Time is Money



Kochkin, The Hearing Review June 2011

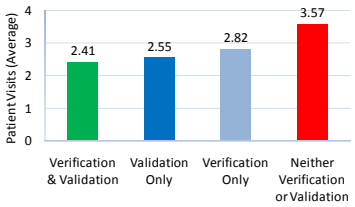
Verification is the First Step in the V&V Process

- However…

Reasons Why Clinicians Don't Always Verify the Fitting

- Don't own up-to-date equipment
- The patient is happy, who cares?
- There is no CPT code
- "My return rate is really low, I don't need it"
- Changing technology (open, digitals …) negates real ear
- Probe placement may be uncomfortable for patients
- Difficult to interpret and explain to patients
- Not knowing when to verify
- Lack of confidence in procedures
- Time

Time is Money



Kochkin, The Hearing Review June 2011

What are the goals of HA verification?

- Provided gain matches a validated, prescriptive target per the patient's hearing loss
- Speech is audible and comfortable
- Amplification does not exceed tolerance limits
- HI's perform as the manufacturer specifies
- Advanced features work as they should

Why Verify?

- Shows discrepancies between simulated gain and actual gain in a patient's ear canal
- Provides an objective way of quantifying the amplification of a hearing instrument (probe mic measurements)
- Demonstrates performance of advanced hearing aid features
- Helps to diagnose problems when instruments are in need of repair
- Improves counseling regarding hearing aid use and expectations
- Documents performance

Verification: Why It's Essential

- Less than 12% of targets on the manufacturer's fitting software screen match what is actually measured in the patient's ear[1]
- Fitting software may not be indicative of the maximum output[2]

1. Aarts NL, Caffee CS. Manufacturer predicted and measured REAR values in adult hearing aid fitting: Accuracy and clinical usefulness. *International Journal of Audiology.* 2005:44(5); 293-301.
2. Mueller HG, Bentler RA, Wu YH. Prescribing maximum hearing aid output: Differences among manufacturers found. *The Hearing Journal. 2008:16*(3); 30–36.

Another Reason to Verify: First Fits

Gain/Output

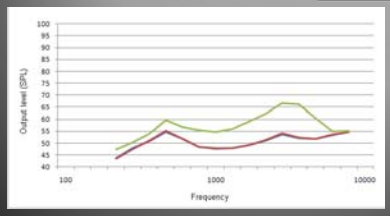
- Settings for first time, comfort, experienced linear, experienced non-linear have a significant effect on the gain and compression of the hearing aid.

Rationale for acclimatization levels

- Experience with amplification affects acceptance
- Initially acceptable gain may be suboptimal for speech understanding
- First fit was never meant to be "last fit"

Effect of Experience Level Setting: First Fit for Two Manufacturers– same audiogram

Mild sloping to moderately-severe HL



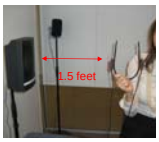
2cc coupler output with 65 dB SPL ISTS (international speech test signal)

Performing Probe Mic Measures for Verification

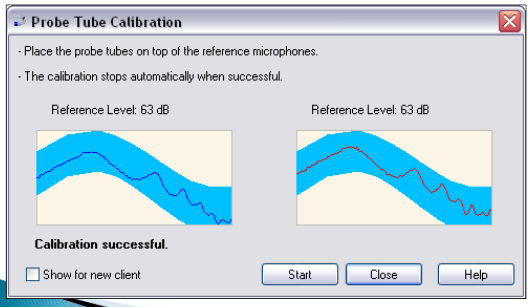
Probe Tube Calibration

Purpose: Calibration removes the acoustic effects the probe tube can introduce during PMM…makes the probe tube/probe mic acoustically invisible.

- Place the end of the tube in the middle of the reference microphone as shown below.
- Hold the headset approx 1.5 feet (Aurical) or 6 inches (Verifit) from the front of the loudspeaker, run the calibration

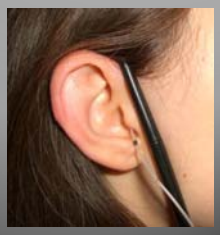


Probe Tube Calibration (Aurical)

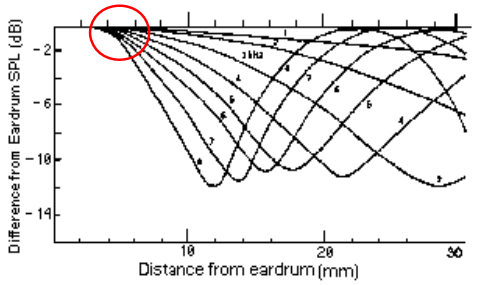


Probe Tube Insertion

- Insertion of the probe: Otoscopic Exam
- Goal: Tip of the probe tube should be placed 3-5 mm from the TM
- Mark the probe tube for the appropriate measurement depth—about 28mm for females, 30mm for males.
- Insert the probe tube until the marker reaches the tragal notch as show



Ear Canal SPL Variability per Frequency and Distance



(Adapted from Gilman and Dirks, 1986, with permission)

How do you know?

- Measurement gives you an approximate idea
- Otoscopy
- Measure the REUG—probe mic in the ear with no hearing instrument
  - Average REUG= approx 17 dB at 2700
- Visualize the resonance of the ear canal
  - Run a continuous stimulus while inserting the probe tube in the ear canal

Speech Mapping

Speech Mapping

- Provides information regarding targets for aided listening
- Uses output (frequency response) rather than gain
  - Includes interactions from various algos
- "Real world" test signals can provide a more personal fitting technique
  - Spouse's voice
  - Environmental sounds (paper rustling, etc)
- Display of results provides a useful talking point for counseling

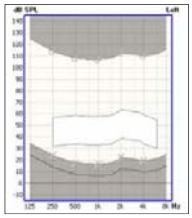
Goals of Level Dependent Amplification

- Soft sounds should be audible
- Moderate sounds should be comfortable
- Loud sounds should be loud but not intolerable
- Test signals can be presented at levels comparable to "soft" "medium" and "loud"
- Provides real-time analysis of hearing aid performance with features activated or deactivated as desired

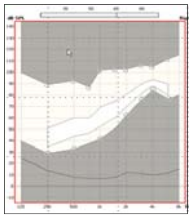
Verification using the audibility area

- To verify soft speech is audible
  - Deliver speech stimulus (50 to 55dB SPL)
  - Response curve should be at the lower level of the audibility area
- To verify moderate speech is comfortable
  - Deliver speech stimulus (65 to 70dB SPL)
  - Response curve should be covering the audibility area
- To verify loud sounds are tolerable
  - Deliver speech stimulus (80 dB SPL)
  - Response curve should be at top of audibility area – AND/OR
  - Deliver swept pure tone/MPO stimulus (90 dB SPL)
  - Responses should not exceed UCLs

Speech Mapping-Aurical VSM

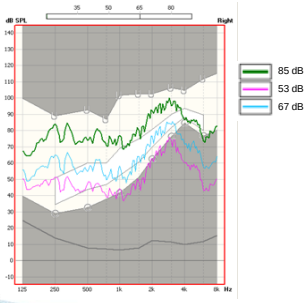


10 dB threshold
Speech Banana

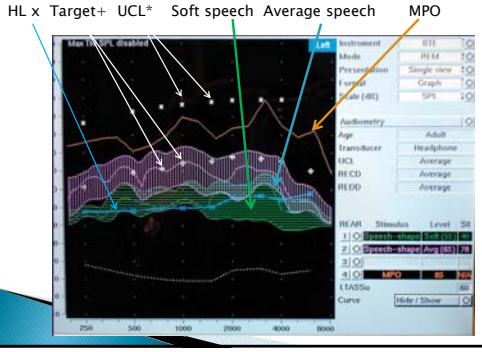


Customized
Speech banana

Speech Mapping-Aurical VSM



Speech Mapping – Audioscan Verifit



The Open REM Setting

Why change to the "open" REM setting?

- Modified pressure method using concurrent equalization regulates the loudspeaker signal to provide a constant sound pressure level.
- A reference microphone is placed near the patients ear, and measures the sound pressure level.
- If a deviation from the desired sound pressure level occurs, the loudspeaker output is instantly adjusted.
- Therefore relatively unaffected by small head movements.

Why change to the "open" setting?

- Lantz et al., (International Journal of Audiology, 2007, 46:11-16)
  - "One risk with the pressure method is that when an open fitting is made, amplified sound leaks out and may affect the reference microphone and thus the sound field from the loudspeaker."
  - This causes the front speaker to adjust its levels downwards resulting in an underestimation of insertion gain*
  - The error gets larger with increasing levels of gain

*Staples C, Aiken S. Where did my gain go? Thin Tube Open Fit BTE Verification (2006) http://www.bernafon.ca/eprise/main/ca_en/_downloads/Bernafon_Gain_Tech_Topic.pdf

Why change to the "open" setting?

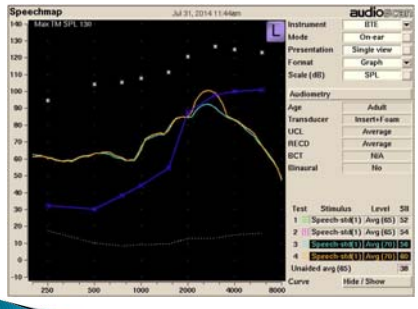
- The "open" setting (typically, a modified pressure method with *stored* equalization) uses the data collected when the REUR/REUG was run and saves that as a reference for the following measurements.
- Advantage: Any leaking gain will not have an effect on the loudspeaker levels.
- However, counsel the patient not to move!*

*Aazh H, Moore BCJ, Prasher D. Real ear measurement methods for open fit hearing aids: Modified pressure concurrent equalization (MPCE) versus modified pressure with stored equalization (MPSE) *Int J Audiol.* 2012;51:103–107.

Why change to the "open" setting?

REIG with regular/concurrent setting (green) and with open/stored setting (red) for a profound loss

Not a big deal??



Speech mapping results with regular/concurrent setting (teal) and with open/stored setting (orange) for a severe steeply sloping hearing loss. The orange curve represents the true response; the teal curve underestimates the response.

Verifying Advanced Features

Using Speech Mapping to Verify Features

- ~~Digital Feedback Suppression~~
- Directionality
- Noise Reduction
- Wind Noise Reduction
- Environmental Steering

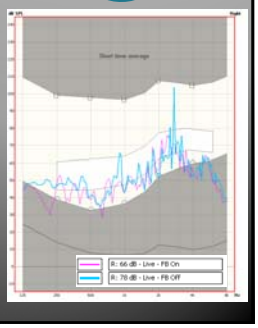
Digital Feedback Suppression

- Demonstrates how DFS can reduce feedback while not notching out the frequency response
- Also demonstrates the amount of headroom that can be gained through the use of DFS technology

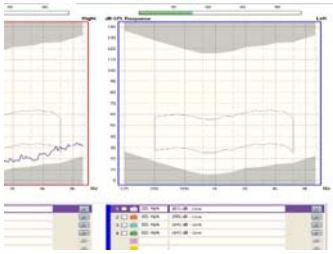
How To: Digital Feedback Suppression

- Enable probe mic but do not use any stimulus
- Turn off all features
- Increase gain to the point of feedback measure output
- Turn on DFS and measure output
- Turn up gain if headroom demonstration is desired

Use Caution with Patients!



Another Way is to Demonstrate Feedback by Holding a Phone to the Ear with and without FB Control

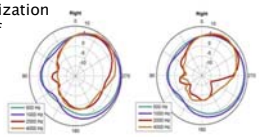


Directionality

- Typically incorporates 2 or more microphones into the hearing instrument in order to determine the direction of incoming speech sources
- In directionality mode, the hearing instrument will reduce gain of signals presented from behind and/or to the sides of the individual

Bandsplit Directionality

- Omni response for low frequencies and Directional response for high frequencies
  - Useful for
    - Maintaining audibility in LFs for directional mode
    - Better sound quality than traditional "bass boost"
    - Improved front-back localization (more natural treatment of LFs and HFs as sounds pass around head)[1]



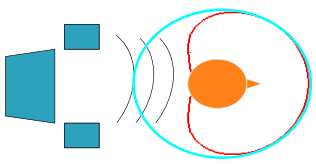
  - Reduction of wind noise[2,3]

1. Keidser G, O'Brien A, Hain JU, McLelland M, Yeend I.The effect of frequency-dependent microphone directionality on horizontal localization performance in hearing-aid users. *Int J Audiol.* 2009:48;789-803.
2. Thompson SC. Directional microphone patterns: they also have disadvantages. Audiology Online; 2000.
3. Kates J. *Digital Hearing Aids*. San Diego: Plural Publishing; 2008.

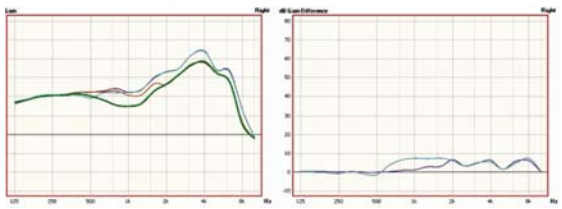
Directional Test Setup

- Verify with a single noise signal presented behind the patient
  - Turn chair to 180˚
- Present ANSI speech noise or babble at 65 dB SPL
  - Present stimulus with directionality ON
  - Present stimulus with directionality OFF
- Curve obtained with directionality ON will have a smaller amplitude than the curve obtained with directionality OFF

Directional Test Setup



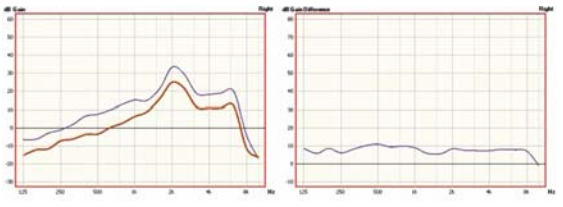
Demo: Directionality



Noise Reduction

- Demonstrates how noisy signal levels are reduced through the use of this algorithm
- Use continuous noise
  - White noise
  - Test with all other algorithms disabled
  - Obtain 2 measurements
    - 1st with noise reduction disabled
    - 2nd with noise reduction set to strong
- Use speech babble/café noise
- Patient may hear as well as see the impact of this algorithm

Demo: Noise Reduction



Developing a Verification Protocol

- Define: Why do you want verify?
  - To show what's in the ear canal
  - To demonstrate optimal settings
  - To assess the performance of certain device features
- Considerations
  - REUG, REIG (50dB & 80 dB inputs)
  - Speech Mapping (soft, medium and loud speech/pure tones)
  - Demonstrations (Directionality, Noise Reduction, Wind Noise Reduction, Environmental Steering)

Sample Protocol

- REUR to ensure good probe placement
- Speech Mapping
  - 3 levels representing soft, medium and loud speech
  - Or, at least do soft speech, medium speech and RESR/MPO
- Other testing/demonstrations
  - Demonstrate noise reduction, directionality, etc.

Verification as a Counseling Tool

- These tests can be slightly modified to be tested in the coupler before the patient arrives.
- However, real-ear verification can also serve as a valuable counseling tool
  - Clinician can explain how the hearing aids are making sounds in the real world to be loud enough to hear based on the patient's hearing thresholds
- Advantages:
  - Builds the professional relationship
  - Further educates the patient about the function of his or her hearing aids

Validation

Validation measures

- Provide information regarding the benefit patients receive from amplification
- Validating hearing aid benefit may also be necessary for third-party payment*
- Measurement techniques:
  - Objective measurements
    - Information obtained within the clinic
  - Subjective measurements
    - Real-world information

*Humes LE, Amos NE. Are Your Hearing Aid Fittings "On Target"? *ASHA Leader. 2009.*

Hearing Aid Outcomes

- Issues in Evaluating the Effectiveness of Hearing Aids in the Elderly: What to Measure and When
  - Larry Humes, Ph.D.
  - Seminars in Hearing, 2001
    - In clinical practice if one can identify those that are not benefiting from their hearing aids, then it might be possible to intervene with more counseling, rehabilitation, or different technology.

7 Independent Dimensions of Hearing Aid Outcome

- **Subjective benefit and Satisfaction**
  - Hearing Aid Performance Inventory (HAPI)
  - Hearing Aid Satisfaction Survey (HASS)
  - Satisfaction with Amplification in Daily Life (SADL)
  - Abbreviated Profile of Hearing Aid Benefit (APHAB)
- **Aided performance**
  - Connected Speech Test (CST)
- **Hearing Aid Use**
  - Use Diary and/or Datalogging
- **Objective Benefit**
  - Aided-Unaided CST scores
- **High-intensity Speech in Noise**
  - CST score at 80 dB SPL, 0 dB SNR
  - Aided-Unaided CST-80 score
- **Handicap Reduction**
  - Aided-Unaided HHIE (Hearing Handicap Inventory for the Elderly) score
- **Judged Sound Quality**
  - JSQ ratings for speech and music stimuli

Not Much Time?

3 Areas of Particular Importance

Outcome Measure	Objective Tests	Subjective Tests
Aided and unaided speech understanding, with real-world characteristics such as noise	Connected Speech Test (CST; Cox et al., 1987)	
Daily use	Data-logging through fitting software	Use diary
Benefit and satisfaction		Hearing Aid Performance Inventory (HAPI; Walden et al., 1984); Satisfaction with Amplification in Daily Life (SADL; Cox & Alexander, 1999); Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995)

Humes LE. Modeling and predicting hearing-aid outcome. *Trends in Amplification. 2003:7*(2); 41–75.
Humes LE. Hearing-aid outcome measures in older adults. In Palmer CA, Seewald RC, eds. *Hearing Care for Adults*. Stafa: Phonak AG; 2007: 265–276.

Open-Ended Validation Assessments

- Client Oriented Scale of Improvement (COSI)* allow patients to specify the areas of improvement that are most important for their daily lives
- Non-formal interviewing of the patient at the follow-up visit can highlight areas of improvement that have already occurred and other areas that are still difficult
- Results used in counseling to address the problems patients are experiencing

*Dillon H, James A, Ginis J. The Client Oriented Scale of Improvement (COSI) and its relationship to several other measures of benefit and satisfaction provided by hearing aids. *J Am Acad Audiol. 1997:8(2); 27-43.*

Summary

- Verification measurements are not just about gain and output. Many advanced signal processing features can also be verified and used in counseling.
- Validation measures are important for end users to recognize benefit, and can also be helpful for fine tuning and counseling.
- Both verification and validation are important for documentation, professionalism and increased patient satisfaction.

Top 10 Ways To Create Consumer Delight with Hearing Aids

- Hearing Aids that Actually Work
- Motivation
- Professionalism
- Evaluation
- Counseling
- Strong Recommendation
- Experimentation
- Verification & Validation
- Continued Connection
- You, the hearing care professional

Taylor & Rogin, Hearing Review, July 2011