I n the days before programmable hearing aids, the patient was "fitted" to the best gain and output through the use of numerous screwdriver adjustments and even by trying different instruments until the desired real-ear outcome was obtained. Today, because of our ability to conduct precise pre-fitting programming of hearing aids, this "*fitting* procedure" has become more of a "*verification* procedure." Does the hearing aid function in the real ear the way the software says it should?

Much of what needs to be verified regarding real-ear hearing aid performance can be accomplished with probe-mic measures. These test procedures have been used clinically for the past 25 years, and are cited as "best practice" in published fitting guidelines. There are some dispensers, however, who do not have this equipment. What do they do? Push a few programming buttons and hope they get lucky? Or, is it possible to verify the fitting to a reasonable degree using alternative measures? At least one person thinks so, and she's our Page Ten author this month.

**Robyn Cox** received a PhD in audiology from Indiana University in 1974, then joined the faculty of the University of Memphis shortly thereafter and never left. She is currently a professor and the director of the Hearing Aid Research Laboratory (HARL). You all know her numerous publications regarding improving hearing aid fitting procedures for older adults, and studying how to achieve fitting success.

Dr. Cox is perhaps best known for her work in developing standardized several questionnaires, including the clinically popular APHAB and SADL. You might not be aware of the most recent questionnaire developed in the HARL, the DOSO (Device Oriented Subjective Outcome) Scale, designed to yield a personality-free measure of the success of a hearing aid fitting. One of her current areas of interest is "comparative effectiveness research"—a focus on just which aspects of hearing aid provision give our patients the biggest bang for their buck?

Robyn was born in Toowoomba, Australia and grew up in Aussie-land. She says, "When I was growing up, no one ever cooked shrimp on the barbie, fair dinkum! We only cooked steak and sausages." Another myth exploded! What is not myth, though, is that real-ear verification of hearing aid performance is a critical component of the fitting. This article provides some very useful guidance on how to accomplish this, even if your probe-mic equipment is on back order.

GUS MUELLER
**Page Ten Editor**

# Verification and what to do until your probe-mic system arrives

*By Robyn M. Cox*

*Robyn M. Cox*

## 1 I saw your title! What do you mean "arrive"? I haven't even ordered one! I do verification by asking people, "How does that sound?"

Actually, that is not verification; that's fine-tuning. Verification is the process of making sure the hearing aid is doing what you, the dispenser, think is best for the patient. It should include a consideration of the way the hearing aid amplifies soft speech and conversational speech as well as the maximum output levels that are produced. In addition, you should verify the functionality of special features such as directional-microphone (DM) processing and digital noise reduction (DNR).

In contrast, fine-tuning is the process of making sure the hearing aid is doing (as much as possible) what the patient wants it to do. Fine-tuning should begin after verification because we know that it is important to begin patient-driven adjustments after the hearing aid has been programmed for near-optimal performance.[1,2] Fine-tuning is important, but it's a topic for another day.

## 2 Why do I need to bother with verification as well as fine-tuning? After all, the most important thing is for the patient to be happy, right?

Yes, but in the long run the patient will be happiest when you provide the best possible amplification. When she comes to you seeking hearing aids, the patient often does not know what amplification will be best. Hearing loss usually advances insidiously, gradually eroding available sound cues. The patient becomes accustomed to an auditory world that is very diminished compared to that of a normal-hearing person. In time that world comes to sound natural.

So when we rely on the patient to guide us in adjusting the programming so that the hearing aid "sounds good," she will often nudge the fitting toward producing sound that is like the distorted auditory world she is used to. This is not in the patient's best interest in the long run. It is the dispenser's responsibility to guide the patient toward reconnecting with the real auditory world as well as possible. This means that you need to have a pretty good idea what will be best for the patient and help her to head in that direction.

## 3 That's easy for you to say. But how do I know what amplification is best for the patient? People are so different.

We have good research on what amplification for conversational speech is best on average for a patient with a particular hearing loss. In addition, we have very sensible ideas about how soft speech and loud sounds should be produced for a given patient. These considerations have resulted in well-studied prescriptive targets to use when we fit and adjust hearing aids. Verification includes adjusting the hearing aid until it produces soft speech, conversational speech, and loud sounds that are as close to those targets as possible.

## 4 Okay, but how can I use the results of the research in my practice? I don't have time to read all those articles.

I understand, but you are in luck because the two most thoroughly researched prescription methods are now at your fingertips in most mainstream real-ear/test box systems. These are the Desired Sensation Level input/output (DSL) method, which recently released its fifth version,[3] and the National Acoustics Laboratories Non-Linear (NAL) method, which is approaching release of its second version.[4] Using one of these prescription methods included in your probe-mic system allows you to have the benefit of more than 20 years of R&D without opening a journal, if you wish (I'd still recommend a little reading!).

By the way, when I said "included in your probe-mic system," I meant that you would be measuring ear canal SPL for the verification process. This is important. Some people fitting hearing aids simply look at the "simulated" fitting in the manufacturer's software and assume this is what happens in the real ear canal. There is ample evidence that this assumption is often wrong, because the manufacturer cannot possibly know all the variables affecting the fitting for your particular patient.

For example, Aazh and Moore programmed hearing aids by selecting NAL-NL1 in the manufacturer's software, then verifying the match to the NAL-NL1 target using a probe-mic system.[5] The NAL-NL1 prescription was matched in the ear canal (±10 dB) across the frequency range only 36% of the time. However, using the probe-mic measures, 83% of the fittings could be matched to the prescription. This is a compelling demonstration of the importance of probe-mic measurements in optimizing your fittings.

## 5 I see your point. But some folks say DSL targets are the best whereas others say NAL targets are better. How do I know which prescription to use?

In past years, there has been some conventional wisdom that DSL is just for children and NAL is just for adults. This is a myth. Both methods were developed for use with people of all ages. Also, both methods now promote different targets for adults and small children, which is an important point.

Originally, there *were* some differences between NAL and DSL targets, but as each has been further refined these differences seem to be disappearing. The targets for the most recent versions of the two methods are quite similar (especially when viewed with reference to the level of precision that is typically possible in adjusting real hearing aid fittings).

It makes sense that this should happen as we learn more about amplification needs. After all, there can be only one optimal average prescription for a given audiogram in patients of a given age. In new versions of DSL and NAL, the major differences might be in refinements such as slightly different targets for men and women, or for quiet and noisy places. So, the most important thing for you is to use one of them to establish targets that you can shoot for in the verification phase of the fitting.

## 6 Let's say I pick one. What do I do then?

You use your probe-mic system to measure amplified sounds (soft speech, conversational speech, and loud sounds) in your patient's ear and then compare them to the prescription targets. If your fitting does not amplify sound to match the appropriate target, you should try to change the hearing aid programming to come as close to the prescribed target as possible. This will get you to the best place to begin fine-tuning.

Did you notice that I said "soft speech, conversational speech, and loud sounds"? Maybe you remember that we used to use warble tones for probe-mic measurements. That doesn't happen much any more. The only exception is that we still use loud tonal signals to measure the MPO of the hearing aid in the ear canal. This is because tonal signals drive the hearing aid's output as high as it can go for any kind of signal, which is what we need to know for MPO verification.

However, when we want to determine how the hearing aid processes speech, it's a different story. Modern hearing aids have become so complicated that simple signals cannot predict accurately how the hearing aid will perform with a speech signal. So you really need to use real speech or an artificial speech-like signal in your probe-mic measurements. A speech-like signal is a broadband sound with the long-term spectrum and temporal modulations of typical speech. It might not sound much like speech to us, but it does sound like speech to a hearing aid. Your probe-mic system should include either real speech or an equivalent speech-like sound. Sometimes they include both.

## 7 Earlier, you said I also need to check the functioning of the directional-microphone and digital noise-reduction features. Why must I bother with that and how do I do it?

That's all part of *verification*. You need to check DM and DNR functioning because different hearing aids behave very differently and you have no other way of finding out if the features are working as you want for your patient.

The best way to do this is to use a screening process with the hearing aid in a test box. I call this a screening process because there are limits on what you can measure in a clinical test box. Nevertheless, you can get a very good idea about the functionality of the feature for the way you have programmed the hearing aid.

To demonstrate this, we used a test box to measure directionality in hearing aids from six different manufacturers. Also, there were measures on two of each type of hearing aid (see Figure 1). We obtained a Directionality Score by measuring the directional separation (difference when sounds come from the front versus the back) in 1/3-octave bands, averaging it within low frequencies (250-500 Hz), mid-frequencies (630-1600 Hz), and high frequencies (2000-4000 Hz), and then summing these three averages. Thus a higher Directionality Score means that the

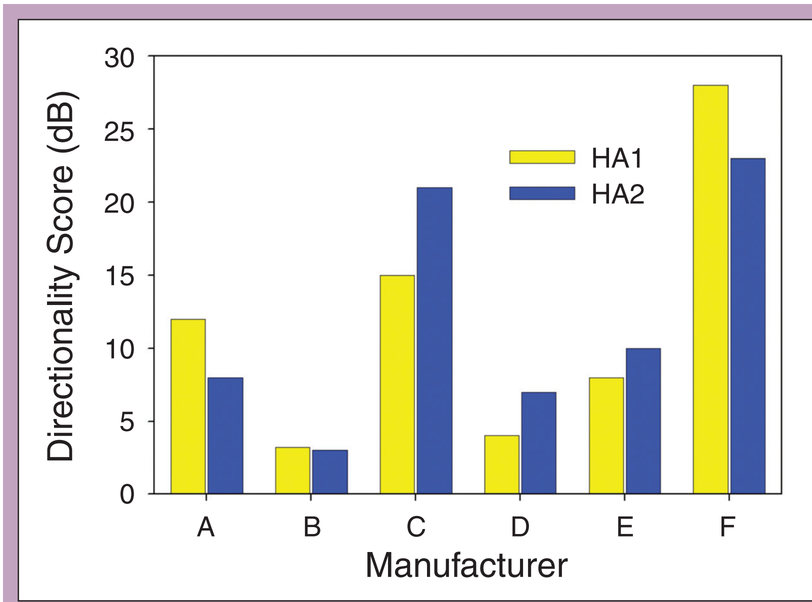


**Figure 1.** *Test-box measures of directionality in hearing aids from six different manufacturers.*

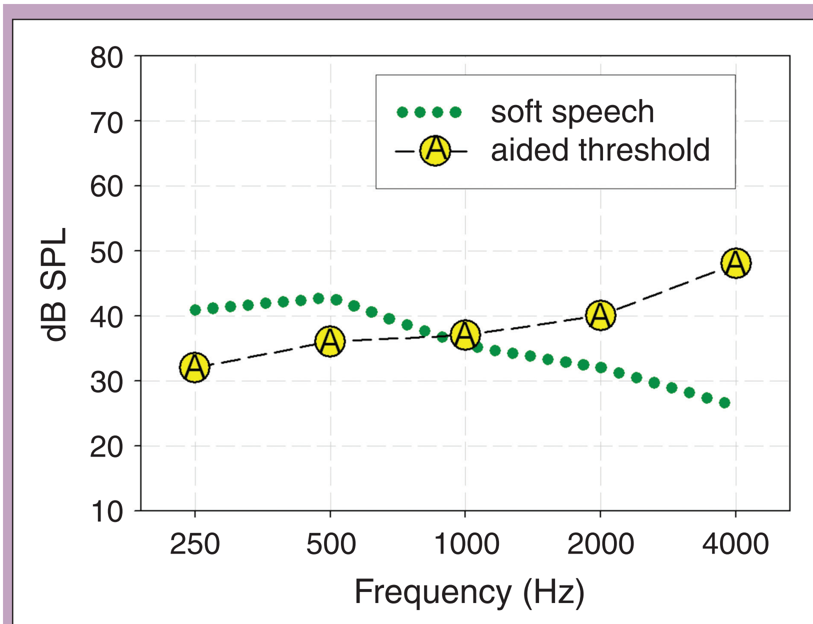


**Figure 2.** *An SPLogram showing the average 1/3-octave band speech spectrum for soft speech (50 dB SPL) and a typical example of measured sound field thresholds for a patient wearing his hearing aid.*

hearing aid more effectively reduces sounds that do not come from in front.

We learned two important things: (1) Different models of directional hearing aids provide different amounts of directionality, and (2) two examples of the same model are not always consistent in their directional performance. I could talk about similar measures of DNR functioning, but I think you get my point. The bottom line is that the only way you can know how the DM or DNR feature is functioning in a specific hearing aid that you have programmed is to check it.

While we're talking about verifying DM and DNR functioning, don't forget that their real-world effectiveness in a particular fitting will be influenced by factors such as how they are programmed, the orientation on the ear, the openness of the fitting, and so on.[6] That is why the test box measures do not give the final word.

**8 That's all very well. Actually, I've heard it all before. But as I said, I don't have a real-ear system or even a test box. So I can't do all this stuff you're talking about. So I skip verification. What else can I do?**

Hmmm. I hope you're able to get a probe-mic/test box system soon. However, all is not lost. There are other ways to do verification. These methods are low-tech and less accurate than probe-mic and test box measures, but they certainly are much better than nothing. There are low-tech ways to check soft speech audibility, conversational speech loudness, and maximum output. Also, you can check the functioning of your DM and DNR features. You just need a few simple items and your own resourcefulness.

**9 I'm intrigued, and pretty resourceful. For starters, could you tell me how to verify that I have appropriate amplification for soft sounds?**

I'd be glad to. Actually, there are two handy low-tech ways to do this.

For the first one, you simply measure aided sound field thresholds (using warbled tones) in dB SPL and plot them on an SPLogram (see Figure 2). As I'm sure you know, an SPLogram is a frequency-by-sound pressure level plot with soft sounds at the bottom and loud sounds at the top. If you are thinking, "My audiometer is in HL, not SPL," you need to convert those dB HL thresholds into dB SPL to use an SPLogram.

That's easy. All you do is add the following numbers to your thresholds in HL: 250 Hz = 13, 500 Hz = 6, 1000 Hz = 4, 2000 Hz = 0.5, 4000 Hz = -4.5. For example, if the sound field threshold you measured at 500 Hz is 35 dB HL, you would add 6 to give an equivalent threshold value of 41 dB SPL (I assumed that your patient was facing the loudspeaker for the threshold measurement). You would plot that on the SPLogram at the intersection of 500 Hz and 41 dB SPL.

In an SPLogram, we draw a line showing the average 1/3-octave band speech spectrum for soft speech (50 dB SPL). Then we add another line showing the sound field thresholds measured for a patient wearing his hearing aid (see Figure 2). Using this method, we quite often see that soft speech is only audible at low frequencies, because at higher frequencies the speech is lower (softer) than the thresholds. In this case, your patient's understanding of soft speech would improve if you increased the gain for soft high-frequency sounds. Every manufacturer's software has a control or handle to do this, labeled something like "soft gain" or G50.

Are you getting a déjà vu feeling? If you've been around for a while, you might remember that we used to use sound field thresholds for verification of linear hearing aids. When WDRC became widespread, aided thresholds fell into disrepute. But they are actually quite a good way to get an estimate of potential hearing for soft sounds with a WDRC hearing aid. You might be surprised to know that the answer they give is not terribly different, on average, from the result you get with a probe-mic system.

I can demonstrate this point. Dawkins and Cox compared aided audibility measures obtained using an Audioscan Verifit probe-mic test system with aided audibility estimates obtained using aided sound field thresholds.[7] In the probe-mic method, real-ear aided response (REAR) for soft speech (50 dB SPL) input was compared with thresholds plotted as SPL in the ear canal. For the threshold method, aided sound field thresholds were plotted on an SPLogram and compared with the 1/3-octave band levels of soft speech (50 dB SPL) in the sound field. There were 22 ears and subjects wore their own modern hearing aids at their routine settings.

The audibility of soft speech derived from the two methods was compared (see Figure 3, adapted from Dawkins & Cox[7]). On average, the two methods gave very similar results, and both showed that the subjects were receiving limited information from soft speech. Audibility values at several frequencies were below zero, indicating that the overall level of amplified soft speech did not rise above threshold at that frequency. One thing we learned from this study is that measuring aided sound field thresholds is one way to get a pretty good idea about the audibility of soft speech in your patient's fitting, even if you don't have a probe-mic system.

### 10 Whew! That déjà vu is making my head spin. But guess what? I don't have sound field test equipment either.

Not so fast, my friend. Remember I said earlier that there are two handy low-tech ways to verify soft speech audibility? The other approach is another oldie but goodie: the Ling Six Sound test.

In case you haven't heard of this test, it was developed by Daniel Ling in the 1970s. It has been widely used since then with young hearing-impaired

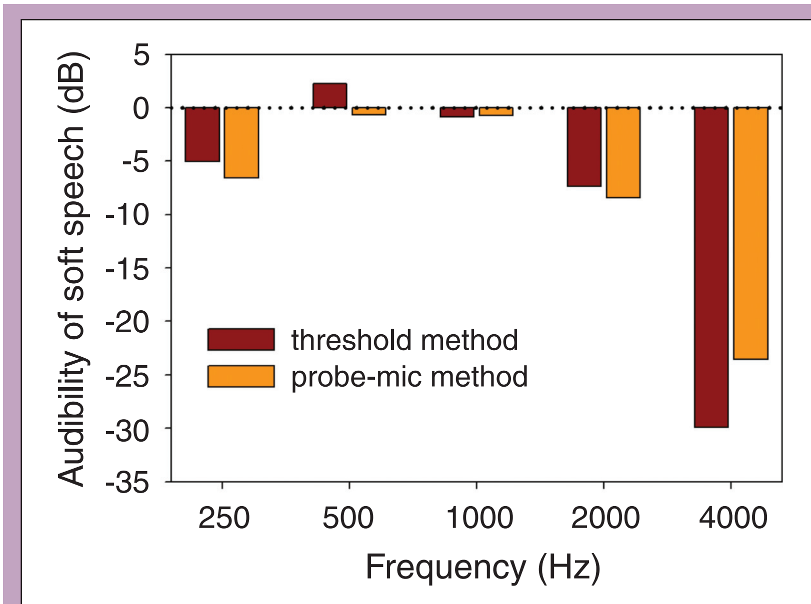


**Figure 3.** *Audibility of soft speech derived from two methods of measurement.*

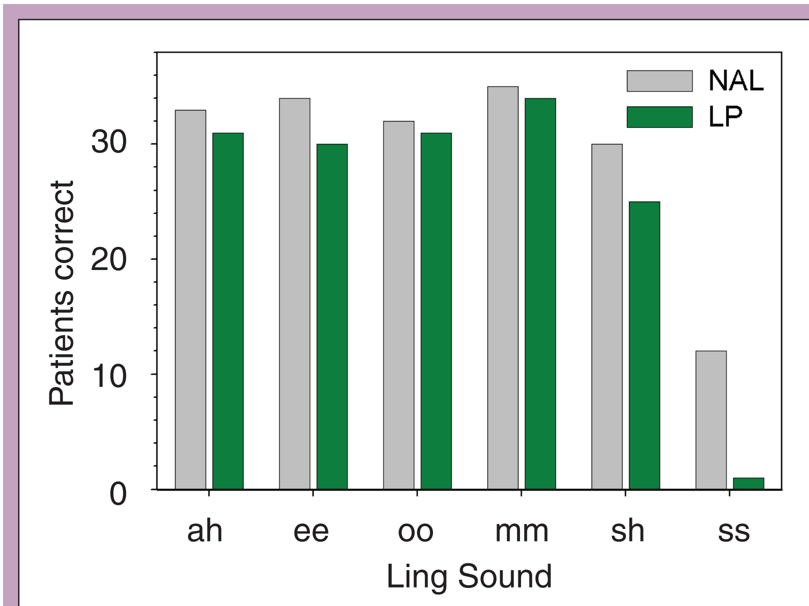


**Figure 4.** *Ability to identify the Ling six sounds by 36 individuals wearing hearing aids programmed to each of two prescriptions.*

### So, nice try, but I still don't think that verification stuff is going to work for me.

children, and now is extensively used with children who have cochlear implants. If you Google "Ling Six Sound test," you'll find many sources to learn more.

The sounds are "ah," "ee," "oo," "mm," "sh," and "ss," and when these are spoken in a soft voice, they produce levels of about 30-50 dB HL and cover a frequency range similar to most hearing aids. Tell your patient to close his eyes and repeat the sounds you say. Stand a few feet in front of him and speak each sound fairly softly. Your hearing aid fitting should certainly allow most hearing aid wearers to hear and repeat "ah," "ee," "oo," and "mm." The ability to repeat "sh," and "ss" is a test of how much high-frequency gain you have provided for soft sounds.

We recently used this test to verify fittings for 36 subjects who wore modern hearing aids in two conditions (see Figure 4). In one condition, the hearing aid was adjusted and fine-tuned beginning with the NAL-NL1 prescription. In the other condition, the NAL-NL1 prescription was modified with a high-frequency gain roll-off starting about 2000 Hz (the low-pass LP condition). Both fittings allowed most of the subjects to repeat "ah," "oo," "ee," and "mm." On the other hand, they could repeat "ss" and "sh" more often when the hearing aids provided high-frequency gain similar to the NAL-NL1 prescribed level. Reduction in high-frequency gain in the LP fitting made it less likely that "ss" and "sh" could be heard.

So, you see, even if you don't have a probe-mic/test box system, you can still learn a lot about your patient's ability to hear soft speech either by measuring aided sound field thresholds or by using the Ling Six Sound test. Sure, it's not the most accurate possible, and yes, it's low-tech, but it's much better than nothing. You and your patient both can gain an appreciation of the extent to which he is likely to benefit from the hearing aids for soft sounds in daily life.

## *Editor's note*

*Sometimes things are just too good to finish in one installment of Page Ten. Dr. Cox and her inquiring friend are going to take a little break right now, but they will be back in the October issue of the* Journal *to continue their intriguing discussion of low-tech hearing aid verification.*

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