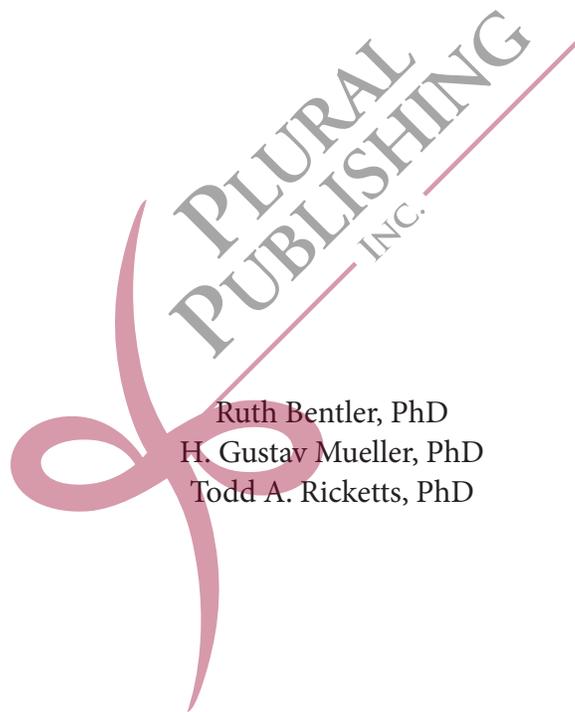


Modern Hearing Aids

Verification, Outcome Measures, and Follow-Up



Ruth Bentler, PhD
H. Gustav Mueller, PhD
Todd A. Ricketts, PhD



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Preface

You perhaps have heard the old adage that “fitting hearing aids is both an art and a science.” We mostly agree, but want to point out that, if you get the science part of it right, you will inevitably be more artful. Verified audibility trumps the artisan most every time.

So what is the science part of it? In our first book, *Modern Hearing Aids: Pre-Fitting Testing and Selection Considerations*, we talk about pre-fitting testing and selection considerations, and in our forthcoming book several chapters are devoted to signal processing, technology, and special features. The bulk of the science used by clinical audiologists, however, revolves around verification and validation procedures, and that is the focus of this book. There are millions of ways to program today’s hearing aids for any given patient, and audiologists are faced with the task of using mouse clicks that ultimately result in appropriate audibility, optimum intelligibility (in quiet and in noise), normal loudness, good sound quality (for music as well as speech) and an overall fitting that is acceptable to the patient. What makes this task particularly daunting is that some of the fitting goals we just mentioned work against each other; for example, boosting audibility may *reduce* sound quality. In many cases, a compromise is needed, and most importantly, the fitting must be verified—the big player in this category is the measurement of the output in the ear canal for different input levels. And of course, we need to validate, in a reliable manner, that benefit and satisfaction are present in the real world.

Several chapters in this book focus on verification. Others on validation. Terms that may sound similar—and to some—mean the same thing. We prefer to think of verification as “does it work the way we want it to work?” and validation as “does it do what we want it to do?” Hearing aid fitting protocols from several professional organizations have clearly outlined the components of Best Practice verification and validation. We really haven’t added anything entirely new or radical in our chapters, as most of these protocols are up-to-date and quite comprehensive. Unfortunately, however, these Best Practice guidelines have not been embraced by most audiologists when fitting hearing aids. Maybe this is because of a lack of awareness or that the guide-

lines just haven’t been spelled out appropriately. We’ve attempted to lay out all the verification and validation tests and procedures in a clinically friendly manner, and hope that this book encourages readers to adopt at least some of the protocols we suggest.

Clinicians often ask—is all that work really worth it? The answer is a resounding “yes.” Forgetting for a moment the ethical and possible medical-legal ramifications of fitting hearing aids and not providing patients with appropriate audibility, considerable data show that as verification and validation measures increase, so do patient benefit and satisfaction. For example, over the past few years, Sergei Kochkin has rolled out several articles regarding the value of hearing aid verification and validation using the patient satisfaction data from the large MarkeTrak VIII database. His findings clearly show that as audiologists add various verification and validation components of Best Practice to their fitting protocol, satisfaction increases accordingly, patient loyalty increases significantly, and follow-up visits for hearing aid adjustments are reduced. In one related study, Sergei Kochkin’s analysis revealed that audiologists who do not use a comprehensive fitting protocol have patient satisfaction rates worse than what are obtained when patients use mail-order PSAPS!

To state the obvious, to verify something, you must have a reference standard. We believe an excellent starting point is the use of a validated prescriptive fitting approach. Today, we have two well-researched methods, the NAL-NL2 and the DSLv5.0. We provide a detailed review of both of these fitting algorithms, and we believe that both offer an excellent starting point for the verification process. Of course, we know whether we are using a given prescriptive method only if we observe aided ear canal SPL output. A large portion of this book, therefore, focuses on the use of probe-microphone measures, or what is often called *speech mapping*. This is the cornerstone of the verification process, not only for determining whether prescriptive targets for various input levels are met, but also for assessing the function of a multitude of special features in hearing aids. We also review a variety of speech tests that can be used to supplement the real-ear verification process.

Palmer concludes her article with the following.

I hope we can continue to discuss the reasons that hearing aid acceptance is not higher in the hearing-impaired population. The fact that a doctoral profession is arguing about whether or not to individually verify the gain and output of a hearing aid in a patient's ear that takes less than 5 minutes might just be a good place to start. If you are wondering if providing this level of verification will establish you as an expert and set you apart from other providers, keep in mind that it does not require any particular expertise to attach cords to a HIPRO Box, double click on NOAH, enter a patient name, click hearing thresholds on a graph, double click on a manufacturer icon, and click "first fit." This level of "expertise" does not require a doctoral degree. As a profession, it is time to be an expert. An expert knows exactly what levels of sound are being produced in an individual's ear canal and how those levels correspond to the listener's residual dynamic range of hearing. (*Audiology Today*, 2009, p. 34)

Reasons for Not Conducting Probe-Microphone Measures

More important than the recommendations of best fitting practices and experts is that the research evidence

that we detail in the following discussion clearly demonstrates the importance of completing probe-microphone measurements. Despite being the intuitive thing to do, the right thing to do, the evidence-based thing to do, and therefore we think the ethical thing to do, probe-microphone testing is *not* conducted by most audiologists when they fit hearing aids. Over the years, there have been many reasons postulated regarding why this is true, as well as articles written on the topic (Mueller, 2005). We review several of those reasons here.

Equipment Isn't Available

Why would one choose to set up a practice without the necessary equipment? Certainly cost must be considered. Used systems, in good working condition, however, are available for a few thousand dollars, and the more basic new systems sell for only a little more. Lease-to-buy deals in 2015 were available for around \$100.00/month. Given that many clinics and offices will have gross annual hearing aid sales of \$300,000 to \$500,000, a \$5000 equipment purchase that leads to improved patient satisfaction and benefit does not seem very unreasonable.

Not Enough Time

Indirectly, the time issue takes us back to our "bundle versus unbundle" discussion in our book *Modern Hear-*



SOAPBOX: LEO TOLSTOY AND PROBE-MICROPHONE MEASURES

As we've reviewed in this chapter, there is an unexplainable reluctance for audiologists to conduct probe-microphone measures, and as a result, most audiologists fitting hearing aids do not use this measure routinely. To make our first Soapbox point, we quote Leo Tolstoy: "Wrong does not cease to be wrong because the majority share in it." You're the only student who refuses to go to a placement because they don't use probe microphone for fitting hearing aids? Good for you. You're a practicing audiologist and you're the only one in the clinic doing probe microphone? Good for you. The place where you work doesn't have probe-microphone equipment? Buy it. Your employer tells you that there isn't time to do probe-microphone testing for your hearing aid fittings? Find a new job.

There is considerable evidence to show that the use of hearing aids will improve individual's lives. There is also evidence to show that well-fitted hearing aids will have an even greater impact.

ing Aids: Pre-Fitting Testing and Selection Considerations. What percent of the total cost of a pair of hearing aids is for the hearing aids themselves, and what portion is for our services? But even when the price of hearing aids is bundled, we know that a good share of the money paid by the patient is for our professional services. These professional services include optimizing gain to provide as much hearing aid benefit as possible while ensuring satisfaction and comfort. This is the very goal of many of the validated prescriptive gain and output procedures we are verifying through probe-microphone testing. As professionals, we take as much time as necessary to get the job done right.

Not Valid with Today's Technology

Those of us fitting hearing aids for several years have heard a lot of "what you can't do." It started with you can't do probe-microphone testing with wide dynamic range compression (WDRC) hearing aids. Then we heard, you can't do probe-microphone testing with programmable hearing aids, which then led to you can't do probe-microphone testing with digital processing (Mueller, 2001) hearing aids. Even today we hear a clinician say: "I was told by the rep that probe-microphone testing really doesn't tell you much with their product." All this simply is not true. In fact, in many cases, the more sophisticated the processing, the more things that you can verify, and the more important it is to verify. With today's real-speech inputs, the probe-microphone findings provide a very reasonable estimate of real-world audibility for speech. Sure, there are a few caveats to this, but they are easy to overcome. We will discuss those in Chapter 7. The bottom line is, if one of our primary goals is achieving the right amount of audibility for speech, it seems to make good sense to measure the audibility.

Poor Training?

Could it be that AuD students simply are not trained properly regarding the importance and use of probe-microphone measures? This has been suggested by some. We find it unlikely that an accredited AuD program would *not* teach the verification procedures recommended in best practices guidelines. However, there is sometimes a disconnect between academic training and clinical practice and mentoring. Here is a comment

on the topic from Mike Valente, certainly one of the strongest advocates of probe-microphone testing that you will find in an AuD training program.

According to the clinic coordinator at one graduate program, in 16 of 20 external clinical sites where she sends her students for clinical experience, probe-microphone equipment is never used or used only in "special cases." Therefore, some students wonder if probe-microphone verification really is necessary if seasoned audiologists with successful practices do not use it. Also, I believe a majority of students graduate understanding the need for probe-microphone measures to implement a "best practice," but the facility in which they are then employed either does not have the equipment and/or has staff who do not promote its routine use. It is very difficult, if not impossible, for new graduates to arrive at their first job and change the method of practice. (Mueller, 2005)

We agree with Mike's comments, as we have heard the same thing from others. You would think that doctoral students in audiology would be allowed to do practicum only at sites that follow Best Practices, but for some reason that doesn't always seem to be possible. Changing the culture in the workplace is probably related to the reason we discuss next.

The Fitting Software Gets It Right

The biggest factor in the failure to use probe-microphone verification is probably the general belief of many audiologists that the fitting software will somehow get things right. That is, if you click the default button in the fitting software, the patient will most likely have the best fitting. If you click the NAL-NL2 button, the patient will most likely be fitted to NAL-NL2. Or, if you look at the simulated gain or output displayed by the fitting software, you actually see a true representation of the actual gain or SPL levels in the real ear. Unfortunately, research has shown that none of these assumptions is true, as we detail in the following sections.

Of course we would not expect the software fitting to be perfectly accurate for individual patients, as average correction values are used, and there are differences in individual ears. We already address this in Chapter 4 of this book, and also extensively in Chapter 4 of *Modern Hearing Aids: Pre-Fitting Testing and Selection*

Considerations. What we are talking about here, however, is something different: Variances that have a greater impact than the usual 3 to 4 dB differences in RECDs or CORFIGs. In general, the issues surround both the manufacturer's proprietary fitting (what actually happens in the ear when you activate the default fitting for a specific hearing loss) and the manufacturer's software implementation of a validated prescriptive method such as the NAL-NL2. We will address each of these issues separately.

Proprietary Fittings are Best?

As discussed in Chapter 4, all major manufacturers have a proprietary fitting. How this fitting was developed probably varies from manufacturer to manufacturer. To some extent, this fitting relates to specific processing of a given manufacturer's product, but for the most part it is based on two types of data from research studies and/or patient or clinician complaints compiled by the manufacturer: (1) preferred sound quality including naturalness and (2) initial acceptance data (e.g., return for credit rates). Sometimes, these proprietary fittings have been simply employed to compensate for past problems, or perceived problems. For example: (1) Patients say our first fit sounds tinny, let's roll off the highs; (2) Patients (or audiologists buying our instruments) say our first fit results in feedback, let's roll off the highs; and (3) Patients (or audiologists buying our instruments) say the first fit of Brand X sounds better than ours, let's make ours just like Brand X.

How this relates back to the non-use of probe-microphone assessment is that it is very difficult to verify a proprietary fit in the real ear, starting with the term *proprietary*. If you want to verify to the NAL-NL2 or DSL v5, you simply select this in the software of your probe-microphone system, and the prescriptive targets will appear on the screen. But if you want to verify to Starkey Fit, or Siemens Fit or Phonak Fit . . . there are no real-ear targets in your probe-microphone system. Now, it could be that there are some simulated curves in the fitting software, you could maybe print these out, and then eyeball them while conducting probe-microphone testing, but this is more trouble than most audiologists want to go through. And, even if you went through the trouble of trying this, your results only would be valid if the LTASS used to construct the proprietary gain and output curves was the same as the as the LTASS of the input signal with your probe-microphone equipment

when the real-ear measure is performed. This is probably unlikely, and ensuring the same LTASS is used is sometimes difficult to even determine.

So, maybe the first question should be: Are proprietary fittings a reasonable starting point for the fitting? If so, then maybe you really don't need to do probe-microphone testing. Experts have commented on the use of proprietary fittings for some time. Denis Byrne, for example, expressed his concerns in 1996: "Scientifically, the concern is that amplification may become prescribed by a wide variety of proprietary formulae of which few, if any, are validated by published research. A possible philosophical problem is that control of the fitting process is taken away from the fitter, who is responsible for the care of the client" (p. 378).

The concerns of Byrne (1996) appear to be well-founded. Here is a brief summary of research that has looked at how these strategies compare to validated approaches, adapted from Mueller (2006):

- Keidser, Brew, and Peck (2003), in a study examining the recommended algorithms of five different major manufacturers, showed that it is common for prescribed gain to differ by 10 dB or more from the NAL-NL1 targets in the high frequencies for average-level input signals.
- Bentler (2004) examined the default algorithm of the premier product from six leading hearing aid manufacturers using a real-speech input (long-term 65 dB SPL input). In general, all algorithms prescribed gain below the NAL-NL1 target levels. Of particular concern was that for key frequencies such as 2000 Hz, the difference in prescribed gain was as much as 15 to 20 dB, with some algorithms only prescribing 5 dB of gain for the sample patient with a 50 dB hearing loss at that frequency.
- Bentler, Wu, and Jeon (2006) calculated the real-ear insertion gain (REIG) for four different open canal (OC) products based on the manufacturers' recommended fitting. The hearing aids were programmed for an individual with a high-frequency hearing loss (50 dB at 2000 Hz, 60 dB at 3000–6000 Hz). They observed about a 5 dB difference among manufacturers, but in general, the average "recommended" gain fell 10 to 15 dB below NAL-NL1 targets in the 2000 to 4000 range.

Two of the four products provided no more than 7 dB of gain at 4000 Hz for this sample patient with a 60 dB hearing loss at that frequency.

These studies suggest that the default proprietary fittings fall seriously short on providing appropriate audibility. Even if you are not a believer in validated fit-

ting methods such as the NAL, Hearing Aids 101 and a little horse sense tells us that a patient needs more than 5 dB of gain when they have a 50 dB hearing loss. It's true, however, that the studies cited are somewhat dated. Mueller (2014a) provides an example from three major manufacturers that suggests that not much has changed. As shown in Figure 6-2, observe that for this hypothetical patient with a sloping loss from 30 dB in the lows to

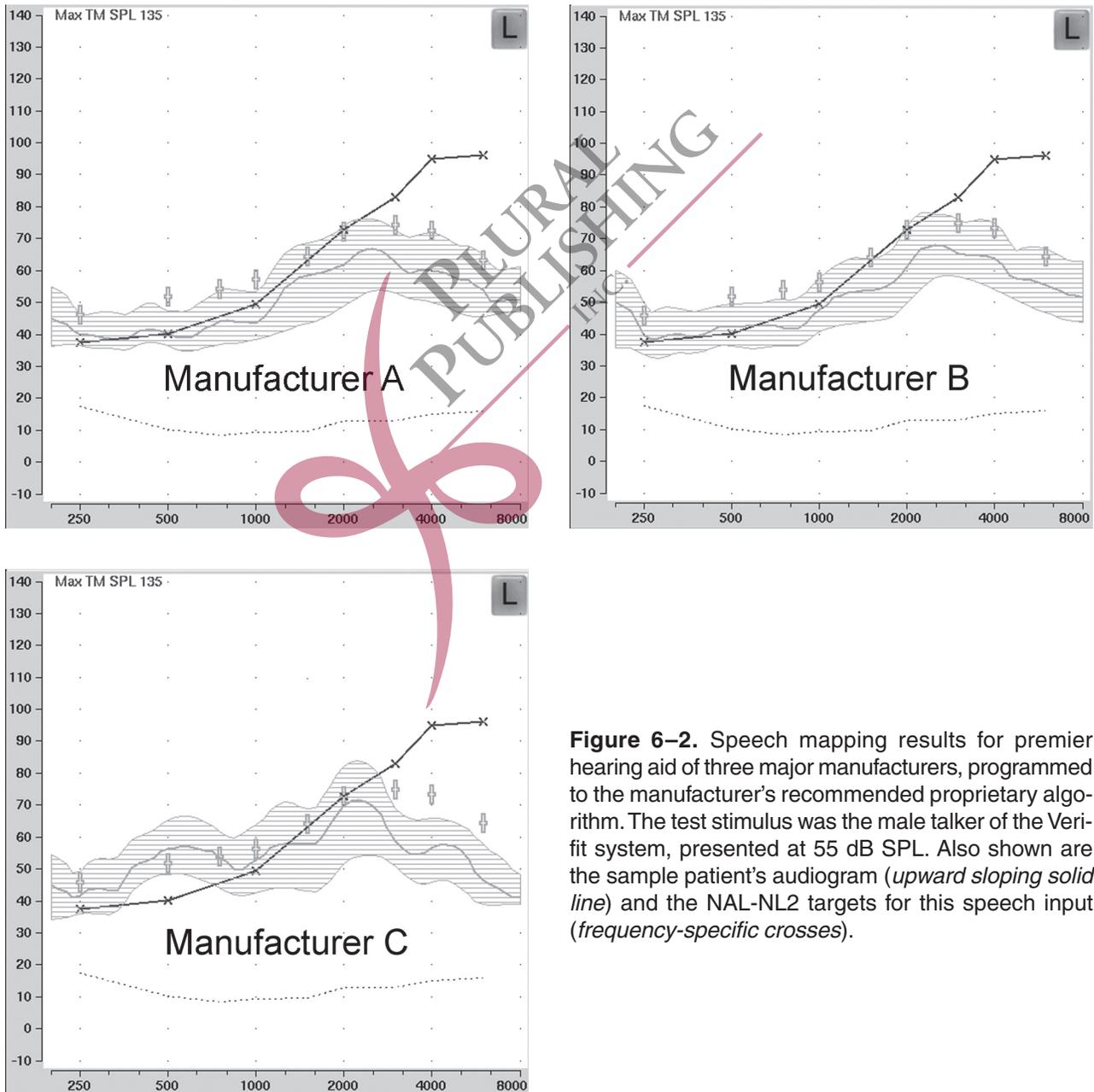


Figure 6-2. Speech mapping results for premier hearing aid of three major manufacturers, programmed to the manufacturer's recommended proprietary algorithm. The test stimulus was the male talker of the Veri-fit system, presented at 55 dB SPL. Also shown are the sample patient's audiogram (*upward sloping solid line*) and the NAL-NL2 targets for this speech input (*frequency-specific crosses*).

70 dB in highs, the default fittings of these premier hearing aids provide only minimal gain for the frequencies above 1500 to 2000 Hz, where not even the peaks of the speech signal are audible (the NAL-NL2 fitting targets are included as a reference). Observe that the average of the amplified signal falls 10 to 15 dB or more below the NAL-NL2 targets for the higher frequencies. Obviously, this minimal amount of audibility will not allow for useful speech recognition cues!

In a unique and eye-opening study, Leavitt and Flexer (2012) reported how modern-day default fittings actually impact speech recognition in background noise. They compared the premier 2012 product of the six major manufacturers to a single-channel analog product from 2002. Subjects were fitted bilaterally and tested using the QuickSIN, presented at 57 dB SPL—slightly below average speech. The old analog hearing aids were programmed (and verified) to NAL-NL1 for each subject. Two different settings were used for the six pair of premier hearing aids: the hearing aids were tested while programmed to the manufacturer's default setting, and also when programmed to NAL-NL1. The old hearing aids did not have directional technology or digital noise reduction. The new hearing aids did, and these features were activated at the levels suggested in the default software. The mean results of QuickSIN speech recognition testing are shown in Figure 6–3.

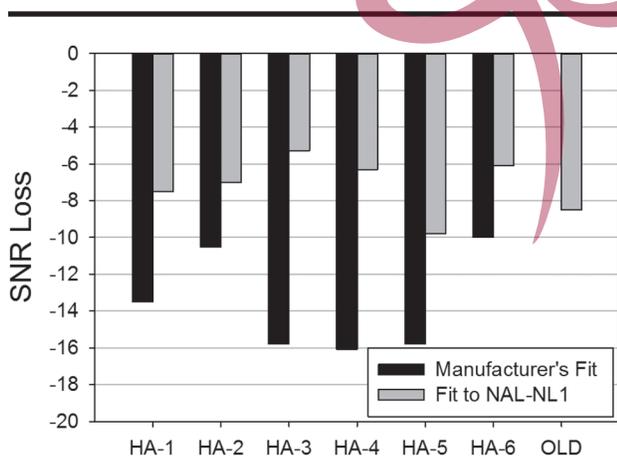


Figure 6–3. SNR-loss is shown across five premiere hearing aids and one older style analog hearing aid as a function of the manufacturer's default setting and the NAL-NL-1 fitting. Lower numbers show better performance. Adapted from Leavitt and Flexer, 2012, with permission.

As described in Chapter 5, the QuickSIN is scored as signal-to-noise (SNR) loss, and therefore, the lower the bar extends downward in Figure 6–3, the worse the performance. Note that the average SNR-Loss for the old hearing aid was about 8.5 dB. What stands out, however, is the poor performance for all the modern-day hearing aids, when fitted to the manufacturer's proprietary fitting. Note that for HA-3, HA-4, and HA-5, the SNR-Loss is greater than 15 dB, about a 7 dB drop from the mean performance obtained with the old analog hearing aids.

Let's put the Leavitt and Flexer (2012) findings into practical terms—we'll say that an audiologist has fit someone with a pair of new high-end hearing aids, programmed to the manufacturer's default settings. The patient was a previous user of old analog hearing aids programmed to the NAL-NL1. The audiologist's counseling would have to go something like this. "Bob, thanks again for the \$5000, but I do have to tell you that when you go back to your favorite restaurant this weekend, you'll somehow have to convince management to reduce the background noise level by 7 dB if you want to understand as well as you were with your old hearing aids." Why would an audiologist ever do that to a patient?

Notice, referring back to Figure 6–3, that by simply programming the hearing aids to the NAL-NL1 prescriptive targets, average SNR-Loss improved significantly for all models and 9 to 10 dB for HA-3 and HA-4. When programmed to NAL-NL1, all products except HA-5 had performance better than the old hearing aids. Patients often walk in the door looking for the best and latest technology. These findings clearly show that it is not just the technology. Simple technology programmed well will outperform fancy technology programmed poorly almost every day.

In the most current study examining today's proprietary fittings, Sanders et al. (2015) conducted probe-microphone measures for the premier hearing aids of the five leading manufacturers, using products and software current in 2015. The hearing aids were all programmed to the respective proprietary fitting, for a gradually downward sloping hearing loss (25 to 75 dB HL), and real-ear output was obtained (16 ears) for inputs of 55, 65, and 75 SPL. The testing was conducted with the Audioscan Verifit, which calculates the SII, and these values were used for comparison. The findings from Sanders et al. (2015) are shown in Figure 6–4. The SII values reflect a familiar theme—reduced audibility.

It appears, however, that the differences among manufacturers, and the variance from the NAL-NL2 become smaller as the input signal increases (most probably

because the proprietary methods are more linear than what would be prescribed by NL2). For example, for the 55 dB SPL input, SIIs among manufacturers vary from a low of 0.25 to 0.40 compared to a 0.47 values for a NL2 fitting. For average inputs, the different products vary from 0.46 to 0.57, compared to 0.65 for the NAL-NL2. For the 75 dB SPL input, the products were similar, and were only 0.1 to 0.5 below the NAL-NL2 SII. The authors did not measure speech recognition directly, and it is somewhat difficult to predict speech recognition from SII values; however, if we look at the 55 dB SPL input, we would expect that the lower SIIs from some instruments would result in 20% to 50% poorer speech recognition than if the patient had been fitted to the NAL-NL2 (e.g., based on the SII conversion chart of Killion and Mueller, 2010, shown in Figure 6–5).

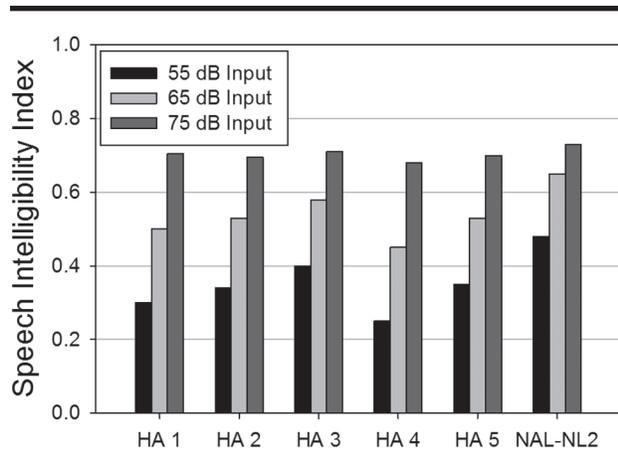


Figure 6–4. Derived Speech Intelligibility Index (SII) values (ANSI, 1997a) across five premiere hearing aids and compared to the NAL-NL2 prescriptive gain as a function of the input level. Adapted from Sanders et al., 2015, with permission.

Of course, the most critical factor when comparing default fittings to validated methods is the patient-reported outcome. The laboratory data of Leavitt and Flexer (2012) are quite compelling—improvements of the average SNR of 6 to 10 dB for most manufacturers. If we look at real-world outcomes, however, it should be noted that the sensitivity of these measures is limited,

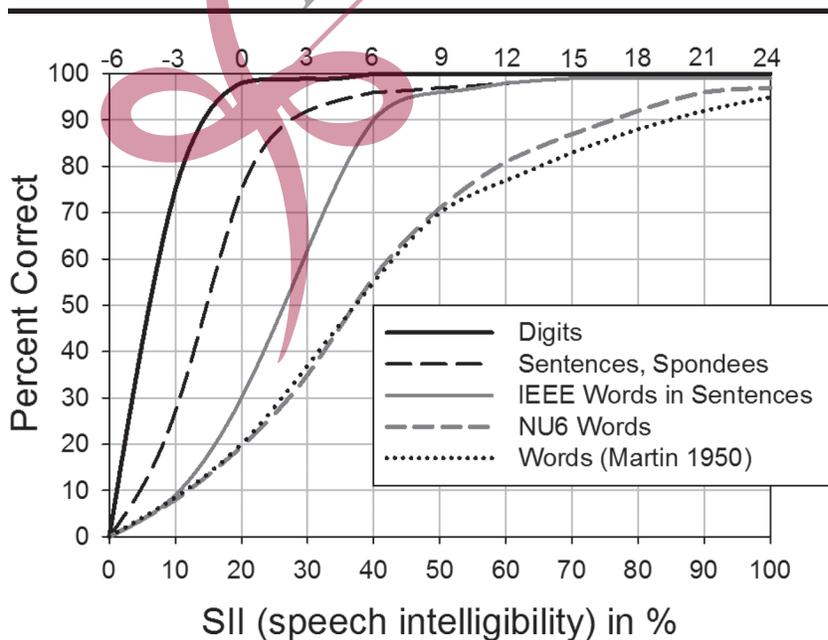


Figure 6–5. Predicted speech recognition performance as a function of SII for different types of speech materials. As contextual content increases, a lower SII will result in higher speech recognition performance. Adapted from Killion and Mueller, 2010.