Okay, here's a little quiz for you older readers. Imagine this scenario: You're driving your newly released Ford Taurus, drinking your first can of New Coke, listening to *We Are The World* on the radio on your way to the movie *Back to the Future*. And the year was? That's right, 1985.

If you were fitting hearing aids back then, you probably sat down at your newly purchased probe-mic equipment and became a little overwhelmed at the prescriptive fitting options. On this equipment alone there was the Lybarger 1/2-gain, the Berger method, and POGO. But wait, you also just read about the Libby 1/3-gain method and a year or so ago you learned about Pascoe's research and Cox's MSU procedure. And then there was this Australian fitting method that people were starting to talk about. It was all so confusing.

But something else was happening on the prescriptive fitting front in 1985 that only a few people noticed. A fellow named Richard Seewald, writing in *Ear and Hearing*, introduced a new procedure for children called the Desired Sensation Level method, or simply DSL. While most of the prescriptive methods of the 1980s are now long forgotten, the DSL has become the standard for pediatric amplification and is one of the few validated prescriptive methods in use today. The procedure and the software have evolved over the years, and another revised version is being launched this year. We're pleased to celebrate the DSL's 21st birthday here on Page Ten, and provide you with a preview of the DSL v5.0 prescriptive fitting procedure.

Our Page Ten author this month is **Susan Scollie**, PhD, assistant professor at the National Centre for Audiology and the School of Communication Sciences and Disorders, Faculty of Health Sciences, at the University of Western Ontario. Dr. Scollie also serves as co-director of the Child Amplification Laboratory at the Centre. In addition to her previous contributions here on Page Ten, you probably know Susan from her many publications in the area of hearing aid selection and fitting. She also has conducted workshops worldwide on hearing aid fittings for infants and children, and serves on several related committees.

On the next few pages, Dr. Scollie describes the new features of DSL v5.0 and provides a review of the supporting research. While the introduction of New Coke didn't fare very well back in 1985, the flavor of the DSL always has been tasty, and it just keeps getting better. For that, many audiologists and hearing-impaired children and parents are thankful.

Gus Mueller
Page Ten Editor

The DSL method: Improving with age

By Susan Scollie

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1 I've heard some rumors that there's a "new" DSL. Is that true?

It certainly is. It's been 21 years since the first publication of the DSL Method,[1] and we've recently finished writing up the latest revision to create DSL version 5.0.2 This new version builds on the original DSL [i/o] algorithm, and is called DSL m[i/o].

2 What does the "m" stand for and how is this software different from the older [i/o] version?

The "m" means multistage. You might remember that DSL[i/o] was an input/output prescription, so it would prescribe an input/output plot at each frequency that allowed us to compute target compression ratios. We still do this in DSL m[i/o], but there are four stages (hence the "multistage") in the input/output plot: expansion, linear, WDRC, and limiting.

This provides us an optional expansion stage if the hearing aid offers expansion processing. It also allows us to recommend a compression threshold that gets higher as the hearing loss increases. We also can group the m[i/o] calculations across frequencies, according to the number of channels in the hearing aid. This produces target compression ratios per channel, rather than one per audiometric frequency as was done in the previous version.

3 Okay, that makes sense. But I'll bet there are a lot more changes. There had better be, as I have 16 questions to go!

Oh yes, we're just getting started. There are actually five main categories of changes.

First, we made some changes that allow the DSL software to work more effectively with modern technology.

Two, there are changes to help infant hearing aid fittings proceed more smoothly.

Three, there are changes to accommodate DSL for the different listening needs of adults and children.

Four, we adjusted the prescription for listeners in noisy environments, monaural versus binaural hearing aid users, and people with conductive hearing losses.

Fifth and finally, we reviewed and updated all our transforms to include a broader range of target formats.

4 Before you go on, let me interrupt for a moment. You mention adults. I thought DSL was only for children.

That's a good point. DSL has always been, and still is, focused on pediatric amplification specifically. However, in developing DSL, we've focused as much on the clinical methods for fitting hearing aids as we have on the numeric prescription.[3] By "methods," I mean the clinical protocols for making probe-mic measurements, generating transforms, and graphic display formats. What we see happening is that some clinics like to use the "method" part of DSL with patients of all ages, and see that as being as important as the "prescription" part.

5 Can you give me an example of that?

I'll give you two! One is the SPLogram. Many clinicians, researchers, and equipment manufacturers now favor viewing hearing aid measures, preferably for speech signals, in real-ear sound pressure level.

This type of measurement uses the real-ear aided response[4] (REAR) rather than measures of real-ear aided gain or real-ear insertion gain. For years, the DSL Method has relied on speech-based REARs, together with other important measures such as threshold and upper limit of comfort, to create the SPLogram display.

Once you become used to fitting and talking about hearing aid performance in this format, it's hard to go back to insertion gain. Not only can this procedure be used for determining appropriate ear canal SPL, but these SPLograms are also informative and useful for troubleshooting and counseling.[5]

6 Didn't you say you had two examples?

Oh yes, here's the second. As you probably know, it can be a challenge to measure hearing aids in the REAR format in all cases, especially in babies and children. So the DSL Method, even our early versions, developed an alternative approach that predicts the REAR using the real-ear-to-coupler difference (RECD) and other factors.[6]

This is a really convenient option. It can allow you to fit an infant's hearing aids in the 2-cc coupler. But, it also can let you preset *adults'* hearing aids in the coupler prior to a final verification in the real ear. We see some clinics applying this approach across all ages because it is helpful to have in your fitting toolbox, and in many instances it saves time and improves fitting accuracy.

7 I see what you are saying. Some of what we think of as "DSL" has to do with clinical protocols rather than fitting targets per se.

Exactly! And while that doesn't mean that these protocols cannot be used with other prescriptions, it does mean that we have observed some of the DSL fitting techniques used with non-pediatric populations in recent years. This has helped us learn more about what works and doesn't work with adult hearing aid users. And it isn't necessarily the same thing that works with children. We think this is very interesting.

8 Are you saying that children and adults need different gain and output targets?

We think so. The DSLm[i/o] prescription and clinical methods are also different, depending on the pediatric age group one is working with.[7] We have three age ranges of clinical methods: infants, children, and adults. We have two age types of prescribed targets: targets for pediatric/congenital losses and targets for adult/acquired losses.

9 So you are really saying that it isn't necessarily "adults" and "kids." It's more like "acquired" hearing loss versus hearing loss since birth, right?

It certainly could be. This is probably an area that needs more research to better understand the underlying factors. Some animal researchers are hypothesizing that infant mammals, such as chinchillas, need adequate auditory stimulation in the neonatal period in order to develop normal auditory pathways.[8] If this is also true for humans, it means that hearing impairment in infancy (and perhaps childhood) has implications for how the auditory brain develops, and that people with congenitally acquired hearing impairment are different from people who have acquired hearing impairment as adults after they have formed their auditory pathways.

This would go a long way to explaining what we see in infant and child speech perception studies. That is, infants and children need higher levels of speech (or in some studies, a higher signal-to-noise ratio or a broader bandwidth of speech) to do as well as adults.[9-11] So, DSL 5.0 prescribes a higher level of gain and output in the pediatric/congenital prescription than in the adult/acquired prescription, for most hearing losses. The difference is about 7 dB for a flat 50-dB HL audiogram.

10 You also mentioned different clinical methods for infants and children. Why aren't they the same?

They are similar, but infants *do* need a slightly different approach for at least two different reasons. First, they are more likely to have their hearing aids fitted based on tone-ABR or other electrophysiologic tests. Secondly, as we've already discussed, the RECD is a critical component of the fitting, and infant RECDs change rapidly across ages, particularly in the first 2 years of life.[12]

For these reasons, we have specific corrections built into DSL v5.0. The tone-ABR thresholds can be corrected from nHL to HL values, and there are new RECD norms that change in age by months. Together, these changes help infant prescriptions to be more accurate.

11 So there are new RECD norms. Does that mean I don't have to measure the RECD in babies?

I'm glad you asked that. Our data show that individual babies vary considerably in their RECDs. So, as we have always recommended, it is best to measure the individual RECD whenever possible.[7] We've started testing an alternative method that can sometimes make this a little easier to do, and it seems to give reliable and valid results in 4-6-month olds.[13]

Let me explain it briefly. The tough part about measuring an RECD in an infant is placing the probe tube into the ear canal and keeping it in the correct position while you follow up with inserting the earmold (if you have an earmold!). In the alternative method, we tape the probe tube to the eartip and insert them together. It's similar to the early days of the RECD in which the probe tube was threaded through a foam tip, and it's also similar to today's real-ear SPL probes offered by some audiometers.

What's new, though, is that we found that a probe insertion depth of about 11 mm from the ear canal opening gave good

results for the infants we studied. That's a helpful piece of information for the clinic.

12 That's interesting. I may need to look at those infant protocols in a bit more detail. What new things do you have for the older child?

The new RECD norms extend through childhood by age in months, which provides a more detailed look at the RECD than was previously available. Also, we have new norms for earmold RECDs; the previous norms had been gathered using eartips. Since older children's earmolds have longer tubing than eartips, the new norms may provide a better starting place.

We also now have corrections that can be used with longstanding conductive hearing loss, binaural fittings, and listening in noise. Given that many kids who use hearing aids encounter these situations pretty regularly, they may be useful to know about.

13 How are you correcting for conductive losses?

We add 25% of the average air-bone gap from 500, 1000, 2000, and 4000 Hz to the upper limit of comfort (ULC). The correction is limited so that the maximum air-bone gap is 60 dB. As you may know, the algorithm uses the ULC to determine targets for different inputs, so the effect is that the target input/output plot is slightly more linear, has slightly more gain, and uses slightly higher output limiting levels.

14 Okay, thanks for the explanation. Do you now have adjustments for bilateral fittings?

Yes, we do. The gain for speech inputs is reduced by 3 dB across frequencies. This is a fairly (yawn) common approach to binaural corrections, but it's something that was requested pretty frequently in the past, so we thought we should add it.

We apply the same correction regardless of input level. The literature actually suggests that binaural corrections could be a bit larger than this, but also that binaural loudness summation is somewhat dependent upon the signal type, level, and procedure. For these reasons, we kept the correction conservative.

15 So, am I correct in concluding that the DSL prescription for children hasn't really changed a lot?

For listening to speech in quiet, that is a good conclusion. Experimental evidence tells us that children recognize speech sounds and understand sentences very well at the DSL[i/o]-prescribed settings,[14] and recent research at Boystown[9] convinces us that children need access to the high-frequency cues in speech for their speech and language development. Our measures of preferred listening levels also show that the DSL[i/o]-prescribed listening levels are acceptable for conversation-level speech.[2,15]

For these reasons, we wanted to have DSLm[i/o] *maintain* the DSL prescription for children's hearing aids, but update it to work better with the newer hearing aid technologies that we have today. For clinicians, this means that new features for kids may have more to do with the hearing aid, such as multichannel processing and expansion, but that the prescribed listening level is actually pretty similar.

16 Are there any exceptions to that?

There are a few changes that people may notice. We've updated the audiometric values to use the ANSI 1996 standard.[16] This may cause threshold curves on the SPLogram to change a little, but this is not a problem if your audiometer is also calibrated to ANSI 1996.

You may also notice that target gains are not quite as high for sloping losses and profound losses. This is due to a new output-limiting threshold for speech and the use of a slope correction. We also recommend a slightly higher compression threshold and slightly lower gains when using DSLm[i/o] to prescribe a noise program.

17 So, in that last point, are you saying that DSLm[i/o] has a different prescription for quiet versus noise?

It does. There are really four different prescriptions now: kids in quiet, kids in noise, adults in quiet, and adults in noise. The research evidence and our own experiences tell us that one fixed gain/compression prescription doesn't necessarily handle all environments.

I think that clinicians and industry would agree with this. That's why we have so many multimemory devices out there. Older children and certainly adults like having more than one listening option, and most make appropriate use of having multiple memories. We wanted to support that.

18 Speaking of adults, we were talking about that earlier but I didn't get to ask all my questions. How is the adult DSL different from the children's DSL?

As we discussed earlier, the adult prescription has less gain and a slightly lower compression ratio. We still attempt to give audibility across frequencies, but at a lower overall listening level. The result? The DSL adult targets are about 10 dB lower for mild losses and gradually move closer to the children's targets as hearing loss increases. The differences are only about 3 dB for severe losses, in order to maintain the audibility of speech for these patients.

19 Is that the same kind of correction as the effective audibility limit in the NAL-NL1?

Not exactly. The effective audibility approach limits gain if it isn't expected to improve speech recognition. Our approach was based on studies of adult-child differences in preferred listening level, speech-recognition performance, and loudness perception as well as a clinical study of DSL[i/o] fittings in adults.[2] Based on this information, we believed we could lower the recommended listening level to improve loudness results without reducing speech understanding.

There are some similarities between the two approaches, but conceptually we aren't taking a stand on whether audibility needs to be judged as effective *at the prescription stage*. We think that this needs to be determined on an individual basis in the clinic after a trial with amplification that provides audibility.

20 Whoa, we're at our last question already! When will I see DSL 5.0 in my fitting software?

The first implementation of DSL v5 is currently available in one manufacturer's fitting software. Several other manufacturers of hearing aids and real-ear measurement systems should be releasing it soon. We offered a stand-alone computer-assisted implementation of the DSL Method for previous versions of DSL, so we're often asked if we will offer a stand-alone version of DSL v5 (see how I've snuck a 21st question in!).

We have been working on a stand-alone version, which we hope to complete by the end of the year. This computer-assisted implementation will likely be most useful to researchers, course instructors, students, and clinicians who are not using computer-based fitting programs. Many clinicians find helpful information and clinical protocols at our web site (www.dslio.com). When we're ready to release the stand-alone version we'll update the web site to provide purchase information.

P.S. We hope to update our web site in 2006 as well. There is always so much work to do!

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