The Prescriptive Hearing Aid Fitting Formula Landscape

Presenter: Andrea Hannan-Dawkes, AuD, FAAA

- Welcome everyone. I'm Dr. Andrea Hannan-Dawkes, a member of the education and training team at Starkey, and I'm delighted that you have elected to join me today to learn more about the prescriptive hearing aid fitting formula landscape. Before we get started, I have the housekeeping items to cover. If you would like to ask a question during the presentation today, please use the Q&A area, just type in your question and click send. I'm going to address all questions at the end of the talk, but please feel free to enter questions as they come to mind. There is a PDF handout of the talk for you through. You can access that by clicking on the link in the chat within the classroom today, or you can go to your pending courses on Audiology Online, one CEU hour or 0.

1. CEUs is available for this session if you participate in the CEU program offered by Audiology Online. After completing the course, just go to your pending courses on AO and pass the short multiple choice exam. Keep in mind that you have seven days to complete the quiz when viewing live courses and 30 days when viewing recorded courses. And finally, if you need any technical assistance, please stay logged in and request help by using the Q&A window or by calling or emailing Audiology Online. Here are the learning outcomes for this course. After this course, participants will be able to list at least three different goals of hearing aid fitting formulas, identify the differences between generic and proprietary hearing aid fitting rationales, and you'll be able to describe the features of at least three hearing aid fitting formulas and the patient populations for whom they are intended.

So again, welcome everyone. I'm excited that you've elected to join me today. I'm gonna be talking about the history of fitting rationales. I'm gonna provide some important good to knows and differentiators between fitting formulas, and I'm also gonna share some clinical considerations to assist you as you move forward in helping individuals being fit with amplification. My hope is to break down the substantial topic of hearing aid fitting formulas into digestible segments to help you gain a better understanding of them. Or for some of you perhaps just provide a nice refresher.

There's no way to say everything that should be said in 60 minutes. So I definitely wanna encourage you to follow up on anything you find interesting or helpful in this talk.

There are some incredibly accomplished professionals in our field who have published research, written articles and contributed textbook chapters to provide you with all of the details you could possibly want. As we go through the information today, I've tucked in some fun facts and trivia along the way to help you embrace the timeline around the hearing aid fitting formula landscape, there will be times during the talk when I ask for your participation to help make things fun, I'll be using a program called Slido to provide some interactive experiences. So in just a moment, you should see this slide with the white bra background change over to blue. And what you'll be able to do is using your smartphone, you just need to scan the QR code.

So go ahead and do that now if you like, just scan the code with your camera and then use the passcode Starkey to join the session. Join session questions will then automatically populate on your phone when I get to different parts of the presentation. All responses will be anonymous so everyone can participate. And don't worry if your phone goes to sleep, I'll have the QR code on the passcode on all of the relevant slides. So this should provide some fun and some engagement during the talk. So let's go ahead and jump in. So when it comes to hearing aid selection and fitting, I think Dr. Jerry Northern really captured it well. "The goal in hearing aid selection and fitting is to provide comfortable hearing instruments that will meet the lifestyle needs of the patient while easing the patient's communication difficulties and maximizing performance in different listening environments.

" This is definitely well said. And within the important framework of patient-centered care. When we choose hearing aids for a patient, we have a lot of variables to consider. We select the product, family, the technology tier, the style, the matrix. We've gotta consider coupling, venting and even the need for advanced features. And we make decisions using audiometric test results like air and bone conduction, most comfortable listening levels, and even UCLs or uncomfortable listening levels as well, by considering the patient's preferences, their lifestyle, unique listening needs and goals, their expectations. And we always wanna include the opinions of loved ones as well, because the effects of hearing loss almost always extend to important others. We wanna think about their word recognition, performance in quiet and also in noise, very important.

And any previous experiences with amplification ideally include a cognitive or memory screening as well. And then last on my list here is to consider physical or dexterity challenges. All of these things help us choose the best possible technology and features. The research tells us that primary contributors to hearing aid satisfaction are performance and sound quality, followed by the effectiveness of the hearing care professional. If we dig a little deeper, we find that the top drivers of performance and sound quality are things like natural sound that is rich and clear. The ability to minimize background noise and provide comfort for loud sounds, the ability to tell direction as well. Fitting formulas serve as the foundation for performance and sound quality by providing the initial frequency response, a calculation of gain and output as a function of frequency.

The selected prescription can even play a role in the patient's acceptance or rejection of amplification inherent in the use of prescriptive fitting methods. It's the belief that appropriate gain and output can be calculated for an individual most fitting rationales attempt to optimize one or more of the goals you see here, they're designed to minimize initial rejection, maximize speech intelligibility, maximize use of the residual dynamic range, maximize patient comfort, maximize sound quality, and even to maximize patient satisfaction. But sometimes these goals can be in opposition to one another. So for example, a patient might desire very little gain for maximum comfort, but require a significant amount for maximum intelligibility. The more factors that are considered, the more complex the rationale becomes.

So here's our first interactive element. In just a moment, you will see the screen turn blue. If you've scanned the QR code, you'll see the question that I'm posing here on your phone, which is to name as many hearing aid fitting formulas as you can. So it looks like we've got some contributions here, right? So send one at a time. If you need to join us at this point, just use the QR code that you see on the left side and use Starkey as your passcode. Love it, so these are great. Everyone is entering some different fitting formulas and we're creating a word cloud. Well done everyone. I'll wait just a few more seconds here to see if anyone else wants to contribute.

So these can be current fitting formulas if you like, ones you're using, or maybe one that is from the past, maybe not used as much or any longer. So, hey, well done everyone. I see some great responses here. Okay, fantastic. Yep, great, fantastic. All right, so there have been quite a few fitting formulas developed over the years, so thank you all for those contributions. I've got a significant number of them here on the screen for you. Some have been named after people, others after places, some after what the method attempts to accomplish. And one was reportedly even named after a figure from a journal article. And that would be the FIG six fitting formula. So with the many options that exist for the many that have been developed over the years, there's an extraordinary number of resources available, including many that are just a click or two away.

I recently did two internet searches using the key phrases you see here bolded. There were 27 million hits using the phrase hearing aid fitting, and a little over five and a half million for the phrase hearing aid fitting formula. So way too many options for any professional or student to navigate easily. My hope today is to provide some organization and clarity around this very important topic, and as I said, make it digestible. I thought it would be interesting to start with a timeline for some of the different fitting formulas by plotting them alongside the evolution of various hearing aid technologies. The very first fitting formula is arguably that developed by Watson and Knudsen in 1940 at the time when vacuum tube hearing aids were in use.

And then the half gain rule was introduced in 1944 along with transistor technology. The Harvard report came along in 1946, which threw a wrench into the development of prescriptive rationales because it proposed that the metric configuration was irrelevant to the right hearing aid response on here. Notice the big jump in the timeline to the 1970s. Once research determined that frequency gain characteristics of the hearing aids were indeed important for optimizing speech signals. So we see a significant significant growth in the number of fitting formulas in the 20 years or so spanning 1979 to 1999. And finally, we see the last two independent or generic formulas introduced in 2005 and 2008 with DSL version five and NAL NL2 respectively. Notice though on the far right hand side, we also see that proprietary prescriptive rationales, those developed by the manufacturers, those continue to evolve even into 2023.

And that's actually one of the helpful characteristics of proprietary fitting formulas. They can change as the hearing aid, signal processing and physical attributes like venting change over time. So let's go ahead and take a closer look at the underlying work leading up where we are today with the approaches to hearing aid fitting. The idea of selective amplification and individual hearing aid fittings came on the scene as early as 1940, promoted the notion that a frequency response would be prescribed based on a person's audiometric configuration and degree of hearing loss, and that the greatest amount of amplification should be provided where there was the greatest degree of hearing loss. While there were a variety of early hearing aid fitting strategies that adopted this perspective, Watson and Knudsen at UCLA appeared to have been the first to actually prescribe hearing aid parameters using audiometric measurements.

I guess in 1940, yeah, it was an article in 1940, they remarked that one should not, and I quote, "Rely on the subjective impression of the patient in selecting a correct response, as he or she has not heard the loss sounds for a long time." So we have certainly come a long way since then. But let's continue. So they proposed a method for determining the required gain and response for an individual with hearing loss by comparing their pure tone MCLs plural to those of normal hearing individuals. And in doing so, they were the first to use super threshold measures in a prescriptive formula. And so this is largely considered to be the first one on the scene. And selective amplification actually remained the premier approach to hearing aid fitting until the Harvard report appeared in 1946.

So with regard to that report, this done by Hollowell Davis and colleagues, it included some of the most distinguished names. This report, several most distinguished individuals in the auditory sciences at the time, and really this interrupted the development of prescriptive fitting method, recommended the use of a common frequency response for fitting hearing aids. They stated that most patients perform best with regard to speech intelligibility using a flat or slightly rising frequency gain curve on the order of 6DB proactive, regardless of audiometric configuration. And while they felt the primary objective of hearing aid evaluations was the intelligibility of speech using word tests, they didn't see any merit in either the concept of selective amplification or in the detailed fitting of hearing aids.

Many audiologists adopted their perspective and the development of prescriptive rationales was significantly impacted. And next, the comparative approach. So this was already in use when the Harvard report was published, belief that frequency gain characteristics were not important for optimizing speech. Intelligibility fueled its use in hearing aids selection because with this approach, patients were tested with several hearing aids, using a variety of speech recognition tasks, and then fit with the hearing aids that provided the best performance. And it was suggested that one hearing aid could be differentiated from another if the word recognition scores differed by 8% or more. And this really remained the primary method for choosing hearing aids for over 30 years until the early 1980s. So 1946 brought us the Harvard report and a paper on the comparative approach to hearing aid fittings, both which had a significant impact on the progression of hearing aid fittings and our profession as a whole.

All right, so now let's use our phones to answer this question in a moment. You should see the background go blue and you should see it on your phone. So I wanna know who you think is credited with developing the comparative approach to hearing aid fitting. So we should see this populate here in a moment. Looks like I've got a little delay on my end. Okay, there it is. So hopefully you see it now on your phone. Go ahead and answer your answer. Do you think it was Cordia Bunch, Raymond Carhart, James Jerger or Jerry Northern? All right, Raymond Carhart in the lead right now. And then James Jerger, Jerry Northern. All right, so with that, go ahead and pat yourself on the back if you chose Raymond Carhart.

That is the correct answer. This is a very common audiology trivia quiz question, so this will probably come in handy down the road. All right, so next up, research began to show that common frequency approach and the comparative method were not valid. So if we do a quick run through the history here. In 1975, David Pascoe published an article that contradicted the earlier findings of the Harvard report, found that frequency gain characteristics of hearing aids are important for optimizing speech intelligibility in patients with sensory neural hearing loss. And that brings to mind a noteworthy element, which is that all of the data in the Harvard Report, all of that data was collected through coupler measurements and the majority of subjects had conductive or mixed hearing loss.

So this was an important contribution from Pascoe, sorry. 1978, Thornton and Raffin showed that the NU6 word recognition task had very poor test or retest reliability, which could impact the ability to identify differences between hearing aids. So that posed a problem for the comparative approach to hearing aid selection. In 1980, Studebaker and Hochberg summarized things by saying 30 years of extensive research have failed to demonstrate that hearing aids can be chosen reliably or validly by, in reference to the comparative method and a reasonable period of time. And then in 1983, Brian Walden and colleagues and found that a comparative procedure was not valuable unless hearing aids with very dissimilar frequency responses were being tested, which was unlikely in clinical practice.

So that kind of rounds out our early timeline here of development. Another noteworthy event of early 1980s was that real ear measures became available and audiologists began to appreciate the difference between 2CC coupler measures and the real ear, right, and those measurements made in the real ear along with the impact of ear molds on the hearing aid response. So today I would propose that fitting formula landscape looks more like this. Okay, the independent or generic fitting formulas were developed by researchers who were independent of hearing aid manufacturers. They're also considered generic in the sense that they are not designed for specific hearing aid or compression architecture. Proprietary formulas are developed by hearing aid manufacturers and they do account for proprietary signal processing.

So that's a quick look at the landscape today. Before we dive into some specifics on the different formulas, I think it's important to talk a little bit about the underlying principles of prescriptive rationales. They fall into three primary categories, so those would be based on theoretical rationale, the amount and type of audiometric information that's used for calculating the target response and the type of signal processing for which they were designed. First of two, primary theoretical rationales for fitting formulas is loudness equalization. With this thought or rationale, the goal is for loudness to be equalized across frequency bands so that all bands are perceived as equally loud. And as a result, speech sounds should be perceived as equally loud.

Overall loudness is normalized and the result is for the patient to perceive overall speech levels like a person with normal hearing. The second primary underlying rationale is focused around loudness, normalization your patients. The goal is to restore normal loudness perception so that what the normal hearing person perceives to be soft, normal and loud is judged the same way for the person wearing hearing aids. Normal relative loudness is maintained across frequency bands, but lower frequencies should be perceived as louder than higher frequencies because vowels are more intense than consonant sounds. Okay, so that's a little bit behind the two different theoretical rationales for fitting formulas. We consider the second underlying principle for the fitting formulas, which is the audiometric information.

We know that fitting rationales take into consideration all of the various things you see here, right? Or may take into consideration air and bone conduction, we've got MCLs, UCLs, right, the transducer type as well. So some important considerations with regards to the amount and type of audiometric information. And then the third core principle, if we just touch on that quickly, this centers around the type of signal processing for which the formula was designed. So with linear signal processing gain and frequency, the response is fixed across input levels. Gain can vary as a function of frequency, but not as a function of input level. So as a result, there is one prescriptive target produced by the fitting formula.

With non-linear strategies, goal here, gain is gonna vary as a function of frequency and input level. So a big difference there, right? Multiple targets are produced a target, for example, for soft signals, average signals, and loud signals. Non-linear strategies were developed for use with compression instruments to keep sounds within the user's dynamic range. And in a minute we're gonna discuss some of the fitting formulas, excuse me, that fall into each of the categories. But before we do that, I thought we could take a quick break and have some fun with the topic of formulas with a formula.

Fun fact, so here you see the Pythagorean theorem, which says the square of the hypotonus of a right triangle is equal to the sum of the squares of the other two sides.

Who remembers this from math class, right? So have you ever wondered what it might be used for in today's world? So I'm gonna launch another interactive element. In a moment here, you're going to be able to select which of four items is not reliance on the Pythagorean theorem today. So if you're seeing the question, go ahead and answer. In a moment here, I should have this populate with the blue background, and then we'll take a look at your guesses. All right, so which one of these activities is not reliant on the Pythagorean theorem today? Is it building a staircase, navigation, constructing bridges or designing tires? Right, I see some responses coming in. Yep, leading the pack here is designing tires, but we do have some responses for each of the items listed.

All right, so go ahead and there you go. I was gonna say, go ahead and finish up. You would be correct if you selected designing tires. Tires do not involve the use of the Pythagorean Theorem, but navigation systems, building a staircase and constructing bridges all do use the Pythagorean theorem. All right, let go ahead and move forward now and talk a little bit about the independent or generic fitting formulas. As I mentioned, right with the linear fitting formulas, they create one target response for the listener as gain only varies as a function of frequency and not as a result of input level. So you can see several of the different linear fitting formulas developed over the years.

On the right hand side, I'm gonna share some of the key concept for the ones that are still used today. And I'm gonna try to highlight one or two noteworthy elements for each so that you can see the development of thought over time. So the Half Gain Rule, this was introduced in 1944 by Sam Lybarger. He was the chief engineer and later president of Radio Ear, which was one of the original big four hearing aid manufacturers in the United States in the 1920s and 1930s. This particular formula advocated for aided thresholds to be improved by half the degree of hearing loss, hence the name of the formula. Reason that if thresholds for very soft tones were improved by half gain, then the intensity of average conversational speech would be amplified so that it's situated in the middle of the listener's dynamic range.

However, less than half gain was provided at the lowest frequency to reduce the upward spread of masking, which can impact speech understanding. And that was really an important consideration for amplification and actually remains an important consideration for amplification in hearing aids. And then finally, the hacking rule became the basis for the development of multiple subsequent linear fitting methods. And what I'd like to do now is just take a moment, talk a little bit about this notion of the upward spread of masking. I mentioned that it's an important consideration with amplification because it can impact or compromise speech understanding. And so the idea that greater power in the lower frequencies can potentially overpower or mask high frequency sounds.

And here you're seeing the different sounds of speech plotted as a function of frequency and importance gain in the low frequencies, for example, may cause the vowel sounds or maybe even some of those nasal sounds to overpower the consonant sounds of speech that are so important for the clarity of a message. So the half gain rule was the first to consider this important concept. The burger method was introduced in 1979 and was a modification of the half gain rule. While its premise was that amplification should increase input levels towards average conversational speech, it recommended that more than half gain be provided at one in 2000 hertz, as those were considered to be the most important frequencies for speech cues.

And then keep that notion of less than half gain for the low frequencies to reduce the upward spread of masking and optimize speech and palatability. And it also provided guidance for maximum output by subtracting three to 60 B from the listeners UCL. And then also this formula called for 10DB of reserve gain. So we see that concept introduced here and it's actually a fitting formula that can be used with linear and non-linear hearing aids. All right, so let's have a little fun, in just a moment, you should be able to respond to this question. What else was introduced in 1979? Choose two items, go ahead and respond. Remember that all responses are anonymous, so absolutely okay to participate.

You will not be identified. Give everybody a few more seconds here. All right, nice job everyone. The answers are that the Trivial Pursuit game launched and McDonald's introduced the first Happy Meal. So both of those things happened in 1979. Kind of helps put things in perspective, right, by way of the timeline. All right, so now we'll move on to NAL-R. Byrne and Fillon introduced its formula in 1986. It stands for National Acoustics Laboratories revised. The goal here was to amplify adjacent speech frequencies so they sound equally loud at a comfortable listening level because vowels are normally more intense and lower in frequency than unvoiced consonants, they reason that it would be helpful to reduce the intensity of louder speech sounds so that when aided, all sounds were equally loud.

And even though that's not the way people with normal hearing hear speech, they suggested it would equate to maximize speech intelligibility. So this formula provides slightly less than half gain across audiometric frequencies and prescribes less high frequency gain than Berger for steep high frequency losses with the resulting target gain looking flatter than other linear fitting formulas. And it even called four 15 DB of reserve gain. So the R in the formula indicates as well, another important side note I guess, the R indicates a revision from the original NAL fitting method, which overcompensated for the reduction of loud vowel sounds. So some important considerations here. In 1990, so that's four years later, NALRP was introduced with the RP referring to revised profound.

It includes a few considerations for individuals with severe to profound hearing loss. So this group proposed that if the pure tone average was greater than 60 DB, approximately 10 DB more than half gain is preferred. And if hearing threshold at 1000 hertz or greater than 90 DB, more low frequency gain and less high frequency gain is desirable. The idea was to amplify less at frequency at frequencies where there is severe and profound hearing loss and amplify more at frequencies where there's better hearing. And so here we see an attempt to consider cochlear distortion and dead regions. Now if we shift our attention to look at a few of the generic non-linear fitting formulas, as a reminder, these were designed to be used with hearing aids offering compression to ensure that aided signals fall within the user's dynamic range.

In these rationales we've got gain varying as a function of frequency and input level. So the results are multiple targets. So soft, average, and loud targets, for example. Well, let's just jump in. Let's take a look at a few of these here. So NAL NL1, so NAL, the National Acoustics Laboratory back on the scene in 1999 with this fitting formula, again, a compression based method that evolved from their linear based NALR method and the same underlying philosophy as the entire NAL family of fitting methods. And that was to equalize loudness relationships among the speed frequencies. It could determine the gain required for several input levels that would result in maximal speech intelligibility, while ensuring that overall loudness perception of aided speech is consistent with that experienced by normal hearing individuals.

It also prescribed less gain in regions with severe hearing loss because hearing impaired listeners for reduced ability to extract useful information from speech where speech frequencies where the hearing loss is more severe according to their perspective. And it also included a couple of helpful age appropriate correction factors as well. So that was nice opportunity to consider some various aspects. And the inclusion of age appropriate correction factors also allows this fitting formula to be an option for use with the pediatric population. All right, so 1999 NAL NL1. And now let's jump to 2005. And here we see introduction of the desired sensation level version five. This method actually began development in the 1980s with five versions to date, and it was designed to provide a systematic science-based approach to pediatric hearing instrument fitting.

Version five can actually be used though for individuals of all ages. So infants, children and adults. Some of the preferences, or I should say premises of this formula include that pediatric patients with congenital hearing loss require more gain than adults. Adult patients with acquired hearing losses. It calculates a full range of targets for any audiogram with two or more thresholds. Compression ratios and compression threshold are calculated with consideration for the channel architecture. Targets for aided speech are limited so that speech cannot exceed the listeners' uncomfortable listening level. Target for speech computed to deliver full audibility in quiet environments. And targets for noise include less gain at speech frequencies of lower importance with a raised compression threshold.

It also offers a binaural correction that reduced its speech target by 3DB. And then finally, gain and output target for conductive and mixed hearing losses are slightly higher than for sensory neural hearing losses. So let's take a moment for an interactive opportunity. And when we think about DSL version five being introduced in 2005, I thought it would be fun to ask how old you were 19 years ago. So remember that all responses are anonymous, so please participate. I thought it would be fun to get an idea of the years of experience in the audience today, so love it. Love it. I personally was two, no, I'm just kidding. Was not two. Yeah, this is great. Look at the range of ages from 19 years ago, right?

It's fantastic. So we've really got a nice diverse group of professionals logged in today. This is great. All right, give everybody another second here to participate. Great, fantastic. All right, so, love it. Great, thanks for sharing everybody. My contribution would be 37 if I was able to participate from presenter mode. All right, so NAL NL2. So we from 2005 to 2008, the second generation prescription procedure from the National Acoustic Laboratories for fitting wide dynamic range compression instruments like NAL NL1 the first version, that aimed at making speech intelligible and overall loudness comfortable. Interestingly, this adaptation considers different attributes of the hearing aid user, including gender, experience level, age, binaural listening and language. So let's look at a couple of these points.

Female hearing aid users, they found that female users prefer lower overall gain than male users on the order of 2DB. New hearing aid users with more than a mild hearing loss prefer increasingly less gain with increasing degree of hearing loss than experienced hearing aid users. Unilaterally and bilaterally fit hearing aid users prefer overall gain levels that vary less than estimated by the bilateral correction factor. The correction factor for binaural summation is two db at low input levels and as much as 60 B at high input levels for symmetric losses and less needed for asymmetric losses. In addition, those fitted binauraly like more compression than. Adults prefer lower overall gain than children. Individuals with severe profound hearing loss prefer lower compression ratios than predicted when fit with fast acting compression, it prescribes slightly more low frequency gains for speakers of tonal languages where the tonality of a word can change its meaning.

Like with mandarin, where the same word spoken with rising tone has a different meaning than when spoken with a falling tone. So some very interesting developments here with the NAL NL2 fitting formula. So now it's time for another formula fun fact, this one pertains to the fundamental theorem of calculus, which establishes, as you can see here, the relationship between differentiation and integration provides a way to evaluate definite integrals on stuff, right? So let's go ahead and have everyone use your phone to select one application of calculus today. So in a moment here, my screen should turn blue and you should see the question on your phone listed four items for you. There you go, so which one of these applications uses calculus today?

Is it engineering, medicine, economics or architecture? Give everyone a moment. Great, super, okay. Strongest, our most popular response was engineering. We'll go ahead and call it, if you were correct, if you selected any of the items listed, all of these different activities use calculus. I thought that was very interesting and would be fun to share. All right, so now let's move from the topic of independent generic formulas that have been validated using large subject pools and shift our attention to the proprietary formulas that are created by manufacturers of hearing aid technology to account for unique compression architecture, signal processing, and even hearing aid designs. Proprietary fitting formulas, which include both linear and non-linear applications have their origins in custom hearing aid technology.

When those styles became popular in the 1970s and 1980s, at that time, performance characteristics were usually decided by the manufacturer. The frequency gain response was chosen at the factory. While the independent rationales are validated by published research using or the independent rationales, right are validated using large subject pools, they're not frequently updated or really aren't updated and therefore are unable to consider the latest signal processing algorithms or research. So that's where the proprietary formulas really have a hand up. They can evolve when new features are introduced or new things are learned. All manufacturers have a proprietary fitting formula that is designed, developed, researched and validated in-house before it comes to you. With the growing popularity of digitally programmable hearing aids in the early 1990s, right?

That's where we started to see those programmable devices come on the scene, it really became important to provide professionals with the ability to program hearing aids with considerations for different signal processing characteristics like the items

I've got listed here. So the types and speed of compression, the attack and release times, the number of hearing aid channels, even microphone location effects, and the acoustic effects of hearing aid style and coupling because we know that these variables can differ between manufacturers, and can impact the frequency response of the amplified signal. So showing you an image now that shows the real ear responses of four hearing aids from different manufacturers programmed to their recommended best fits using the NAL NL2 fitting formula.

Okay, that's what you're looking at. And what you don't see is one solid line. All of the measurements do not fall directly on top of one another. There are variations between manufacturers, even when the same fitting formula is used and normal hearing subjects can hear the differences. And so for example, while all hearing aid companies offer multi-channel compression, implementation can vary significantly, threshold knee points, the compression ratios, right, the attack and release times, all of these things can impact the hearing aid response. Another example of where or how a proprietary rationale can be helpful is with music. We know that hearing loss impacts the enjoyment of music. There are individual preferences for music and those can vary significantly.

And we also know that music and speech are very different signals. In fact, if we compare speech and music, we see that the average level of speech is softer than it is for music, and that music has a broader bandwidth than speech. In addition, we know that the intensity and frequency envelopes of music are much more variable than they are for speech. Music has a greater range for softer and louder sounds. So it doesn't make sense to use an independent generic fitting formula designed to optimize speech when the signal of interest is music, that then at least one manufacturer offers a unique fitting prescription for music signals that's not reliant on adjustments to a speech based rationale, it provides a compression system tailored for music.

And the unique prescriptive formula was designed to focus on making music enjoyable. So the idea is to make quiet music audible, using shaped gain according to the hearing loss, and then achieve acoustic transparency by restoring desired loudness at high input levels with flat linear insertion gain that mimics the unaided ear. So again, the idea or the overarching idea here is to provide a natural music listening experience because the music signals differ significantly from speech signals. Another example of how a proprietary rationale can be advantageous is with dual speed compression, where two independent compressors are active at the same time. And what that does is it allows the system or the hearing aid to seamlessly adapt to dynamic situations.

The use of both fast and flow compressors simultaneously is helpful to compensate for damage to both outer and inner hair cells, as both can be compromised with hearing loss. So like with music signals, the available generic fitting formulas, don't consider this capability in hearing aids today. Alright, one example, I just talked in one as I was polling and talking with the different manufacturers, this is Starkey. Just a quick mention of Starkey's e-STAT 2.0. This was introduced last year with the new Genesis AI product family. It offers more gain for soft sounds, which lends itself to better speech intelligibility scores and more gain at higher frequencies for a broader, more well-rounded response. It also incorporates improve event modeling.

All of these things as examples of important considerations for patients. And as I mentioned earlier, right, the proprietary fitting rationales can evolve as the technology evolves. Okay, so again, just one example of proprietary rationales. Each manufacturer has their own. So there are a variety of clinical considerations that require professionals to make decisions not only about which fitting formula to use, but in many instances may require us to adjust away from the initial prescribed gain and output of a formula. So let's take a closer look at each of these areas. We're gonna talk about some patient populations first fits strategies, the impact of acoustic options. We'll talk a little bit about advanced features and then we'll wrap up with sound quality.

So when we talk about clinical patient populations, individuals with sensory neural hearing loss often have a reduced dynamic range. And compression is usually necessary to fit sounds into the usable dynamic range. For these patients, the use of a non-linear fitting formula is usually optimal. So based on our conversation today for these individuals, the proprietary rationales or perhaps NAL NL2, or even DSL version five, version five are often used. So I pulled a significant number of professionals to tap into what the primary formulas are that they use. So you may use something different, but I just wanted you to know where I landed or how I got to what I'm showing here by way of common fitting formulas.

So this is based on input from a significant number of professionals in the field. Alright, so along that thread, I'd love to know what fitting formula you use most often for sensory neural hearing loss. So in a moment here, we'll see the opportunity to respond. You'll see that on your phone. Do you use a proprietary fitting formula most often? Are you using DSL version five? What about NAL NL2? Or is there another fitting formula that you like better for sensory neural hearing loss? Great, give everybody just a second here. All right, it looks like the majority of individuals logged in today use the manufacturer's proprietary. And then, but we do have several others, right? Or several that are using NAL NL2, or even DSL version five.

Okay, great everyone, thank you for participating. So if we move to conduct for mixed hearing losses, those individuals usually want more gain than someone with sensory neural hearing loss. They don't have that reduction in dynamic range. And as a result, a linear strategy may be more appropriate. So based on our conversation today in the information in this talk and my polling of professionals, Berger NAL and DSL version five were the most common fitting formulas for conductive or mixed loss. Had a few of course with NAL, yeah, I will mention that. So children, very important population here, right? So what we're trying to do, what we need to do with children is make speech audible to minimize the impact of hearing loss and speech and language development.

So it's very important to use a fitting formula that has been developed for children because there are so many physical differences between children and adults. And I've got some of those listed here, right? Ear canal properties, the middle ear, central auditory systems, as well as differences in the way the audiometric test results are obtained. So we really need to ensure these variables are accounted for in the prescription of gain and output for kids. And so the gold standard for fitting children is DSL version five, but NAL NL2 is also a possibility for children. So in addition to selecting the best fitting formula to use with each patient, I wanna kind of move away from clinical populations for a second or kind of move into some other important topics.

And one of those is the first fit strategy of the manufacturer, right? So adjustments to the hearing aid response may be made automatically to help promote the successful use of amplification. First fits strategies tend to take into account the hearing loss, coupling, venting and experience with amplification. And we know that quite often, new hearing aid users can't handle target gain right out of the gate, right? They need a period of acclimatization. So the approaches used by hearing aid technology companies fall roughly into two camps, deliver audibility and let the professional manage comfort or deliver comfort and let the professional manage audibility. There's no right or wrong because patients need both of those things, right? But we just need to know the company's perspective to ensure that we account for it.

So on this slide, I'm showing you the variability that can exist in the frequency response with first fit strategies. So the images here show the first fit calculations for six hearing aids from different manufacturers, got new users on top and experienced users on the bottom. And then I've kind of zeroed out one to serve as the baseline for the purposes of comparison. And you can really see right, a significant amount of variability. So the first fit strategy that's being implemented or used is an important consideration. The very best friend we have for verifying audibility and comfort and hearing aid fitting for any patient using a generic or proprietary fitting formula is real ear measurements. Hearing aid verification should be completed using REMS or coupler measurements based on the patient's real ear to coupler difference if necessary to ensure that the fitting objectives have been met.

Really, our measurements are considered to be best practices by our professional organizations and consumer organizations like Consumer Reports even advocates for this practice in their hearing aid buying guide. So food for thought there. And then another important consideration with fittings is the impact of acoustic options. Earbud and ear mold acoustics can impact the frequency response. So for example, there are very big differences in real ear gain when using open versus occluded coupling with the same gain prescription. If you change event diameter or tubing length on an ear mold or make any one of 100 different changes to acoustic variables, you will change the frequency response of the hearing aid regardless of the fitting formula you started with.

And the Microsonic Custom Ear Mold Manual is a great resource. It's free by visiting their website and signing up with your email address. I do not have any professional relationship with Microsonic, nothing to disclose. I just work with quite a few universities who value this tool and use it with their students. So wanted to mention it to you. Advanced hearing aid can also change the gain or output of the hearing aid regardless of which formula we started with. You know, things like feedback management, cancellation, frequency lowering and even on-demand adaptive tuning. These can all result in adjustments to the frequency response, but certainly can be very valuable to a listener. So just a few more examples of why a fitting formula provides a good starting point for the fitting, but sometimes we end up adjusting or moving away from that starting point for good reason.

These slow peering losses, these are one of the more common losses that require special consideration. Fitting these losses can be more complex than just restoring audibility because hearing the high frequencies may not be useful. In fact, amplifying the high frequencies may even introduce distortion, right? So we just have to pay close attention to the mid-frequency region with these individuals and maybe even consider things like frequency lowering to be of assistance. And I'm just kind of wrapping things up today. I think it's very important to talk a little bit about sound quality as a whole, because we know that this is going to make or break the patient's experience with amplification. You know, there are a lot very large individual differences.

Frequency gain responses that you know appropriate for restoring audibility may result in unacceptable sound quality perceptions. High frequency amplification can be detrimental for some users, right? Depending on the degree and sight of lesion of the hearing loss. Sound quality and distortion certainly have to be considered when determining the appropriate fitting response. And so it really stands for reason that the fitting formula provides a foundation for the hearing aid fitting and response adjustments. You know, and in many forms, allow us to address the unique needs and preferences of each individual listener. So also I think this quote summarizes it well the role of fitting formulas individual individualized adjustments may be needed to obtain a good fit. In this respect, the use of prescriptive formulas should probably be regarded as no more than a first estimate of the best frequency gained characteristics for an individual patient.

So again, some solid and important reasons why we sometimes make adjustments that adjust or shift that initial response of the instrument based on the fitting formula. And because hearing aid, fine tuning may be needed for optimal performance and satisfaction. And again, sometimes that fine tuning even, that shifts the response of the hearing aid away from the prescriptive target. Simply matching responses to real ear targets isn't enough. You know, shifting away from target may be okay as long as the patient performs well and finds benefit in all of the ways that are important to them. So real ear measurements are a very important aspect of fitting. But I would argue that there's also a need for validation measures as well.

'Cause we need to ensure the hearing aids are providing benefit in meaningful ways. And there are a number of subjective and objective outcome measures that can be used to validate hearing aid benefits, improve performance and even satisfaction with amplification. So wrapping up today, the fitting formula really is a foundation of the hearing aid fitting. Don't restrict yourself to just one option. Be sure to consider the type, the degree, and the configuration of the loss, as well as experience with amplification, the age of the individual, and any other special considerations for each patient. Generic and proprietary fitting formulas are valuable. And also keep in mind that fitting strike a balance among ability, loudness and sound quality. So some important considerations there.

All right, with that, I want to thank all of you for joining me today.