# Exploring Oticon's Proprietary Fitting Rationale: VAC+

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Hello, I'm Virginia Ramachandran, Vice President of Audiology for oticon. Thanks for joining me today to learn more about Oticon's proprietary fitting rationale, voice aligned compression, or what we call VAC plus. Before we begin, please note my disclosures. I am an employee of Oticon and receive a salary. I also have financial relationships with Pool Publishing as an author and editor.

Here are the learner outcomes expected from this course. After this course, you should be able to describe at least two key benefits of vac, list the options available to verify Oticon's proprietary fitting rationale when completing real ear measures, including the use of the sii, and describe the results of a pilot study examining the audibility provided by VAC plus and measures of subjective experience. Please note the risks and limitations inherent in today's course. These are available in your course handout. The agenda for this course is as follows.

We're now completing the introduction. The remainder of the course will include assumptions underlying rationales, the evolution of VAC Plus, VAC plus in Gini 2, verification of VAC plus, and a pilot study with results of vaccine.

So let's begin with the assumptions underlying a hearing aid fitting first, we need to recognize that our goals based on what we've learned about psychoacoustics and auditory dysfunction might be very different from the goals of a patient. Most people do not want hearing aids Many people have a negative or bad feeling about the idea of needing hearing devices. So if they're in your office, it's often because something has happened in their life that made them feel worse than not wanting hearing aids. This is often some relationship issue or work or safety concern that's related to communication disorder caused by hearing loss. What they want from us as clinicians is to make that bad feeling go away for patients.

It's not about decibels, it's about disconnection. So when fitting, we have to begin with the ultimate goal in mind that your patient walks out the door with hearing aids that meet their unique needs and

preferences. We want the hearing aids to help our clients thrive in situations that are important to them. Our goal from Oticon is to support people with hearing loss to engage most effectively and with ease in communication. This is the ultimate goal of our brain hearing philosophy.

Simply put, you hear with your brain, not with your ears, and it's that interface between what the brain hears and what's happening in their world that creates a good or poor engagement experience for patients.

So how does this relate to gain and prescriptive algorithms? Well, audibility of sound is of course, a critical bott up requirement for hearing sound so that it can be attended to and comprehended. And when the sound of interest is speech, to be able to use that sound for communication in a disordered auditory system. Reduced audibility interferes with all of this, so ensuring that the patient has an ideal amount of gain is necessary. A fitting rationale, also known as a prescriptive formula or fitting rule, is an algorithm or a mathematical formula that guides the prescription of gain in a hearing aid.

Fitting rationales use information about the patient, such as their audiogram and in some cases uncomfortable loudness levels, whether those are measured or predicted, to provide gain targets. These targets provide a guide as to how much gain is needed at different frequencies and for different input levels. Historically, hearing aids provided linear gain, which means that the sound was amplified the same amount regardless of the input level. So a loud sound was prescribed just as much gain as a soft sound. And of course that runs the risk of over amplification and distortion.

Modern hearing aids make use of compression, which is where weaker sounds are amplified more by the hearing aid than intense sounds. And the goal here is to make soft sounds audible without over amplifying louder sounds. You see this in the insertion gain graph on this slide which shows gain prescribed by VAC plus for a moderate flat sensorineural hearing loss. At a 50dB input, more gain is prescribed than at a 65dB input and the least amount of gain is prescribed for the 80dB input.

I really like this quote from a textbook called Essentials of Modern Hearing Aids by Ricketts, Bentler and Mueller. So really good hearing aid minds. And this describes what a prescriptive method is. So they say in general, prescriptive methods are based on the assumption that using the patient's pure tone thresholds and perhaps some super threshold measures, hearing aid gain and or output can be prescribed that will result in the best fitting for the average patient for the desired attributes such as intelligibility, sound quality and listening and comfort. There are a few important takeaways in this message.

First, the idea that we can get a quote best fitting from pure tone thresholds and potentially some supertold measures. This is stated as an assumption, not necessarily truth. We have to start with something, but we may find in the future that there are better methods for determining ideal gain for a patient. And as we continue to learn and technologies continue to evolve, we need to be willing and able to adapt our thinking on this. The second point is this assumption that this is for the average patient.

And so note that I added the emphasis here in red, because this is a big assumption. I'll go into more detail on this in a moment, but the assumption that your patient is average is an inherent limitation of current prescriptive algorithms.

So this definition of a prescriptive algorithm is important because it highlights that while fitting rationales provide a starting point for the level of amplification that might benefit your patient, matching to targets is not the end of the story. Fitting rationales themselves are based on average data and people are very different. This means that even when you have matched a target perfectly, including using real ear measures to ensure that the ear canal acoustics are accounted for, the amplification provided might still not align perfectly with your client and their preferences. So it's important to consider the purpose of matching to target and to fine tune based on the client's feedback. As we identified at the beginning,

your main goal is to meet the patient's unique needs and preferences.

I also really like the second half of this quote from Ricketts, Bentler and Bueller describing prescriptive algorithms. They state that with modern hearing aids, the intent is also to accomplish these goals for a wide range of sound input levels and listening environments. There are a number of variables to consider and no procedure is going to get it perfect for all patients all the time. So these authors do a nice job of pointing out that we are trying to meet the needs of patients in many different types of scenarios and environments and that the number of variables to consider is very high. Also, the number of variables that can be considered by modern hearing aid technology continues to increase, so things like noise reduction and so on.

So with this we have to remain flexible in how we consider when and how gain should be applied in light of these many situational and patient specific variables.

An example of this is shown in our use of the Oticon intent hearing aids. The brain uses a lot of information to engage with the world and to inform communication. It's not just auditory input. Your other senses play a role as well. And there's a significant top down component to communicating and engaging.

So we should not forget that it's not only about delivering sound to the ear, it's about what the brain's going to do with that sound. In the same way that the brain takes in additional information. Modern hearing aids often adjust automatically to respond to the immediate needs of the world around the patient. So with their intent hearing aids, they use the intensity of sound entering the hearing aid to understand the overall loudness of the environment. They use signal to noise ratio estimates to understand the Complexity of the environment.

There's a voice activity detector function to understand whether the user is listening to speech, and there's an accelerometer to understand the person's listening intentions based on head and body movement. These additional sources of information act in a dynamic way with the prescription of gain, and we need to be cognizant of that. And so this is the case for VAC plus, that it's optimized to ensure that the dynamic functions work as intended, that it's not a static gain application. All of this is to say that your professional knowledge and skills are extremely important in in actively choosing which prescriptive formulas to apply, if any, and when and how to apply them to best meet your patient's needs. Our patients obviously deserve much more than simply clicking on a single formula and assuming that it's going to work effectively for everyone.

It might, but it might be that we can do better. So the purpose of this presentation is not to convince you to choose one formula over another. It's to provide you some background information and context about the Oticon Vac plus formula so that you can use this information to help you as you choose what might be the best place as a starting place for your individual patient.

This concept is really about the idea of individualized care. And frankly, believing that individualized care is an approach that we should strive for is also an assumption. And so that's an assumption that we work with from Oticon is that precision care should be the goal to work toward. According to the FDA's definition, most medical treatments are designed for the average patient as a one size fits all approach, which may be successful for some patients, but not for others. The goal of precision medicine is to target the right treatments to the right patient at the right time.

The goal of personalizing gain and all of the other hearing aid fitting parameters is a work in progress. We don't currently have all of the evidence base that we need as a profession, but we do believe that this should be the direction that we strive for when it comes to evidence. Let's talk about what we mean by evidence based practice. This is something we talk about within medicine in general and in

audiology. I think it's important to consider this concept as we discuss how to apply evidence to fitting amplification of patients, including the prescription of gain.

So when most people think of evidence based practice, they immediately think of research that is published in peer reviewed scientific journals. And this is definitely a valuable component of evidence based practice, but that's not all of it. We have to Marry that knowledge base with the evidence of our clinical experience and to the patient's values and beliefs. The fact is, we do not know everything today that there is to know about the ear and the brain and how it uses sound. Part of practicing with an evidence based mindset is to be open to new ideas and possibilities and to be willing to examine new tools and new solutions in determining their effectiveness.

So I'm going to share a historical example of this where you can go the wrong way if you're not, if you're over reliant on evidence in a certain direction. In 1950, the Consumers Reports ran an article on hearing aids and honestly, it reads like it was written yesterday by Anyway. So there is a part of this article that is very intriguing. This article describes the notion of providing gain in a frequency specific way based on pure tone thresholds, which is what we all do today. For the most part they describe it as being antiquated and illogical.

So it says that research has shown that a threshold audiogram may be a wholly misleading guide to the way you hear sounds louder than threshold sounds. Since the earphone of the hearing aid delivers sound well above threshold levels. Fitting a hearing aid to your threshold audiogram was a wholly illogical procedure, they state. The whole elaborate theory of, quote, selective amplification, which again is what we practice today, was finally disposed of in 1947 when Dr. Halliwell Davis and his associates published their findings. They had started their federal research project at Harvard with the usual quote, personalized fitting theory, which had constructed a master hearing aid that could be set for a wide range of frequency response curves.

They then tried various curves on a group of trained hard of hearing listeners and gauge the results by means of carefully designed tests of speech intelligibility. Their finding was that two types of curves were suitable to practically all of the hard of hearing subjects tested. The selective amplification theory is still being pushed by some companies, but CU believes that it's on its last legs.

So that's interesting because of course the vast majority of what we're doing today is frequency specific amplification. So what happened here? Well, nowadays people haven't heard much about the Harvard Report, but as you can see from the Consumers Report article, it was kind of a big deal in its time. As described, they had created a master hearing aid that could provide amplification in a frequency specific manner and then they tested the outcomes on speech understanding among various patients. I have actually located a copy of the Harvard Report and the conclusion reached was indeed that the authors had Quote, disproved the fundamental assumption of the desirability of selective amplification based on the characteristics of the individual's audiogram.

So if you're fitting hearing aids today using a prescriptive algorithm that is based on the pure tone audiogram, this might be surprising to you. But in this case, the evidence demonstrated this as truth. But as with all research studies, it's important to understand the nuances of the methodology and very important to understand who was included in the study and who was excluded. In the case of the Harvard Report, there were a total of 18 subjects. At least half of them had or were presumed to have conductive or mixed loss.

Three of the subjects had no audiogram and another three had no bone conduction testing. Only three of these subjects were confirmed to be sensorineural hearing losses. So if you consider that the group of test subjects predominantly had conductive hearing loss, the conclusions of the Harvard report actually make a lot of sense. But today we're kind of shocked that this is the subject pool. We actually shouldn't be though.

This was 1947, before the time of widespread use of antibiotics, before the operating microscope, before vaccines of some types and fluoride in the water, otosclerosis and middle ear disease were very common. So this really was a valid sample and a valid conclusion for its time. But since then, honestly, the entire population of people that we treat has changed. Nowadays we predominantly fit people with sensorineural hearing loss. You can also look at the ages of the people in this study.

Most of them were middle aged, the oldest was 70. Nowadays we routinely fit people into their hundreds. The conclusion of the Harvard report and its interpretations in the Consumers Report article was ultimately wrong, at least by today's standards. But not because of the data, but because they assumed that this sample was representative of everyone. And fundamentally that hearing loss is one thing, but hearing loss is not one thing.

Right? Hearing function relies on over 30 different structures that have to work in precisely coordinated sequences in order to create the right neural code to represent sound. And there are hundreds of known causes of hearing loss in humans and each of them has unique consequences for how sound reaches the brain.

So a reasonable question is who do we have an evidence based for? There is a so called normal hearing loss and I know it sounds like an oxymoron, but there is epidemiological evidence that helps us understand what a typical age related hearing loss looks like. Are separate graphs for men and women. The one you see here is for men. It's from Bob Dobie's book on medical Legal audiology.

And if you look at the graph, you can probably relate to the patients you see every day in each of these age groups. Their audiograms might look very similar to this graph.

What you're seeing in this group of audiograms is the mean, but for every group, there is a distribution around that mean, and that distribution can vary among groups. So in some cases the distribution is

very narrow, and in other cases it can be quite large. So, for example, when you have a mild hearing loss, you will typically have a fairly narrow distribution of word recognition scores. But for people with severe hearing loss, there's typically a broad distribution of performance on speech recognition testing. Some people perform extremely well and others very poorly.

So targets are based on the average of what was required to have the best outcome for a sample of a population. In a lot of cases, these samples consist of people who are very typical. However, we often have patients who have medically complex hearing losses or atypical configurations. And in a lot of studies, these patients are excluded. So when we look at research to inform our clinical decisions, we need to be aware of who was included in the study and who was excluded, because a lot of the people who are excluded from these studies are the same types of people who are sitting in front of you in your office.

So it's important to know where the scientific evidence ends and then where your clinical experience and your knowledge of the underlying disorder needs to take precedence.

And finally, before getting to the prescriptive algorithms, I want to talk about the importance of where your patient has been on their journey before they appeared in your office.

So this is a case of a 30 year old female who came into an audiology practice stating she felt like she had a hearing loss after a concert. So this is what that looked like. And for most of us, our attention is immediately drawn to the massive low frequency hearing loss. We have good reason to believe that this reverse slope hearing loss probably wasn't caused by the reported noise exposure. So why is she reporting no hearing loss until after the concert?

Well, it's possible that she did experience high frequency hearing loss from the concert.

We don't know what her hearing looked like prior to the concert, but let's imagine a scenario where the audiogram on the left was before the noise exposure and the audiogram on the right was after. Wouldn't she have noticed this hearing loss prior to the concert? And I would argue that that's not necessarily true. The reverse slope hearing loss could have been missed because of her age. It's entirely possible she wouldn't have been screened for hearing loss at birth or that even if she was, it could have been missed.

Because the purpose of the screening is to ensure normal speech and language development. So it really emphasizes high frequencies. And she may have gotten enough high frequency sound to develop normal speech and language, especially if this loss was progressive in any way. And the point here is that you have to assume what you're seeing today is not the whole story. And how I might treat this hearing loss is going to be largely influenced by her history.

You can put this hearing loss into manufacturer software and fit to some prescriptive target. In general, though those targets are not specifically designed for reversal of hearing loss. The programming software will come up with a gain prescription. The question is, will that gain be appropriate to the etiology of the hearing loss? Many types of dysfunction can cause reverse slope hearing loss.

Some of them you might want to treat with gain, and some of them you wouldn't. And in addition to that, we have to consider the patient history and how her brain is going to use the information that we're giving to it. If we give this patient a lot of low frequency gain, she might say that that's great and do very well, or she might do pretty poorly. And that was actually why I saw this case to begin with. The patient was not doing well with amplification.

And my guess is that her brain didn't know what to do with the low frequency information that was prescribed. It was possible that all that was done by providing gain in this 250-2000 Hz region was to potentially introduce an upward spread of masking that actually made things worse rather than better.

So one option here would be to treat the high frequency hearing loss and not the low frequency hearing loss. But the point is that we have to respect how the individual's patient's brain is going to react to these situations where someone was before they walked in the door matters, right? And whether they were treated in the past, whether they had linear or analog technology in the past, whether they grew up with a pediatric fitting rationale, all of these things are going to impact how their brain works with sound.

And we need to be thinking about that in terms of optimizing their current function.

When it comes to our evidence base, we have to ensure that we're focused on the right problem. This is a quote I came across recently that I just love. It's a mathematician named John Tukey. So he was the co developer. He was actually the co developer of the most widely used fast Fourier transfer algorithm.

That's Actually the tool that we use to divide sound, entering a hearing aid into the frequency bands that we use for frequency specific programming. I was just kind of tickled to come across this quote by him and that I think summarizes this idea really well, which is that an approximate answer to the right problem is worth a good deal more than an exact answer to an approximate problem. And I think that's true to a large extent with prescriptive algorithms. I think it's an important concept to remember. Algorithms are not the final answer.

They are not truth. They are a shortcut to get us to a starting point for an average patient with a typical hearing loss. And they work well for a huge portion of patients because most people do present with an age related, gently sloping, mild to moderate sensorineural hearing loss. But there's going to be patients that don't match up to these assumptions and current algorithms are based on right now. And so you should feel empowered and obligated even to try something else if that's not working for your patient.

The good news is that there is work going on in the field to better understand how we might use tools other than just prescriptive formulas and audiograms to create an individualized hearing loss compensation approach. At Eric's Home Research center, this is Rukhan's commitment to personalizing care in this way because they're doing research to understand how physiologic models of auditory processing and impaired inner ears can be used in conjunction with things like deep neural networks to predict ideal individualized gain. Alternatively, or in addition to that, individual loudness scaling could be used to predict the best gain for a patient. The day may come someday in the future when rather than programming to prescriptive targets, you as a hearing care professional are instead spending your time training a deep neural network to best support the individual brain and auditory system for your patient.

But that's in the future. So today we've got prescriptive gain targets and that is our best starting point for most fittings. So let's look at some of the underlying assumptions and goals. Prescribing gain for patients can be tricky as we have to consider multiple outcomes simultaneously. So I mentioned at the beginning, the primary goal that we're looking for in is audibility, particularly for speech to address the communication needs that patients are seeking care for.

But if, you know, a pure focus on restoring audibility isn't quite enough and could potentially have some drawbacks depending on the hearing loss. So we already know that not all sounds contribute equally to speech perception and that patients often report difficulty hearing in background noise. So we don't necessarily want to create the same level of audibility for all sounds.

One additional goal might be to maximize speech intelligibility, particularly focusing on those sounds that will have the greatest impact on improving speech. Understanding these are important goals, but focusing only on making sound, even if it's speech loud enough, could also have some negative consequences if the sound is too loud. Providing too much gain can cause distortion of sound. It could

also potentially harm residual hearing function via noise induced hearing loss.

And of course, if we look at an audiogram, the challenge of prescribing the right amount of gain becomes apparent. A person with normal hearing has a wide range of sounds that are audible to them, from those that are at the threshold of hearing to sounds that are uncomfortably loud. This large dynamic range means that there's plenty of opportunity for soft sounds to be perceived as soft speech sounds to be audible, and loud sounds to be perceived as loud. But as we know, when a sensorineural hearing loss is present, the dynamic range reduces. Hearing sensitivity is reduced, meaning that sounds have to be made louder before they're audible, but they can very quickly become too loud.

Because the patient's tolerance for loud sounds does not necessarily change. And in fact, depending on the etiology of the hearing loss, the patient can sometimes be even more sensitive to loud sounds due to abnormal growth in loudness perception, which we of course refer to as recruitment. So in this example, the patient has a moderately severe hearing loss. The shaded area shows that there's only a small range of sound levels in which the sounds are both audible and comfortable. Without amplification, this client is unlikely to hear soft sounds, and yet loud sounds are still perceived as loud and maybe uncomfortably so.

What we do need to note is that loudness perception is personal. Two patients with identical audiograms can have very different loudness growth. One person may perceive a sound as soft where another person perceives the same sound to be moderately loud.

Because of the individual differences in this perception, a goal of a prescriptive formula might include ensuring that the patients experience sufficient comfort to wear their hearing aids and obtain the benefits of audibility. And on top of all of this, a prescriptive formula might also have the goal of preserving good sound quality. Numerous surveys, including Market Track, consistently show that sound quality is a paramount factor for hearing aid users, often ranking as the most important aspect of

hearing aid satisfaction. Sound quality encompasses more than just volume. Patients want clearer, more natural sounding audio, lack of feedback, and good handling of background noise.

Patients spend their time in a wide range of listening environments spanning a wide range of input sound levels, and when we use compression amplification to ensure that these first five challenges are met, the natural relationships of sound are necessarily distorted and in some cases feedback could occur if we have a goal of maintaining the gain we desire. This makes the goal of preserving sound quality a special challenge that has to be balanced with the other goals. Modern prescriptive formulas, regardless of their origin, generally take all of these factors into account, but the weight that any given method uses might differ, which is why different fitting formulas generate different gain levels for different hearing losses. They all have some different philosophy. There are many different widely used rationales and have been since the invention of hearing aids.

And as hearing aid technologies have evolved and we've continued to learn more about the function of the auditory system and as our patient populations have changed over time, prescriptive gain algorithms have either been discontinued or have evolved. There are several different fitting rationales currently in widespread use, with a common goal of prioritizing speech audibility. Choosing which prescriptive rationale you might use as a starting place for an individual patient should depend on whether the underlying assumptions for rationale meet the needs of your patient.

What you see here is a list of potential assumptions that an individual fitting rationale might adhere to or potentially reject in determining how much gain would be appropriate for an individual patient and their hearing loss. Some of these assumptions are about bottom up versus top down processing of speech. Remember, of course, that we hear with our brains. An example of where this assumption becomes important is in the case of fitting pre or paralingual children versus fitting adults. Children might be presumed to need much greater access to speech and audibility because they're highly dependent on

bottom up pinpoint input to develop speech and language to begin with.

On the other hand, an adult with a lifetime of speech and language experience might be better able to make use of some of those top down processing in order to make sense of the sound that the brain receives. So the choice of prescriptive approach at all is another assumption. In some cases, clinicians might choose to use an audibility based fitting where real ear measures are used to ensure that the softest speech sounds are above threshold, the loudest sounds are below patient's uncomfortable level, and moderate speech lies in between those. So that doesn't use targets at all in that type of fitting. And you could see even from the Harvard report they said you don't need this, so the fact that we use it at all again is an assumption.

Prescription prescriptive Algorithms generally rely mostly on pure tone thresholds, and the assumption may be that we're trying to correct for the patient threshold loss. But the growth of loudness may differ for different patients, so too much focus on threshold could be detrimental because patients are generally listening to sound much louder than this. The idea that measurable hearing is usable and should be compensated for is one that may or may not be true for a given patient. We saw that with the reverse slope hearing loss. In some cases, patients may be able to make good use of sound presented at super threshold levels for a given frequency band.

In other cases, the underlying damage in the auditory system could create potential dead zones or other types of dysfunction and distortion where the auditory input becomes so distorted that providing it to a patient causes more harm than good. There is evidence showing that most patients do better at understanding speech with greater bandwidth, but for the reasons described above, we can't necessarily assume that for every single patient. When it comes to compression amplification, the general idea is that soft, moderate and loud sounds should be made to fit within the patient's dynamic range. However, the more severe the hearing loss, the smaller the dynamic range becomes, often to

the point that the intensity of speech sounds becomes highly distorted relative to one another. So the extent that which the that this assumption works for any individual patient could be very individual.

Different algorithms might vary in their approach to how they treat asymmetric hearing thresholds. Does the rationale assume that both ears are contributing equally to a fused auditory image in the brain, or does it work by trying to make large differences between the ears be more comfortable? Assuming that the ears may not be contributing equally in cases where the brain does not use both ears, the same is with the same effectiveness, such as in the case of like a binaural interference. This could be an important factor to patient success. Prescriptive rationales could also differ in their assumptions regarding how the patient is physically fit with the technology, such as with a closed or more open ear canal.

They can also differ in the underlying assumptions regarding the environment in which the patient is operating. Some algorithms are focused more on overall listening experiences in both quiet and in noise, while others might be focused more specifically on one situation like quiet alone or noise alone. Rationales can also differ depending on what the patient is presumably intending to listen to. In most cases the assumption is that speech is the signal of interest, but algorithms can be made to account for other potential signals of interest, such as music, and you see that from a lot of the manufacturers. So as you can see, there are a lot of assumptions inherent in any given prescriptive strategy, and it's important to understand the potential benefits to a specific patient, and it's an important clinical decision that each hearing care professional has to make for each fitting so fitting rationales can be characterized as either proprietary, which refers to a rationale developed by a hearing aid manufacturer, or as generic yes by hearing, or generic, which refers to a rationale developed independently from a manufacturer.

So examples of commonly used generic rationales are the family of rationales from National Acoustics Laboratory or NAL in Australia, or the desired sensation level or DSL formulas from Western University in Ontario.

Generic fitting rationales offer a more standardized approach to fitting, so these are available in multiple manufacturer software and are widely used in audiology education programs. Proprietary fitting rationales are created by individual hearing aid manufacturers. Oticon's proprietary algorithm is called Voice Aligned Compression or VAC plus. Historically, there's been limited information disseminated from OTICON about the VAC plus fitting rationale, but we're really starting to realize that this is important because as newer algorithms become available, it's important that you have some underlying information in determining how and when you might choose this particular rationale. One of the benefits of Oticon's rationale is that it's updated regularly to best support Oticon's evolving hardware and technology.

This would be in contrast to generic fitting rationales, in which the length of time from development to revision can typically be pretty lengthy given the rapid development to hearing aid hardware and software. It's often the case that when you're using a generic rationale, you have to generally make the assumption that they were not developed using contemporary hearing aid technology. The most common generic fitting rationales are NALNL 2 and DSL version 5, and these will be discussed in the following slides. A little bit more so the National Acoustic Laboratories in Australia has a long history of audiologic research and tool development. They published their first fitting rationale almost 50 years ago in 1976 which prescribed linear gain.

There have been numerous subsequent revisions and nal's philosophy has always been to maximize speech intelligibility while ensuring overall loudness remains comfortable. NAL's non linear fitting rationale, NAL NL, which is now known as NAL NL1, was released for clinical use in 1998. This was

based on a set of explicit assumptions and models that included a speech spectrum with a long term average speech target, which is a method for estimating how much audibility in each frequency region contributes to intelligibility. This is called band importance weighting and they used a loudness comfort framework that penalizes too much overall loudness. They were using these constraints to say okay, how can we maximize speech intelligibility without making it too loud?

And they put these constraints into a machine learning tool that was then able to provide computational rules for how gain should be distributed across frequency and level. The second generation, NAL 2, which was released in 2011, is one of the most commonly used generic fitting rationales. NAL NL2 has the same underlying philosophy of maximizing speech intelligibility and ensuring overall comfortable loudness. It was adjusted as needed based on empirical feedback from patients who had been fit with NL1. Changes included a reduction in overall loudness compared to its predecessor with slightly increased compression ratios.

There were other personalization options incorporated including providing less gain for new users compared to experienced users, different prescription for different genders based on research that showed males preferred slightly more gain than females, more gain for children compared to adults particularly at quieter input levels, more gain at low frequencies for tonal compared to non tonal languages, and less gain for bilateral fittings compared to unilateral fittings that varies with input level due to loudness summation. NAL NL2 does model for the effects of open ear canal fittings. However, it is important to note that the auditory models for NL2 are based on speech in quiet only, not on the acoustics in the environments where patients struggle the most. NAL has released the latest update to their fitting rationale called NAL NL3 to hearing aid and diagnostics manufacturers. According to NAL, the newest version of the core formula provides fixes for some of the more challenging fitting configurations that were not effectively addressed in the NL2 formula like reverse slope and mixed losses.

In addition to the core formula, the NL3 rationale contains modules that can be used for specific situations or patients needs. In contrast to NL2, which was designed for speech and quiet, NL3 offers a comfort in noise module that has been created with the aim of improving listening comfort without compromising speech understanding noisy situations. There's also a minimal hearing loss module available designed for people who have auditory complaints but have minimal measurable hearing loss, at least in terms of their thresholds. It is early January 2026. At this time limited data has been released on the outcomes of NALNL3, so right now, to my knowledge there are no formal peer reviewed journal articles that specifically report on this prescriptive formula, its derivation or controlled clinical outcomes in the scient literature.

Right now we do have real ear targets currently available in Medrex Studio which can be used across various MEDRECS systems.

All right. The desired sensation level or DSL family of rationales was developed at the University of Western Ontario and has seen evolution through five versions. The DSL method became available as a first fitting software program to assist with hearing aid fitting for young children. The initial focus was on children with the goal of providing support for speech and language development. It remains widely used today for pediatrics especially.

The DSL Formula version 3.1 worked with linear hearing aids and included a prescription for hearing aid output limiting. Similar to the NAL formulas, DSL was meant to prescribe a comfortable level of speech that was associated with maximum speech sound recognition performance in children. These early versions of DSL incorporated children's ear canal acoustics and child friendly verification procedures. By 1999, wide dynamic range Compression Technology offered a range of input signals for soft, average and loud speech, which prompted a major overhaul of the DSL formula and DSL version 5.0 was introduced in 2005, updating protocols and targets from its predecessor. The philosophies of

DSL 5.0 are to make speech audible at all frequencies and to normalize the loudness at each frequency, aligning the amplified sound with what a typical normal hearing person would perceive, which is what is meant by the desired sensation level.

This differs from NAL where the goal is not to restore normal loudness but ensure comfortable loudness. DSL was the first generic hearing aid prescription that adjusts for different listening needs of infants, children or adults. Generally, a higher listening level is prescribed for pediatric patients, presumably who would have pre or paralingual hearing loss compared to adults who would be assumed to have acquired hearing loss. It was also the first generic prescription that provided different amounts of hearing aid gain for use in quiet versus noisy pulses. Having a special protocol for noise program.

The version also included an optional binaural correction where targets for speech are reduced to account for loudness summation, and a correction for conductive hearing loss that varies depending on the magnitude of the air bone gap. Oticon's fitting rationale VAC plus emphasizes natural sound processing as well as audibility and comfort. It differs from the aforementioned formulas and that loudness compensation is not the goal. The goal is to improve perceived sound quality without loss of speech intelligibility, minimizing the risk of distortion and discomfort. Compared to generic strategies, VAC plus provides less gain at high input levels, more gain at low input levels by means of a lower compression knee point.

The most recent update of VAC plus, which was in 2024, you'll see in the that was the most recent update and what you'll see in a moment is that it's really refined and optimized alongside Oticon's hearing technologies. So it's been around for 20 years and it's evolved over that time. There are two main personalization options associated with VAC. These are soft sound perception and brightness perception, which enable you to adjust the hearing aid gain to your patient's needs and preferences.

And then finally, Vacplus has adaptations for open fittings and complex audiogram types including minimal hearing losses, steeply sloping and reverse slope hearing losses, asymmetrical and mixed conductive losses.

It's important to note that VAC is designed for post lingual acquired hearing losses. Oticon does not have a dedicated pediatric algorithm. In addition to VAC Plus, Oticon has a separate proprietary rationale for severe to profound hearing losses called dynamic speech Enhancement, which is not covered in this training.

Technology is constantly evolving and over the last 25 years hearing aids have evolved drastically each time a new product is developed or new feature introduced. The hearing aid hardware features and Oticon's fitting rationale are tested and optimized together to ensure maximum benefit for end users. So in this way, VAC remains an evolving and central component of Oticon's hearing aid technology development the first iteration of Oticon's VAC Voice Aligned Compression was deployed in 2004. This prescription was developed in collaboration with Eric's Home Research center and was based on existing prescriptions used by Oticon at the time and a loudness growth model from BOOS and Florentine. The objectives of the rationale were to restore natural loudness perception while ensuring the preservation of sound quality and speech intelligibility.

To put this in the broader timeline of other fitting rationales, NAL NL1 was introduced in the late 90s and DSL was introduced. DSL version 5 was introduced in 2005. In 2007, VAC was updated on the RISE platform. At this time, additional gain was prescribed to ensure audibility for clients with minimal hearing losses. In addition, a VAC open algorithm was used to accommodate open ear canal fittings, providing less gain for mild losses and imposing a limitation of gain for severe hearing losses to balance audibility and feedback risk.

This was applied automatically when an open fit was selected in the software. In 2010, structural changes to the algorithm were introduced to accommodate a new platform and at this time no changes were made to the prescriptive intent of VAC, but the gain estimation was streamlined. Again for reference, NALNL2 was introduced in 2011. In 2013, VAC underwent refinement for the Oticon Indian platform. While the core rationale remained unchanged, minor modifications were made to tailor VAC to new hearing aid form factors.

In 2015, VAC was renamed to VAC to acknowledge larger updates to the prescription for use on the Ename Sense platform. These updates included a more powerful anti feedback system that allowed for higher frequency knee points and VAC plus to be lowered while still increasing gain at medium levels to maintain speech clarity. Five previous sub rationales were simplified into one rationale which is great with expansion knee point adjustments that were now handled through a soft sound perception control. Furthermore, the existing precipitously sloping or ski slope hearing loss prescription was refined to prevent large shifts in gain and resulted in a more stable fitting. VAC plus was updated again in 2016 for the new Velox platform with the Oticon Open hearing aids.

Because the philosophy of open included a new approach for handling background noise, the assumptions underlying gain with an open sound experience needed to be taken into account. In addition, in the fitting software a unified style independent VAC target display was shown. Prior to this each style had its own correction factors so this removed the influence of acoustic leakage and ventilation effects from the target display and simplified the fittings. In 2019 Act plus was revised for the Velox S platform and basically updated because we had now the open sound optimizer feedback prevention technology so again it gives opportunity for more gain than previously. The VAC prescription for steeply sloping hearing losses was also updated and ensuring that the categorization of steeply sloping high frequency loss would now be required for both ears when fitting binaurally.

So there was a lot of adjustments to the assumptions underlying that binaural correction. VAC plus was updated again in 2020 for the Polaris form with Oticon Mohr. This was updated to provide continued support for a hybrid compression strategy. Those are part of more sound amplifier so we had a 24 band fitting system for both fast and slow acting compression. It was also aligned to support the sound quality needs of the AI DNN based noise suppression strategy of more sound intelligence.

A newly updated conductive hearing loss component was also addressed and then in 2023 VAC was updated for the Polaris R platform. At this time all of the rationales in gene 2 including VAC were updated to have speech shaped knee points providing alignment between simulated insertion gain graphs and gain control values. The most recent update to vac occurred in 24 with the introduction of the Sirius platform for the Oticon intent hearing AIDS VAC was updated to leverage the capabilities of the new platform including speech enhancement, which is a dynamic high frequency gain adjustment responsive to noise reduction occurring in complex environments. It was also adjusted to ensure naturalness in the presence of Oticon second generation of AI noise reduction and the algorithm was adjusted to accommodate an extended low frequency bandwidth down to 80Hz. And so for perspective, this brings us to 2025 where NL3 will be has, but it's not yet widely available in commercially available hearing aids.

So you can see that over time it was really responsive to the changes in the hearing aid platform technology and really sensitive to the dynamic aspects of what a hearing aid is doing, not just static game. With these many updates you might be wondering how validation is accomplished. With every new hearing aid platform or product. There's a structured testing process which ensures that the technology is performing as intended. This testing process is holistic considering the hardware, signal processing and VAC together.

Testing begins with small scale development which are designed to assess how VAC performs with the new hardware and signal processing. This often involves a small group of hearing aid users wearing the hearing aids at home or in simulated real world environments. Users provide important feedback which feeds into adjustments early on. Once the platform has matured, larger scale development tests are undertaken to validate audiologic performance. We maintain a test participant database of over 200 adult hearing aid users who support these studies and these tests include things like technical improvements that can be evaluated electroacoustically, speech intelligibility improvements that can be measured, subjective evaluations that can be made over time for benefit there.

All right, so VAC plus in practice ways you can optimize it in genie it is the rationale default for adults, but you can make changes as needed and to do that you would go into the Genie 2 to navigate to the fitting screen and you can do that there. GENIE offers personalization for your patient as well. The personalization tool gathers information about patients 18 and older to ensure a good starting point. You can access this from the task pane in the prepare step. There's two methods that you can use to personalize the ACT audible contrast threshold or the personalization questionnaire.

So the parameters for personalization are gender, age, language, experience with instruments and listening preferences. Experience is chosen independently for right and left ears from none, short term or long term. The assumption here is that different levels of gain may be more acceptable to newer versus long term users due to exposure and acclimatization client language. You can choose from a list, but basically what it's doing is trying to Narrow down between tonal versus non tonal language. And this is actually only used if you were using the NAL and L2 formula.

Gender, as I mentioned, is used in the NAL NL2 fitting formula. And then with age you can have default settings that are a little bit different for things like noise reduction management and directionality for VAC plus, but not necessarily to the other algorithms for act. You can see that you can actually just go

in and either automatically pull over the ACT value if you have it, or you can enter it manually. And this is designed to provide you with a super threshold score of how the person would potentially do with speech and noise. And there's our other trainings available on Audiology online on ACT if you want to learn more about that.

If you don't want to use the ACT value but still want to personalize the fitting, you can use a questionnaire tab as well. And you have sound demos that will help you to answer patient questions. And then depending on the parameters that you've chosen for the patient, there actually are different lists of questions and so can be used to also tailor the sound experience and sound quality experience for patients. That includes the targets for VAC plus and you'll be asked to recalculate when you make changes like that. GENIE does require you to select your preferred acoustic coupling for the patient, and you'd do that by either navigating to the Acoustics tab or with a pop up.

You can access the fine tuning screen from the task pane in the Fit step and the algorithm will be calculated as shown. GENIE offers multiple options for types of graphs, so you can use different applications of GAIN to simulate performance.

A variety of graph settings exist for different signal types and for different input levels, so you can understand how nonlinear gain looks. If you want to make changes to the prescriptive algorithm that you're using, or add a different algorithm to another program, you can access the program manager from the task pane under the Fit tab. In the primary program, you can choose from a drop down list of all the available algorithms for the instrument in question. And then in additional program slots you can also add other main programs or special purpose programs like Music, Speech and Noise, Comfort, Lecture, Phone. The game for these programs is adjusted to accommodate for assumed needs in those situations.

The adjustments for any additional programs are based on the algorithm used in the primary program. So if it's a VAC plus, it's going to act on a VAC plus rationale modifications in an NAL or DSL will also act upon those rationales there are numerous variables relating to the application of gain that can be adjusted in the settings section of the software, and so you can set these as preferred defaults as needed.

And I do want to emphasize that the vast majority of oticon's fitting features remain accessible to you regardless of the prescriptive algorithm that you're choosing to use. This includes oticon's noise reduction system, wind and handling stabilizer, sudden sound stabilizer, feedback suppression. It is important to recognize that while you can access all of those and still have the benefits of them, you should just know that VAC plus is specifically optimized for use of these advanced features, and that does not occur with NAL or dsl.

So one exception to that is. Sorry about that. One exception to this is what's called soft Speech booster and brightness perception. And so soft speech booster provides 3 decibels more soft gain above 1500 hertz. And it's been shown to improve soft speech understanding for those patients where it's an appropriate sound quality.

And so you're default settings for soft Speech booster and brightness can be found under the Sound controls tab. And you can see the little target is what was selected. And basically this was done by the personalization.

Once you've chosen which fitting rationales, you want real ear measures, of course, the best practice for ensuring that hearing aids are providing the desired gain and output, taking into account the patient's individual ear canal acoustics. Before we move on to the details of this, I'd like to address an important issue that I often see in practice. Performing real ear measurement is not the same thing as matching targets. Real ear is about measuring what's happening in the ear canal, and it can be used to

match targets. But regardless of which algorithm you choose to use and whether or not your clinical expertise leads you to deviate from those targets, you should still perform testing to determine what's happening in the patient's ear canal.

If you don't want to match targets at all, you can remove them from the screen but still measure what's happening. And there's other methods of verifying function without necessarily attempting to hit targets. And I'll talk about that in a moment. I do believe though, that in a lot of cases there's conflation of these two things, hitting targets or performing real ear. And I think that then in some cases that does us a disservice because people sometimes think they shouldn't do real ear when they're not trying to hit targets.

And I think it's really important that we understand what's happening in the ear canal. Regardless if your goal is to use REM to evaluate your gain relative to targets, there are many ways to access these both for generic and proprietary rationales. Specific opportunity depends of course on the real ear system that you have. In this slide you can see which OTICON algorithms can generate targets in which real ear verification assistance along with those for NAL and dsl. For both Medrex Interacoustic systems, OTICON proprietary rationales and generic rationales can be calculated for both manual and auto fit rem, and you do need to do that by launching the REM module, however from the rem tool in Oticon Genie 2 and then you can do that within Genie and in this case GENIE calculates the targets and communicates them to the real ear system and then the real ear system is making the measurement and then communicating them back to Genie while the gain adjustments are being managed by Genie.

Options for Audioscan VeriFit and VeriFit 2 and Natus are shown here. Currently the Audioscan software is only possible to generate generic targets in the natus. Generic targets can also be generated for either manual or autofit rem and for oticon proprietary targets you can conduct auto REM

but not manual.

There is, you know, While matching frequency specific targets is one way to measure audibility and verify hearing aid function, you also might want to be open to other strategies such as an estimate of audibility on speech Audibility of speech like the Speech Intelligibility Index, Speech Intelligibility Index predicts the degree to which speech can be understood based on how audible the speech signal is. The SII value is between 0 and 100. Higher SII indicates that more of the speech information is audible and therefore more likely to be understood. If speech is interrupted by noise, for example, fewer cues will be available to the listener and thus the SII value will be lower. SII is an available option in many REM systems that present a calibrated speech signal and then calculate CSII from the measured hearing aid output, and research does support that this method has utility in assessing hearing aid benefit across different fitting rationales.

So if your REM system does not support VAC target verification and that's what you want to use, you could use the SII to allow you to verify that VAC plus is providing appropriate benefit to your patient. If you have interest in learning more about using SII for hearing aid fittings, I would highly recommend either of these two articles. First is from 2025 by distinguished group of pediatric hearing aid researchers from Boys Town, University of North Carolina, Boston Children's University of Iowa. The second is a 2018201820 questions article by Susan Scully, available here at Audiology Online. Lastly, I just want to take a couple minutes to show you evidence collected during a pilot study to look at the benefits of patients for VAC plus.

So it was actually used to compare patient benefits of VAC plus up against NAL NL2. So again not looking to prove a benefit of one versus the other but really just to have a reference point that something that people are very familiar with because a lot of people do use NAL and L2. So they compared a range of different outcome measures including sii, Speech Intelligibility Index, some

subjective questions and so on. The main highlights of the study were that VAC plus performed very comparably to NAL NL2 across all of the outcome measures with most of them demonstrating no significant difference between the rationales. There was a subjective overall hearing performance question and VAC plus for that was shown to have higher ratings, but overall SII values for VAC and NAL NL2 were comparable across a wide range of hearing losses, although it was slightly higher for vac plus for a 50dB input speech just so you get a sense it again was a pilot study with a small number of participants with bilateral sensorinetal hearing loss.

All were inexperienced new users aged 52 to 82 years with a mean of 68. Audiometric thresholds range from normal to profound hearing loss bilaterally and the way this was done was Participants attended three appointments over a five month period during which they did a trial of hearing AIDS program to VAC or NAL NL2 at the beginning, randomly assigned to one of those two groups. At the first appointment they underwent testing including ACT. They had Oticon Intent mini right hearing aids set to either VAC plus or NAL2. They were instructed to wear the hearing aids for a minimum of eight hours a day for two to four weeks.

At the second appointment, participants completed questionnaires evaluating their experiences. They were then refit using the counterbalanced fitting formula. So the vac plus group was then refit with NAL2 and vice versa. Again they were instructed to wear the hearing aids for a minimum of eight hours a day for two to four weeks. At the third appointment they completed the same questionnaire about their auditory experiences and other questions were asked added to compare the two rationales.

Aided SII values were measured for both of the rationales to provide an estimate of audibility and so they had questions to answer but These are the SII results. Here you can See SII for NAL NL2 at soft, moderate and loud input levels for these groups. And here you can see the SII values for VAC plus. The SII value was significantly higher for the hearing aids when they were fit to vac plus for the SOSP

gen compared to NAL and L2. So there's a little bit more audibility coming from vac plus overall for this group compared to NAL2.

This is likely attributed to the benefits of the soft speech booster which I mentioned earlier. For the others, there was no significant difference demonstrated for SII for VAC plus or NALNL2. So you're really kind of getting from at least from an SII pers similar type of outcome.

The majority of the questionnaire items again showed no significant differences or preferences between the two fitting rationales. However, there was a single question about overall benefit and for that one they actually did see an improvement or an increased preference for VAC plus compared to an ALNL2. So when you go to the individual level we didn't see what about it was different, but it was an overall and so that gave us some confidence that you can have a similar user experience between VAC plus and NAL NL2 and that you're not really necessarily sacrificing anything if you do go to vac plus over an algorithm like NAL and L2. But again, we just need to make sure that we are looking at this in the future with other sample sizes, more varied participants, other types of outcome measures, and so on. But it gave us some confidence to go forward with that and share it as well.

We do have a VAC plus fitting rationale white paper that we will include with the session for handouts. Please note that the references are available here for your convenience and in the course handout. And with that I just want to thank you for your time and attention and hope that this has provided you with some additional information for you to make those good clinical decisions with your patients going forward. Thank you very much.