Understanding Individual Variability Among Older Adults with Hearing Loss, in partnership with American Auditory Society

Presenter: Pamela Souza, PhD, CCC-A

Hello and thank you for joining today's webinar, Understanding Individual Variability Among Older Adults With Hearing Loss, which is presented in partnership with the American Auditory Society. It's my pleasure to introduce our presenter today, Dr. Pamela Souza. Dr. Souza is an audiologist, researcher and teacher in the Department of Communication Sciences and Disorders at Northwestern University. As a researcher, she studies speech recognition, hearing aids, and the effects of aging and cognitive change on communication. Dr. Souza's clinical interests include hearing aids, severe hearing loss, hearing assistive technology, and patient counseling.

Her research and practice are motivated by personal experiences with hearing loss and dementia in her own family. Dr. Souza, the floor is yours. Thank you so much, Christy. Can you hear me all right? Can everyone hear me all right?

Yes, I can. Wonderful. Welcome, everyone. Thank you for joining us today. Just a few housekeeping items.

Here are my disclosures, and these are the limitations and risks for today's course. And here are the learning outcomes for today. So to start off, I have to say this is my work, but I also owe thanks to others who really did a lot of the heavy lifting in this. I want to especially thank Kathy Earhart, who spent a lot of time with me thinking about individual variability and try to understand it. So we're going to go through a series of topics today.

We'll begin by talking about individual patient variability and what we're doing currently in the clinic to understand that variability. Then we'll move on to talking about hearing aids, what they do, and some reasons why we might see such variable benefit among patients, what contributes to that individual variability for hearing aids. And then we'll end by kind of thinking about where we could go as a field. So I'm going to call this, you know, my wish for precision hearing care.

So first, let's just think about patients. Many of you in the room, the virtual room here, are probably clinical audiologists who see patients who come to you with various communication needs. So those patients are all different. Their audiograms obviously are different, but also the way they process sound through their auditory and cognitive system is different, and the environments that they're listening in are different as well. So these are just some snapshots that show the kind of things where patients might say, I'm not hearing very well and I need some assistance.

And I almost think of it as layers of complexity. You've got the patient, their audiogram, their processing, their cognition, their environment, all of those things coming together for their communication.

Now, when we see a patient, we could think about how individuals are assessed in the clinic. So let's imagine that we're seeing an adult with hearing loss who may eventually be fit with hearing aids. It is the case in our audiology appointments that the majority of our diagnosis is built around speech audibility. So if you think of that patient in front of you for maybe half an hour for a hearing assessment, probably half that time at least is spent doing the pure tone audiogram. We certainly do speech testing to understand their communication needs, but the basis of that speech testing is often speech in quiet, especially simple speech in quiet, even monosyllabic words in quiet.

And we know from studies, including studies with things like the speech intelligibility index, that pure tone audibility is a very strong predictor of speech recognition in quiet. Less often in the clinic, we are doing tests of speech recognition in noise, but they're still pretty general tests. So they might be sentence in noise tests, and those are not really done universally. So the surveys tell us that about 30% of us are testing some kind of speech recognition in noise. Then in an even smaller percentage of the time, clinicians are doing something that we could think of as fine tuning, testing specific listening abilities, perhaps noise tolerance, dead regions, things like that.

So after you get through the assessment phase, then we're going to prescribe hearing aids for the individual, and so we can think about how those hearing aids are selected and fit. Now, by and large, it's based on the pure tone audiogram. And the idea of prescribing gain to pure tone audiogram is a very well studied, very well validated approach. But I would suggest to you that the specific signal processing that is used in the hearing aid, and we're going to talk about what that processing is, is not yet as well studied and well validated as things like the target to the pure tone audiogram. So very often in the clinical approach, you give them some signal processing.

We'll talk about how you might make that decision. Maybe it's great, maybe it's not great, but if the patient is dissatisfied with how the hearing aids are working, we then often enter this period of kind of trial and error to find processing parameters that can really maximize hearing aid benefit. And it can be not that easy to tell if you've reached the sweet spot, if you've really optimized that hearing aid for the patient, because usually when they're happy enough, we stop and we start, stop making adjustments. So it's this kind of trial and error, trying to figure out if we've really suited the processing to the patient abilities that I want to make. One of our themes today, now Patients and many audiologists feel like advanced technology is going to result in better speech perception for each patient.

Because we get stuff with advanced technology, right? We get better directionality, we get more channels, we get more processing, more options, more fine tuning ability. So there is this sense that the patient who pays more gets more and specifically that they get better speech perception compared to having a very basic hearing aid. But really there's very little evidence to support that view for patients in general. And there is some evidence to the contrary.

I've got one reference on this slide here, but there were actually four or five studies by this group where they made comparisons of basic to advanced technology, where the patient was blinded, they didn't know what they were wearing, and generally they didn't find huge advantages, or maybe not as large an advantage as we would hope. So in this slide are reports from a survey that we did where we asked audiologists how they chose their hearing aids. And what you're seeing in this listing are the things that audiologists said were most important. So what mattered to them? Well, the top thing was patient listening environment.

And they said that was the most important factor. 87% of audiologists said it was very important, and another 12% said that it was somewhat important. So I think we would probably all agree with this that we need to consider the patient's environment, quiet environments, noisy environments, group environments in our decision. Now, the next most important features according to survey results was hearing aid signal processing. And so almost all audiologists said that that was either very or somewhat important in the choice of hearing aid and hearing aid features.

By signal processing, we mean the way the hearing aid manipulates sound, including things like compression, digital noise reduction, frequency lowering. And then from there we go to factors like the degree of hearing loss, which 78% of audiologists said was very important, and then the audiologist experience with or comfort with that particular product, with about 3/4 of audiologists saying that was a very important factor to their decision of what to fit the patient with. So we can also look at where we might need more guidance, more evidence to make good clinical decisions. So this is a little bit of a busy slide, but I'm going to walk you through this and I'm going to see if I can get a pointer. So hopefully you can see this.

Okay, so the top part of the graph was asking questions about the initial fit. And this again is from a survey of audiologists. The bottom part of the graph is after the initial fit when the patient comes back and we're doing fine tuning. So let's just concentrate on the top part here, her initial fit. So most people were using some sort of prescriptive procedure.

And what I want you to do is look at the green here. So the green shows the majority responses. So what audiologists said is that 80% of them were using the manufacturer's first fit to determine the wide dynamic range compression time constants, 58% were using that first fit to determine the noise suppression settings, 69% were using the first fit to determine feedback suppression, and 67% were using the manufacturer's first fit to set directionality. And the manufacturer's first fit is largely based on the pure tone audiogram. That's what we enter into the fitting software.

So is this patient specific? And if it isn't, what other information do we need to be able to really fine tune that first fit for the patient? Now if we go down to the bottom section here is fine tuning and again we can just draw your eye to the green settings here. So when it came to making processing decisions at the fine tuning stage, the follow up stage, people were relying very heavily on patient report. So 98% asked the patient questions to fine tune gain, 96% asked the patient questions to fine Tune Noise Suppression, 81% for feedback, 86% for directionality, and 82% for frequency lowering.

So patient report of course is when they come back and say this worked well, this didn't work well, liked the sound, didn't like the sound. The other big reliance for fine tuning was either what the manufacturer recommended to do in a particular circumstance or simply applying clinical expertise. So what strikes me here is that typically a particular brand of hearing aid will use the same default processing, that is the wide dynamic range, compression speed, noise suppression, directionality for all or most fittings with a particular audiogram. So if you fit that product, you're getting that products recommendations for your individual patient. And that may or may not end up being the ideal situation for the patient in front of you.

Okay, so my question here is, could we better individualize hearing aids if we understood more about individual variability in how the patient uses the information they have, that auditory super threshold speech information? What if we could choose hearing aid signal processing, not just the gain, but the processing according to individual abilities. And what if we can think about the interaction between how the processing works and the listener abilities in their own environments? So I'm going to show you a graph here which is from a lab study that we did. And just to orient you to this, on the x axis are a whole bunch of individual people.

These were all older adults with mild to moderate hearing loss. On the Y axis is their speech recognition score. These are sentences. Blue is what they could do in a pretty favorable situation where the sentences were 10dB above the noise. So that's, you know, kind of like a living room or not very noisy environment.

And you can see they're all doing really well. You know, they're all probably between 80 and 100% correct. Then when we increase the noise, we get the red triangles, which are a little more spread out. So now most people are doing well, but some are really struggling. These red triangles down here at 40, 50% correct.

And when we increase the noise even more and we have noise and speech at equal levels, so a signal to noise ratio of zero, look what happens to this group of older adults. There is huge variability. I mean, some of them really can't even recognize that speech, and some of them are doing very well still. So I like this graph because I think it really shows in a research way what ends up happening with patients. We test them in quiet, we fit them in quiet, we send them out, they go into noise, and then they come back and they tell us what happened.

And sometimes what happens is not as good as you would hope.

Okay, so this is the way I tend to think of patient variability. So we have speech and we have noise, and those two things are mixed together in most environments. And then we put them into a hearing aid and then we send it to the listener. Right. So now they're listening to an amplified signal that has a target and some interference in it.

But that listener has their own set of abilities, their own hearing loss, including their audiogram and the way that they process thresholds through their cochlea and auditory nerve. And then they also have their own cognitive ability. Right. So it's not just listening, it's processing as well. And especially in those more difficult, noisy situations, there's a lot that depends at this cognitive level, their ability to inhibit distractors, focus on the key signal, assemble something that makes sense out of bits of information that they're getting through that noise, and then we measure outcomes.

And those outcomes might be speech intelligibility, speech quality, how easy it is to listen, how satisfied they are with the hearing aid. So I like this kind of schematic because I think when you lay it out this way, you start to see how complicated the situation really is. Does audibility matter? Absolutely. But there's a lot of other things in the mix here.

So that's what we're going to Go on and talk a little bit about what is the hearing aid doing, what is the listener receiving?

All right, so I'm going to switch to a set of slides that walk through some of the things that hearing aid processing is doing to that speech signal. And let's start by thinking about the spectrum of the speech. So we all know that when we fit hearing aids, we're fitting a hearing aid that's a multi channel processor. And the figure you're looking at here is a survey that we did. It's a few years back now, but looking at the range of things across manufacturers.

And so every manufacturer sells their basic, their mid, their high technology levels, generally with more channels in the higher level technology that gives us more fine tuning capabilities. But although more compression channels can more closely control how that hearing aid responds across frequency, it's also altering the speech. And specifically it's changing the peaks and valleys of the speech spectrum.

For some sounds, every hearing aid is trying to do good, but in trying to do good and emphasize the speech, it's also creating modification. And so this is one modification that occurs in hearing aids.

Now, also in the spectral domain, we can think about frequency lowering. Now we're looking at a figure that was just summarizing the use of either frequency compression or frequency transposition. Frequency compression a little bit more common, but frequency transposition is also being used by manufacturers. And so of course, here again we have a goal that is a good goal. Frequency lowering is meant to improve audibility of high frequency speech cues so the listener can hear them, but it's also altering spectral information.

And so when we think of frequency compression, we have to think about what it is really doing. And what it is not doing is improving the audibility of all consonants. It is working only on that high frequency speech information. So the consonants that are low to mid frequency are not treated by the frequency lowering and their audibility is not going to be affected by this particular processing. As I'm going through these, I also just want to.

Where's my pointer? It's not moving. Call your attention up here when you see the little quiz hint. You might be preparing for there to be a quiz question on that particular thing. So, yeah, so frequency lowering, a great tool built into a lot of hearing aids, but not something that you would expect to improve audibility of all consonants because it is high frequency focused technology.

Okay, so now we can think about the other domain, which is temporal processing. And here we really have a range of what happens in hearing aids. So they're all using wide dynamic Range compression. That compression is responding at some speed to the input sound. But it might be either a very fast responder, fast acting, wide dynamic range compression, or it might be a very slow responder.

And generally the manufacturer has decided which they think is the right approach. I'll talk later in this presentation, but we are starting to see more customized choices here, particularly manufacturers who are trying to do the right things for severe loss or trying to do the right things for different patient ages. But yeah, wide dynamic range compression speed is an important factor and it may not be something that you have control on once you control over, once you have chosen your product. But we know that there's a trade off here. So fast acting, wide dynamic range compression is quickly, as you can see in this speech graph, very quickly turning up the soft sounds.

So if you look at the top graph where there was a low intensity phoneme here, probably not audible, the wide dynamic range compressor has taken that very soft sound and it's bumped up the gain. So now the person can hear that, hopefully. But it's also altering what we would call the temporal envelope. So these variations in intensity from high to low are a cue to speech recognition and they're very different when it comes out of the hearing aid. So audibility is good, but is that temporal distortion right for the patient here again, we have a little bit of a summary of the trade offs.

So remember, the goal of course, is to improve audibility of soft sounds and keep loud sounds comfortable by applying wide dynamic range compression. Depends on the level and it varies over time. The fast compression in theory is going to give us better audibility of brief low intensity phonemes, but it's also going to give us more distortion of that speech temporal envelope. The slow compression is going to not give quite as much benefit of soft sound audibility, but it is going to maintain the envelope here to something that perhaps is more natural. Now, there are hearing aids that make the best of both worlds by using an adaptive compression.

There are hearing aids that try to select the wide dynamic range compression speed to match something about the listener, perhaps the severity of their hearing loss. But I'm going to put this in the category of hearing aid processing that we need to think about choosing the right thing for a particular patient.

Okay, Kristi, I think things are showing up in the Q and A, but you'll tell me if there's a burning question that I need to answer, I think, and then we'll have some time for questions at the end.

Okay, now let's talk about digital noise reduction. So Digital noise reduction is a great thing. It is intended to improve the signal and suppress at least some of the noise. But it's not perfect. And so what it's trying to do is decide if any particular component that's coming into the hearing aid is either speech or noise and treat it accordingly.

There can be errors in that labeling or classification. And so it may fail to remove noise or mislabel speech as noise and remove speech component. And of course, this is especially likely to happen if the background noise is other speech because it doesn't always know who the listener wants to hear. We're starting to see much more sophisticated noise reduction in terms of machine learning, learning and neural networks managing the noise reduction. And I hope the situation will improve.

But right now most of our hearing aids are using more conventional digital noise reduction. So there are a bunch of different things that it can do. It works by looking at the signal modulation, do spectral subtraction, filtering out components that are identified as noise suppressing impulse noises. Suppressing wind noise is very common. And some hearing aids also reduce echoes.

And what you see in this graph is from the survey that we conducted what's commonly used and what's not commonly used. So you can see that wind noise reduction, almost all of the manufacturers we looked at had that built in as a noise reduction type, but it was less common to do a reverberation suppression or an echo reduction.

Now when we think of signal distortion, one of the things we have to remember is that signal distortion can occur due to classification errors during the digital noise reduction because the hearing aid is accidentally taking out some of the speech which it has mislabeled as noise.

So to put this all together, we can look at our list of common signal processing strategies and we can say, well, these are all meant to be good, right? WDRC improves audibility Digital noise reduction reduces noise Frequency lowering improves high frequency speech Audibility directionality is also meant to improve the signal to noise ratio, but each of them has a potential consequence of distorting something about the speech. So as mentioned, WDRC changes the speech envelope. Digital noise reduction can unintentionally and incidentally affect the speech by mislabeling and suppressing speech components. Frequency low lowering creates a spectral overlap or space change.

And MIC directionality can change the spatial, the natural spatial cues in the room.

So if we come back here and we say, okay, now I'm thinking about a patient, we've got speech, we've got noise, they're mixed together, they're sent into the hearing Aid, they get some kind of processing or sets of processing applied to them, and then the listener hears what comes out. We can also say that all of those types of hearing aid processing are modifying the signal in some aggregate way. So instead of thinking about what is the digital noise reduction setting, what is the directionality setting, what is the WDRC speed in the set of studies I'll talk about next, we start to think about what is the aggregate or collective effect of all of those processing factors, the way they interact with each other and kind of reducing the dimensionality of the situation.

And I'm going to do that here by using a signal modification network that we call the kepstral correlation. So this is basically a number that you assign to the speech that captures the cumulative hearing aid processing effects. And it is mostly an envelope fidelity metric. Okay, so it's looking at a bunch of things, but it's heavily dependent on the fidelity of the envelope of speech. So let me kind of talk through this.

So we have speech and noise at some signal to noise ratio gets processed by the hearing aid. And then the way this metric is calculated is then we consider the listener and we do that by modeling the effect of their auditory system. If you've got a mild hearing loss, for example, you've probably got pretty good spectral resolution. If you've got a severe hearing loss, you've got a lot of audibility loss, and you've got broad auditory filters. And so we want to consider how all those things process the signal.

So this kind of complicated calculation assumes that your speech plus noise signal is going into the listener's ear and based on their audiogram, it's being processed by a set of auditory filters. And then we look at the envelope that's coming out. So it is incorporating the speech level, the noise level, the listener's hearing thresholds, and then some of these expected super threshold distortions that occur because of the severity of hearing loss and the severity of super threshold processing in that person's auditory system. So in the end, what you get out is a number that ranges between 0 and 1 where 1 would be a high fidelity signal with not much distortion or no distortion on it. And if you get a number of zero, that's pretty terrible, it means there's a ton of noise or really the listener is not able to process that sound.

And so we would expect that more background noise results in more distortion. And we would also expect that stronger hearing aid processing because we said that digital noise reduction, wide dynamic range compression, frequency lowering, all of these things are Actually altering the speech acoustics. And so if you have a lot of heavy aggressive processing, you're going to get more speech envelopes distortion. So when we think about the factors that are incorporated into the CPOR signal fidelity metric, it is really based on envelope fidelity. We are not considering here listener factors like age, working memory, duration of hearing loss.

They're not part of this number. Okay, so now as a clinician and a researcher, I think about, well, what about the patient? Are some people more susceptible to this distortion that is occurring from the noise in the environment and from the way the hearing aid manipulates that signal? So here I want to talk about hearing speech and I want to talk about the role of working memory. So working memory is important to speech recognition.

Working memory is really storing and processing. So I'm talking here, you're listening through your computer speaker or your headphones and you're using your working memory. And you must be using working memory because you have to, to store the acoustic information from my voice, you have to retain that information and you have to process it so that it has meaning. So in this figure we think about language input. And I've got here multimodal, just meaning that you might be watching the talker as well as listening to them.

It comes into your auditory and cognitive systems and we can think about it going into this kind of buffer in your memory where you're processing information. And if it's quiet and the talker is clear and your hearing is good, it should be a very easy match of that auditory information to its stored representation in long term memory. And then you'll understand whatever it is. Right? This is, this is the ideal, this is the way it's supposed to work.

I heard it, I stored it, I processed it, I've got it understood, what you said. Next word, please. But sometimes it's not that easy to match what you heard to its representation in long term memory. And that happens especially if the signal is really distorted. So on the right side here we've got the kind of nightmare environment for a listener with hearing loss.

Lots of people talking, lots of distorted signal. Difficult here. And when that occurs and the multimodal language input comes into the buffer, it then is going to require working memory to expand more heavily, engaged under suboptimal listening conditions such as background noise or reverberation.

And what that working memory is doing or attempting to do is to reconcile the mismatch where you've got a distorted signal and it doesn't get quickly matched to the acoustic representations in your long Term memory memory. So if your working memory is doing explicit processing, people with a higher capacity and more efficient system can do this better.

They'll have good speech recognition even in challenging conditions, whereas people with a lower working memory capacity are going to be more disadvantaged in challenging listening conditions. So if you think about a situation that's likely to result in this mismatch between the auditory input and the stored lexical representation, what you might think about is the really bad environment, right? A presentation, perhaps, where the talker is far away in a noisy, reverberant auditorium. That auditorium, distant talker, noisy situation, is probably going to be a mismatch between the distorted auditory input and the stored lexical representation, and it will require this explicit processing to resolve.

So I'm going to just show you one of the tests that can be used to measure working memory. And this is a visual test. And you might be going, well, wait a minute. You know, my patients have hearing loss. That's exactly why it's a visual test.

Right. It doesn't require auditory input. It doesn't rely on having good hearing, but it asks listeners to process and store information. And it's a version of the reading span test. So the way this works is sentences appear in segments.

After each sentence, you ask the listener to say whether that sentence made sense. So that's the processing aspect. And then after a block of sentences, you ask the listener to recall either the first or last words. So that's the storage. So you'd see on the computer screen something like this.

So here is. The train sang a song. Did that make sense? No. The captain sailed his boat.

Did that make sense? Yes. The bottle drank water. Did that make sense? No.

And so then at that point, the tester would say, please give me the first words of each of those. Now, you just saw this on your screen, and you might say, oh, that's pretty easy. I remember all those first words. But then it goes on up to blocks of six sentences. So eventually, it's exceeding the working memory capacity of the listener and they're no longer able to do it.

But we've got a score that represents that person's working memory capacity. Okay, so now what I want to do is take you through a short set of studies that we have done in our lab to try to untangle some of these factors. I've got them on this chart here, and then we'll go through a few of them. So basically, we're looking at hearing aid processing in conditions, some of which were more realistic than others. So I'm Going to talk about a couple of studies where we looked at specific types of hearing aid processing.

Frequency compression, wide dynamic range compression, where we did it under earphones for speech and noise with simulated hearing aids. So that's a nice controlled lab study, but it's not very realistic. Then we will talk about two studies where we looked at the same set of factors. Wide dynamic range compression, frequency compression, but under much more realistic conditions. People wore hearing aids, they sat in a noisy room, and they in some cases had directional hearing aids on.

So let's begin with those. All right, so the way I'm going to do this is by creating a couple of patients for you. So let's say we have Lydia, and let's suppose that Lydia is 72 years old. She has a mild to moderate bilateral sloping hearing loss. And I'm going to give Lydia high working memory score on the reading span test you just saw.

So I'm going say that she's one standard deviation above the mean for her age. So let's say her score on that reading span test was 50%. Correct. That's a good score. Then let's create John.

And I'm also going to make John 72 years old, mild to moderate sloping bilateral hearing loss. So he looks like Lydia in terms of his audiometric characteristics. But I'm going to give John low working memory. So we're going to say he's one standard deviation below the mean for his age and his score on the reading span test is only 30%. Correct.

So should we be making any adjustments to our hearing aid processing to accommodate these differences in cognitive ability? And let's first talk about this earhart et al. 2012 study, which focused specifically on frequency compression as the signal processing. So in that study, we absolutely found that working memory affected listeners, speech recognition scores for sentences that were presented in a background babble and were amplified with frequency compression. And what we found is that as we increase the level of the distortion from the hearing aid, specifically as we applied more aggressive frequency compression, the listeners with low working memory were more negatively impacted by those distortions than the listeners with high working memory.

In fact, working memory accounted for almost 30% of the variability in speech intelligibility. So that's a lot, you know, because we don't measure working memory in the clinic. Clinic. And we probably are not thinking about setting frequency compression according to anything about the patient's cognitive ability. So if I bring up Lydia again, so remember, Lydia had high working memory.

And what the study data predict for Lydia is that when you give Her a mild frequency compression, something like a 1.5 to 1 frequency compression ratio, she'll get 100% correct. And if you give her more aggressive frequency compression to make those high frequency consonants more audible, she'll still do very well. 96%. That's what the study data would predict for Lydia with her high working memory. But what the study data predict for John, who's got the low working memory, is that he also does very well with mild frequency compression.

But if we give him a more aggressive frequency compression setting in an attempt to make those high frequencies more audible for him, his speech recognition is going to drop to 84%. Okay, so that's based on predictions derived from a large set of subjects. So there's lots of reasons why you might be adjusting frequency compression, including patient sound sensitivity and their preferences. But I would say that none of our decision factors right now are considering patient working memory. And this study says maybe we should because of that reaction to signal distortion that is different for patients with low working memory.

Okay, so now we might say, well, wait a minute, that's a lab study. It's simulated hearing aids. They're listening through earphones. I'm not sure, you know, I'm not sure if I should worry about that. So I'm going to do one more lab study here.

And this was a few years later, and this time it's still laboratory simulation, but they've now got both wide dynamic range compression and frequency compression. So we definitely have those both in a wearable aid. And basically the results were the same. So the listeners with low working memory performed more poorly for signal modification compared to listeners with high working memory. The more we modified the signal, the more we distorted it, the more the scores for the low working memory listeners went down.

And working memory again accounts for about 30% of the variability in intelligibility. So if I bring back Lydia here now, predicting her performance from the data from this study, if we give her mild frequency compression and slow wide dynamic range compression, right, which are much less distortive of those speech acoustics, she's going to get 90% correct if we crank up the processing. So she's now getting more aggressive frequency compression and fast wide dynamic range compression, and she's listening to sentences in noise, she's going to go down to 55%. You know, so that's a drop. But look at John.

He's also going to do well with the mild, less distorting signal processing. But he's going to be more affected than Lydia by aggressively processing that sound. He's only going to get 45%. So similar pattern to what you saw before. And again, this relationship with working memory as the patient is processing that modified sound.

Okay, so we know that aided speech recognition certainly depends upon the audiogram. It also depends on working memory. And we don't have time to talk in detail. But it does depend on age too. So when we start talking about those much older patients, there's some extra age factors in the mix.

We know from laboratory studies that individuals with poorer working memory simply have to work harder to understand speech. They tend to do worse with fast acting, wide dynamic range compression and better with slow acting. And these effects are exacerbated by having more background noise or other distortive hearing aid processing.

But those studies are lab studies. They're not fit the way a clinical hearing aid would be fit. And an important factor I think, is that patients didn't get a chance to get used to the processing. You know, they just walked in and tested. So let's look at a study that is more realistic.

So this was a 2019 study where we fit people with hearing aids and we let them wear those hearing aids for six weeks. And then we tested them them and then we switched the hearing aid fitting and we let them wear them for another six weeks. So the idea is we give these folks a hearing aid fitting that is minimally modifying to the signal, and we give them a fitting that is more aggressively modifying the signal. Patient doesn't know what they're wearing. And then we took a bunch of outcomes to look at the results.

So this is the trial where they came in. They had a bunch of pre tests, they got their fitting number one, they wore that for a period of time and then had outcomes assessed. They got switched to fitting number two, wore that for a period of time and got their outcomes assessed. And it's a wearable, you know, regular commercial hearing aid. So in this case, what we found is something interesting.

We found that the people with higher working memory could actually take advantage of a clearer, higher fidelity signal. There was also very little effect of the amount of hearing loss. But honestly, I think this is because they were all mild to moderate listeners with a really good fit, you know, good match to target. But we did find, similar to the laboratory studies, that working memory accounted for about a third of the variability in speech recognition. And if we bring back Lydia and John again.

So here's Lydia, she's getting in this study with wearable hearing aids, about 90% correct. With the low distortion process, no frequency compression, nice slow wdrc. And when we gave her the high distortion processing, she went down to 80%. So looking at Lydia's scores, you can say, well, she did better with the low distortion processing and she did about 10% better with that. Here's John.

His scores are a little bit lower according to the study predictions. So he's getting about 75% correct with the high distortion processing, about 80% correct with the low distortion processing. But what you can see is his benefit of going to the low distortion processing was smaller than Lydia's, only about 5%.

So I'm going to tell you about one more study and then we'll kind of summarize and go to a Q and A period. So wearable hearing aids, again, sentences and background noise. Noise is surrounding the listener the way it might in an everyday situation. And the patients are wearing directional hearing aids. So I think this is a really important, important study.

And I have to give full credit to Varsha Rallapalli on doing this work because we fit directional hearing aids all the time and that's what we really want to understand about clinical fittings. So here again, we found, similar to the study I just told you about, that the people with the highest working memory got the biggest benefit from having these nice, clear, high fidelity signals. Importantly, directionality really, really helped. So the consequences of having low working memory were not as severe in this study. And I think because they simply weren't getting as much noise, you know, the hearing aids did a good job in this case at reducing the background noise.

And people with low working memory really, really need to not have background noise. You know, it's a problem for them. There was an interaction between working memory and distortion. So yes, individual working memory affected how sensitive people were to those envelope distortions. So that's exactly what the working MEM models and the signal modification metrics would predict.

And so if we look at Lydia now wearing a beam forming directional hearing aid and slow wide dynamic range compression, she's going to get about 80% correct there. And if we add distortion in the form of noise, we go to omnidirectional processing and we add distortion in the form of fast wide dynamic range compression, she really drops to poor sentence recognition.

John has also a very low score in that high distortion condition. But his benefit of making the signal good is not quite as high as Lydia's. Right. He, he just isn't able to get his scores up as high. And that's the low working memory effect.

Okay, so from this whole series of studies, we can really See a pattern that the susceptibility to signal distortions, when those distortions coming from a combination of background noise and the way the hearing aid processes that signal, that susceptibility depends on working memory. So we really think cognition is in the mix here. So what do we know so far? Well, we know that part of what determines how well you understand speech is your age and working memory ability.

We know from these lab studies that we can measure the modification in the signal and we can put a number on on it. We used that KEPCOR metric where 1 is high fidelity and 0 is a lot of distortion. That's also a strong predictor. And that happens under a lot of circumstances, including one type of processing, aggregate hearing aid processing, directional processing. And it happened in both simulations and wearable hearing aids.

So, you know, in my lab, as we went through this research, I think we became more and more confident that cognitive mattered and that specifically working memory mattered. In considering the patient's overall performance and also in considering how we might make decisions about what they get in the clinic. We saw this under clinically realistic conditions. And we have some data that we're also seeing in regular fits, you know, regular clinician driven fits that I haven't presented here. And it comes up with a lot of different patients and a lot of different ways of fitting in the audiology clinic.

So we are confident that the individual ability to recognize speech and noise depends on several things. How much hearing loss you've got, your working memory capacity, your age, which we haven't had time to talk much about, but it does matter. And so all of those things are going to influence speech and noise recognition.

Now, in our last 10 minutes or so, I'd like to go on to the last topic, which is, which is whether we could use research data and use these ideas to improve clinical care. And so I'm going to ask you now to think more broadly about precision testing that we might consider beyond the audiogram and maybe a clinical world where we were a bit more intentional in selecting our hearing aid processing for the patient. And as a clinician, I'm also going to say patient counseling, we know that's important. The patient, patient needs to understand why they're getting what they're getting. And so patient counseling might also acknowledge that there are multiple factors, including patient abilities and listening environment in the mix.

So there's some signs that we're going in this direction. So entheos, I think some of, you know, entheos, which is a practice group, they have really been focused on Implementing practice innovations. This is a, you know, a lot of private practice clinics in entheos, but they're putting into place some practice innovations that could individualize diagnosis and hearing aid selection. Now, because entheos is made up of private practices where different people are doing different things, it's not a mandate that we all have to do it the same way. But those member practices are adding in extra testing to try to be more individualized in the way they diagnose the listener abilities and in the way that they do hearing aids selection.

There's also some research, and this is not translated to clinic yet, just in the research world, but people who are considering whether we might want to think about the etiology of the hearing loss or maybe the genetic profile of the hearing loss and whether that should dictate in part the hearing aid processing. So I think that work is very, very, very, very, very early. But it is a direction that is more like medicine direction. Right? What can I learn about this patient that will help me treat them in an individualized way?

Now within easier reach for us as clinicians are super threshold testing that go beyond the audiogram. So something like the act, the audible contrast threshold test, auditory profile based hearing aid fitting. You know, there are a couple of groups who are really trying to do that. So not just the audiogram, but other tests that collectively give you a profile that should tell you something about how to treat that patient. And I want to talk for a few minutes because we focused somewhat heavily on working memory here about some of the working memory tests that are clinic ready right now that you could use.

So we already talked about the reading span test. This is a test that's available. The contact is here. Elaine from Oticon distributes that test. And so it's a reading test that gives you a working memory score that you could consider in some of your clinical decisions.

There's also the warm, the word auditory recognition and recall measure. And the nice thing about this is that it layers the working memory score on top of a monosyllabic word recognition test that we're probably doing already. So let me just see if I can play that for you so you can hear one second. Get rid of the pointer, you will cite flip, you will cite boost, you will cite say.

So the patient hears that. And remember working memory is processing and storage. So the processing task in this case is to say whether the, the first letter of the word is the first half or the second half of the Alphabet. So you say they hear, you will say flip and they should say first Half you will cite boost first half you will cite, say, second half. They processed that, and then they're prompted to recall the words.

And as in the reading span test, the set sizes get bigger, so it gets harder, but it gives you a monosyllabic word recognition score in the usual way, and it gives you a working memory score. So that's quite nice. You will cite flip. Okay, the last one I want to mention is put out by ORCA usa. And so this is the repeat recall test.

And maybe some of you have seen this. So it's a sentence in noise test. And then after the patient repeats the sentences in noise in the usual way, they're asked to recall information. And they can also rate listening effort and noise tolerance. So this is another attempt, attempt to kind of layer up a cognitive test on top of an auditory test that we're, you know, we're going to do anyway because we do want to know sentence recognition and noise.

So I'm going to kind of end this talk and move to a Q and A section by, I guess, wishing for more precise care. You know, I've been an audiologist for a long time, and I think the pure tone audiogram is amazing and it tells me a lot and it helps me make decisions, but it doesn't go as far, far as I would like it to go. And I think that we, probably everyone in here who fits patients has had this experience where you have two patients, they've got similar audiograms, they seem to have similar needs. You fit them with your favorite hearing aid, with your favorite processing, and one of them does well, and one of them, for whatever reason, does not. And so as we started this talk, talking about what you then do for the patient who's not doing that well, you then usually enter this trial and error adjustment to try to arrive at a better solution for that person based on what you understand their difficulties to be.

And it's just really fuzzy. I don't. I don't know. I wish that we had a little bit more precise evaluation procedure where we could get specific information about the patient that would get us to the solution sooner. So we have some of these tools.

It's always a challenge to make sure that they are efficient and integrated in clinical care. And if we did develop more of these tools, you could imagine that they might be implemented in different ways. Right. So maybe there's a, you know, a test that the patient can take on their own that doesn't take up your clinical time but provides information to your decision.

So I'm going to come back to these people in their different situations and their different auditory environments and with their different listening needs. But when I look at this slide and I look at all of these kind of imaginary people in front of me, I think about their acoustic environments, I think about their listening needs, and then I think they've probably all got different auditory and cognitive processing too. And it would be nice if we had a way to assess them in the clinic that would provide some of that information so that it could be exploited for more effects, efficient fitting choices, and the patient benefits too, if we're able to do that. So I'm going to end there with this slide and I see that there might be a few questions and open it up for questions.

Let me just skip over here, Christy, while you're talking. Okay. Please remember things. Yeah, no, though we do have a few questions. Does the frequency lowering interfere with the mid frequency constants?

Yeah, that is such a great question.

Probably not. I'm going to say probably not. And the reason I'm going to say probably not for two reasons. So frequency lowering is targeting those high frequencies and either squashing them down or sliding them down. Right.

So if it's frequency compression, you're sort of literally compressing them into a narrower range, and if you're moving them down, you're moving them on top of something else that's at a lower frequency range. Those operations could interfere with lower frequency consonants, but usually you're working in such a high range that it doesn't impact the mid frequencies. So frequency compression or frequency transposition tends to be things like above 4000 Hz or maybe above 3500 Hz, so really confined to that very high frequency range. So that's one reason why the mid frequency consonants are generally safe. But the other thing I wanted to mention is that some of the manufacturers are now applying a more dynamic frequency lowering.

So instead of being on all the time like it used to be, it turns on only for the brief time of that very high frequency consonant that that plural S sound, let's say. So that's another reason why it has less unintentional interference on the mid frequency consonants, because it's not there when the mid frequency consonants are going through the hearing. It only activates when that high frequency sound is. So, you know, I think that's a really astute question because, yes, it seems like it certainly could and you kind of have to not overdo it or it will. But in practice, those mid frequency consonants are largely safe.

Great, thanks. Could you also refresh us on the name of the first working memory test that you talked about. Sure. The first working memory test is the reading span test. Sometimes you see rst for reading span test, and it's a visually based working memory test to try to not have it contaminated by the fact that the patient couldn't hear it.

So when I give that test to patients, they say, why are you showing me this thing on the screen? It's hearing that I have trouble with. But as soon as I say that's why it's on the screen, so that it won't be affected by your hearing loss. And we want to know how you process and store information, they go, okay, fine, then it makes sense. But yeah, reading span test.

Thank you. Okay. Another question. Would these cognitive tests be just as valuable if the person has a beginning or undiagnosed diagnosed cognitive issues, such as the early stages of dementia or Alzheimer's? Yeah, that is such a good question.

Because they're not dementia screeners. Right. And they're not MCI screeners. They are working memory quantifiers. So I wouldn't try to use them to make a decision about whether to refer the patient for care.

There's better tests for that, things like the MOCA and the Slums, which are cognitive screeners. But you would. Presumably someone who is in the early stages of cognitive decline would not score very well on working memory. Right. Like that tends to be affected.

I think the difficulty is if you get a low working memory score, there's no way to know whether that's just a good cognitive person who happens to have low working memory or whether the working memory is part of some general decline that they're having. So when I think of these, I think of them in buckets. One is, I want to quantify your working memory, whatever it is, and the other is I'm concerned about your cognitive ability, and I want to assess whether there might be a problem. And then I would choose a cognitive screener that probably has working memory questions, but also other things. Executive function, visuospatial, stuff like that.

That's probably a whole audiology online talk, but yes, sure. Great. Thank you. Okay. Another question.

Do these studies consider other cognitive factors such as attention or processing speed, and how they might influence the effect of working memory on speech perception? Yeah, another great question. So I would say that after working memory, which seems to have gotten most of the attention, then the next target people talk about is executive function. So executive function is the ability to focus and inhibit, and it just seems like that must matter. To listening in noise because part of what we're doing in that noisy situation is focusing on a target and inhibiting the distractor.

There are some studies that have looked at executive function and said yes, it matters and that it matters to things like setting the digital noise reduction settings. So again, this is a sort of a longer conversation. If that questioner wanted to contact me, I'd be happy to chat about it. But yeah, for sure there is interest in other than working memory. Executive function has gotten the next most attention.

Processing speed, not so much. I think it's just maybe hard to measure the kind of processing speed that we use in a couple conversation. But you know, it stands to reason that those things would all matter and interact.

I want to just let you know that the participant who asked about the value of these cognitive tests for earlier undiagnosed cognitive issues. Thank you. She said it was a great clarification. And we have one final question. Are there recommended therapies or structured therapy programs to help patients improve working memory and support patients ability to get more from their human hearing aids?

Yep, there are programs and I wish I could be more optimistic about these because that would be great, right? You train the working memory and then everything gets better. That's the idea. Unfortunately, what tends to happen is that people get better on the things they're training on, but it doesn't necessarily generalize to all of the kinds of tasks that you use working memory in. So we don't really yet have a path where we could say, let me improve these cognitive skills which you really need, and when I improve those, everything will get better.

We can apparently improve those cognitive skills and working memory somewhat, but it doesn't always make the jump to everything being better in using working memory for communication. Okay, great. Well, thank you very much. Well, I'd like to thank you, Dr. Souza, for sharing your time and expertise with us and and also like to thank everyone who participated in today's course. Please don't forget to complete the brief examination that should be in your pending courses page shortly after we conclude here.

And we look forward to getting your feedback on those course evaluations as well. We hope to see you in future webinars. This concludes today's course and have a great rest of your day.