Optimizing Performance in Noise: A Review of the Evidence Supporting Signia's AX Split Processing
Recorded February 21, 2023

Presenter: Brian Taylor, AuD

- [Melissa] And welcome to today's course, "Optimizing Performance in Noise: A Review of the Evidence Supporting Signia's AX Split Processing," by Brian Taylor from Signia. Excuse me. It has been said that innovation is seeing what everybody has seen and thinking what nobody has thought. This month on AudiologyOnline, we are celebrating innovation in the hearing industry with our third industry innovation summit. Thank you for joining today, and we hope to see you again in more classes. We would like to thank our title sponsor Carecredit, and, of course, Signia, for joining us today and all of the companies in our summit this year. It's my pleasure to turn the microphone over to Dr. Brian Taylor.

- Thanks, Melissa. Great to be with everybody. Over the next hour, we're gonna be talking about optimizing performance and noise, and I'm gonna be talking specifically about some of the internal research that Signia has conducted over the last few years to support the AX platform. Here are the learning objectives. It's mainly to talk to you about the unique advantages, the unique properties, and some of the research supporting the effectiveness of the AX platform. Generically, we call the type of processing under the hood of the AX devices, split-band processing. So if you hear me use the term split-band processing, I'm talking about the signal processing inside of the AX platform. A few disclosures. I am the senior director of Audiology for Signia and hold a few other appointments in the profession.

My overarching objective today is to help you have a better understanding of how you can apply the research around the AX platform and around its noise reduction properties. And I think the whole idea is the more well-versed and more comfortable you are with the research and how it fits together, the more likely you are to be a promoter of trust and confidence with your patients. The more confidence you are in the platform, the more you know about the research and how it might apply to the everyday needs of your patients. I think the more trust you can promote and from that we hope stems greater satisfaction and benefit from the devices. Before I get into the nuts and bolts of my presentation, I think it's really important to kind of revisit and remind everybody of the rich 30 plus year legacy of research that Signia and prior to that Siemens brought to the profession.

It's sometimes not a well-known fact that we have several locations around the world as a company where we conduct internal research. And over the last 10 years alone, we've published more than 50 white papers, trade journal publications, even a few peer-reviewed papers that promote the research that we do really to demonstrate the efficacy of the features and the devices that we bring to the market. And for anybody that wants to see all of that research, I would invite you to google Signia Scientific Library, and you will see a plethora of great papers supporting our entire product line that goes back many years. I also wanna give an acknowledgement to all of the outstanding independent researchers that have decided to partner with Signia over the years.

And as I mentioned, some of these partnerships were prior to the existence of Signia, when Siemens was the brand that everyone knows. Here are some of the key people from just the past few years really around the world. You might recognize many of these faces. We have researchers in the United States, Australia, Western Europe, Canada, and all of these excellent independent researchers have brought a tremendous amount of knowledge to our studies and we're really proud to work with them. Here's a few more from the United States. All of the names and faces that you see here have partnered with us and have their names on some of the studies that support our products. I do wanna give a special acknowledgement to someone that I think everyone knows that's Gus Mueller, who has been an independent consultant for Siemens and now Signia for well over 30 years.

He is very creative, very pragmatic in his approach, and many of the studies that we've conducted over the years have his mark. So a special acknowledgement to Gus. Let's get right to the heart of the talk now and let's try to address this question first. I think it's an important one. Why is research important to you as a clinician? I mean, you see every manufacturer, some of it is, because of FDA obligations, has to conduct some amount of research. Why do companies spend millions of dollars on research and development? Why does it matter to you and why does it maybe matter to your patients? That's the question that I want to ask first. And I think really what it boils down to is the decision making process that you use in the clinic.

When you think about your role as a clinician, there are a tremendous number of decisions that you have to make with every single patient. What style of hearing aid? Are they going to be a user of Bluetooth direct streaming? What type of coupling system, should it be more open, should it be more closed, does it need to be customizable? What level of technology does it need to be? Are they going to do better with premium? Are they going to be okay with basic? What research might support our decisions? And this is an important, I think, we kind of take it for granted, but we're doing this all of the time with every patient that we see, a tremendous number of decisions.

And I would argue this is what your expertise is all about. You're trained to make decisions in the clinic, in an ethical, responsible way that reflects what that individual in front of you might need. And I think many of you know that when you make decisions, really, you can think of it maybe as a three-legged stool or in this diagram, three sides of a triangle. There's really three components to how decisions are made in the clinic. By the way, we call this model evidence-based practice. And I'm sure many of you have had courses on this. There's a mythology to it, methodology I should say to it. But just to kind of remind everybody, there are three components to evidence-based practice and how it's implemented in the clinic.

One is the patient's perspective, what the patient is expecting, what they want, what they might need. Gathering that information during the appointment obviously is very important. Another component of the decision making process is your own clinical expertise. How you've been trained? What your experiences are? You think about the patient in front of you, they have some very specific needs and maybe you start relating their individual needs to other patients that are similar that you've seen previously that would fall under the clinical experience factor. And then the third and final one that I wanna focus on today is the availability and use of evidence, both internal and external. External really meaning evidence that's collected by independent researchers, perhaps by a manufacturer that's been published.

And we all know there's a hierarchy of evidence in how you use that evidence and apply it to making decisions. There's also maybe internal evidence that you may have collected in your own clinic. But my point is this is how decisions are made in the clinic. And I would argue that client perspective and clinical expertise, those are kind of intuitive and we use those all the time. The one that's maybe a little bit more challenging because it's time consuming and there's a methodology around it, is the ability to apply evidence. You have to find the papers, you have to read the papers, you have to relate the findings to the individual in front of you. You have to have some knowledge of statistical analysis.

You have to know a little bit about the limitations of the study and how it may be doesn't apply to the patient in front of you. And it's important just to re kind of remind everybody around these three sides of the triangle about how important evidence-based practice is and how often the use of evidence in the decision-making process from well-designed studies is not readily at our fingertips. I also wanna remind everybody that I think good research is really a virtuous cycle. And what I'm gonna show you next I think kind of speaks to the legacy of Signia's involvement in research and why we take research and development very seriously. And why I'm proud to represent Signia and talk about all of the research that we've done over the years.

Because once you get ramped up and start doing research and publishing it, I think it really leads to this virtuous cycle I'm gonna talk about. You can start at the top of the cycle here and you can think about better data coming from well designed studies, maybe studies that reflect important questions that are happening in the clinic. And that better data from those well designed studies we think leads to better products, the design of better algorithms, maybe more effective features, and that leads to better decisions in the clinic. If the product is better, the next logical step is that you're gonna be making more effective, better decisions in the clinic with that product. That leads to, we hope, better patient engagement.

Patients tend to be more satisfied if the product and the decisions are to their liking. They're more engaged in the process, they're more satisfied, they're benefiting in the real world. And, of course, that begets and leads to greater patient loyalty and maybe a willingness to share results, which we hope leads to the creation of better data, and you have this virtuous cycle that embarks. That's an important part of research. And I think Signia and all of our work over the last 30 plus years reflects how this virtuous cycle works pretty effectively. So when you think about the virtuous cycle, another way to look at it is when a new feature maybe is developed by engineers, how can we gather with well designed studies, better data that will help us create a better product and ultimately lead to better patient engagement?

And the new feature that came to market relatively recently, almost two years ago now is on the AX platform, the branded name is Augmented Focus, as I said before, the generic name is split-band processing, but this is a really unique feature that essentially uses beam forming technology to process sounds from the front differently than sounds coming from the back. So sounds from the front maybe are given because we think speech is primarily coming from the front, is given more linear processing and sounds coming primarily from the back is given more compression. So they're processed in very different ways. That's patented technology and it's unique to Signia and as I said, we brand it as Augmented Focus, but I'm gonna use the generic term today, split-band processing.

And for those of you that aren't familiar with how that works, we have many webinars and white papers that get into the details of how split-band processing actually works. So I'm just kind of giving you a summary of how it works and expecting you that those of you that maybe are not familiar with it, to revisit some of those white papers and webinars that go into the details of split-band processing. But when a new feature comes to market, it's important, it's actually in some ways required by the FDA that you have some product claims that are supported by research. So here's an example of a product claim that you might see in a marketing piece that we've generated.

94% of wearers reported excellent speech intelligibility with Signia AX. So we all know the purpose of these product claims, really, there's a lot of resources, a lot of time used in R&D to develop these claims. You have to collect a lot of data, you have to analyze the data, you have to publish it, you have to create the marketing materials. But at the end of the day, as a clinician, the important thing to know about a product claim I think is that it really helps you promote trust and create confidence. And I think it's part of a two-way street. I think a good product claim that's supported by research, it promotes trust between you and the brand.

You're more likely to trust the brand and have confidence in what's happening in the hearing aid when the product claim is supported by evidence. And by that same token, I think you can create more trust and promote more confidence with patients when you have those beliefs about the manufacturing partner that you're working with. But it's easy to talk about those things. You can see these product claims everywhere, every time any manufacturer puts together a marketing piece, there's always at least one product claim on there that is supported by evidence. But as a clinician myself, I want you and I encourage you to be skeptical about those product claims. I think it's completely legitimate to ask questions about the efficacy of split-band processing.

Does split-band processing actually work? I said it was unique. I very briefly explained how those two beamformers and how it works and how it might be different than traditional processing. But is it unique? Just because I said, it doesn't mean that it is. Is it effective? That product claims that I mentioned there, 94%, that's a high number. Is it really effective? Should you believe me? And just because it's effective, does it mean that it's better? So I think these are legitimate questions and I invite all of you to be a skeptic of what I've said so far. What I wanna do now and throughout the rest of the presentation is I want to use research to show that these questions could be answered, I think in a pretty legitimate knowledgeable evidence-based way using the research that we've conducted.

But before I do that, I mentioned before that the application of research in the evidence-based practice paradigm, that sort of, there's a hierarchy, there's a certain methodology to how you use the research to make decisions. And I just wanted to kind of remind everybody, some people call this the hierarchy of evidence. It's not really in my mind a hierarchy, it's more of a progression. So I wanna talk about the progression of evidence and how different types of studies kind of fit together and how they complement each other, and when you understand how these different types of studies fit together, how you can use that information to help promote trust and create confidence between yourself and the brand?

So let's kind of talk about the progression of evidence in the three different types of studies. The first type of study I'm just gonna mention is what we call a benchtop study, which is essentially looking at proof of concept. Like maybe a group of engineers have patented some new algorithm that sits on a chip. And then the next logical question will be, well, does it work? Is it any better than what we have? Is it worth commercializing this? How does it work? And you don't literally use a workbench like this, but it is done in a lab and usually a benchtop studies typically don't involve people. And so we call it a benchtop study. And usually benchtop studies are the work of engineers, individuals that create the patents, that create the algorithms, DSP engineers, electrical engineers, firmware engineers, usually a team of them that work together to create some new type of signal processing, like maybe split-band.

And that's the first sort of foundational element of evidence, doesn't work in the lab or on the benchtop. Then we move to the second type of evidence where we take it from the bench and we put it in the lab using ideal or simulated conditions. On the right, there you see a slide or a photo of what I think is the R-SPACE, which was created by Larry Revit about 20 or 25 years ago. There to kind of simulate what it's like in a busy restaurant. And, of course, you can design the study to make the product or the feature look as good as you want it to be because it is a controlled environment. And the question that laboratory studies essentially asking are, does the feature, does the platform, does it work under ideal simulated lab conditions?

And that really is the work of hearing aid researchers. I showed you examples of some of the excellent independent researchers that we've partnered with over the years. Many of the studies that we've done with those independent researchers fall into this level of on the progression, work that's done in their lab under simulated conditions. Now we move to the third and final progression of evidence. And that's real world evidence. Basically taking the product from the lab where it's been tested in contrived conditions and putting it in the real world where you can't control those variables. All bets are off as far as where the person is gonna be wearing the devices. And essentially real world evidence is kind of looking at does the product work in everyday life?

And real world studies are asking that question, does it work in everyday conditions that are experienced by a typical hearing aid wearer? And often that type of work is done by clinical research audiologists. People that might see patients three days a week and maybe two days a week, they're running some tests not only in their lab, but they might be collecting some information that comes in from the patients that they fitted with the hearing aids. Historically, we've used self-report kind of pencil and paper, but now as many of you know, we're kind of moving away from that to collecting the data in real time on a smartphone. And in the evidence-based practice paradigm, evidence that's collected in the real world is kind of the highest level that you can achieve because you can't control all of the variables and it relates to what everyday patients are going to experience.

So that's kind of the progression of evidence. And the point that I wanna make is that for studies that support the split-band processing algorithm inside of AX, we have studies at all levels of the progression. I'm gonna share with you a couple of benchtop studies, a few lab studies, and even one real world study that shows you just how effective split-band processing can be. You don't see many real world studies done in the hearing aid industry for a number of reasons, but I'm happy to say that we have one that I'll share with you towards the end of my presentation that should give you a lot of confidence that this product works very effectively in noisy situations for the vast majority of wearers.

So let's kind of relate all of what I've talked about so far to what happens in clinical practice working with patients. And as I mentioned before, I think foundationally one of the most important parts of why we do research is to help you promote trust and create confidence with your patients. And, of course, when it comes to hearing and noise, we know that that is a major challenge for many patients. So I want us to kind of imagine you're working with patients that are dining in maybe their most favorite popular restaurant. Maybe it's a Friday night, maybe they're a patient that is savvy enough to have a sound level meter on their phone, we know that the overall noise level is quite high.

It might be approaching 80 dB. And it's a really an important fun event that they wanna participate in. And we wanna make sure that they're wearing technology that is the most effective in these really important high leverage kind of situations where they wanna engage with their family and friends in a fun, entertaining kind of activity. I'll use the term acoustically challenging social situations. I think all of our patients, even patients that maybe don't go out very much, they might be in these kinds of situations only one or two times a month, but very often these are the most important situations for them. And I think as hearing aid fitters, you know when patients come in, how disappointing it can be when they say they went to the wedding reception, they went to a party, they went to a graduation, whatever it might be, where there's a lot of commotion and the devices really fell short of expectations and maybe they even removed them from their ear.

And all of us have experienced situations like that. And I wanna talk about how split-band processing can help us address and even overcome some of the most challenging social situations where there's a lot of background noise. Which leads me to this question. You know, I think I wanted to make the point a minute ago that those acoustically challenging social situations for many of our patients are among the most important, most valuable situations day-to-day. Even if they're only in that situation maybe one time every month or so. And the question I want us to ask ourselves is how do hearing aid wearers judge success in those kinds of situations? And I think all of us would agree when they get hearing aids, they judge their success by how they hear in the situations that I just described and their performance in background noise.

In fact, if you look at data and you could look at Market Track 2022 that came out a few months ago, seminars and hearing, it tells the same story with every iteration of market track, along with this data that was published a year or so ago. This comes from Abram Bailey at Hearing Tracker and essentially says in all of these studies and surveys, when you ask both hearing aid wearers and individuals with hearing loss that don't own hearing aids yet, where do they want to hear better? Invariably, it is better hearing in background noise. So we all know, and this is not new information, and I'm sure no one is surprised that at the top of this list, when it comes to hearing aid preferences and what improvements they wanna see, it's better hearing in noise.

And, of course, every manufacturer knows that and they all marshal the same basic features to try to fix the problem. So all hearing aid manufacturers have approached the problem and essentially the same way, they all use some combination of directional microphones, noise reduction, and wide dynamic range compression and expansion. So we have the same basic components, but the way that they implement those technologies or maybe the recipe is a little bit different. So in other words, all manufacturers use the same ingredients, but the recipe might be slightly different. I'll make the argument. And that, of course, when you look at the schematic, you can see how the speech and the noise mixed together, the hearing aid using those different ingredients process the signal and then there's an output to the ear.

But, of course, as I mentioned before, we might use the same ingredients in split-band processing, but I would argue that the recipe and the way it's implemented is totally unique and different and stands apart from other manufacturers. I mentioned before, it's a novel approach to using beamforming where the sounds from the front are processed and shaped in a different way than sounds coming from the back, more than just simple gain reduction. There's actually shaping and amplification using compression and using noise reduction that's different from sounds emanating from the front relative to sounds emanating from the back. Anyway, that split-band processing is unique. But as I mentioned before, I invite all of you to be skeptics.

So the question really is how do we know that AX processing is different than this traditional approach? And that's what I wanna talk about next. And this is where the first progression of evidence benchtop studies can help us. So the basic question I want you all to be thinking about is how do we know that split-band processing is different than those traditional approaches to trying to manage speech in the presence of background noise? So we're gonna look at two different studies that I would classify as benchtop. Study number one is an electrophysiologic study. Now, you could argue that this is more of a lab study and that I'm not gonna quibble that, but I put this as a benchtop study.

This one was conducted, the primary researcher was Christopher Slugocki, who is a neuroscientist and a researcher for WS Audiology. This study was published in the Hearing Review back in September of 2021. And it uses an electrophysiologic measure that some of you may remember from about 25 years ago. It was more of a hot topic then, the mismatch negativity response. Before I go through what the mismatch negativity response is and what the results of the study were, the question that this study was really trying to address as shown here on the slide, does split-band processing enhance changes in the wearer's soundscape compare to other types of processing schemes that you might see on a hearing aid? So let me show you the mismatch negativity response for those of you that recall it, maybe you went to graduate school in the mid 1990s.

It's a passive involuntary response and the bigger the downward wave, you see the reflection. I'm gonna get my little telestrator out here, down here you see it represented with the red arrow. But the bigger the downward wave, the more the brain is automatically detecting the change in the soundscape. And you also might remember with mismatched negativity that they use what's called an oddball paradigm where there's the same simple sound in a chain, and then there's a deviation from that sound. So it could be pa, pa, pa, da, something like that. And when there's that deviation is when you see, you expect to see that negative deflection in the waveform. And as I mentioned before, that's an an involuntary response.

It requires no participation from the the subject. They just have to sit there. So the idea is the more novel the stimuli, the more negative deflection you might expect to see in the response. And this is kind of, let me show you in the next slide what they found. So on the left, you see the basic study design. You see the electrophysiologic, the sort of the map of how the electrodes are set up on on the scalp. And then you see where the speech is coming from the front and noise is coming from two angles in the back. And then you see towards the bottom on the right side, the three different types of signal processing used in the hearing aid, we'll call it non-split omnidirectional, traditional directional processing and then split processing.

And so long story short, if you look to the right where the red circle is, you'll notice that the waveform, the mismatch negativity response is greater for the sounds that are processed through the split-band approach relative to the other two. So that's a really interesting finding that kind of shows you that there's some differences that split-band processing is changing how the sound is processed. So to answer the question, does split-band processing enhanced changes in the wearer soundscape compared to other processing schemes based on Chris's study with the mismatched negativity? I think the answer is yes, there is some changes there showing that you get a greater response on the mismatched negativity potential when the sound is processed through split-band compared to the other two approaches.

So that's kind of exciting and shows you that it's novel and doing something differently and you can measure it with that involuntary passive response. That brings me to the second benchtop study. This one's using an electroacoustic technique. I would again call it a benchtop study, giving us proof that AX processing, split-band processing is different. This study was conducted by one of our senior engineer, scientists, Petri, and this was published about a year ago at AudiologyOnline. Petri is the guy on the left, KEMAR is the guy on the right. And in this study, they're attempting to address the question that you see here on the slide. Does split processing improve the overall signal-to-noise ratio more than other types of noise reduction technology?

So, essentially, what they're doing in this study, is they're putting the hearing aids on KEMAR, and they're using some sophisticated measuring techniques to look at the speech, the SPL at the eardrum, the SPL, how it changes as the signal-to-noise ratio inputted through the hearing aids might change. And measuring those changes at KEMAR's artificial eardrum, let's say inside of his coupler. So this is a study that's looking at changes in the signal-to-noise ratio as a function of the different types of processing inside the hearing aid. So there was a lot going on in this study. You can see that KEMAR is there in the middle, there's the unaided condition, omnidirectional, omnidirectional plus digital noise reduction, then there's automatic directional, automatic directional plus digital noise reduction, and then finally split processing.

So six different listening conditions, basically six different hearing aid algorithms or five different algorithms plus the unaided condition using KEMAR. And then we have three different speech input levels coming from the front, soft, average, and loud. And then from the back directly behind KEMAR, we have five different signal-to-noise ratios. So everything from -10, which is really adverse to +10, which is fairly favorable at those five different signal-to-noise ratios. And then measuring with your pro mic system inside of KEMAR fake eardrum, the changes in the signal-to-noise ratio that result from those six different listening conditions. And here is what they found. This is some pretty interesting data that kind of shows you at the eardrum how different types of signal processing change the signal-to-noise ratio.

So you notice on the x-axis we go from easier to more challenging signal-to-noise ratios, +10 is pretty quiet, -10 is very adverse. And the 0 on the y-axis is kind of the benchmark and tells us its benchmarking omnidirectional performance. And then you see the pink and the red bars that's showing you the improvement in the signal-to-noise ratio at KEMAR's eardrum as a function of those two different, I'm just showing you two different listening conditions. We have split processing that's dark red and we have the old experience platform, which was a combination of automatic directional and digital noise reduction. So you can see both types of processors improve relative to the omni condition, the signal-to-noise ratio at those five different listening conditions.

What I wanna point out is just how much improvement you get for some of the more adverse listening conditions like 0, -5, and -10. So this is showing you relative to the omni condition, let's just say at -5 SNR, you're getting almost 14 dB of improvement relative to the omni condition when you use split-band processing. Notice, in the pink at -5, it's still pretty darn good at -10 improvement relative to the omni condition. I just wanted to point out the bar graph is showing you the relative improvement. But then if you think about it in absolute terms, the improvement is actually even more remarkable with split-band processing. So for example, at -10, as I showed you in the slide before, the absolute improvement with split-band is it goes from -10 to +4.

So that's a huge improvement in the absolute signal-to-noise ratio in an adverse condition. So just imagine that if a patient is, at least potentially, because we're using KEMAR here, this is not a human subject, but when you go into a into a listening situation where the signal-to-noise ratio is -10 and you're using split-band processing, you change that -10 condition to +4, that's a huge improvement. And you can see the red bars get higher as the signal-to-noise ratio gets more adverse. That just kind of shows you that in the most challenging signal-to-noise ratios, you're getting optimum improvement when you use split-band processing relative to an older platform that doesn't have it.

So to me, that's really compelling data that shows you just the potential of split-band processing. But remember this is on KEMAR, not on a person. So it kind of shows you before the sound is processed by the human ear, how much improvement to the signal-to-noise ratio you're getting with AX technology. So back to the question that Petri was asking in the study, does split-band processing change the overall signal-to-noise ratio more than other types of noise reduction technology? I think the answer is pretty clearly yes on this benchtop study and the best results are in the most adverse conditions. So that's really I think great information. But here's the kicker. On a benchtop study, just you're showing that it's unique but sort of like this bent fork, just because it's unique and different, that doesn't necessarily mean that it's useful or beneficial to patients in the real world.

I mean, we can think of all kinds of examples throughout our daily lives of things that are kind of unique and cool and different, but are they meaningful, are they useful? And oftentimes the answer is no. So the next several studies I wanna look at and try to answer the question, is it effective? Is it useful for patients in noisy situations? So to do that, let's go back to one of my original questions. How do wearers judge success? And I think most of us would agree, it's performance and background noise. But if we look a little more carefully, what do we mean by performance and background noise? And I think you can really put performance and noise in two different buckets.

We have listening effort. How much work does a person have to do to try to follow the conversation at the restaurant? And the second bucket is speech intelligibility. How easy is it for me or how much can I understand the person? How much am I able to take in what he says and participate in the conversation? So when it comes down to it, I think there's really two different dimensions of performance. And, of course, there's many many studies that have looked at both of these categories and the impact that amplification and different types of processing schemes have on them. And, of course, Signia is no different. We have done studies that look to attempt to do the same thing.

So the next question is, how do we know that AX processing is better and maybe more effective than traditional approaches? And I'm gonna share with you a combination of lab-based and real world studies that help answer those questions. So really the question here is, does split-band processing make listening less effortful? And does split-band processing improve speech intelligibility and maybe does it do it better, more effectively than other types of processing that might be on the market today? That's kind of the question that we're looking at next. And that brings me to study number three. This is another one done by Chris Slugocki, one of our outstanding researchers who's done a lot of important work in this area.

And notice that this is another electrophysiologic study using alpha EEG activity. This one was published last May in the Hearing Review. I also believe if you dig around in the peer reviewed research, there's a version of this study, maybe a similar study that was published in either International Journal of Audiology or maybe Ear and Hearing relatively recently. But Chris was trying to address the question, does split processing reduce alpha wave EEG activity? And many electrophysiologic experts believe that alpha EEG activity is what we would call a proxy or an indirect measure of listening effort, meaning the more EEG activity, maybe the more effortful listening is. And he's looking at this using and comparing split-band to other types of processing schemes inside the hearing aid.

And to do this, it's an electrophys study, so you're hooking up the electrodes and then measuring the brain waves. He's using as an input stimulus what's called the Repeat-Recall Test, which is in my mind sort of a version similar to the QuickSIN, where the signal-to-noise ratio changes and the person has to repeat sentences. In this case, they're not looking at the number of words maybe that are said correctly, they're looking at as the noise changes, how much does the alpha wave activity change and is it a function of the different types of processing schemes? So here you kind of see a setup, on the right, you see the RRT and then on the left side of the schematic, you see the setup in the lab where the speech is coming from the front.

Noise is coming from two different sides behind the patient and at different signal-to-noise ratios that varies throughout the test. And, basically, the more red you see, the more alpha band EEG activity. And I want you to notice here where the red is the greatest, you see an awful lot of red for the traditional omnidirectional processing, then you see a little less red for directional microphone processing there in the center, and then when the sound is processed through split-band, you notice that the red is still a little bit there but much less relative to both omni and directional. So this really shows you if you believe that alpha band EEG activity is a proxy for listening effort, that you get significantly improved listening effort when you use split-band processing.

So go back to performance and noise and listening effort. And here's one lab study that shows you split-band stands above other types of processing that are on the market today. But that's electrophys study, involuntary passive response from the patient essentially, do you see similar results when you put somebody in the lab and ask them for a voluntary response? There's a number of different tests that you can use behaviorally in a simulated noise condition that might measure listening effort. And that's what study number four gets at. So here is study number four. This was published in a peer review journal back in December of 2021. And it asked the question, does split processing reduce listening effort in a controlled condition more than other types of processing schemes?

So there's a lot going on with this slide. I'll just suffice to say that in this study using human beings, 19 listeners had to respond, they were fitted with hearing aids matched to the now target for four different conditions, one of those conditions being unaided. And they used a test called the Tracking of Noise Tolerance, sort of similar to maybe what some know as the acceptable noise level test. There's some slight differences, but it's basically asking somebody, how much can they tolerate the noise. And you'll notice here that speech was coming from the front at four different intensity levels directly in front of the patient. And continuous noise was coming directly behind the patient at different levels.

So speech was presented at four different levels and for each one of those four conditions, the level of the noise adapted, it changed, went soft, loud, and yet the patient essentially as the noise got louder, had to tell the researcher that they could no longer tolerate it and then the noise was enough. And, of course, there's some evidence out there that kind of test if someone does poorly on a test like that, they might be apt to maybe take their hearing aids out or avoid a situation because they can't tolerate noise. Here is what they found. Now notice on the x-axis, we have the four different speech conditions and then on the y-axis, you have the actual results.

I want you to focus on 75, because 75 is a typical level of speech when there's a lot of noise in one of those acoustically challenging social situations. Now I want you to notice at the bottom here, let me get my handy telestrator back out, right here, I'll circle it. Those two conditions are for unaided and omnidirectional. Now if you can see me, here's the speech level at 75 with my right hand and both for the omni and for the unaided condition, when the noise got about 5 dB, you moved it up, it was still 5 dB below the speech, the people were saying, on average I can no longer tolerate it. I need to take my hearing aids out or I'm gonna leave this kind of situation, I can't tolerate the noise when the noise is 5 dB less than the speech.

Now, I switched the hearing aid processing to traditional directional. Speech is at 75 right here and the noise keeps going up to about the same intensity level, 75. And at that point, the patient is saying, I can no longer tolerate it. I need to take the hearing aids out or leave the situation or maybe turn the hearing aids off. And then finally for split-band, we're up here. So speech 75 and noise goes above about 2 dB, almost 3 dB, above it on average, before the person says I can no longer tolerate it. So you get essentially, and you notice the pattern is the same for all different intensity levels, soft and even louder here. And really the interesting thing is that both directional in the middle there and split-band give you quite a bit 5 dB when you switched from omni to directional and another almost 3 dB on top of that when you have split-band processing inside the hearing aid.

So in other words, about 3 dB, more louder, more tolerance in a noisy situation. And 3 dB in most cases is noticeable by patients. So to me, when it comes to listening effort, this is a pretty big deal, some really important findings. Let's move to study number five. This one looks at speech intelligibility. So I showed you in number four, listening comfort. Now we're gonna look at a study that evaluated another dimension of performance and noise, which is speech intelligibility. Now this study was conducted in June of 2020, or this was published in June of 2021 in the Hearing Review. And this is a lab-based study in a simulated restaurant. So again, we're designing the study to simulate what might happen in a noisy restaurant.

And the question that we're asking here is, does split-band processing improve speech intelligibility and challenging social situations more than traditional processing schemes? So there's the question, and here's the design of the study. 16 adults, you can see the average age, you can see how they were fitted there on the left, they used a test called, similar to some of the other speech and noise tests that are used clinically called the American English Matrix Test, used a lot in research. And you'll notice that the speech was coming directly in front and then noise at seven different angles from the subject, from the participant. And you'll notice that in five of those speakers, it was soft, continuous noise.

And from three of the rear speakers sort of randomly, the noise would appear in 76 dB bursts. And the whole idea there is to kind of simulate maybe what happens in a cafe when a table next to you all of a sudden maybe burst out laughing, there's some commotion there for a few seconds and then it goes away. And then maybe on the other side the same thing happens. So you can kind of see trying to simulate a common occurrence in a relatively busy restaurant. And here is what they found. So we're looking here on the y-axis at the SRT, where 80% of the words on that matrix test are understood. So I want you to notice the pink bar, that's the old experience platform, which is essentially a bilateral beamformer.

And notice that the SRT, to achieve 80% correct, was about 70 dB on average. And now look on the left, the dark red bar. You take those same patients, put them in that same simulated restaurant environment with augmented focus or split-band processing on and notice how the SRT to achieve 80% is at about 11 dB. In other words, when you switch from traditional bilateral beamforming processing to augmented focus, you squeeze an additional 4 dB improvement in the signal-to-noise ratio. And again, 4 dB is probably noticed by many patients. I would say and argue that that is a clinically significant finding. And that's really good news to show you that in these simulated conditions, we're seeing some remarkable improvements in how AX works relative to other device, other types of processing that are on the market today.

But as I've said at the beginning, I invite you to be a skeptic, don't take my word for it. And as you know from your knowledge of the progression or the hierarchy of research and evidence, I am not showing you any studies so far that look at real world conditions. We've looked at benchtop and lab studies, but we know that there are some limitations to those kinds of studies. So what I wanna close with is a study that looks at how patients perform in the real world with AX processing. This was a study that was published in a couple of different places. Last year, AAA, Eric Branda had a Poster on it. There was also a publication about a year ago at AO on this.

And it looks at self reports of benefits using a questionnaire called the SSQ, speech, spatial, quality, used quite extensively in research and there's a couple of different versions that can be used clinically, the SSQ. And the question that they're asking is, does split processing improve everyday communication compared to a group of same age adults or similar age adults with normal hearing? So to me, this is a really important study that kind of serves and reminds everybody of the importance of benchmarking how individuals that might be of a similar age with near normal hearing might perform. And to remember middle age and older adults that have essentially normal hearing, we shouldn't expect our hearing aid patients to outperform them.

That if our patients with hearing aids do as well as somebody in those challenging situations, we should be satisfied with those results. I'll just kind of show you here a snapshot of the data that was collected. The gray bar is the self-report average for people with normal hearing. And the red bar are people that were wearing the Signia AX devices. Notice on the x-axis, the SSQ, like a lot of other self-report are 1 to 10 or a 0 to 10 rating. The higher the number, the more benefit the patient is perceiving in the condition that you're asking about. And notice some of the conditions we're asking, able to ignore competing sounds, sounds appear jumbled, follow conversations without missing new talker, conversations in noise with many talkers.

And notice the gray bar that we're getting average results between 6 and a little over 7. Now, we shouldn't expect any hearing aid wearer to really outperform those. And which you notice here is that the results from the AX wearers are on par. They're very close, in fact, in one of them you'll notice sounds appear jumbled. The AX wears are actually a tick better than the average for people with normal hearing. To me, this is a really big deal because this is a study using with a real world component and you're sawing very favorable results. And also it's a meaningful study because you can use the gray bar sort of as a benchmark for how any hearing aid wearer would do in these challenging kinds of situations.

Anyway, really good study to know about and really should build a lot of confidence in the overall effectiveness of split-band processing. All right, so now that we're at the end of my talk, I mentioned several different studies, benchtop, lab-based, and one real world study and hopefully you see, how they fit together to tell a really good story about how AX processing helps a person perform better in noise, both around listening effort and speech intelligibility. I shared with you two benchtop studies that showed that AX with split processing is different and unique. And as I mentioned, just because it's different and unique doesn't mean it's better. But I did show you some studies that indicated that you see better performance relative to other types of processing in a hearing aid, improving speech intelligibility, listening comfort, and probably most importantly using the SSQ, those real world outcomes.

Anyway, I also wanna mention that when we do studies like this, we're very careful to optimize the way the hearing aids work, the coupling, the gain targets that things are working and customized to the person's ear using best practices and that we sort of expect that people in the field are gonna be doing the same thing. And to acknowledge that to optimize individual results, there's some really critical decisions that still need to be made, like the coupling system, the matching of a validated gain target, maybe the provision of a manual program that some individuals might need when they get into really noisy situations. And to ensure that people have adequate time to adapt to the hearing aids and that they're counseled on that entire process and the importance of brain plasticity and using hearing aids consistently.

So all of those things are vitally important even though that we have research to show there's incredible effectiveness with this, we still expect in the field that you have to think about these things and get them right for the individual in front of you that you just can't take it out of the box and expect good things to happen. You have to spend the time and use your expertise around getting some of the things you see listed here on the slide, correct, as well. And to remind everybody that, and this speaks I think well to the legacy of Signia's research, that there's a virtuous cycle here. The better the data that we collect, the better the study design, the better the product, the better the product, the better the decisions you can make in the clinic, the better the decisions you make in the clinic, the better patients are engaged, the more benefit they should experience.

And from that we hope greater patient loyalty, willing to buy from you, willing to share the results and the enthusiasm around all of the great benefits they experience from the hearing aid. And that leads to even better data that we can collect and build better products with. And at the end of the day, of course, I think this research really helps us bolster and boost your confidence and trust in the algorithms that we bring you in the field. And that you see that there's not a better device out there when it comes to optimization of the signal-to-noise ratio. That we have a tremendous amount of multi-layered research that gives you trust and confidence that you're optimizing the signal-to-noise ratio with every single patient that you fit AX product on.

Now here at the end, now that my time is up, I want to acknowledge our just fantastic group of global researchers in Germany, at the ORCA Lab in Chicago, and in Denmark, we have a just a fantastic forward thinking group and team here that have done all of the work, gathering this data, creating the studies that I have the privilege of talking about. And with that, I'll field any questions and I wanna thank all of you for your time and attention.