Research Quick Takes Volume 1:
Speech Understanding in Background Noise

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Some Background on Background Noise

- Hi all, Brian Taylor here. Wanna welcome you to Research Quick Takes a quarterly series that addresses common clinical challenges. In our first installment of the series we're gonna be talking about challenges associated with hearing and background noise. And joining me today and throughout the series is Dr. Gus Mueller, a consultant for Signia. Welcome Gus.

- Hey and hi to you. And thanks for the invitation and this is gonna be fun. If I understand it, I know we've just written a paper to get this thing going and my understanding then is we're gonna do a quick review of the paper together. Does that sound right?

- That sounds right. You're in the right place, you're in the right chat room.

- Good, good, good.

- It's good to have you. Our first episode here on this topic of challenges associated with hearing and background noise is just, as you can see from the slide here, some background on background noise. So I thought Gus, a good way to get started was maybe a little bit of a philosophical question, but what is background noise?

- Yeah. Well, it depends who you are, you know? What might be pleasing to one person might be noise to another. You know, if you're in astronomy for example, you get into all kinds of noise that comes from space. Psychologists has their own theory and audiologists probably have theories. You know, I tried to come up with some examples that might be controversial. This one isn't, I think we'd all agree that a jackhammer is noise. But you know, if it's your kid who is crying out "daddy," it's probably very pleasant. If it's somebody else's kid sitting next to you on an airplane, not so much so, it becomes noise. If this is your party and you're doing tequila shots, it's not noise.

If you're trying to read a book, I don't know why you'd be there to read a book, but it probably is noise. And then of course I put this in Brian, 'cause you're much, much younger than I, I don't know if you think that Metallica is noise or not, but to me it's noise.

- At one time it was.

- What's that?

- I would tend to agree with you at my age now.

- You would? Okay. All right, all right. Well I'm sure we have some listeners who think of it as very soothing music.

- So what you're saying Gus, is there's a lot of different kinds of noise out there.

- That's for sure. And of course we all know when the patient comes in, one of the first things they're gonna say is they have trouble in background noise. Now, their background noise, in most cases we all know this, is probably either being in groups or being in a restaurant is probably the two most common things. Some of them might be in the bar that you see pictured here. You never know. But what we need to think about when we're counseling our patients about this and what also helps us understand it is there's really two different types of noise. And the terms maybe sound a little complicated, energetic and informational, but it's really pretty straightforward. Energetic just simply means that the energy that's in that noise is in the frequency range of speech, or at least part of the speech, and it's actually physically covering up what we want to hear, it is a true masking type of noise.

No different than when we use narrow band noise in pure tone testing to cover up a pure tone. So it's an noise that it has an intensity that is greater than the intensity of what we wanna listen to, it's the energy in the noise. Now the one that's more interesting but is also more common, and what's called informational or perceptual masking. Now this usually is also partial energetic but there's information contained that the brain wants to decipher in many cases. And that's like meaningful words. So this could be, you're trying to talk to somebody with the television on and coming from the television are words that mix in with the words that you're trying to understand.

And in the real world if you're in a typical cocktail party, for example, it's usually both energetic and informational because you're picking up a word here or there. But then there's also sort of a rumble of noise that is also doing masking. I couldn't resist throwing in, speaking of the cocktail party, way back in the 1950s a guy named Colin Cherry actually wrote about what he called the "Cocktail Party Problem." So it was going on way back in the 1950s. Interesting that a guy named Cherry wrote about the cocktail party. Obviously a Manhattan drinker I guess. So, anyway.

- Yeah, exactly.

- At any rate, there's lots of noise and interesting relative to informational noise, a good example would be the QuickSIN has both energetic and informational, 'cause there's only four background talkers. And so it's easy when people are taking that test that they'll start to pay a little bit attention to one of the background talkers, when you get up to an SNR of well, +10, +5, usually they don't pay attention to anything at zero. But where some other speech tests have multi talker babble, the babble then would just be all energetic masking, there wouldn't be informational.

- Right.

- So speaking about parties and noise, here's some data I know Brian you're familiar with, from way back in the 1970s.

- Yeah, this goes back about 50 years and it shows you the relationship between the level of background noise and then the level of the talker. So it's kind of interesting if you look at the middle of the chart, like 55, 60 where the level of background noise is, I guess, kind of common. You can see where the level of the talker would be about a +5 signal to noise ratio. But what's interesting is as the background noise level gets louder, we're not really able to at least, keep or maintain the vocal effort, you know? We can't be shouting all of the time. So becomes really challenging when the noise level gets up, you can't maintain that +5 signal to noise ratio.

So, I know that this data, Gus, came from Pearson like in 1976 but I don't think that this chart actually came from his research. I think, well it came from his research but I think you recreated the chart right?

- Well to some extent, yeah. It was for the article, the companion article that goes with our little talk here. And yeah, I just dug through and took out the levels. And it's really interesting is every time background noise goes up, the talker's voice gets louder as you were saying, Brian. But it gets to a point where we just can't raise our voice anymore and it reaches zero up at around a background of 75. Now if you have normal hearing, you probably can still function at that level. But as you mentioned, in fact I think I have an example of what you said, Brian, yeah. If you assume a person with a hearing loss is in trouble once it gets more adverse than +5, well that's a background noise of only 60 dB.

Unless you just happen to be hanging out with somebody like us who tends to talk loud. But for the average person, according to the data that these people collected, when the background is 60, the average person will be speaking at 65. By the way, these are all an SPL, not to be confused with HL. Which is why the numbers change, because now we've converted everything to HL and we're now looking at the average speech spectrum. Now, I remember way back in 1990 or so, Brian, you were writing about these dots or you had it tucked under your pillow I think, if I remember correctly.

- In 1990 I was not an audiologist yet, but that's when you first-

- Well you should have been.

- Almost. I can tell you that in the late 1990s and in 2000s I used this count the dots audiogram a lot counseling my patients. And I know you are one of the co-creators of this with Mead Killion.

- Right.

- Now this is a really handy tool. If I remember right, each one of the dots on here contributes an equal amount to intelligibility and it really tells the story of how audibility is directly related to speech intelligibility. And the interesting thing, really to me the takeaway is, if you look at all of the dots on there, how many are packed in that mid to high frequency range between one and 4K, it's really important. What this tells you, it's really important to create audibility of those mid and high frequency sounds if you wanna improve somebody's speech intelligibility. So, maybe Gus, you could maybe explain a little bit about how a hearing loss in noise make it harder for people to understand the speech.

- Yeah, just to state what I think is obvious but there's a hundred dots here and so if you just want a quick estimate of what a person's SII is, all you have to do is count the dots that are audible. So think of each dot as a little piece of information that that person needs. So yeah, here's the way it works and back when I was seeing patients full-time, I actually had this paper and paper task and I had a piece of construction paper, red I think it was, cut just like you see there labeled noise for my patient counseling and it actually is pretty effective. So if you assume that noise is typically low frequency, so in comes this noise and the person will still have an SII of 65.

Now if you haven't thought a lot about the SII, you can do quite well with an SII of 65. You can pick out words in sentences quite effectively. So you're still in pretty good shape if that's your SII. And of course then there could be a person who is not in noise but has a hearing loss. And of course now you see they're missing all the high frequency dots and they have an SII of 56. But you could still probably do okay with an SII of 56. But what happens when that person with the hearing loss goes into noise, you're now left with an SII of 26. You're not going to do well at all with an SII of 26. And so this very clearly then indicates what your job is as a person fitting hearing aids is if you can't get rid of the noise to get the SII back up, you're gonna have to restore those dots that they lost due to the hearing loss.

Notice they still have a lot of dots in the mid range, but you need all those high frequency dots to come back and that's the task of fitting hearing aids with these people with downward sloping hearing losses. You know, they're also, other than hearing loss of course, aging's a big factor. Brian, you want to tell us about that?

- Yeah, sure, I mean, I think we've talked about this before and we did a series, I think it's on AudiologyOnline or on the Signia Learn platform that looked at hearing loss, hearing aids and quality of life and talked a little bit about these things. But as far as the relationship between hearing and aging is concerned there are three different theories that kind of all are interconnected and probably work in combination, that explain how hearing loss and aging impacts somebody's ability to hear in noise. So just kind of briefly, I'll go through the theories that you can see them summarized here on the slide. But the first one is called the common cause theory which essentially says that there's structural and neural degeneration that's kind of happening in the entire auditory system.

Of course the inner ear and the auditory centers of the brain are all part of that. The second theory is called cascade or sometimes people use the term "use it or lose it." Basically the hearing loss starves the cortex of the brain, the language centers of the brain, its ability of information and that causes then cognitive decline. And then finally we have another theory called dual task where the hearing loss diverts cognitive resources away from other functions of the brain and the end result is people feel tired at the end of the day when they have a hearing loss 'cause they have to work that much harder to try to understand what's being said and maybe commit it to short term memory.

So anyway, I think all of these theories have credence and they're probably all kind of related in some way. So that kind of explains, I think, or summarizes the impact that aging and hearing loss have on somebody's ability to understand speech and noise. But maybe on the other end of the spectrum, Gus, you could talk about younger individuals that have normal thresholds but have trouble hearing in background noise.

- Yeah, yeah, just the main point I think here, what you just said, and I do have a slide about younger people too. But the main point that I think we sometimes forget is all these things that you just talked about is packed on top of the hearing loss, you know? So all those dots I was talking about, some of those dots still might be audible but they're fuzzy, they're not a clear dot.

- That's a good way to look at it.

- Yeah, so, you know we've heard a lot lately about younger people, by younger I mean maybe thirties, forties, fifties, who have problems hearing in background noise. It's sometimes been called a hidden hearing loss. You know, I think the hidden part of it probably depends on the protocol that the audiologist uses. If the audiologist is doing the QuickSIN and maybe an ABR it's probably not hidden anymore or not hidden so much. But since that oftentimes is not typical testing these are losses, this is a problem you won't pick up with pure tone audiometry or traditional word recognition testing. There could be several causes of it. One of them that's been written about considerably is that it's actually a subtle loss of synapses that occur.

This could be due, and most commonly it's due to, some form of noise exposure, even though they don't have a noise-induced hearing loss. Could also be auto toxicity or disabled for some other reasons. But as illustrated in the chart, there are simply just less synapses going to the inner hair cells. And then of course the last, I might be slightly off on this, but I believe data shows that a 5% of all school-aged children have some type of auditory processing disorder. So you have to ask, "what happened to those people when they grow up?" I doubt that it just all of a sudden goes away. So that also could be a problem unrelated to the other issue of the cochlear synapsis.

- Right. Well and I do know there's a couple of different studies, I don't think we cited them in the article that corresponds to this little talk, but I know of at least two different studies where somewhere between like 12 and 15% of adults might have hidden hearing loss, normal thresholds and some complaints hearing in noise. And I also know of a survey done, I think it was published at American Journal of Audiology maybe a year ago, that something like half of all clinicians see at least one patient a month, they report, that have normal thresholds but report trouble hearing in noise. So it's a pretty big problem.

- Sure. Yeah it is, well and if you look at some of the data Larry Humes has published recently too, the self report on the HHIE, a lot of those people have close to normal hearing. Depending exactly how you define normal. You know what, maybe we can finish up. This is a study that just came out recently that also talks about poor understanding in background noise and how it might have a link with dementia. They did a pretest, this was not audiologists doing this, so it wasn't an audiologic speech and noise test. Rather it was self-identification by the patient of how well they were doing in background noise. And anyway, what they found is, they follow these people for over 11 years and they found if this person reported that they had trouble understanding speech in background noise, there was a 91% increased risk for developing dementia.

Now, from what I could tell they didn't really do a good job of partialling out who had hearing loss and who didn't. But just the same, that's a pretty significant finding and again, something we need to be thinking about when we're selecting patients for hearing aid use. So I think we can wrap this up. I don't know if any of our listeners are old enough to have had a poster of this hanging on their wall, or to be familiar with it, but this could be noise. I think it was a stereo company probably promoting how great their music was. But a very iconic photo of days gone by.

- Yep I remember that poster well from the 1980s.

- Yeah, yeah, well I think we've done it. And so to remind everybody this little blurb we just finished, what do we call this blurb, is there a name for it, Brian?

- Some background on background noise?

- Okay that's good. But this isn't a podcast, is it?

- No, this would be called a webcast I think.

- A webcast, okay, yeah, well let's call it a webcast. So this webcast actually goes with the article that was just released where we go into detail on all the things we said here and a lot more. So that's all I got.

- Sounds good, Gus, see you in the next one.

- All right, thanks.

- All right, bye.

How Big is the Problem?

- Welcome to Research Quick Takes, a quarterly series that addresses common clinical challenges. And in our first installment, we're talking about some of the challenges associated with hearing in background noise. Today is episode two. We're gonna be talking about background noise, and how big the problem really is. And as usual, with me today is Gus Mueller, a Signia consultant. Welcome, Gus.

- Hey, thank you, thank you. And good to be here. This is the second one of these that we've done, and looking forward to it. I know we have a corresponding article that just came out, and I guess we'll do our best today to try to hit a few of the high spots from that article.

- I thought a good place to get started was for you to maybe share with us how big this problem of background noise really is.

- Yeah. Well, we can look at it in a lot of different ways. We can look at it from clinical testing, or we could look at it from what patients report to us. And actually in the next few minutes we're gonna end up doing both. But I thought I'd start with clinical testing. There's a speech test, a speech-in-noise test, that is used across the US called the words-in-noise, or the WIN. Very popular in the VA, and used in a lot other places. I was rather impressed when I saw this article about 10 years ago from Richard Wilson, impressed that his N was 3,430. I know, Brian, you and I have done some research where we had trouble finding 24 people to get it finished, he could have shared some of those with us, maybe.

But the finding was what really caught my eye, and so on the WIN is you have to have a SNR of 6 dB or better, which would then be defined as having normal understanding in background noise. So if you see there in the first bullet point, of the total, only 3,291 received testing for both ears. And of those only 7% had normal speech-in-noise findings. I know that there are some clinics and offices out there that do not do speech-in-noise testing, and they look at the word recognition-in-quiet to make a judgment about the patient. And the data from Richard Wilson shows that that simply doesn't work. And that's shown in the second bullet point.

50% of the individuals who had abnormal NU-6 score, had no abnormal WIN scores, had an NU-6 of 90% or better. So you just can't look at the word recognition-in-quiet and say, oh yeah, this person's okay, 'cause if they have a hearing loss, there's a good chance they aren't okay. And this plus six is gonna come up later in our little talk here, so sort of file that away, plus six SNR. Brian, I know you're familiar with this.

- Yeah, before we talk about this, you reminded me, and I just wanted to kind of reiterate, number one, based on what you said around the last slide, how many people out there complain about hearing-in-background noise that come into a clinic? Those numbers that you just shared with us are in alignment with why hearing-in-noise is such a big problem for everybody, and also the importance of doing speech testing and with noise as part of the evaluation process. So anyway, thanks for reinforcing that for us.

- Yeah, I mean, even people with normal hearing can have trouble in background noise and so-

- Exactly.

- We talked about that in the webcast we did a couple weeks ago.

- Exactly, episode one. But anyway, this slide really shows us some of the average vocal levels for men and women. And the first thing that should capture your attention is, regardless of the overall level, men have a tendency to talk a little bit more loudly than women. So you see those numbers there, that's dB SPL, and you can see for

Casual settings, we're about 55, around 64 Normal, a Raised Voice around 65, and then a Loud Voice upwards over 70. Now what's kind of interesting to me, Gus, so maybe you could elaborate on this, is when we do probe mic testing, we say that average is 65, but I'm seeing here average is called Raised. What's the deal with that?

- Yeah, I don't know how we all sort of got locked into average being 65. Even in a lot of research people will say, well, they did a given test that 65 dB SPL, you consider your conversions around 15 dB, you put your dial at 50 and saying, yeah, I'm testing at average speech. The data that I'm finding, though, really shows it's a little softer than that, and by the way, this is from the Pearson's data. This was done at a meter, at distance of a meter, so, of course, as soon as somebody gets farther away, obviously it's gonna be softer. But you mentioned probe mic. When we use real speech, which I trust everybody is doing these days, a thing relative to what you just mentioned in that yes indeed we use a 65 dB, and this is a 65 dB signal right here, that you're seeing displayed on this chart.

And what you see on that dark line in the middle is what's called the LTASS, that's the average of this signal. But what we're showing is the peaks and the valleys on this particular side, but mostly just focus on the LTASS. Now it is really tempting, I think, I don't think, I know, because when I work with students who are just starting to do probe mic, it's easy to think that when you put it on 65, it's a 65 dB signal across all frequencies. And of course, this isn't true, and in fact it isn't 65 dB at any frequency because it's all the frequencies added together equal 65. If you notice, the loudest at any one frequency is around 60 dB at about 500 hertz.

But when we're trying to make high frequencies audible, we're looking at this 2K to 4K region, and I think it's important to remember that the SPL of these sounds for average speech is only about 45 to 50 dB SPL. So if somebody has a hearing loss of 78 dB, if you wanna make these audible, you need to crank in some gain, because these are indeed soft sounds. Being a man around the house that you were, Brian, I bet you experienced this almost every day. I know you use a hair dryer every day.

- You can tell from my-

- I think you came up with this list, so I don't know-

- Yeah, I'm not exactly sure-

- Did you just take a sound level meter around your house?

- I probably could have come up with something kind of similar, but it does show you that even around the house, we think it's relatively quiet, but there can actually be quite a bit of background noise. I mean, washing machine at 55 dB, a weighted vacuum cleaner 72, I think mine's a little bit louder than that. I can't say about the hair dryer because, believe it or not, I don't use a hair dryer, but dishwasher 58 dB, and now these are averages, I don't know if they are in alignment with what happens in your house, Gus.

- Yeah, well, the first thing I wanna say is that going back to the fact that those high frequency sounds are only 45-50, I mean, even if the dishwasher's running, it's going to be masking out those high frequency sounds, unless, not too long ago, my wife and I bought a new dishwasher and we shopped by dB level. And so I'm pretty sure the quietest is a Bosch, and you gotta pay more. It's about 60 dB, costs you $200 with Bosch, as I recall. Anyway, we got it down to 48 and it does make a difference if you like quiet. The other thing I noticed, Brian, is that a blender is 69, and the vacuum 72. So if it's between making a margarita or vacuuming, I'm going with the quieter one. That's my-

- You save your hearing.

- All right. Well, here's something I think you might've been the one who sent me this article. This is some data they collected down in Orlando, Florida.

- Yeah, this is really interesting. Well, before I try to explain this, let me just say that only you, Gus, would shop for a dishwasher based on dB. But yeah, this is a really interesting study, and I think for anybody that's been in a more modern restaurant, it's probably not too surprising. What you're looking at here is the range of loudness SPL intensity level in 30 different restaurants in the Orlando area, and I guess any given time when it's busy and a lot of people are in the restaurant.

- Yeah, I think they particularly pick the busiest time of the day.

- Yeah, which kind of makes sense. But you can see there there's that dark horizontal line at 70, you can kind of see which ones are exceeding that all of the time. It's a fair number of them that are exceeding that 70 dB number. In fact, that one, Gus, you might wanna, it's really loud right there. It's not really very different than working in a factory, and a place like you said where you probably wanna wear some earplugs.

- Yeah, exactly. It's pretty amazing. Well, now you never know about these surveys. To make a point maybe they purposely tried to find noisy restaurants. I don't know how they selected them, but what struck my eye on their data was that only 23% had significant portions below 70. And so that goes back to what we've talked about in the first webcast we did, that talkers can only raise their voice so much, and where they cannot, where they typically do not raise their voice above the background noise is once it gets to be 70 dB. And so here we have it that people would be in trouble in almost all of those restaurants, really, if you had a hearing loss, and maybe even wearing good hearing aids, who knows?

- Right, you'd be shouting all the time.

- Yeah, so relative to how noisy is it out there in the real world, this is an interesting study. I think the primary authors were from University of Iowa. I know Dr. Hu was one of the authors on this paper. And what they really did is they had people walk around and recording sounds in their everyday environment. These were people with hearing loss. So my guess is they didn't go to those really noisy restaurants, because why would you, if you couldn't understand anything? So this is sort of more typical of the noise that one of your patients might be in. And they had a lot of recordings on this. And what they found, actually, is very similar to what I was just saying.

And that is that as the noise levels increased from 40 to 74, speech also increased, except that the speech didn't get any higher than 74. So in fact, this is exactly what we talked about in our first webcast, Brian, from the results that were from the Pearson's group that showed that you get to a SNR of zero once the noise gets loud. And that's what happened in their study. We know that lower down on the fourth bullet point, they had 7% of the SNRs, 7.5 were below zero dB. So if you have a hearing loss, you're just not gonna be understanding in that. And an important thing is you might say, well gee, that was only 7.5% of their life for these people with hearing loss.

But it could be a very important 7.5%. I mean, it could be the family reunion where they all went to a restaurant and they didn't hear a thing for four hours. And also then when we looked at the average, the average of the noisy environments, remember I think the first thing we reported the results from Rich Wilson, that 93% could not score 50% at an SNR of 6 dB. And here we are looking at noise of 7.4 on average in one group, a subset of observations, it was only about 4 dB. So going back to our title slide, Brian, if you wanna say, is noise a problem? The answer is absolutely, absolutely it's a problem.

- It's interesting how these studies kind of fit together. They come from very different places, over different long range of time and how they-

- Oh yeah, well, they're separated by 50 years.

- Yeah, exactly. But they're all telling the same story.

- And yet they come out very similar. And here's another one that also is similar. This is yet another way of looking at how loud is it out there. And this is some data from Smeds and her colleagues where they looked at the average noise level. Again, we're looking at that plus five mark. And you look out at, in the kitchen, in a car, babble. The babble actually is what you'd expect in a restaurant/bar kind of thing. And you're seeing, again, their averages show that it would be very common to be in plus five. And again, our hearing-impaired patients aren't gonna do very well in plus five unaided. Yeah, well, so let's talk about what they do report.

This is the APHAB, as many of you know, you've used the APHAB. APHAB has a category that is specifically how well a person does in background noise. And so this is the norms for the APHAB, this is the average 50th percentile. They report 75% of problems in background noise. That's huge. It gives us a lot of opportunity to improve things. But even at the 20th percentile of their data, the problems are still 58%. Now I wanna toss out one thing here for those of you who use the APHAB and you look at percent of problems for aided, and I think, Brian, down the road we're gonna have an article on how hearing aids help all these situations. I think we have that on our planning, our roadmap. It's on our roadmap.

- We have an episode coming up on that.

- Okay, good, good, good. So let me toss this out in advance is that I think one of the things we have to remember with the APHAB scores is even people with normal hearing report 25% of the problem. So that's as good as it's gonna get, probably. If you can get somebody's problems down to 25%, they're performing as good as normal hearing. Remember they're starting at 75, so you got your work cut out for you, you need to take away 50% of their problems is basically the goal. And this is from MarkeTrak, I know you've worked with MarkeTrak a lot, Brian.

- Yeah, well, I just wanted to mention that APHAB, I wanted to chime in on that, I think that 25%, even when you have normal hearings, is a great thing to remember when you're counseling your patients that you're never gonna get it down to zero. You wanna keep that in mind, but I know, yeah these MarkeTrak surveys have been invaluable over the years. They look at thousands of individuals that have at least self-reported hearing loss. And many of their survey questions are addressing people that don't own hearing aids. And here's some data from the last MarkeTrak 10 that kind of shows you, I would say, the relatively low levels of satisfaction for people that are in that category, self-reported hearing loss and don't own hearing aids.

You can see for three different situations where there's probably background noise, small groups, large groups, watching TV with other people, and this general communication and noise, you can see that those satisfaction scores are relatively low, at least in my opinion. I know, Gus, if you had any other comments you wanted to make about it.

- No, I like that with MarkeTrak that they collect all these data. Now this is self-report hearing loss, but from what we could tell, it's pretty similar to the data from the people who own hearing aids, as far as what degree of hearing loss they have when they actually compare that. So yeah, these people are not doing well at all. Are not doing well. And if our schedule goes according to plan, two episodes from now or so, I think we will be talking about data for their peers who wear hearing aids. And a spoiler alert, it's a lot better. Thank goodness. Thank goodness. So noise is a problem, yeah. It's a big problem.

- Answer the question, right?

- Yeah, it's a big problem. But stay tuned. As I mentioned, we have ways to make it better, and I think you might be surprised how we can take some of these problems and maybe not make things excellent, but...

- Make it a whole better.

- Very functional and livable, yeah.

- Yep, all right. Well, thanks, Gus. Good to see you. We'll catch up with you again soon.

- Yeah, yeah. I think we got a couple of more of these to do down the road, so looking forward to it.

- All right, likewise. Bye.

Yes, Hearing Aids Work!

- Hi everybody. Welcome back to Research Quick Takes. A quarterly series that addresses common clinical challenges. I'm Brian Taylor with Signia. And with me today, as usual, is Gus Mueller. Welcome, Gus.

- Hey, good to be here, Brian. I think this is- This is the third one of these webcasts.

- [Brian] Episode three. Speech Understanding In Background Noise. And hearing aids work.

- Well, I've been looking forward to this one, because, as I remember, the last one we did a week or so ago, it was sort of depressing. It was like, how bad is the problem? And it was pretty bad.

- [Brian] Yeah.

- So, hopefully, we have better news this week that maybe we're making, maybe we're making some improvements.

- Well, I think we have some, some ways to do that. I think most of our viewers are probably familiar with it, but it bears repeating that, when it comes to better hearing in background noise, there's really two ways that we address that problem. You see those listed here on the slide. Of course, directional technology. Directional microphone technology that is. And the idea there is that, if the sound of interest is in front of the person primarily, or historically at least, and it can be spatially separated from the background noise, directional microphones can work pretty well by not reducing any gain. And you can compare directional microphone technology to noise reduction technology, where the hearing aid, the classifier on the hearing aid, it recognizes that the sound is likely to be noise it actually reduces the gain. And, of course, it does that gain reduction in a very channel specific way. So, those are the two primary ways that we can reduce background noise, kind of as a reminder. I'm thinking, Gus, maybe you could talk a little bit more in depth around polar plots and how those work.

- Well, yeah, the- And this is, almost falls into the too much information thing, but as we get talking about, as we go down the road here, if we stick on our plan, we'll be talking about how you can modern directionality can be manipulated very easily. And, really, what's being manipulated is the polar plot. So, I just thought I'd show you some examples. If you go to the far left, that's when their speech at noise and speech at zero degree, noise at 180, this is what you're seeing there, is a hearing aid on the right ear, it's on the right. On the left ear is on KEMAR's left ear. So you're seeing the right and left. Which is why it isn't a perfect, symmetrical kind of thing, because you're also seeing KEMAR's head shadow on this.

So think of a sound going around the person, and the greater, the farther the circle is from the center of the circle, that represents the amplitude. And, if, the closer it would be to the center, it represent what is being reduced. So, you see there, speech at zero, noise 180. Is doing exactly what we want to do. It's knocking out everything from behind. Well, what if, then, you flip that around, which is what we did when we did this measurement. Actually, this was done in the lab at University of Iowa by our friend Wu. When we flip this around and put speech at 180 and noise at zero, thank goodness it does exactly what we want it to do.

Notice that it's taking out everything from the front and giving maximum amplitude to the back. That's where the distance from the middle is the greatest. And then, here comes in something that's only been around for maybe seven, eight years or so. What happens if you put speech at 90 and noise at 270? And it behaves very nicely. The hearing aid found the speech and flipped it around. So, now we're focused over there. So, when we talk about these different features, and we will, this is what we're referring to, is how all these different polar plots. And you can really have any combination in between the far left to the far right. Every combination is available. And with some special features we actually make use of that.

And speaking of special features, Brian, you probably, your audiology career probably started about the time that automatic switching came about. Is that right? Or were you still dealing with little buttons, and levers, and everything?

- I was a big believer, back in the day, of the mechanical switch, or the button.

- Well, you were the only one, because the patients never used it.

- Not too often. But I guess that's the value and the benefit of automatic switching, which has been around now for a long time. And, you know, things get fairly complicated in a hurry. In the digital era, we have adaptive polar patterns. The last slide I think kind of illustrated that pretty nicely. And the ability to not only adapt, but they can track. The null can change based on where the hearing aid thinks the background noise is the greatest. And, of course, those polar patterns happen with different frequencies, which adds more complexity. And that's been around for a while. And then, we have all these other more sophisticated directional systems that kind of combine directional technology with digital noise reduction.

And narrow directivity where the two hearing aids basically talk to one another. So, there is a full range, or a full menu, over the years, of these different types of directional technologies. Maybe, Gus, you could talk a little bit more, 'cause this narrow directivity is really an interesting one, in terms in a lot of hearing aids.

- You know, and I'll be happy to, I wanna make one other comment that just popped into my mind, thinking about tracking polar patterns, which we don't hear so much about anymore. But you really can get, when you're tracking something, you really can get an SNR benefit of about eight db, because you're locked right on that noise. And, the classic research on that, in fact, I think some of the only research on it, was done at Vanderbilt by Todd Ricketts. And I remember when he wrote his grant for that, his idea was, because you want a moving noise source, right? So, how do you have a moving noise source? So, his thought was, he'd always wanted an electric train when he was a kid.

And he thought he would buy this electric train and mount it on this elaborate track, and then the train would like carry the loudspeaker around behind the person. Anyway, that didn't get funded. And so, what he ended up with was a PhD student pushing a grocery cart. So, he went with this elaborate train system to a PhD pushing a grocery cart with a loudspeaker sitting on it. Earl Johnson, by the way, he had to push the cart for every sentence of the hint. So, imagine how many times he pushed that cart in a given day. Anyway, onto narrow directivity. Remind Earl, if anybody out there knows Earl Johnson, ask him about the day, the days that he pushed grocery cart from eight until six.

Neural directivity, it's something that really works. And is pretty amazing. To make it work, you have to have a full bilateral data sharing. Meaning, all the information that is in the pair of hearing aids on the right ear goes to the left, and vice versa. This is way different than just pushing a button and changing the volume, or changing the program, which we've had for almost 20 years. This is the full data sharing of this information. And it allows us to focus in the look direction. And also, then, we get this, where it focuses, we also, then, give a little gain boost, since we know that it's a speech signal, or it wouldn't have identified it in the first place.

And the person wouldn't be looking there, then it's okay to give it a little bit of boost. And, I wanna add, there's been rumors or rumblings about that this narrow directivity really is a problem, because if you're sitting at a table, and people start talking from a little bit off focus on your left or on your right, that then you're gonna miss the conversation. And that simply isn't true. There are data at that, on that, collected at Vanderbilt. Todd Ricketts, Aaron Petu. And one of their students, Aspal, I believe her name was. Anyway, they showed that, as long as you keep your eyes open, there's not a problem. So, when you're at a dinner table, if somebody, your patients are using this, just tell 'em not to close their eyes.

Because people- People are very aware of who's talking and they might miss the very first word. But, in their research, it showed no difference for off angle. So, that's good news. And what, maybe, some of you have heard, but in case everybody hasn't, with this type of processing, patients with mild to moderate hearing loss actually do better than somebody with normal hearing. The fourth study on that was just completed this year. And so, we're now declaring it a four peat. And that is 'cause there's now been four different studies. In all four, it was significantly better. You say, well, how much better? Well, first of all, it was significant. But, second of all, right around two db.

In fact, it's almost always turned out right about two db in every study. And two db can matter in a lot of listening situations. So, that's the directional end of it. But, as you mentioned Brian, another approach is to try to take away some of the noise. And so, how does that work?

- Well, there's been a, that's- We're talking about the second app, second type of noise reduction, that's noise reduction technology, or noise reduction algorithms. And there's been an awful lot of research over the years that look at this, and like you said, digital noise reduction does its magic by reducing gain for sounds that the hearing aid thinks are likely to be noise. One thing we know, at least, I can only think of maybe one or two studies that aren't in this category, but for the most part, digital noise reduction doesn't provide any kind of improvement to the signal to noise ratio. So, you know, directional microphones, luckily, do that in most cases. But digital noise reduction does a lot of other, I think, really beneficial things.

And you see those listed here on the slide. There's studies out there that says that it does provide relaxed listening. And I guess you could argue, if somebody's more relaxed, that's gonna enhance their ability to understand speech. That's a good thing. There's all kinds of evidence from studies that says that it does reduce listening effort. And for the same reason, that probably indirectly improves somebody's ability to understand speech, or at least enhances it. There's studies out there that show that digital noise reduction freeze up cognitive resources. That you're more likely to focus on the speech. And, if you can focus on it, eat more easily, then you'll probably understand it better. And then, there are some studies out there that just overall say that the majority of hearing aid users actually prefer it when the digital noise reduction is on versus off. And, no reason for us to really get into the details of each of these individual studies. You can go to the paper that corresponds with this episode and you can find all of that great research.

- Yeah, exactly, we have in, in that paper, we cover each one of these areas. And, sort of, have the the classic article or two that covers each one of those as referenced there for the person who wants to dig down a little deeper. Yeah, it would be pretty unlikely, I think, to not have digital noise reduction on. It would be some sort of unusual circumstance.

- You'd have to deliberately turn it off.

- Right, right. Exactly. Exactly. You know, there's a lot of 'em. The difference, and you mentioned how this works. Here's just a sample of what kind of noise reduction. I mean, we typically think of the modulation based. That's the one that gives the big reduction in gain. Channel specific, I would say, though. So, it could be reducing gain in a low frequency channel and not at all on the high frequency channel. We have spectral subtraction. Which is very similar to what Signia uses, which is the Wiener filtering, which, what you try to do there is, you try to go in and pull out noise in between words, in between syllables, in between sentences, just to clean up the signal a little bit.

It isn't an overall gain reduction. So, modulation and spectral, they work hand in hand doing different things. Then there's what's called sound smoothing. It's where you're trying to reduce amplitude peaks, clanging of dishes maybe, something like that. Then there's echo reduction. Reverberation is noise. So echo reduction makes things quieter. There's some data showing, conducted at Western University in Canada. Actually showed an improvement in speech understanding using echo reduction. And, of course, then there's wind noise reduction. And all of these things can, it isn't like one is working and the other one isn't turned on. Several of these could be working simultaneously. So, it's pretty amazing. And there's more, I hear. Brian, you're telling me that Signia has an advancement in noise reduction that we probably should talk about, since this is a Signia gig, right? So, we should- It's okay to mention Signia, I think.

- Yeah, no, we definitely wanna mention augmented focus. I think, one point I wanna make Gus is that, a lot of clinicians forget that all of those types of noise reduction are kind of working at the same time and found in many earing aids. So it gets, you know, it gets complicated in a hurry. But, anyway, back to augmented focus. This is a, really, a first of its kind, or one of its kind feature, that's available only in a Signia hearing aid. And the basic idea here is, it takes beam forming, it's a different, we think of beam forming as for directional microphone applications. But, here's kind of a unique application of beam forming, where the sound is split into two separate streams.

So, sounds, primarily, but not always, but primarily coming from the front. That's called the focus stream. And sounds, primarily, but not always coming back, are in the surround stream. And those two streams are processed differently. Meaning, sounds in the focus stream, the compression, I'll just say the compression, is a little bit different than the sounds that are processed in the surrounding stream. Anyway, once those two sounds, once it's split and processed, it's remixed. And, what we're finding is that, when you do the, use the split processing, patients experience a more contrast between speech and background noise. So, it's a pretty cool feature that's got some evidence to support the effectiveness of it.

- So, you know, I'm thinking, for at least 20 years, the patients have come in and said, "Yeah, I like my new hearing aids, but I was in a restaurant and the the guy at the table away from me was louder than the person at my own table." Are you telling me that's gonna go away now with this?

- Well, I'm not gonna say it's gonna go away, but I think you'd probably be more, it would be more effective with a processing strategy like this.

- I don't know that that really even is possible, that it could be louder. But it sure is a common complaint. So, if you can make it go away, that's great. Speaking of that sort of stuff, we need to talk about what really happens out there in the real world when you are experienced all these kinds of noise that people do complain about. This is a study that caught my eye. Of course, all the research from Mike Valente is good, practical stuff. This one in particular I liked and I couldn't reset. This is actually a chart I made, it's not one from Mike, because I wanted to add something to make a teaching point. And what I added on this was the data from Robin Cox of APHAB for normal hearing, older individuals.

So, what you see there, this is the percent of problems solved. So, this is not problems, but problems solved. And we talked about, in one of our earlier webcasts, that normal hearing people still have problems. And so, they have 20%, 25% problems. So, you're seeing the reverse here. These are problems solved. So, the good news is, in this study, Mike compared fitting to the NAL versus a proprietary fitting. And we won't get into that today. Except, surprise, surprise, people do a lot better when they're fitted to the NAL. And I'd like to point out, for background noise and reverberation, that the point I want to make here is that, when they were fitted correctly to the NAL, what you see is their performance was no different than their age match peers with normal hearing. You know, and you can't get much better than that. And that's, that wasn't really the intent of this study, but I couldn't resist pulling out to make a point. What's that, Brian?

- That's a really handy slide there. I think it really tells a good story.

- Yeah, and I know there's a lot of good data also from MarkeTrak. So, I'll let you take over here Brian, 'cause I know you follow MarkeTrak pretty closely.

- The cool thing about MarkeTrak is you can, it's 30 years of data. It's done every four or five years, so you can kind of see some changes in the marketplace and how technology might, improvements in technology could translate into better benefit or satisfaction for individuals out here, out there. But, anyway, what you see here are what the last MarkeTrak three, which was in 1991. MarkeTrak 10, which was published in 2020. And, you can see here, how satisfaction has for the most part, improved over time for three different types of situations with, assuming background noise in all three, really. But, small group, large group, and background noise. And you can see, I guess smaller group, probably, relatively quiet. And you can see, how back even in 1991, satisfaction levels were 60% or better.

And then, there was a pretty big jump in MarkeTrak 9 and 10 where it went above 80. Notice the big, the even bigger jump for large groups where it's between noise and reverberation, probably a little bit more difficult to hear and the situation with background noise. Notice how those numbers through the 90s and into the 2000s were around 25%, 30%. And then, a really significant jump in MarkeTrak 9 and 10 where it went above the 60%. So, I think that kind of shows you how improvements in technology translate and drive satisfaction, particularly over the last few years. The other point, and maybe Gus, you maybe wanna weigh in on this, when you're seeing numbers around 80% for all three of those situations in the last MarkeTrak, those numbers are probably approaching what people with normal hearing would survey at, don't you think?

- Yeah, you know, and in fact, it might be interesting, you can toss it out to the MarkeTrak honchos, that maybe in their next survey, just for a control, check what people with normal hearing answer to some of these same questions. Maybe that data's out there and I missed it. But, yeah, you're right, I mean, you know, consider that with APHAB, normal hearing people are having 25% of problems. Now this, you know, it isn't apples to apples. What we're looking here is that, I mean, people in background noise are satisfied almost 80% of the time in this most- By the way, this MarkeTrak 10 data, when I constructed this slide, Brian, I don't know if I told you this, I used the data from people who had, whose hearing aid was only a year old or less.

'Cause I really wanted to say is how, you know, how good is it with the current data that we have, current hearing aids that we have? So, these are people with relatively new hearing aids. And, you know, I think it may not get much better than 80%. You know, I think- I think, you know, if you and I sat down and said, "hey, you've gone out to ten noisy places in the last two months, how often were you satisfied?" You know, 80% is pretty good, really.

- Right, and when you think about that study we talked about in episode two, where some restaurants are upwards of 90 db on the scale of noise.

- Well, right away, you're not gonna be satisfied there. You know, the other thing, before we wrap this up, that sort of fascinates me is that big jump that happened with MarkeTrak 8, which was around 29 I believe it was, when that was conducted. And MarkeTrak 6 I think was around 2000. So, it's that first decade, that first, everything was flat. And, all of a sudden, that first decade of the 2000s is where we really saw it change. Now, to think, well what happened during that decade? Well, there was certainly advancements in directional microphone technology, which we just talked about. The other thing that I think really happened was the widespread, the widespread use of adaptive feedback. And I think what we have planned for our next paper is we're gonna talk about little things that can make big differences.

And of them, for sure, is audibility, which isn't such a little thing. And I'm wondering if the whole, you know, adaptive feedback doesn't get a lot of credit. But I'm wondering if, because people are now able to use more gain in those situations. And if they're using more gain, they're gonna get more benefit. You know, it's pretty simple.

- We'll talk about that in episode four.

- I think that's a great idea. So, to finish things up, this shows the increase in satisfaction for aided versus unaided. It isn't absolute satisfaction. It's when you compare people using hearing aids to their peers who say they have hearing loss, but are not using hearing aids. And I think there was 16 different categories total. What you're seeing here is just seven of them that sort of have to do with background noise that I pulled out for this slide. But the important point is, how much more people using hearing aids are satisfied than their peers who have chosen not to use hearing aids. It's pretty overwhelming numbers.

- Yeah. 30 to 50% depending on the situation. And, of course, the biggest one, conversation in the noise at the very top there at almost 50%.

- That overall, I think that overall satisfaction, you know, is up in the 80s. Well, we just saw in the previous slide, it's up at around 80%. I mean, if a patient says, "well, do these hearing aids work in noise?" I think you can say yes. Research shows that about 80% of people are satisfied. That's pretty darn good.

- Oh, I just, if you could go back, click one. I just wanna make sure the viewers remember that that's relative improvement. Not absolutely.

- Yes, absolutely. The absolute scores, I can tell you, that one of the ones that fascinated me is in the workplace, absolute satisfaction in the workplace is 92%. 92%. That showed the biggest jump over the ten years than anything else.

- It shows you how much hearing aids have improved over time.

- Yeah, exactly. Exactly.

- More to come on the next episode. Again, it is great catching up with you again, Gus.

- Yeah, yeah, this is always a good time. And I think we're, I think if we we stick to our plan, next time we're gonna talk a little bit about some fitting techniques and some fitting tips that's gonna make sure that we maximize all of these features that we just talked about.

- Looking forward to it.

- All right. See you next time.

- See you next time. Bye.

Ensuring Optimum Feature Benefit

- Hi everybody, welcome back to another Research Quick Takes. We're on episode 1.4, and today we're gonna talk about speech understanding and background noise, ensuring optimum feature benefit. I'm Brian Taylor, and with me today, as usual is Dr. Gus Mueller. Welcome back, Gus.

- Hey, thank you Brian, thank you. It's been, I guess, a few weeks, a couple weeks since we've been on doing these little shows. And I have to say one thing before we get rolling, that during the first ones I was a little concerned because you had this gorgeous brick background, and all I had was a blank wall. And it's like, you know what, wait, I'm the senior guy here, so I brought some of my boys in the last week, and I added some stones, so you know, you got brick, I got stone. But we got a lot of reverb going for us for these things.

- You kicked it up a notch, yeah.

- You know, you think you can outdo me, but you know, I got boys who can do stones.

- You know a mason or two out there.

- Of course, it only made this room even more reverberant, but we'll work our way through it. Yeah, good to be here.

- Well, I think today we're gonna kind of put together some of the things we talked about in the first three of these quick takes around understanding speech and noise. And I know today we're gonna talk about optimizing benefit from some of the advanced features that we've talked about, particularly around how to help a patient understand speech and background noise. And if I remember, as we were putting these together, Gus, you said there were three things that clinicians really need to be concerned about when it comes to optimizing patient benefit and noise.

- Oh exactly.

- So do you want to remind everybody what those three things were?

- Yeah, and well, exactly, and you know, this is after you and I pouring over article after article. And basically after we reviewed them all, we came up with audibility, audibility, and the third one I think was audibility. It really all boiled down to audibility. And so for you listeners, hopefully we can make that point. To help us with the audibility, I know, Brian, you're gonna talk about this, but I can't resist mentioning that this is the world famous Count-the-Dot audiogram. And we talked about this way back in one of the first ones that we did relative to how you use that. But this is an example of what could happen, if you're not careful when you're fitting hearing aids. So you know the story here, Brian, right?

- Yeah, I know, exactly. I think this is one of the best tools out there to really understand the importance of audibility, and how it relates to intelligibility. Remember that each one of those dots contributes equally to speech intelligibility. And notice that a lot of those red dots are packed pretty tightly between 1,000 and 4,000, so everybody should know those frequencies are especially critical. But what you see here is you take a hearing loss, mild to moderate-severe, so maybe 25 or so in the lows, sloping down to 70 in the highs, and then you program the hearing aid, and you fit it to a proprietary target. And then you do your real ear measures, and then you take those measures, and you kind of translate it onto this Count-the-Dots audiogram.

And you see that's represented on this slide with the triangles, the shaded in triangles. And notice where that slopes down and notice that those triangles equate to a speech intelligibility index of 49, which is not very good. Take that same hearing loss and program and fit it to the validated NAL target and exact same hearing aid, just change the criteria, change the formula, and that's represented by the black Xs. And notice how the speech intelligibility index raises up to about 70, which really is about as good as you can get when it comes to matching a target and restoring audibility. Because remember the NAL target is really more than just maximizing audibility. It's also balancing sound quality and comfort, and things like this. So I think this slide right here, Gus, really underscores why it's important to stick to a validated target like the NAL, and use your probe mic measures to confirm that you've done that.

- Sure, yeah, audibility trumps everything else. And you know, I might mention Brian, as you said, for adults, when you're looking at your SII results for, again, this is average speech, so for average speech with adults, an SII around 70 is actually common and expected, unless it's a very mild loss or a very severe loss. Just in case Susan Scully and her colleagues are listening, 'cause you know they are, for children the rules change. So for children, you're gonna want more audibility. And they actually have put out some very nice charts to tell you what SIIs you should be looking for in children, but we're talking about adults today. And now you might say, well, does that really make a difference for understanding speech?

Theoretically, 0.7 versus 0.4 certainly should. This is one of my favorite studies over the last few years. Ron Leavitt and Carol Flexer did this. And I'd like to spend our whole time going through it, but let me give you the quick answer because it's an important one. And that is that they looked at a group of individuals, and what they did, they took the six premier hearing aids, and they programmed them, first, to each company's proprietary fit, and then they programmed them to the NAL. And the testing you see here is the QuickSIN. So down is bad because down is QuickSIN loss, okay? So the the point I want to make and that is if you look at the light blue ones there, that's the proprietary fit. And notice with some of those products, like hearing aids three, hearing aids four, the QuickSIN loss is -16.

I mean that basically means that that patient who just bought a pair of brand new hearing aids for $6,000 can really not go into any restaurant, and carry on a conversation, unless the SNR is better than +16. And really who wants to go in a restaurant like that? Even Applebee's is louder than 0.6. But the key point here is look at the orange or yellow bars, this is the exact same hearing aids, except they're programmed to the NAL. And notice in some cases, the QuickSIN's score, average this is, improved by almost 10 dB. And one of the interesting things is if you look at hearing aid three, which on the surface you would say, well that's a really crappy hearing aid. If you program it correctly, it turns out to be the best of the bunch, okay? So this goes to what we were saying before, technology is only good technology, if you, the fitter, program it correctly or otherwise, not so good.

- No, no doubt about it.

- Here's another aspect of audibility, Brian, from our friend and colleague, Steve Marcrum, that I think you're familiar with this study.

- Yeah, this goes back to maybe 2018. This was published in the International Journal of Audiology and it compares the feedback cancellers for what is that, six different manufacturers. We can show you the Signia results, but we really can't show you the others. Not that it matters too much. But this is a calculation of added gain before feedback, basically showing you how well the feedback cancellation system in each hearing aid works. And the idea here is first you run a measurement, match a target, I do believe, Gus, with the feedback canceller off. And then you turn up the gain until you get feedback with the feedback canceller on, and you're seeing the difference here. And you see that Signia hearing aid A and hearing aid E are all pretty much the same, but then you're seeing up to about a 10 dB difference, less additional gain before feedback for hearing aids B, C and D. And of course, 10 dB, that's quite a lot of gain, quite a big difference in the integrity of the feedback system when you think about it.

- Yeah, you know, I'm on some of the social media sites. I often see somebody ask the questions and go, hey, does anybody know what hearing aids work well, and have less feedback and all that? Here it is. The data's out there. You don't actually have to have people vote. There's actually data and very well done by the way. If you look at the article, Steve actually explains how each one of these feedback systems work. So if you know how your favorite company's feedback system works, you probably can go in and figure out what company has what.

- That's a good point.

- But we didn't do that, nor is it really important, because you all can make those decisions on your own. Which takes us to the next then 'cause actually now we were talking about open fittings, but open isn't always good either, right, Brian?

- Yeah, I mean this is a really interesting topic, I think, because you know, feedback cancellers, I think are kind of a reason why you see more open fits. And I was just checking some data at Signia, and I know that a huge percentage of RIC products that are sold are with an instant fit, open-type mold. And that can be a good thing in a lot of cases. It can be comfortable for the patient, you know? They're less likely to have problems with occlusion, with the sound of their own voice. But on the downside, sometimes I would argue that a fitting can be maybe a little bit too open. And you see some of the reasons why being too open may not be such a good thing.

When you think about the open ear canal, you remember that there's a direct pathway for all sounds, including noise, directly to the eardrum. And then you think about the ear canal resonance, that's an extra 15 to 20 dB boost in the higher frequencies. That can be a bit of a problem as well. So I think Gus, you might have some data from a study that was done by our colleagues at Widex that kind of shows you the variability.

- Yeah, actually, you know, there's two points here, and the one is just what you were saying, Brian, relative to how open do you want it really, what's your trade-offs? But the other point I think that a lot of people fitting hearing aids have been misled by the labeling of the instant fit tips, and that is when something is labeled closed, it's really tempting to think that it's closed. The fact is it really isn't closed. And here's the data from Laura Balling and her colleagues. This is published in here in review about two years ago or so. And I'm just gonna focus on that top red line, and that's the amount of venting that is still present with a double dome.

And notice all the sound, everything's going straight to the eardrum. It isn't labeled down on the bottom, but I can tell you that's 1,000 hertz you're looking at. So really from 1,000 hertz and below, noise is going straight to the eardrum. There's no attenuation at all from this supposedly closed system. For those of you who routinely do probe mic measures, which I hope is all of you, you can look at this very simply with your REOR measure. And indirectly we're looking at the same thing here that was on the previous slide 'cause what you see here is we have the REUR, and then we have an open fit, so that's the dotted red and the blue. And then we have a closed fit.

And notice that yes, there is some blockage of sound from about 1,200 hertz and above, but for 1,200 hertz and below it's the same as the open ear. So the sound is getting around or through that closed fitting. And guess what? Most noise is low frequency. And so low frequency, you might think you have 20 dB of noise reduction on your hearing aid, but you don't, because the noise is going straight to the eardrum. Not to mention that the gain is also leaking out. And this is a very nice demonstration of how that affects directional processing. Over on the left you see the REOGs for each one of the fittings, and then on the right you see the speech and noise, the SNR, the SRT50 when hearing aids were fitted with that particular ear mold configuration.

And so if you look at the far right, which you see the custom closed, and you have the closed click sleeve next to that, you're seeing an SNR benefit. Well the SNR is down around -7, -8. And if you go over to the left column, notice that when you fit open, it goes all the way up to -5. In other words, you're losing about three dB of SNR benefit for the directional processing by going open. Well, directional processing in the best of all worlds, as we talked about a couple weeks ago, is only going to give you, I say only, this is really a lot, it's gonna give you five or 60 of SNR benefit. But as soon as you fit somebody with open, you just took away half of that, and that often can make a difference. And of course it's not just directional, right, Brian?

- No, the same thing is applying with the process-based noise reduction. When you fit an open canal product, even a closed dome, to your point can be an open product, you're not seeing nothing from nothing is nothing because in the low frequencies because it's open, it's already being attenuated. So your noise reduction system is really not working below 1,000 hertz, definitely below 500, so.

- You know, and this is critical with troubleshooting because you can have a patient come in, and they'll describe a certain noise that's really bothering them, the air conditioner or something and I've seen people then go in and take the noise reduction, and change it from medium to max. Well if you're at zero, it doesn't matter. It doesn't matter what you have noise reduction set on. You're still at zero. It doesn't matter. You have to treat it in a different way.

- Well, again, shows you what you do in your software, and what's actually happening in the ear are often two very different things.

- Oh, absolutely. And you know, I know the people who do the simulations on the screen are probably very brilliant, but there's no way that they can predict what's really happening in the ear. There's just too many variables. Too many variables, which takes us back to this slide here that we showed you earlier, that the openness is much greater than you probably think it is. So that takes us back to the three things to remember, do a validated method, ensure audibility, pick a product with good feedback, which will help you get to audibility, keep the fitting as closed as possible so bad things don't get in, and good things stay in. That's the way I think about it. And that's sort of like a screen door, right, sort of that same philosophy. Well I don't know what good things stay in anyway. I don't have a good analogy there, but we hope that good things will follow when you do all that. Any closing remarks from you, Brian?

- No, it just shows you that you can take the best quality, best sounding hearing aid on the market isn't very good until a professional has kind of done this analysis, makes sure that they've closed it off as much as possible, that they're using a good feedback cancellation system, and that they're ensuring audibility, and matching a validated target.

- Exactly and that's sort of why the world will always need us, right?

- That's what I would think, yes.

- I'm hoping, I'm hoping. All right, thank you for inviting me, Brian.

- Well, I think our time is up here, Gus, so yeah, thanks and see you in the next one.

- All right-y.

- [Brian] Take care, bye.

Recent Innovations and Insights

- Welcome back, everyone, to another Research Quick Takes, episode 1.5. Speech Understanding in Background Noise: Recent Innovations and Insights. I'm Brian Taylor, and with me as usual is our senior consultant, Dr. Gus Mueller, welcome back, Gus.

- Hey, thank you, thank you, Brian. Always good to be talking with you and always fun to talk about new ways to improve speech understanding in background noise. I think this is, what? About the fifth one or so that we've done. Well, it's labeled 1.5, so I'm gonna say it's about the fifth one. It has to be. It's somewhere between four and six, I'm thinking.

- You got it, and if anyone's wondering where that one comes from, this whole series is our first volume of Research Quick Takes that look at speech understanding and noise and why it's a challenge and some solutions for it.

- Well, great, that suggests that there might be a volume two or a volume three maybe.

- Well, sometime in the near future, I think there'll be at least a volume two.

- All right, good, good, good.

- In this episode, 1.5, we're gonna talk about three different innovations, directional CROS and BiCROS. We're gonna talk about directional in a CIC product and then we're gonna talk about motion sensing inside of a device and how that's used in directionality as well. So Gus, I think I'll let you, kind of an old topic that probably needs to be reviewed a little bit and that's directional microphones and polar patterns.

- Yeah, well, when you say old topic, you're absolutely right. I did my doctoral dissertation on directional microphones and I had to go down to the Vicon Labs in Colorado Springs to their anechoic chamber and have Jim Nunley down there run polar plots on my research hearing aids as part of the deal. So I've been thinking about polar plots for a long time, but here's just a real short version for those of you haven't thought about it and that is basically if you see the middle plot in that white arrow. The way it works is think of a sound surrounding the hearing aid and the distance from the middle to the outer portion is the amplitude or the gain, okay?

So these are all different types of directional processing and so what you would expect then is that the maximum gain will be directly to the front and indeed on all three of these examples, it is. Now you should also notice then that there are places where the pinkish portion does not go all the way out to the same distance. In some places it's reduced considerably. On the two middle and far right, these polar patterns have what is called nulls, two nulls. The cardioid pattern on the far left has a single null directly in the back. So if you go over here and look at this cardioid pattern, you'll see that there's a lot of attenuation from the back.

So where the plot is the closest to the center, that's where there's the least amount of amplification and so that way you can just typically glance at a polar pattern and you can get a good idea of how good the directional processing is. Now these are very pretty because they were done on a microphone stand in an anechoic chamber, not on somebody's ear. But when you get to the ear, then other factors start entering in and Brian knows all about those factors.

- Well, here's an example of a CROS system that is on a person's ear. So in this example, you see on the left side in blue, that's the unaided, the unreadable side, the so-called dead ear transmitting sound to the so-called good ear or at least better ear which is represented with the red pattern. And what you see here is something we call the skewed directionality because remember if the better ear is on the right side, if this person walks into a place where there's a lot of noise, they probably don't want all of that noise on the right side and they wanna be able to hear at least what's going on maybe to more from the left.

So in this example, you can see how the polar pattern is skewed to the to the unaidable side, to the left side, where it's able to bring in more of the sound and reduce the background noise for the better hearing right side. So that skewed directionality is, it's been out for a while and to this day it's still unique in Signia CROS devices.

- Yeah, and just to state what you stated in a slightly different way is that in traditional directional processing, you want maximum amplitude to the front. But in a true CROS fitting, the person has normal hearing in one ear so it isn't that critical to have maximum amplitude from the front. You want it from the side that you wanna pull it over from and that's sort of the principle of the skewed. And yeah, you're right. I don't know any other manufacturer who uses that, but there are data to show that it's pretty successful. This was the original study and in all these studies, what was done was to create a worse-case scenario and that's to present speech to the transmitter side and noise to the good ear.

So that's a situation that the listener might not be involved with a lot, but common you'll see this sitting at a dinner table or something where the person didn't get positioned correctly, and the person they wanna talk to is on their bad side. And so you see here that there is a sizeable SNR advantage compared to two different competitors, as much as about 3DB from one of the competitors. These are the two other companies, manufacturers. I think at this time there were maybe only two who did CROS processing of this type, but they didn't have the skewed directionality. This is now another clinical study and this is looking at the BiCROS because that same principle is used with the BiCROS.

And so what this again was done and some of you maybe have tried this in your own clinics where you can do speech testing in a test booth maybe just to demonstrate to the patient the benefit of CROS or BiCROS, what was done in this particular study. And these are now people who have one aidable ear, but the other ear doesn't have normal hearing. It's aidable which is your typical BiCROS candidate. So what you see, and this is word recognition scores. This is your basic NU6 in background noise. And so what you see over there on the left, far left is this is unaided. So both transmitters are turned off. Then we turned on the right ear or the good ear we're gonna say, best ear.

And so this would be if you decided to fit somebody monaurally and you say I don't wanna mess with those CROS hearing aids, they never work. I'm just gonna go monaural for this particular person, and you fit them to the aidable ear and you would have that, they'd get around 50% correct. And then you see what happens if you now turn on the CROS transmitter and it goes all the way up to over 90% mean correct performance, showing the benefit indeed of CROS processing. In this particular study, they pulled in a group of people who were already CROS users from a different manufacturer. At the time, I think there was only one other manufacturer available, and then they were all fitted with the new, these happened to be Signia hearing aids, of course.

They were all fitted with the new Signia hearing aid and they went out for a three-week period and did an A/B comparison comparing the Signia to their current hearing aids. Now I'll be the first to admit that when you give somebody a new product to try out, there's sort of a halo effect and they know what the right answer is, and they're gonna exaggerate a little bit I think. I think that's just human nature, but these results are pretty unbelievable. They're out in the 2:3 ratings in preference for the Signia. I know it was reported in the article that a couple of these people actually bought new hearing aids just because of this home trial and also to point out that maybe it's not as bias as one might think.

If you look at localization of sounds, you would expect that there wouldn't be any difference because the skewed directionality isn't gonna give them any better localization of sounds. And what you see is for localization of sounds, there's no difference. So I could argue that if all they were doing was giving three, three, three, three for the new Signia product, they also would've marked a three for localization of sounds, but they didn't. So I think there's some validity in these findings with are pretty overwhelming and ever since this has been introduced I think, Brian, you know this much better than I, but I think ever since this, Signia has been the industry leader in CROS technology if I'm correct, just from what I hear people talking about

- Well, I think because we're a leader in the ear-to-ear wireless transmission, audio data transfer allows us to do some of these interesting things.

- Yeah, exactly, well, moving on then to our second topic. CIC, yes, you can have directional in a CIC I hear.

- Yeah, no, and I think this speaks again to wireless data transfer and the ability to do that. But when people think of directional processing, they usually think of behind-the-ear devices. They think of full shell in-the-ear devices and of course, with a smaller in-the-ear CIC, even a half shell or in the canal because of the microphone placement, you do get some what we would call so-called free directivity because of the pinna effects. That's kind of working to help you as it would a person that's not wearing hearing aids to get some natural directivity. and of course, you get more of that with a smaller device in your ear. But with full audio data transfer, the two hearing aids essentially talking to one another, you can actually do some pretty interesting things with directional microphones in a CIC product.

And I think if you move to the next slide, you can kind of see how that looks graphically. So here you have a CIC in a left ear. So you see some of the effects of head shadow. If you remember what Gus just said a few minutes ago about polar patterns and how they work, you can see the red. That's the CIC with an omnidirectional response again, in the left ear, so you see the head shadow effects and you see more gain on the left side in the red. But then when that hearing aid is switched into the directional mode, remember it's a CIC product in the left ear, you can see in blue there how much of the gain is reduced, especially on the side.

Notice that at zero degrees when you look at the blue and the red polar patterns, at zero degrees there's really no difference. So you're able to maintain gain for sounds directly in front. But when you're wearing a pair of these CIC devices, you can see how much gain is reduced from the side in the back. Imagine these two hearing aids, left and right, working together. That's a pretty sizable reduction in gain when it's in the directional mode and I think, Gus, there is a study that, or maybe the next slide shows us a little more detail on how exactly-

- Well, yeah, I think in that same study, they did some directivity index measures in the AI-DI. And again we'll just do a quick tutorial for those of you who have not thought about this for a few years. But if you think about the polar pattern and it's a sound going around the person, the way the Directivity Index or DI is calculated is you simply compare what is the output at zero degree? And then you look at all the azimuths going around the person and you take an average of that, and you subtract that from what is at zero. Now in theory, if it's an omnidirectional hearing aid and it's not on the head, the average of all around would be the same as zero and it would have a DI of zero, okay?

If it's a BTE, it actually becomes worse than zero, but we won't get into that. But for directional, what you would expect is there's gonna be attenuation. For some azimuths, not all azimuths and typically when you average them all together, you might end up with something like 74. If zero was 80, you average them all, you get 74 and you say then that there's a DI of 6 dB. This isn't a direct correlation to signal-to-noise advantage, but there's a relationship there, okay? The bigger the DI, the bigger the signal-to-noise ratio. Six might not equal six. Six might equal 4.5 or so, but there is a direct relationship and then normally it's reported for single frequencies. But depending on how you do it, you could average across all frequencies.

The AI-DI then simply uses the importance function for speech which, Brian, you and I have been talking about with the count-the-dot audiogram now. We've talked about that on many occasions. So you basically look at a portion and you do a weighting effect, and I've shown you there how four key frequencies are weighted. To nobody's surprise, the frequency that's weighted the greatest is 2K. In other words, a DI, a big DI at 2K is much more important than a big DI at 500 simply because there's more important speech at 2K. So if you had to pick, you want your best DI where there's the most speech information, pretty logical. So that's the AI-DI. I have to go through that because in this slide we now have the AI-DI values for this new CIC OneMic directional and it's called OneMic because indeed there's only one mic in each hearing aid.

And what you see then is a huge difference from the omnidirectional. Now the omnidirectional has the natural pinna effects from 2K and above. So this is the free directivity that Brian even mentioned. But now when you add the hearing aid in, you get that free directivity and you also get the hearing aid directivity, and you end up with the blue, the top blue directivity index which I have to say is an AI-DI about the same as what you'd get with a good two mic directional processing. So again, we take advantage of the natural ear canal and add in this other, and of course, I should mention many of you saying well I don't fit CICs, or the CICs aren't that deep, or I'm gonna fit a half shell.

You also get some of this free directivity with that, so that's always good to remember. Putting the microphone up behind the ear is really a bad place for good directivity 'cause sound actually bounces off the side of the head and goes right into the microphone from sounds from the side. So it's a battle to get good directivity. It's much easier when the microphone's in the ear which takes us to our third thing. Brian, I know you've worked with this before. You're a motion kind of guy. You probably just finished jogging before this talk I'm thinking. You're all about motion.

- Well, I can't say that I did that, but I can tell you that this whole feature works around the ability to have an accelerometer in the hearing aid itself. I think most people know that cell phones or smartphones have had accelerometers for a long time and a couple of years ago, Signia was able to put an accelerometer inside on the chip basically of the hearing aid and it became part of the hearing aid's signal classification system. And the basic idea around motion-steered directionality is that when a person is in motion, they need to be able to hear sounds all around them. Whereas if they're stationary or standing in one place let's say where there's a lot of background noise present, they probably want the hearing aids to be more directional in the way they process sound. And so we've built, Signia that is, has built some algorithms around using motion-steered directionality, and I know we've done a few studies that show how effective it can be.

- Yeah, this was one of the first ones actually on this and I think it's the only one we're gonna, from a time standpoint, that we're gonna talk about today. For those of you who are interested, I would say just go to the written article on this and there's some other studies that are mentioned in there. Some real world studies and such, but this was a nicely controlled laboratory where we simulated what it would be like for somebody walking down the street and in the software we could actually turn the motion sensor on and off knowing that that's exactly what would happen if the person really was walking. And so we then had traffic noise at a fairly loud level surrounding the person and then there was a male talker as if you'd have a friend, a male friend on one side, a female friend on the other side, And randomly these two talkers would say something and the task then for the participant would be to rate how well they understand it and how much effort it took to understand it, and this was then done with the sensor on and off.

And what you can see up there, this was highly significant at the .01 level I believe. The increased speech understanding for when the motion sensor was on and also increased listening, the listening effort. Well, it didn't increase, it was reduced. But the way the scale was set up, it went toward the seven, seven is good. So it turned out exactly as one would think it would and I should mention if you go to the written piece on this, there's some other supporting data from the real world. I don't know, anything more to add on that, Brian? Or is that enough?

- No, I think that's probably enough. You remind me to remind our viewers that for each one of these Quick Takes that we've recorded in video format, we also have a written article on a companies that that you can probably find on the Signia Learn platform.

- And then they're pretty heavily referenced too so that if you're really serious about all this, you could dig into the original articles.

- Exactly, well, I think we have one more Quick Takes around our first theme, better hearing and noise and why it's a challenge.

- Well, I'll see you in a few weeks and we'll talk about that.

- Knock that out then.

- Looking forward to it, all right.

- All right, yep, bye.

Unique Solutions from Signia

- Welcome back everybody to another "Research Quick Takes." This is episode 1.6, "Speech Understanding and Background Noise." And today we're gonna talk about some unique solutions from Signia. I'm Brian Taylor, and with me as usual is Gus Mueller, our independent Signia consultant. Welcome, Gus.

- Hey, thank you Brian. And it's, we've had a good run here talking about all the various things you need to think about for speech understanding and background noise. And we're sort of at, I think this is the last one of these on this particular topic. And only logically we're gonna end up with some rather unique solutions from Signia.

- Right? We're gonna talk about two different things today, kind of wrapped together. They're almost one big thing, but we can kind of break it out and talk about in separately. One is enhanced auditory or acoustic scene analysis. And the other is this interesting feature that you can't find anywhere else, augmented focus sometimes we call it augmented split-band processing. So, if we talk about auditory scene analysis, it's really about what the intent of the listener is. And of course, even the best hearing aid in the world even the most sophisticated signal classification system on a hearing aid doesn't know the intent of the wearer because their intent can change from place to place. You know, a lot of times we build algorithms so that we try to maximize speech understanding and noise for sounds that are coming from the front of the wearer, but in many cases it could be sounds from the side or even behind somebody that they really wanna pay attention to and hear.

So we keep that in mind when we build these new algorithms and these new features. And if we go to the next slide, I think we can see that in the Xperience platform, which goes back a few years, now in the augmented focus, we have something called Dynamic Soundscape Processing which is our proprietary term for the signal classification system that we look at. And as part of the analysis, it's considering these five factors that you see listed here, overall noise floor, it looks at some, it makes some estimations of the distance for speech noise, speech and noise and other environmental sounds. It looks at and analyzes the signal to noise ratio. It looks and tries to identify the direction of what it thinks might be speech and other ambient modulations in the acoustic soundscape, it tries to account for those as well. So Gus, I don't know if you had anything more to add about Dynamic Soundscape Processing?

- No, I think, you know, it just goes to what we've talked about before that the signal classification system is pretty darn important. I mean, we often talk about all these other components and algorithms, but we really need that to work right. And tell me, Brian, is this now, I know the Xperience product was introduced a few years ago and, but this type of analysis then is also part of the augmented focus. The augmented focus, which we'll talk about later is just is it builds on this, is that correct?

- It builds on, that's right.

- Yeah.

- Exactly. It's a newer faster-

- Sure.

- Version of Xperience.

- Yeah, exactly. Well, you know we, back when this was introduced a couple years ago, we did an interesting study. You know, this came from listening to hearing aid users and what they considered to be occasionally a problem when using our current technology of narrow directivity and well, and directionality in general. And one of the common complaints was that they'd be at a restaurant talking to their partner across the table and a waiter or waitress would walk up and say something from the side or behind and they wouldn't know that person was talking until that person had finished part of their sentence. So for that reason, this research was designed to get at that very situation. And so what it was is that the primary talker was directly in front.

There was background noise going on at a relatively loud level, I think 68 DB or so. And then at random times unexpectedly, there would be another talker that would appear from the side at around, not around, because it was a lab study, it was exactly at 110 degree azimuth. The, and then we could test with this processing on versus the processing off which we could do then in the software. Today, you wouldn't be turning it on and off because you want it on all the time, but the results do show excellent findings. What I'm not showing here is that for the primary talker, the speech understanding and the listening effort was about the same, whether the processing was on or off.

And that's exactly what you'd expect because that's the way the algorithm thinks. But going back to what Brian was saying, relative to intent, the new feature is trying to substitute what your brain might be saying. And that is, "I really want to hear this person off to the side." And what you see then, for both speech understanding and for listening effort, there was a significant advantage for processing on when, and this is the ratings for understanding the random talker that appeared now and then from 110 degrees. So this was a nice validation study, efficacy study that this really works. But there's more, there's more.

- There's always more. Yeah, this is a really interesting feature. No other manufacturer has anything like this augmented focus. I call it split-band or split-processing, but in augmented focus it splits the incoming sound into two separate streams, a front stream and a back stream. And the really, the important point here is those two streams are processed independent of one another. So what that means is you can apply different amounts of compression, different amounts of noise reduction, you can change the timing of the compression in each one of those two streams independently. And then once you've done that, you can mix them back together again.

And that's a real advantage when you get into some of these more complex, noisy situations where you might have people on the side that are talking in the middle of a cocktail party, something like that. This augmented focus feature, as we'll show you in the next few slides, it provides the wearer with a greater contrast between sounds that are coming from the front and the back and the sides. And what I think, what that really boils down to is that's easier to understand when you get into noise.

- And you had some clinical studies on that too, I believe.

- Yeah, this is a study I believe that was conducted a while back at the University of Northern Colorado and it's in a simulated restaurant environment where we've been talking about kind of a cocktail party situation where there might be somebody on the side that you wanna pay attention to and listen to. We tried to simulate this in this laboratory study. And what you see here is the same device, programmed the same, matched to a now target. And you see the performance and noise with augmented focus turned off on the right and augmented focus turned on, that's the left red bar. And notice here it's the SRT 80% correct. You don't see that a lot in studies. In fact that's think that's the first time I've ever seen that metric used.

But anyway, the point here is that with augmented focus on, you get about a 4 DB improvement in that scenario when it's on versus off in the same hearing aid. I know that we also did this study comparing augmented focus in the AX product to a couple other competitive products. And you see the same trend here on the SRT 80% correct. You see, it's at about a negative 11 signal to noise ratio where you get where 80% is obtained with the AX versus brand A, which is about 3 DB worse and brand B, which is about 6 DB worse. So you can see in that simulated restaurant environment how much better AX would perform relative to two other brands.

- Yeah, you know, it's interesting when I remember when I first saw these results, it's the brand B performance is surprisingly low. Usually when you're comparing from hearing aids from different companies, usually you don't see differences quite that big. But my only guess is, you know, this was laughter coming from various locations and it was a burst of laughter of 70 DB or so. All I can guess is with brand B is that something about their processing reacted to that and just sort of shut the hearing aid down so that the person wasn't able to hear the target speaker. That's, you know, my only guess, I don't know. But it's just unusual. And in fact, I looked at the individual data and it wasn't like it was one or two people who drove this down, it was across all the subjects.

- I wonder if it has much to do with Signia classifiers being different in the, for the different products.

- Well that could be it too you know, and again, going back to the split-band, is that it could, and the Signia product, this speech from the front is being processed different then the noise reduction, where if the laughter which would be interpreted as a noise said, "Oh, that's noise. I'm gonna shut everything down by 15 DB." well then the speech is also shut down by 15 DB.

- Exactly.

- A few weeks ago, you and I talked for 15 minutes about the importance of audibility and so there you have it right there. You know, there I, there also was a field study done that was interesting with this processing and the study compared a couple things. And I encourage you to, if you go to the written article for this particular talk that

Brian and I are doing, there's actually an article published on that, at that. And where do they find those, Brian? At?

- You go to Signia Learns. It's the new-

- Signia Learn, Learn?

- Yeah. Signia Learn platform. You can find it by Google.

- Okay. That's a ambitious title.

- [Brian] Well, it is.

- Well, good. I hope it's correct. Anyway, so this was a study where the people in the field trial, they completed a couple questionnaires. One of 'em had to do with, which I think was the most interesting and probably the most scientific valid was the SSQ. I only say scientific valid 'cause the SSQ has been used in a lot of studies. Those of you that that's the speech and spatial and qualities of speech. And for those of you who are not familiar with it, it's a, it's something like the AFAB in a sense that there's a scenario presented and then the listener ranks it on a 0 to 10 scale and on all the questions, although they're worded differently, the 10 is always the best.

And so in this particular study, which I won't get into is the new AX processing was compared to the people's old hearing aid. You know, I don't have to tell you what the answer to that is, that people always like the new hearing aid. But what I found the most interesting is there's SSQ data that for normals, people, older adults with normal hearing. And so what you see here is the new Signia processing compared to people with normal hearing. And hopefully it's obvious, that there basically is no difference. And again, you know, normals aren't scoring 10s on all of these conditions either. But this is five different conditions. And here's what I think with the one on here that really caught my eye was the fourth one from the top.

And that is to follow a conversation without missing new target. See, this is exactly what we've been talking about through this whole thing is that we want to give the ultimate in directional processing but yet not totally ignore signals that are coming from different azimuths. And so, and you notice wearing these hearing aids, performance was the same as with somebody with normal hearing. So those I think are real encouraging findings. And this is some of the things that are new from Signia in the constant battle of improving speech understanding and background noise. Anything else do you have on that, Brian?

- No, I think we've covered this topic extensively. So, now that we're on our sixth and final final chapter here, we're, I think we've wrapped it up.

- All right. Well, I know we have a new topic coming up next month, so we'll see you all again.

- Sounds good, Gus. Take care and we'll see soon.

- All right. Okay.

- Bye.