How to Navigate Naturally in a Noisy World

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- Welcome to today's course, How to Navigate Naturally in a Noisy World, presented by Tammara Stender, the director of Global Audiology External Relations for GN Hearing. It has been said that innovation is seeing what everybody has seen and thinking what nobody has thought. This month on AudiologyOnline, we're celebrating innovation in hearing industry with our third Industry Innovations Summit. Thank you for joining today, and we hope to see you in more summit courses. We would also like to thank our title sponsored CareCredit and all of the companies that participated with us this year. It is my pleasure to turn the microphone over to Dr. Tammara Stender.

- Thank you, Melissa, and thank you so much for having me here today. And thank you to all of you for taking time out of your busy days to log in and join me on this journey. Today, as Melissa said, we're gonna be talking about noise. Something that we talk about all the time in audiology, but with a view to where we are, where we've been, and where we're going, and the innovations that are being developed and are already available on the market today to help people navigate better in a noisy world. So thank you again for joining. I'd be happy to take any questions that you have at the end. We're gonna have a little bit of a interactive component at the very end.

Don't worry, it's not crazy, it's just writing in the chat. And I hope that you enjoy this presentation. We start with learning objectives. Number one, after this course, you'll be able to explain why it is so important for people to navigate as naturally as possible in whatever kind of listening situation they find themselves in. The second learning objective is to describe three main technological advancements of ReSound directionality, and these are new advancements that have been introduced in the ReSound OMNIA product. Finally, we're gonna talk a little bit about an approach to directionality that uses multiple bands so that different frequencies, depending on where they are along the spectrum, are processed advantageously to help achieve these goals for people to hear as naturally as possible for their own voice, for the sounds around them, and for the speaker of which they really would like to focus on.

So let's start at the beginning. Why are we so worried about noise? Well, because we keep on talking about it ever since hearing aids have been around, even before then, everyone knows that hearing in noise is really, really difficult, and it continues to come up as a finding on these large scale surveys. The British Irish Hearing Instrument Manufacturers Association survey on audiologists, what are the issues facing the hearing industry? Absolutely, one of the biggest innovation challenges the industry faces is how to optimize hearing in noise. And it's not as straightforward as it appears, as we all know, being hearing care professionals. What is noise? What do you want to hear at a given time? What is the environment?

How do you deal with it always changing, it's no surprise that this is a big challenge because it is such a major, major problem and a major thing that really keeps people from getting the true satisfaction that we want them to get. MarkeTrak 10 and the Fidelity study in 2021 found that 80% of hearing aid users are still challenged by hearing in noise, despite the fact that every single time we come out with a product, we talk about this product is going to help your patients hear better in noise. And that's true, but we're quite not still there yet because there's always ways that we can improve for the individual user, for the individual listening situation. So despite the fact that our technology has come leaps and bounds even in recent years, and these numbers on surveys are increasing, we're still not at 100%, and 80% of hearing aid users are still challenged at times by hearing a noise, which means we've got some work to do.

Experienced users we're said to struggle to find solutions that allow them to participate in conversations without compromise, without workarounds. So if you're in this cafe, you can sit wherever you want and hear. That is the goal. You shouldn't have to advantageously put yourself with your back against the wall and away from the coffee machine. I mean, these are things that are good communication strategies, most likely

always be a good idea, but this is a compromise. This is a workaround. We can be better. How do we get better? How do we innovate technology to be better for our users? And what do we know from hearing aid users? We know that this is such a big thing on their mind.

Hearing aid performance, including hearing in noise, is the number one driver of hearing aid satisfaction. At the same time, it is the biggest unmet need. Biggest unmet need is sound issues including background noise. So here we have a dichotomy where the number one driver of satisfaction, how do we get them to be satisfied? Number one, help them hear in noise, and at the same time, this is where they need the most help. So again, we have our work cut out for us in the hearing aid industry to be better to help people connect more to what's important to them. Over 2,000 current hearing aid users in this study ranked hearing in noise as the most important attribute when purchasing a hearing aid, which is a very interesting finding too.

And at the surface, it seems pretty obvious, you get a hearing aid so you can hear better when you wanna hear better. Well, you usually wanna hear better when you're having difficulties. And that's not when you're sitting alone watching TV, typically, it's not when you're at the library reading a book. It's when you are in noise. And why is it so important that we focus on noise, and why is it so important for our users? It's because these are the situations where life's memories are made. Look at this picture. Clearly, this is a memorable moment, and I know this is a marketing picture, but you can imagine, when are the times when you have the most memories throughout your lives?

It's times like birthday parties, it's times like going out to a restaurant, having a party, meeting with people, outside doing the things that you love. And if hearing loss is keeping you from fully participating in these things, that is what sticks with you, and that is a motivator to get a hearing aid. It's not necessarily that you need something

else, that you want to be able to track your steps, that you want to be able to even, sometimes, even connect to different devices. But what makes life memorable are the memorable moments shared with others, and those are typically moments that involve lots of noise. And this is where we wanna focus our efforts. EuroTrak found that hearing in noise came in last when he respondents were asked to rate 17 listening situations with regard to hearing aid satisfaction.

So here again, this is a common theme. It keeps coming up. What do we do with this information, and how do we pay attention to it when we develop new products? Well, that is the question that we've been asking at GN now. And ReSound has been focused on this problem for product generations. We know that we're getting better. We want to be as good as possible with what the technology will allow us to do today. So based on these studies, our focus is naturally, we wanna develop better technology for hearing in noise. And the reason why we wanna do this is for the user. We know that individuals need to participate in the life memories and the experiences that make life so great.

So let's help them navigate, not only just to hear the loudest speaker, but to feel like they're part of the environment, that they're surrounded by the sounds that they have come to expect to associate with a gathering such as this, and that they sound good to themselves as well. So introducing ReSound OMNIA. This is the latest advancement of our directionality and hearing aid processing that we have on the market today. And it was developed primarily for this reason to help users hear better in noise and not just to hear better, but to navigate and to do so in a way that makes it feel natural. Now, natural is kind of an overused term. I've heard in the word natural in all of my audiology career.

But what does it mean? Well, to ReSound, it means organic. It means thinking about the way that the human auditory system works, and trying to emulate that in order to

provide the amount of input and the fidelity of input to the brain that the brain is looking for when it qualifies something is sounding good or sounding natural. So organic. You can think of it as it's less processed. If you're at the grocery store, maybe, organic foods, they don't have pesticides or chemicals, et cetera. Or you can also think of it as we're centered on the organic way, the organ, the organ of Corti, if you will. The way that we process sound, how do we support what the human body was designed to do with this technology?

So there's three ways that we are trying to do this. First, we want to sound natural, and that's about emulating the natural hearing process and the natural way we listen as closely as possible. Giving the brain that rich information, that stimulus that helps the brain and the person decide what they wanna listen to if things sounds good, if things sound the way that they should. Additionally, we wanted to feel natural. We wanted to be a no-brainer, basically. You put them on, and you don't have to fiddle all day long. You can put them on, and you have this technology be dependable, it feels good. It feels like part of you. A hearing aid should never be something that you have to adapt your lifestyle to.

We would love it to be that a hearing aid integrates seamlessly into your life. And finally, connections. We can't ignore, even though it might not be the real reason why some of our users come to see us or some of the patients come to see us as audiologists, but we want to connect users naturally to things that are important to them. And a lot of times that's people, but sometimes watching the game, sometimes it's being able to hear that phone conversation, a family member hundreds of miles away. We want them to be able to experience everything and connect with whoever or whatever is most important to them. So with the ReSound OMNIA, we say it sounds natural and that is our marketing, but what is natural?

Let's think about what gets us to that? And how do we really know what is the best way to emulate these natural processes? Well research into the way that humans hear has identified three main strategies that humans use when they are going about their day and learning and interacting with their sound environments. The spatial cue preservation strategy is all about making sure that you can hear all around you, all of the sound signals, the birds in the sky, the dropping of the pencil at your feet, the loved one talking to you on the side. This is where sound quality is really, really important. Taking a nice stroll on a beautiful spring day. I say that as we're having sleet here in Chicago, looks lovely to me right now.

But when we move into a more difficult noisy situation such as a restaurant, we have to use a different strategy, especially if there's several people around that are all having a lively conversation. We need to direct our focus to multiple speakers very quickly, be able to hear when something somebody says something funny as funny little comment off to the side might make everybody laugh. You wanna laugh along with that too. You wanna hear and catch it off. So you're using binaural listening techniques and strategies that the human brain already knows how to do about how to focus and divert attention based on gathering all the information around you and deciding what you wanna listen to. And this is a very dynamic, complex listening environment.

However, it's usually the environment that we find ourselves in when we're in restaurants. And restaurants tend to be memorable experiences, at least some of them are, and so we'd like the users to be able to benefit from technology in these especially. And finally, we have the speech intelligibility strategy. This is when you really need to communicate, and you don't really necessarily care about what else is going on around you. You just want to find out what are the price of these nectarines. I can't hear because there's all this sound behind me. How do I know what this is? Because I got to go, I got to leave the store in five minutes. My kids are waiting for me to go pick them up.

So this is when you say, "I'm not so much interested in being able to hear the birds in the sky," or anything like that. "I'm not having a lively conversation with many, many people. I'm really focused on getting information that I need right here, right now in front of me." And that's a speech intelligibility kind of strategy that the human brain has been conditioned to use throughout time. So we want to preserve sounds around us. When it's a quiet environment, we want to experience it all because that's a pretty easy listening environment, and that's where sound quality really makes sense. We want to be able to focus and divert attention when it's a restaurant situation so that we can be a lively and engaged part of that conversation.

And we want to really focus when we got to get that information quickly, we've got to really know what's going on. And this is very important in a speech intelligibility strategy. So the purpose of the new directional feature in ReSOund OMNIA, which is called ReSound 360 All-Around is to support these natural auditory navigational abilities to the best that we can with the technology available today. And luckily that technology has gotten a lot better in recent years, and we can do things that we weren't able to do even with our last product that really makes a difference in achieving these goals. So there's three areas of ReSound 360 All-Around. The directionality feature that's in the premier levels of our technology that help us achieve this goal.

First, we want to widen the sound environment. So the mapping of the environment, what does that mean? That means that you're able to really hear all around you to get that rich information, which is so important to have so that you know in a binaural listening situation, whether you should be paying attention to something over here or not. If you didn't hear it, then how do you know if you need to turn your head to really focus on it? And this is what we're trying to do when we widen the sound environment. We're also speeding up our processing and steering for faster mode detection and selection so that when we move from a more binaural listening strategy to a speech

intelligibility strategy, and we get there faster, that the technology is smarter and able to make those decisions based on the environment around, the level of the noise, the speakers where they're located, the spectral analysis of the signals, et cetera.

And then finally, we're going to increase the precision of the beamforming. And precision is a word that sounds great, but what does it mean? It means that we're making this technology even more precisely designed for the human body. We are taking into account the head-related transfer function to a degree that we've never done before, 16 times more than we've done before in terms of the coefficients that are used to make these calculations so that our beamformer truly is a beamformer when you need it in each intelligibility strategy. The greatest thing is you don't have to switch between programs to get all of these advantages. All three of these improvements are working at the same time. They're turning on and turning off based on the sound environment that you're in, and it's doing it seamlessly so that users can automatically have what they need as they move through different listening environments in their day.

And furthermore, the hearing aids are not putting them in a tunnel. So even if they're in a very noisy environment where there's just a speaker in front and there's sound behind them, they are still going to have some auditory awareness. And we'll talk about that in more detail here in the next few slides. So first, widen the sound environment. How is this achieved, and why is it important? Well, with ReSound ONE, we had All Access Directionality, which was a binaural directional strategy that put directionality on one side and omnidirectional on the other side, which gives the brain the inputs it needs to be able to take in a very focused and high signal-to-noise ratio and auditory awareness all at the same time so that when you're at a restaurant, and you're having a conversation, you can also hear when the waiter comes up to take your drink order.

This is very important, and we've had this kinda strategy for a while with all-access directionality, we started to incorporate weighted beamforming for that focus side,

which is using all four of the microphones for that focus ear to get that directional response to be more fine-tuned to help with the signal-to-noise ratio in that situation. But if you look very carefully, you'll see that these shaded red and blue circles around the user's head, they're not necessarily centered around the user's head. And this can be a little off-putting necessarily, or it can reduce the amount of audibility that you have for sounds around you. It's not the most natural. So we fixed it. 360 All-Around is an improved, more optimized way of providing that audibility when you're in a binaural listening situation like a restaurant where you need to hear around you.

This time, you're not gonna have any nulls, you're not gonna have any areas where it's a little bit harder to hear. It's gonna sound like you're more centered. The sound quality is aided in this as well, and at the same time, you are getting directional benefit, which studies have shown is useful for these environments to get better signal-to-noise ratio, better directional benefit, hearing the speech a lot easier while at the time being aware of your surroundings. Just so important in a restaurant situation. How this is done is that when the environment signals that the binaural listening mode is in effect, we're gonna stream the off-axis sound, so the background sound from the directional side, from that focus, directional side, we're gonna stream that sound to the omni side.

So think about like a polar pattern with directional, let's just say on the right ear, and you've got a little bit of a null because that's what directionality does in order to make sounds in front and especially speech louder and background noise, it reduces the audibility for sounds around you. Well that null might be just where somebody's saying a joke that's really super funny and everybody else heard it because they're not wearing hearing aids and you did. You wore hearing aids, and you didn't hear it because of that null. Well, we're getting rid of that null, and that null is gone now. And so now you're able to hear much better because that sound that you were missing on the directional side is now being streamed over to the omnidirectional side, so you're having that awareness.

I had a question recently. Doesn't this mess up your localization abilities if you're streaming from one side to the other? We're so focused on having natural sound quality and experience with localizing sounds. Doesn't that mess it up? And great answer is no, this is not going to make a drastic difference in the localization and here's why. We're only streaming from 1,000 to 4,000 hertz. So that midrange. And if you think about localization cues, low frequency cues give you timing cues, interaural time differences, those are usually below 1,500 hertz. Those are below 1,500 hertz. High frequency cues in the higher frequencies above 5,000 hertz give you interaural level difference cues. And again, those start around 1,500, but they become much more strong when they're in the higher frequency.

So by only streaming the off-axis sound in the mid frequencies, we leave most of the localization cues that are the strongest and most important intact, the timing cues and the level cues while at the same time, providing that auditor awareness where the directional null used to be. And this is really a good thing for helping people navigate better in these kinds of very memorable experiences. When you want to hear better, when you make the memories, it's when somebody said something funny on the side and you were looking at someone else who maybe wasn't saying something so funny, but you wanna be able to be part of every conversation because it's a nice little conversation group that they're having, and this is a very typical, looks like a fun experience.

So are we sure it works? Yes, we're sure it works. We compared ReSound ONE, which had the All Access Directionality without that off-axis streaming to ReSound OMNIA 360 and found that does have this new binaural listening streaming of off-axis sounds. Only in the binaural listening mode because this is where you would need it. So those two hearing aids were set to the same audiogram with the same targets, power domes so that we could really get the more of a full spectrum response. And the target was a

female speaker set up at 120 degrees. So that was what the person here, the red little circle is a person. And the task in the sound booth was to repeat what the female speaker said.

At the same time, there's male speaker from a zero degree azimuth in front, and there's noise right off to the side at 270 degrees. So in this situation, the hearing aid and binaural listening mode would be automatically set to the right ear is directional, the left ear is omnidirectional, so that you can focus on the right and monitor on the left. The test was a DANTALE speech recognition test. And this is pretty similar to a HINT test where you get an SRT to determine 50% correct performance, and it results in a dB SNR score. So the lower score means they did better because they performed at 50% accuracy at a more difficult listening situation. Let's see how they did.

Old versus new. So ReSound ONE did pretty well. The average SRT was a little bit more than negative four dB SNR. And with the ReSound OMNIA, you see an improvement there. It was greater than negative 5.2, or I should say less than negative 5.2. So if you're like me, and you're looking at these, you're like squinting, you're like, "Is that significant?" And you say, "Actually it is not significant," because we had to do this with a lower number of subjects to, if we had done more subjects, we could have probably gotten some significance. But what most important thing here is that it is giving them more audibility. And let's remember, this is a very difficult situation because you're not getting any visual cues either.

And even though visual cues are kind of a workaround to acoustic performance, it is a very human performance. So getting this kind of SRT in this difficult listening situation, a noisy listening situation with competing speakers, trying to focus on the back speaker in this situation is a pretty great finding. And the other good news is that no one did significantly worse with OMNIA than with one. So at the end of the day, when you are fitting patients and it's new technology, you wanna see that this technology is

better than what was happening, but at least not causing any problems that weren't there before. And the great news is that this is a improvement over the ReSound ONE All Access Directionality.

ReSound OMNIA will allow your users, on average, to get better audibility in these kinds of restaurant situations for the sounds in back. So before we start talking about the sounds in front because I'm sure that that's what you want to know, how do we get a stronger beamformer to be able to really hear better in the difficult listening situations? Let's talk about how we even transition from the restaurant kind of condition to a condition where you really wanted to focus, you really wanted to listen to that person across the table and you didn't actually care about anything else there. That's a speech intelligibility strategy. So how you transition is very important to look at because you don't want your user to be stuck in a mode in binaural listening mode for a long time, waiting to get the technology going into the next mode to make it sound even clearer.

So we set up a processing and steering for faster mode detection and selection. It's twice as fast as it used be. What this means is that the way that it determines how to change modes is based on the environment. And you see the leftmost picture, that's more of a quiet environment where maybe there's not a lot around, they're really close together, it's probably not very difficult. That would be more spatial cue preservation mode that the brain would be looking for. So you'd be providing a bilateral omni response with 360 All-Around in that automatically. Moving into the second picture, there's a couple more speakers, there's more sound, it's not quite the most difficult situation, it's not very far away, you can hear them pretty well, but you need to divert your attention around to who's talking at the time.

So that would be more of a binaural listening strategy, and that's when you would have that directional on one side and on me on the other, so you can get the best of both

worlds to the brain. And finally, in the last picture, it's a little more difficult still, there's a longer distance, there's people talking off in the distance. This is where speech intelligibility strategy would be pretty good, and this is where you're going to get that bilateral directional response that helps optimize signal-to-ratio. So we transitioned between these modes, and we want them to be as accurate and as quickly as we can. And in the past, we used probabilistic model, which means that it took the probability of being in a quiet environment, for example, versus the probability of being in a more complex, diffuse noisy environment and determined that.

And that was a good way of doing it for the technology that we had at the time. But now we are using a more sophisticated kind of modeling, it's a deterministic model to arrive at those decisions quicker so that as your user is walking around in their daily life in program one which has 360 All-Around, they're not having to worry, is it going to switch into the correct response when I need it to? It will be happening twice as fast as what it did before. Again, we don't wanna be switching too fast. There's a happy medium here, not too slow because then you miss out on audibility and not too fast because then it might sound a little strange like the hearing aid is zooming in and out.

We don't want that either. We want that nice sweet spot in the middle where they're getting the information as quickly as they can, as accurately as they can and as seamlessly without any kind of detriment to the sound quality. Here's where we talk about a lot of the claims that have came out with ReSound OMNIA, and it's all about the precision of the new beamforming strategy to give the best speech intelligibility whenever they are in a situation that they need this. So if you think about beamforming directionality or mic beamforming directionality, uses ear to ear communication between the four mics to be able to determine where that speaker is, usually in front when you're in this situation that you really wanna focus on and there's loud noise in back, so that you can basically make a stream of sound so that you can hear better.

It's like a more close nearfield phenomenon of what a remote microphone accessory would do, like a Multi Mic where it would stream directly to your hearing aids, making it sound like the sound is closer to you. That's what Bean forming directionality does, but more in a near field kind of situation because directionality is only about as good as it can be up to about six feet in front of you. So how do we get the best signal-to-noise ratio in these situations? And furthermore, 360 All-Around will automatically put you in that situation when you are set up for it. But research tells us that that's not all the time. That's, in fact, probably about 8% of the time.

It might be a very important 8% of the time when you really wanna focus, but it's really not all the time. So how do you make it go there if you decide that it's not getting there fast enough or if you really wanna drive that you can get into that focus mode as quickly as possible? Well, Front Focus is a user-driven option in the app, or it's in program two, generally, is what we recommend that user would select when they want to be in the driver's seat. If they want to stay fixed in that speech intelligibility mode despite everything going around them, they're choosing, and that's their choice, that's their prerogative, they can do that, and Front Focus will keep them in that mode as long as they want to be in that mode.

Again, we're trying to put the user in the driver's seat. We don't want the hearing aids to make decisions for them despite the computer modeling, despite the probabilistic, despite the deterministic, all the things that we have with technology, there's never gonna come a time when a hearing aid knows exactly what the user wants to hear, never, because we're all individuals. And what's important that one moment might not be important in another. And that's the same for, that's true individually for all of our users, so why not put them in the driver's seat when they need to, when they really, really need to hear, they can choose to be in that and without even having to have another accessory along with them.

So ReSound binaural beamforming directionality. As mentioned before, we've had weighted beamforming in the past, and it was in our binaural listening strategy and speech intelligibility strategy. But now we've improved it. We're using the cues, the shape of the head, the torso, all of the things that make us human to make that signal more focused and make it be exactly the kind of beam that we'd like it to be. Because when you're in these situations, you really want to listen. So every time you're gonna get a beamformer with ReSound OMNIA, you're going to get that focus in binaural listening strategy like a restaurant situation and also in the speech intelligibility strategy when you need to hear the ticket counter agent at their airport and the Front Focus program when the user wants to manually activate that strength of SNR benefit.

So we put it to the test. Is it better than it was? Is the technology, is the innovation getting better with new product launches? We want to know that because we don't want to be putting out products that are the same or heaven forbid, worse than what they were before. Every time we need to make these improvements for the betterment of the users that we really want to get the best sound quality and the best speech clarity they possibly can. So we compared ReSound Ultra Focus, which was in ReSound ONE to ReSound Front Focus, which is in ReSound OMNIA. They're both users-selected, fixed, strong directional beamforming programs. And so that way we could maintain that they were going to be doing exactly what the user would want in a very difficult situation where they prioritize speech intelligibility.

Again, the same audiogram plus targets for the same hearing loss. Power domes, set it up for Front Focus or Ultra Focus, so we can reduce any variables of switching that could have occurred, although they probably wouldn't have in this kind of situation based on the way it was set up. The setup was that the speech was at zero degrees, and there was noise pretty close to that speech off at 75 degrees. So that's within the first quadrant of the right side here. This actually makes it pretty difficult because one of the things that we remember from our training is that humans have an easier way of

focusing on speech when it's spatially separated from noise. So there's not a ton of separation between speech and noise in this setup.

The task was to repeat the speech at zero degrees. Again, we use the same DANTALE speech recognition and noise test to give us an SRT that's 50% correct performance, so the lower dB SNR score is going to indicate better performance of the feature. And then we ran into a problem. When we were testing this initially, we found that even though we tried to make the speech and noise test difficult by making the noise very close to the speech, with ReSound ONE and ReSound OMNIA, we were getting ceiling effects, meaning that people were maxing out their performance because actually, both beamformers performed very well in the situation, but we knew that we had made changes to the beamformer so we decided to make it even more difficult.

To avoid these ceiling effects, we decided, okay, let's just focus on the beamforming feature, beamforming frequencies. So we're making it more difficult because we're removing acoustic cues of the speaker in the low frequencies and the high frequencies, and we're only going to work, we're only gonna focus on the band pass of the beamforming frequencies, and we included 500 to 4,000 hertz. The beamforming frequencies are 1,000 to 4,000 hertz. So as you can see, we cut out a lot of those low frequency and high frequency cues, which would make it harder to understand the speech on the one hand, but also able to avoid these ceiling effects. We kind of took away some of the affricates and fricatives in the high frequencies, some of the fundamentals because we needed to be able to show what is the difference between OMNIA and ONE because if there's no difference, then what is the purpose of putting out this new feature?

So these were our results. We did omnidirectional as one would do to just set up a baseline. We turned on Ultra Focus for the ReSound ONE hearing aid, and what we found was a 4.25 dB SNR result better than omni. So people were able to perform

better with Ultra Focus with ReSound ONE. And 4.25 dB is a very respectable amount of SNR benefit, definitely, especially in a situation that's difficult like this. The small circle around the user indicates that we have omnidirectional in the low frequencies. So they are getting some auditory awareness, but the focus is to respond, repeat what the speaker in front of you is saying, and so that's what those circles and cones mean. Watch what happened when we put on the ReSound OMNIA.

ReSound OMNIA Front Focus, which is the same feature except for it's in the OMNIA instead of the ReSound ONE gave 8.61 dB better than the omni results. This was pretty astounding. We looked at it. What's the difference between ReSound ONE Ultra Focus and ReSound OMNIA Front Focus? it's about 4 1/2 dB. OMNIA Front Focus is about 4 1/2 dB better than Ultra Focus in this difficult situation in terms of dB SNR performance. If you've seen any of our materials when we came out with ReSound OMNIA, they said that there's 150% improvement for speech and noise, which, to me, as a hearing care professional, I'm like, "Really? That sounds like a lot. So how does that work out? Where's the math on that?"

Well, here's the math on that. So if you think back into dB and what a doubling of intensity equals, if you have two speakers and they're both putting out 60 dB, that's a doubling of intensity. But on the non-linear logarithmic dB scale, that equals a three dB increase, right? So two speakers both at 60 dB is 63 dB as a summation. And this graph shows the relationship about why dBs perform this way. So twice the power, two speakers instead of one, gives you a plus three dB benefit. 10 times the power gives 10 dB benefit. So where did we end up with? We ended up with a difference of Front Focus with ReSound OMNIA versus Ultra Focus with ReSound ONE of about 4 1/2 dB, and that's about 150% better performance.

In fact, it's a little bit more than that but we we cut it off at 150 because that's just illustrating that you can have these dB differences in SNR, make a huge impact on the

performance that you can expect. And it's based on the fact that we are isolating the beamformer that we are really trying to show what is different, what has changed in this new feature. The great news is that these were the subjects that we had. Again, not a whole lot of subjects, but we definitely got a significant result here. And if you look and like me, you're always looking for the outlier, you're looking for the one that doesn't fit. ReSound Front Focus benefit is in red, ReSound Ultra Focus benefit is in gray, and Front Focus outperformed Ultra Focus for each and every patient, every test subject that we had except for number 14 because, you know, there's always gonna be one, right?

That does a little better with the opposite. But if you look and see a two dB difference in SNR, usually corresponds to a significant finding clinically. So the difference between ReSound Front Focus and Ultra Focus for subject 14 was only 1.8 dB, which is not a clinically relevant. It's the same that you would see with test-retest reliability. So again, the take home message from this is that Front Focus will help your patients hear better in those difficult situations. And even for people that you have across your schedule that are like subject 14, it's not going to cause any significant difference at all. So you can only help with this kind of feature and for most people, you will help in a major, major way.

So this is what we're talking about when we talk about giving more precision. We're thinking more about the organic way that people hear. And the organic way that a person without hearing aids would hear is through all of the invisible to us head and torso effects that we don't even think about but that the brain is using as cues to help us be able to focus on a speaker. When you really wanna listen, you're focusing, and when you wanna be immersed in the environment, you kind feel that whole sound environment opening up for you. That's a very higher level cognitive kind of operation. It has nothing to do with hearing sensitivity. It has everything to do with how we hear at higher levels of the auditory processing, of the auditory system.

So it is a very overall kind of experience. It has not been shown to be linked to any kind of detriment with auditory processing disorders. It is a higher function than that, and one that we all take for granted being unaided listeners. When you put on a hearing aid that isn't specifically designed for head and torso body effects, you are going to miss out on some of those cues. So the main difference between ReSound OMNIA Front Focus and ReSound ONE Ultra Focus, and the reason why we get that improvement is because ReSound OMNIA Front Focus is better optimized for the head-related transfer function, better precision for better clarity using many more, 16 more coefficients for anyone who wants to think about the engineering of it, to better emulate the way that sound bounces and diffracts off the human body to get that precise beam as good as it can be.

One of the questions that came up after we launched ReSound OMNIA, what's the difference between 360 All-Around and Front Focus in this kind of situation? Well, 360 All-Around is an automatic program so that the user can go about their lives with basically one program and never have to switch programs because it's automatically moving from bilateral omni and the spatial cue preservation mode, to asymmetric directional in the binaural listening mode, to speech intelligibility mode with bilateral directional, and in any kind of configuration of those. So that's an automatic program that automatically activates for user convenience. Front Focus is user-selected, and that's when the user wants to definitely have control and put themselves in the driver's seat, even though speech intelligibility mode probably could have brought them there, it'll definitely put them there.

And that's very important to users to have that kind of locus of control. So the only difference between the two when you're in a situation such as this where you would automatically be in speech intelligibility mode based on the test setup is the directional mix setting. And this is the crossover between omnidirectional processing that we have

in the lows and directional processing in the high frequencies. All ReSound hearing aids and all directional programs have omnidirectional below a crossover frequency, and we do this for a number of reasons. But the difference here, I'm gonna talk about those reasons in a minute, but the difference between Front Focus and 360 All-Around is that Front Focus is always going to have a high directional mix, meaning the crossover frequency is very low in frequency, giving more of that frequency content for the express purpose of making that signal-to-noise ratio as optimized as can be.

In 360 All-Around, the directional mixed setting is personalized to the user's hearing thresholds based on their thresholds at 250 and 500 hertz, and also based on the mic location effect of the hearing aid that they're being fitted with. So it's more personalized, but Front Focus is really for when they want that best SNR because you're getting all of the as much directionality in those frequencies as you possibly can. So we're getting to the end of the hour, and we need to check our scorecard. How are we doing with navigating naturally in a noisy world? Hearing others' speech well in noise, we've talked a lot about the strategies and the kinds of advancements we're trying to bring to allow people to hear it like they want to in noise.

So let's go ahead and just give that a check for right now. I know we're not perfect, but we will get there and we are getting there with each iteration. Let's talk a little bit about something else that people don't usually associate with directionality, but bears mentioning. When you're in directional program, how do you hear your own speech? Does it sound natural or does it sound different in directional? Let's look at that. And whenever you talk about hearing your own speech, I, all of a sudden, get this, oh no feeling because we're gonna be talking about occlusion and oh no, nobody wants to be stuck with a head in a barrel. Yeah. So how does this relate to directionality?

What do we need to do to make sure that hearing aid users are hearing their own voice as naturally as possible in a directional program? Something that we don't always think

about, but it really, really bears mentioning. So this is a chart that indicates what happens with traditional directionality. So if you remember from when you learn about directionality, there's an inherent roll-off of low frequencies with directional. That's why when back in the old days when I tried to figure out is the hearing aid an omnidirectional or directional program and I take a stethoscope, and I'd talk into the front mic, and if it was louder than the back mic, then I knew I was in directional in the softer setting because there's a roll-off inherent in directionality, and this is like, you know, 20 years ago.

So obviously, you don't wanna hear things softer in the low frequencies when you're in directionality. So what manufacturers do is that they give what is called a bass boost or a low frequency equalization so the audibility is not cut out in the low frequencies when you're in directional, and that's when all of the frequencies are processed is directional. Full band directionality has a bass boost to restore that audibility. So if you're looking at this graph, the one meter line which is the red line is the distance away from the user, and that is where hearing aids are calibrated. So if you're going to make this roll-off come back up to the zero line on the y-axis, you're going to lift that up with a bass boost.

At the same time, directionality is a very near field phenomenon. As we talked about, it only extends to about six feet in front of the user. So that means that sounds really close to you are gonna be even stronger in a directional mode, especially in those low frequencies because as the hearing aid is calibrated for one meter, look what happens for sounds closer, 10 centimeters and five centimeters, they go way above. So imagine that that red line was at zero and the gray and the blue lines are even now about 10 dB above zero. What does that do? Thinking about your own voice, we hear a lot of that in the low frequencies. That's the problem with occlusion.

So having full band directionality with bass boost actually makes users own voice sound louder to themselves than if they were an omnidirectional because then they wouldn't have a bass boost. So that's a problem. This is the main reason why we have omnidirectional in the low frequencies when it comes to the user's voice. As I mentioned before, all of ReSound directionality has omnidirectional in the low frequencies. And where we put that cutoff frequencies is based on the user characteristics of hearing loss and what hearing aid model, the microphone location effect that applies, but omnidirectionality avoids that entire problem I was just talking about. It avoids the fact that near field directionality has a proclivity to make sounds that are closer to you than one meter even louder than what your targets would suggest.

So for the user's own voice, the best way to preserve their own natural sound, so it's not boomy in the directional program is to apply omnidirectional there. It's pretty great that that's kind of a side effect of having omnidirectional in the low frequencies because it's a huge benefit. We don't want people to say, "You know, I sound okay when I'm in omnidirectional program, but when I moved to directional, my voice sounds boomy." Well, why would that be? Because of full band directionality. We can avoid that entire problem by having omnidirectionality in the low frequencies. And this is where this multi-band directional processing idea really starts to shine because we see that having a beamformer for directionality in the mid frequencies maximizes signal-to-noise ratio.

These are the speech frequencies, these are the ones that you determine that give you most of the information that you need to be able to understand speech. But in the low frequencies, you can really mess up things like sound quality if you have directionality in the low frequencies. So keeping it omnidirectional helps the user's own voice. High frequencies will also have different treatment. But before we move on to that, let's think about hearing your own speech and noise. When you're in that directional program,

you don't want your users to say their voice sounds boomy in that situation. So omnidirectional processing is a way of keeping it more natural and making them get the amount of gains for their own voice that you thought that you were giving them when you actually program the device.

And finally, let's end with comfortable navigation and noise because life is more than just understanding speech. And none of us in our daily lives really care that we can hear 100% accuracy in a sound booth because we're just trying to live our lives and we've got to be aware of things around us for safety and for deciding what to pay attention to. So navigating a noise is really important. And this is why, another reason why we have low frequencies with omnidirectional and we have high frequencies set with fixed directionality that is not beamforming because whenever you beamform, you're sending sounds across the head, and they're getting mixed up into where they are coming from. So in the high frequencies where you get those affricates, those fricatives, those high frequency cues that give you indications of level differences, you don't want to mess them up any more than you need to.

So you've got to give directionality, but you're going to give it in a fixed hypercardioid response, and this will be better for maintaining interaural level difference cues. So as I said before, low frequencies, that's where timing difference cues are. Preferred sound quality is often found for omnidirectional. It's the least processing that we can do and it helps with reducing wind noise too just by not having directional in the low frequencies. High frequencies better preserves monaural spectral cues and gives you less internal level difference distortion as sounds go from one side to the other side of the head. So low frequencies, they travel around the head with limited intensity changes. So as a low frequency travels from one side, like maybe from the right side to the left side, the wavelengths are long enough to bend around the head, and that is why when you do a polar response of a low frequency like 500 hertz or 1,000 hertz, you get what looks to

be more like an omnidirectional response, even just on the unaided ear based on the size and the shape of the head.

High frequencies, however, their wavelengths are shorter, and so they're going to bounce off or diffract. Yeah, diffract off of the head. And this makes it be that the side that gets the source of the high frequencies is going to be louder than the other side based on head shadow effect. And when you do a polar response, again, for the high frequencies here in 2,000 and 4,000 hertz, you see that looks a lot like a right ear directional response on a hearing aid. And that's just what's happening organically with an unaided ear. So why not emulate that with our technology so that the technology and our directional programs is directional in the high frequencies, omnidirectional in the low frequencies to maintain these really important localization cues.

And for wind noise as well, wind noise is a tricky problem because wind at ease, wind noise is caused by turbulent airflow around the microphones and it's unpredictable, and there's usually a difference in how it arrives at the microphones. And if you remember with directional microphones, they're all about differences in mic diaphragm movement. Turbulence contains pressure fluctuations, and then the hearing aid mistakes those as things that they need to be processing as directional on a traditional full band directional approach. So what that means is that, again, with the nearfield phenomenon, this amplification can overload the hearing aid, especially in the low frequencies, and you'll get a booming, louder wind response if you have directional in the low frequencies because wind noise is mostly in the low frequencies below 3,000 hertz.

So again, if we can keep it in omnidirectional for the low frequencies, your wind noise is going to be reduced automatically as compared to having a full band directional response. This is a really old textbook illustration. You'll see by the labeling of the different curves here on the right, that the open air is the red plot, and then the

directional and the dual omni, which is just a two mic directional system, are the light blue and dark blue, and four wind noise. You can see that there's much more pressure, there's much more energy in the low frequencies when process does directional versus an open ear. Omnidirectional, again, it's not as perfect as an open ear, but it is better than directional.

That's the yellow line. You can see the reduction in the wind noise energy just by virtue of not having directional in the low frequencies. So it's really great illustration that shows what you get as a added benefit of having omnidirectional in the lows, that multi-band approach to directionality really gives you some nice benefits for the user's own voice, for the localization, and for wind noise. So finally, this is a schematic for anyone who's like really kinda, I don't know what to say, maybe into this, I don't know if it's nerdy or whatever, but I kind of like these because it shows how sound is going through the processor in terms of directionality. So at the top of the screen, you see the input at the front left, rear left, rear right, and front right microphones, those black microphones at the top.

And you see that the multi-band approach is treating different frequencies different, and the directionality is working together, but it's getting the best benefits so that there's low frequency omnidirectional to preserve those natural cues. There's beamforming in the mid frequencies, there's directional that's fixed in the high frequencies to preserve some of those other monaural spectral cues and level differences. All of this is working together in a sophisticated system to get beamforming for mic directionality to make the signals noise ratio better when it needs to be better for the user. So let's check off that we talked about comfortable navigation in noise. And with that, we have a couple minutes to play a couple fun interactives. So please write in the chat, if you can, the answers to these questions, which may be helpful for the quiz.

Which listening mode of 360 All-Around emphasizes naturalness and overall sound quality? I'm going to make the answers kind of fall away so that we can see the correct answer, but go ahead and write it in the chat if you can. I see spatial cue, that is correct. Good job. That is correct. Spatial cue is correct. All right, way to be. Which lessening mode of 360 All-Around uses the brain's binaural processing to shift focus without losing awareness? Let's see what we have here. Which one is it? What we talked about making memories. Binaural listening. Yes, you got it, great job. Which listening mode of 360 All-Around provides the best signal-noise ratio in noise when speech is in front?

By process of elimination. Speech intelligibility, very good. All right, fantastic. What is the proximity effect? The proximity effect was what we were talking about with why full band directional makes a boomier sound quality for the user's own voice. Oh, this is a tricky one. There's three correct answers here. The proximity effect is a longstanding issue with traditional directional microphones that are full band. It is the fact that directional mics amplify low frequency sounds that are near more than far away, and it's made even worse when bass boost is applied. So any of those answers are correct. The proximity effect, it's difficult, but you can avoid the whole thing if you keep omnidirectional in the low frequencies.

What new feature of ReSound OMNIA replaces Ultra Focus? Okay, so what are we calling that new feature to replace the manual selected Ultra Focus? Front Focus. Good job, all right. That is correct. And finally, this one has more than one answer correct also. What is an advantage of a multi-band directional approach? Is it better access to localization cues than full band? More natural own voice perception as compared to full band? Better sound quality as compared to full band? Or the ability to use M&RIE? You guessed it, it's all those three. Has nothing to do with M&RIE at all. M&RIE is the receiver that has an additional mic to be able to pick up more individualized pinna response cues.

So all three of these are advantages of multi-band directionality with or without the M&RIE mic because it has nothing to do with that. So since we talked about M&RIE, let's just give a shout out to M&RIE. It is an option. It's another kind of receiver that is at your disposal. If you feel like you have a patient that fits into the criteria, it's a great way of optimizing pinna response cues so that they get the best in sound quality, spatial hearing, and localization, but it's just an option. And standard receivers will give you all of the benefits that we talked about in this presentation, notwithstanding a M&RIE receiver at all. But if you do fit M&RIE, it has been shown in studies to reduce listening effort, to be better for clarity on phone calls, more natural hearing experience, improved localization, and it also is a nice protector of wind noise because the microphone is picking up inside the ear, and it's basically in a little cave so the wind can't get to it. So I think I'm actually one minute over. I'm sorry for going over. I don't have a lot of time left, but thank you so much for joining me. If there any questions, I can hang around for a couple minutes. Thank you again for your time today.