The Future of Connected Hearing Healthcare

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Presenter: Don Schum, PhD; Annette Mazevski, AuD, PhD

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Partner: Oticon

- [Don] Hello, everybody, this is Don Schum from Oticon and I'm joined today by my colleague Annette Mazevski. And today what we wanna talk to you about as the slide will tell you is the Future of Connected Hearing Healthcare. There's a lot of very interesting technologies that are now available to us as a field and they have come to us from oftentimes from the other medically, related fields in this country and in this world and they are starting to show up in the hearing healthcare realm. And so what we wanna do today is for those of you who are not necessarily familiar with the terminology and the applications, spend some time talking about this terminology and these applications and then spend a little bit of time talking about the potential implications, for the field of Audiology.

So let's go ahead and get started. We will start with a discussion on the learning outcomes. We wanna make sure that you're comfortable with the terminology in this universe of connected hearing health care. So Annette we'll spend some time going through those terms just make sure that you know what they mean. For each of the areas that we'll spend time talking about, we'll talk about some of the key potential benefits for patients and for practitioners in the field of Audiology. But we'll also spend some time talking about some of the potential either professional issues or drawbacks or limitations in each of these areas. So we wanna make sure that going forward you are on a good standing, about understanding these areas. One of the things that I'll say as a caveat as we enter this is that this is a very fast moving part of our field. These technologies are evolving all the time and so what we talk about today will be out of date tomorrow and definitely even more out of date the day after and the week after and the month after. But for now hopefully you'll get a snapshot during the fall of 2019 of where the field is at this point in time. And to give you an idea of what your future as a hearing health care provider will look like, based on some of these technologies. So one of the reasons why I wanted to do this topic for you is that there's a lot of discussion going on right now, in our field about alternative delivery models, things like OTC, things like internet hearing aid sales, other oftentimes patient driven or patient

dominated service avenues where the role of the hearing healthcare provider is starting to be questioned to some degree and that has caused rightfully a certain amount of perhaps nervousness in our field about really what is the role of the hearing healthcare provider in the future? I think after you listen to this course and see what some of these technologies are, you'll very much get the idea that the need for well educated, well informed clinically oriented healthcare providers, in our field is going to be greater than ever as these technologies come online. There is so much knowledge that is necessary in order to get the most out of some of these technologies that we'll be talking about. And so from the Oticon perspective we see the future of Audiology and the future of hearing healthcare quite bright for the professional because these technologies are going to require to have very knowledgeable people who are at the center of this process. And so we are quite bullish on the future of hearing healthcare. Much of what I'm going to talk about is driven out of what we have been doing at our research facility, Eriksholm.

Eriksholm is a freestanding hearing research facility that's part of the Oticon and Demant families in Denmark. It sits apart from our main Development Office, up in the northern part, the northeastern part of the country. It is a facility, a state of the art hearing research facility that is staffed by a large number of very talented men and women who know a tremendous amount about, future technologies, current technologies, hearing, the disorder system and how these things can all come together. And so what I would encourage you to do if you really wanna get a good view of what the future of hearing healthcare could look like is go to the website www.eriksholm.com and you'll see a very interesting vision of the future. They are very forthcoming and transparent about a lot of the research that they're doing so you'll see a whole lot about how many of these new technologies are being investigated and being incorporated into potential future, solutions for patients and it's a very interesting lead. So if you think that the future of hearing healthcare is going to be low cost inexpensive over the counter or over the internet devices, I would encourage you to

take a look at what's going on up at Eriksholm because I think you'll get a very different view of what the future of hearing technology can look like. So next what we wanna do is jump into the terminology a bit and so what I'm gonna do in order to move forward is I'm gonna turn this over to my colleague Annette Mazevski, Annette.

- [Annette] Thank you Don and thank you for the overview. What I'm going to do now is start with discussing what Connected Hearing Healthcare is and what the importance is behind it. And so related to connected hearing healthcare, it can actually mean a number of different things to different people. Like artificial intelligence, it may not hold just one definition but rather it can be considered an umbrella term, for a number of different aspects that relate to it. One of the most common cutting edge areas that people gravitate toward is streaming technology and an individual's capability to be part the information superhighway. But at the same time is just a gateway, there are other aspects to think of and some as minimal as a volume control change is relevant and others that are more significant such as keeping tabs on your overall health. In addition to the ways that one can connect the purpose behind, using connected hearing healthcare can vary. The goal is typically the same though and that is to make the lives of the people with hearing loss or the people who work with those who have hearing loss easier. Perhaps a hearing aid wearer wants to track how much they're using their hearing aids and when they're in difficult listening situations or perhaps they are bedridden and they cannot come in for fine tuning. Their hearing care practitioners can actually remote, into their devices and make the adjustments from afar and making it easier on both ends. And these advances give the hearing aid wearer options that have not been available previously and so lemme go into some details about that. Some of the components that you see here, I would like to go into some greater specifics and I'd like to ask you all, how many of you have a good grasp of what artificial intelligence really is? It's okay if you don't know much, as you can see there are a lot of components here that we have to take into consideration. And what's interesting here is that even those in the field of artificial intelligence say that the

concept and the definition of it is actually a moving target and is constantly evolving. And like Don had mentioned earlier what we have seen in terms of advances may be obsolete tomorrow or very soon after. And so when we think about all these components, there's quite a potential for utility and in a number of fields and this includes healthcare in general as well as our field of Audiology. Related to artificial intelligence. Again, this is considered an umbrella term for a number of concepts that relate to the intelligence of machines that we use for different purposes. And depending on what we want, a particular function can give you a desired outcome and we'll go into a little bit more detail with that especially when it comes to machine learning. But all these components are a means to an end and even deep neural nets for example or in other words, deep learning can create a network that will connect a particular idea or concept to all potential connections. And this can potentially make a machine smarter as it learns more.

These AI components help build the foundation, for other machine related and machine driven solutions and these include things such as apps and wearables and telehealth. Some of these terms I'm sure you're already familiar with. Other aspects such as big data and system integration may be considered supportive but at the same time they're also crucial in the development of machine learning and deep neural nets in order to make the machines using them smart. Of course, we'll get into greater specifics of these components in this talk and we hope that this talk will shed a greater light on how these components can be integrated in our field and why it's so important to understand their relevance. So as you can see here, there are a list of topics that we're gonna go through and as we go through all these topics I want you to ask how can these be integrated and why? Ultimately, all these topics can fall under a quality of life issue. The more we learn about the power that is behind these components, the greater the likelihood that the devices our hearing aids wearers use, will make smarter decisions on their behalf, sometimes without even asking or needing to know about those decisions. But before we actually go down that part of the rabbit hole, let's start

by discussing some of these topics and let's first start with telehealth. One area that's very applicable to making these things easier on both the audiologist and the patient is telehealth and a lot of you are probably very familiar with it. Some of you may already be using it in your office or in your clinic and as you're probably already familiar, it can be utilized in a number of different ways from testing hearing, in very remote locations to making adjustments for a hearing aid wearer, on a super snowy day for example. There are a number of different ways to communicate and share information with patients and telehealth is a fairly recent arrival. So let's go into some greater detail, about the benefits behind this innovative feature. There are a number of benefits related to telehealth. For some the thought of a more modern approach to care is intriguing and appealing and for others time efficiency is paramount and not all appointments require an in depth consultation or significant amount of time. It also allows for simple issues to be addressed that don't require a physical appointment such as hearing aid adjustments or some type of fine tuning.

For some it may just be difficult to get to the office and this can be related to how far they live from their office, the inability to maybe find a ride to get to an appointment. They may be bedridden or even the weather can cause some issues in making it to an appointment. I for example, grew up in Central New York and although we had four seasons, those seasons happened to be winter, more winter mud and construction. So by incorporating telehealth, some of these concerns that we have can be alleviated and they could possibly reduce stress or other headaches that could arise by trying to get to an office appointment. So with this also both the patient and the audiologist have the opportunity to listen to see each other and they can see each other in real time and this can also enhance the appointment of experience. But the big issue here and the big question that may possibly come up is does it enhance or detract from the relationship and the patient and the patient experience with their hearing care provider? And it's not really a clear cut answer so basically, I'm just going to say that it depends. Some people will say it removes part of the report that you build while you

see somebody face to face in the office. However, it can, again alleviate the other issues that we had discussed in the previous slide. No one necessarily wants to travel several hours for an appointment, unless it's absolutely necessary. And a follow up appointment can still cover, the same information virtually as it can physically. Telehealth is constantly evolving but it can instill the impact intended for the patient and that relationship between the hearing care practitioner and the patient can be preserved, especially if the patient chooses not to come in for the reasons mentioned in the previous slide. And a virtual office visit can be a fantastic alternative to no visit at all. So with all that said I want to switch gears again and hand the baton back over to Don where he's going to talk more about big data and cloud-based signal processing.

- [Don] So we're gonna move in a couple of topics that are not necessarily here quite yet in our field but they are very close. And those would be big data and cloud-based signal processing. And again, these are terms that you aren't not necessarily familiar with. Maybe you've heard about them more in the general press, things like that.

Others of you might know a whole lot about this topic and so we don't wanna pretend to be experts in all these topics. But for those who are relatively new to this terminology, lemme talk about first of all what big data means. Big data means a lot of different things and it's used a lot in commercial applications. Of course every time you get on your smartphone or you log into your Facebook account and you see ads based on some search you did for a product, on some other device somewhere, that's big data at play. That's trying to, commercial entities trying to target how they're going to advertise to you to be very efficient about doing that. So big data has a whole other end to it which is from the commercial standpoint. But in the healthcare arena, big data means something different and it basically the opportunity for healthcare providers to create better solutions for individual patients, based on an accumulation of data from many, many patients with similar conditions, across many, many different practitioners. And it's basically the good side of the power in numbers. And I want you to imagine

this scenario. Let's say that you're a cardiologist for example and there's some sort of a rare condition that you might only see once a year. And let's say you've been in practice for 10 years, that means you've seen 10 of these cases over your professional career. And so the path to treating that case might not necessarily be extremely clear to you because your experience in that area has been limited. But what happens if you can connect your 10 experiences with those experiences from 100,000 other cardiologists, around the country and around the world? Now you're talking about a million different cases, if my math is correct. You're talking about a million different cases of this relatively infrequent condition being treated by professionals all around the world. And so the knowledge, the insight, just the critical mass of data necessary to understand which treatment options seemed to work out the best has grown a huge amount. And that's where this idea of trying to join in the experiences, from many different health care providers, into a central organization, a central database in some way, shape or form brings power to the patient. And I'm not gonna get into all the regulation and all the practical aspects of how that gets done.

Of course, anytime we talk about big data or cloud computing or any of these other applications, just assume that all the appropriate data protection, privacy guidelines are in place. We're just assuming that that takes place because there are definitely are people who take a look at this. But the idea of using big data in our field, for example, imagine a unique genetic condition that could cause hearing loss but we're really not sure because not enough clinicians see that issue enough. But if you can start accumulating data all across, many many different providers then you get a, clearer picture about the genetic, the impact on hearing loss of that particular genetic condition. Imagine that for example, ski slope losses that's a condition that a lot of patients see and our treatment options with ski slope losses are not as clear cut as they are for other options. But if we could accumulate data across there that might give a better, clearer picture about how usable for example high frequency information is to people with ski slope losses since that's always been a little bit of an issue. Imagine,

even within a company for example, taking a look at the way many practitioners use our fitting software, for example, would do particular fine tuning adjustments, based on a particular complaint that a patient has. These days fine tuning adjustments are pretty much based, on the knowledge base that individual practitioners have developed over the years of fitting hearing aids but isn't there some value of trying to somehow accumulate that data. So big data has that option or that potential of improving the solutions that we can come up with for individual patients based on an accumulation of data across many patients and many providers. Now, there's always a role for individualization, absolutely, there's a role of individualization but having a more widespread knowledge base to be able to direct that care is important. And that's where the potential of big data comes into play.

There are very few examples so far in our field where big data has really started to affect the way we go about things. And it's mostly because in our field of Audiology there's not a lot of really large sets of data that have been standardized, across many different facilities. And some big healthcare changed, not changed but healthcare organizations there might be some of that. Like, for example, within the VA, there's some amount of accumulation of data. Within a big, let's say a Regional Medical Center, like the Kaiser organization not in California or some of the other kind of very large regional organizations, you had the potential of accumulating data across their system in and of itself. Like I said, within a hearing a company, a company like us who has fitting software, we have the potential of linking the fitting software across providers and things that. Again, all of this done definitely within the view site of the hearing care practitioner, all data privacy, protection issues covered and things like that but the idea being that overall there hasn't been, one big standardized hearing health carried database set up, in this country or in most other countries at this point in time. So big data, I think is something that you can expect to see some improvements on in the future but again it's a matter of managing that data and figuring out how to get the best out of it. But definitely there are options out there that can really make

treatment for individual patients, based on the experiences across a broader group of patients improved as we go forward. One of the questions then would be okay, exactly which problems could be better solved? And I gave you a few examples like genetic, the hearing loss implications of certain genetic conditions, perhaps fine tuning advice, perhaps fitting advice for certain types of hearing losses, different ideologies or audiogram shapes or things like that. So those sort of questions need to be asked, need to be framed and then the data either has to be captured or mined in order to answer those questions. And so it's a different type of problem then we face in our field before. In the field of Audiology we typically don't have, data scientists available to understand how to go into these databases and organize the database and get it out. But you're seeing more and more interest in that area. There's a big project that our group at Eriksholm was involved with in Europe over the last few years about trying to start putting that sort of database together.

So that definitely is interest in this area but at this point in time we just haven't seen that really get to the point where the typical clinician can go to some sort of database to really get good answers that we don't currently have. But the future in that area I think is very bright, I don't think it's gonna be that long before you start seeing, some movement in that area. A somewhat related topic that some people might confuse in terms of the terminology but it really is a different type of topic with a lot of crossover, there's something called cloud-based signal processing or cloud-based computing or cloud computing. And basically what's going on with cloud-based signal processing is the idea that the amount of digital signal processing, available in a hearing aid is not as much as potentially could be available in a smartphone. And the amount of data signal processing that is available in the smartphone is definitely not as great as you can if you send the data up to the quote cloud. Now, one of the things you should know about a cloud, I saw it on a T-shirt one time somebody was wearing it said, all that cloud means is someone else's computer. And that's really what it is, the cloud is just some sort of much larger capacity computer system that can do the sort of signal

processing that is not available on individual devices. And so so much of what happens these days during software, whether it's software on your laptop or software on your desk computer or a unit desk computers even exist anymore or definitely the software on your smartphone, is really all about sending data up to the cloud and letting the signal processing and the analysis and all the other work that has to be done on the data be done off site basically, outside of your electronic devices. And obviously the big advantage of something like cloud computing is that you just have that much more horsepower available to apply to a problem that you just have the capacity of the entire internet of power to be able to do some of the things that you just might not be able to do on a smartphone or on a hearing aid. At this point as we stand in 2019 as far as hearing a technologies go, no hearing aids are directly connected to the cloud.

All hearing aids that are commercially available to these days have to go through a smartphone or some other device to get up to the cloud. And it's simply because having WiFi in a hearing aid that as a technology that is a far too energy consuming technology to put directly in hearing aids. Will WiFi be a hearing aid someday? Maybe hopefully, maybe you don't need to go through a smartphone or some other gateway device to get up to the cloud in the future. But at this point in time, any interaction with the cloud whether it is for IFTT or any sort of language translation service or anything else that has been talked about as being in the hearing aid that all these days all goes through smartphones. And so that is part of the technology that we're facing but is something that may very well evolve as we go forward. Having more and more signal processing, embedded in smartphones or more and more signal processing actually embedded, in hearing aids is something we expect to happen in the future. But right now there are gonna be some limits of course, technology always has some in the now limits and so that's why we would send things up to the cloud. The big issue, when you talk about cloud computing though is what can the cloud help us do better? Meaning that it's one thing to say well, we could just send it up to the cloud and have the cloud take care of the problem. That's an easy thing to say but the question is okay, well,

what are you going to ask the cloud to do? In other words, what sort of signal processing do you need to send the data to the cloud for in order to do better? And that, the answer that question isn't necessarily all that clear because some of the most data intensive signal processing that is being at least talked about, for hearing aids these days are things that are probably going to need to be done in real time. In other words imagine some sort of speaker separation algorithm where you're trying to separate one voice from another and you need just a lot of really heavy duty signal processing to do that and Annette will give you an example about that a little bit later. But imagine something like that, if you're gonna try to do a speaker separation algorithm to allow one speaker to stand out better from another speaker that is far as all sort of signal processing routines that have been talked about at this point in time. That just takes a lot of computing power but it also needs to be done in real time.

In other words you can't send a conversation up to the cloud and have the cloud try to sort through the two different voices and accentuate the voices you're interested in and minimize the voice you're not interested in and then send it back to your computer several seconds later. that does you no good, that is not the sort of user experience we'd ever expect, patients ever be interested in, they need things to happen in real time. So one of the inherent limitations of cloud computing is the fact that it takes time to get up to the cloud, do the signal processing and come back. And as you know for example, if it is a some sort of speech and noise routine where you're trying to separate speech from background noise or whatever, it's so important that the signal that the speech signal that the person hears be done synced with the visual signal that they're getting because visual signals are so important to patients with hearing impairment. And if you get any sort of offset between when the auditory signal arrives and the visual signal arrives that can be very disruptive and so it only takes, I've seen different estimates but 10 20, 30, 40, 50 milliseconds if you even get that much offset between the auditory signal and the visual signal then it becomes disruptive to the patient. So if it is a signal processing routine that requires real time or very near to real

time sort of performance, cloud-based computing is a little bit of a limit on that. Because it just physically takes time in order to get up there and even if we're only talking a couple seconds or so that can be a very disruptive thing. Now there are other applications where maybe the cloud can be very useful. For example, if you're trying to do an analysis of an environment. So maybe some sort of signal processing routine where you're doing more of a long term analysis in the environment to try to identify the types of sounds that that environment is in and then send directions to the hearing aid to change the way it would do signal processing. That's something that perhaps cloud computing, could be very useful for because the absolute real time nature of the technology is not quite as sensitive as if you're doing some other types of signal processing.

So if you're just talking about maybe longer changes, in the hearing aid signal processing, go into a restaurant mode or go into a speech and noise mode if that's what you think is gonna be helpful or go into a beam forming mode or whatever. And that's more of a long term transition in the hearing aid that can go over several seconds then perhaps beam form or then perhaps cloud computing, would be a useful application there. So when we talk about something like cloud computing, it really comes down to can you afford the time to send it up to a better signal processor or more powerful signal processor and then send it back down to the hearing aid? Will the application still be useful to the patient? And sometimes the answer is gonna be yes and sometimes the answer is going to be no. But you're gonna see, I think you're gonna see cloud-based solutions again, come online relatively soon in our field. I think that this is something that may be the sophistication and the the absolute performance of the applications will get better over time. But I think you'll start to see some of these things really start to take hold in the way we do, signal processing going forward. Okay, but now if we wanna turn and really talk about the future of signal processing and really where some of that really interesting future, activities are gonna take place

we need to take a look at the overall topic of artificial intelligence. And so I wanna bring Annette back on to talk to you about that topic for a bit.

- [Annette] Right, thank you Don. So as he mentioned we're gonna have a brief overview of artificial intelligence, machine learning and deep neural nets. And for those of you who aren't as familiar with these topics, the implementation of these types of technologies and learning are very exciting and not surprisingly, very innovative. These are the types of areas that help you and your patients without you really recognizing that it's happening. And by collecting data and the examples that Don was talking about in terms of big data changes are occurring in the background that can elevate the experience that a hearing aid wearer has. One of the best ways to think about these concepts is from a broader perspective, down to a more narrow area. So for all intents and purposes artificial intelligence is a broad term that refers to machines acting in ways that seem intelligent. And not surprisingly there is a lot of discussion over the correct definition of AI but for the sake of this discussion we'll just keep that definition broad. As to digging deeper what I want to talk about in particular machine learning, although there are three categories that do fall under artificial intelligence. So like I said machine learning is the first area that we're gonna cover and actually with deep neural nets that falls under the category of machine learning. And we'll go into couple of examples there of how we can relate deep neural nets and deep learning to our field. The other two areas of artificial intelligence and we're not gonna talk about them in any detail, in this webinar are robotics and natural language processing. I'm sure that you've heard some about both of these areas and they're very, very well off in terms of their development. But I do want to have you keep in mind that those other areas that are also very relevant to our field and our industry. But for now let's go into some greater detail, on machine learning and deep neural nets. So as I mentioned earlier, artificial intelligences utility is ever expanding and some of these concepts are more familiar than others. And in the case of machine learning what we're looking at here is essentially a computer program that has learned from experience and any kind

of information that a human or a programmer may send to a machine this is how machine learning in essence comes about. So when you're looking at a command or a set of commands what the machine is doing or in this case if you're looking on our screen and you're looking at the cell phone, it will try to design, understand and use a computer program that learns from experience. What I found interesting actually over my readings and learning more about this area is that machine learning has been used in Oticon products, for quite a while since the early 2000s with the introduction of the activity analyzer and synchro. And at that time what the activity analyzer was doing, was collecting data from the environment, the hearing aid wearer and the hearing aid itself. And then it ultimately looked at how well the hearing aids responded to the hearing aid wearers listening situation.

Today the improvements in AI have left exponentially and now include the use of personalization and tracking of habits and mobile apps. And you're probably familiar with some of the apps out there that do this and the more information or data that's fed to the machine or to the cell phone or the app or in this case the hearing aid, the easier it will be for the machine to begin to predict particular settings or outcomes that the hearing aid wearer prefers. So what's important to take away from machine learning is that machines do what they're told and learn from what they're given. And that takes a lot of data and a lot of learning for a machine to identify, for example a stop sign or speech in the presence of noise. And because of how much data is required that's kind of the reasoning for the term big data. If for example you wanna think of something outside of the field, think of if you recall the movie "WALL-E", the robot and he's going all over planet earth trying to find and identify plant life. Ultimately what WALL-E was programmed to do the input was to find something that looks like or similar to a plant so that way he can report back to the mothership that there's oxygen present again on the planet. And so as more information like this is fed, possible outcomes are created and going back to the field of Audiology and our types of use cases in the terms of hearing aids the more decisions and feedback that is received, the better the output

and the likelihood of a satisfied customer. So okay, in the audiological sense, artificial intelligence has a lot of potential practicalities, especially in the presence of noise. For example signal processing needs to be predicted and adjusted based off of sound seen analysis. So what you're looking at here are a number of different types of predictions that can ultimately as you collect more data predict better predictions and then get to even better and more predictions after that. So when we are looking at these types of bits and pieces of information, we want to look at what is capable in terms of data and all the data that one can collect. And if you've heard of the adage that more data is better data, that definitely still holds especially in this example. As more data is collected, the better predictions will become and as machines create better predictions, the resulting outputs can become more home to what for example a human may expect. And in addition to all of this artificial intelligence, can assist in analyzing and predicting use patterns throughout the course of the day or maybe learn about a patient's auditory habits and even potentially provide more complex analysis of listening environments.

These predictions which ultimately are a combination of personalization and signal processing will start to delve into the world of deep neural nets and this is where we're going into this next subcategory of machine learning. And the use and application of these predictions by the hearing aids will ultimately create, smarter decisions for the hearing aid wearer, without the need to ask him or her for any feedback. And at least, especially when we think about how far we've come in terms of technology and what we actually can do with hearing aids, I find that aspect to be quite remarkable and I hope that that can really impact the way that you're thinking about this type of advances in technologies as well. And going a little bit more into deep neural nets what I'm going to do here is play you an example and what you're going to listen to are two distinct speakers and I want you to have a better understanding of how these deep neural nets come into play. So what I will do here is I'm going to play this clip twice

because I want you to listen to one of the speakers and then I want you to switch and listen to the other speakers. Hang on one second.

- While I'm in this

- I used to be driving to work all the time

- I need you to take care of a couple of things.

- but I get tired of sitting in traffic.

- I need you to call the exam office and

- At least with the train I can get reading

- last week's sales figures. time but usually saves

- Also this memo

- Some time.

- and distribute it to everyone .

- If I'm lucky, I can catch an express train and be in the office by 8:30.

- [Annette] Okay, and I'm going to play it for you once more, I want you .

- While I'm in this

- I used to be driving to work all the time

- I need you to take care of a couple of things.

- but I get tired of sitting in traffic.

- I need you to call the exam office and

- At least with the train I can get reading

- last week's sales figures. time but usually saves some time.

- Also this memo

- If I'm lucky I can catch and distribute it

- an express.

- While I'm in this

- I used to be driving to work all the time

- I need you to take care of a couple of things.

- but I get tired of sitting.

- [Annette] Okay, all right. So it's a bit tricky but I'm sure you were able to decipher at least some of what each speaker was trying to say. And in this case you as the individual that is listening to the sample, you utilize your cognitive system in order to

separate the speakers and to listen to what they were saying. You most likely employed a number of different cues to do the speaker separation. And as you can see on this slide right here, there are a number of different cues and aspects that you utilized or that your cognitive system and your auditory system will utilize in order to help with that speaker separation. Clearly the more cues that were utilized, the deeper the involvement of your neural network or in this case, again, your cognitive system. So when you think about all the different types of acoustic aspects that can be taken into account and how each component can interact with each other, I hope that you can see how all the exchanges and interactions can start to build what would look like a network or neural network. All these, if you will, inputs in combination with each other can provide a multitude of outputs. And this can include the basis for a new level of complex signal processing for hearing aids.

Let's have another example here. Let's look at this example that's a little bit more visual and it'll show you how deep neural nets could be, utilized in a common situation that a lot of our patients will run into and here you're looking at a restaurant. This crowded restaurant details plenty of the issues that can make listening difficult. I'm sure you can see them all. There the presence of other speakers, there are utensils that could potentially be clinging, reverberation, even different lighting. And clearly this list can go on and on. However if you can apply the speaker separation example, from two slides ago, the use of the deep neural net and its cast of cues can be greatly beneficial, in this type of environment. Another way of looking at deep neural nets is to determine what outputs would be created by the inputs provided to the system. So as you can see here you have, your inputs on the left side, your outputs on the right side and in the middle is what we would call hidden layers which is essentially all the possible next steps of processing that can lead to all the possible outputs that you see on the right side of the screen. This clearly can be complex and it could even seem to be wrong in some cases and what I want you to do now actually is just to keep in mind that the output is the result of the input plus possible possibilities that can occur in those

hidden layers. So an example of this is something that could cause an end result of a miscommunication. So maybe in the input phase plus the hidden layers phase, if you go back to that restaurant example, you have an individual who's having a really hard time really hearing what the person in front of a may be saying. And so that input plus all the cues that are being utilized within the hidden layers, may necessarily give you an output but it could very well be misconstrued and you may not have the conversation understood, in the same manner as the way that you were intending to have that conversation. So therefore that output could actually end up being, something different than what was anticipated. It's not that the output was necessarily wrong but but rather the individual was using the input and the cues that were readily available to conceive the end result. So the design of these deep neural nets, was derived from the visual system of mammals. And you will see in one of Don's upcoming slides a little bit more, about this as well. So as we look again into another visual component or how to look at this visually speaking, we want to apply this to speech and how someone may be listening to this.

So first what I would like to show you here is an example of what a single speaker's voice would look like. And yes this is a great diagram, super stimulating, I know but to hear me out here. What you're looking at here is pretty straightforward and it's pretty easy to distinguish for example between the stops and where there's a lot of energy for vowels and then you're possibly even looking at the here. And when you take that in mind and look at other aspects of for example in this case the vowel e what you're looking at is the phonetic structure among four different talkers. And you can see some of the similarities here in the structures. However the point here is that not all four talkers will produce e in the same way. And as you can see for example with the second format there are some differences here, among all the different talkers. Even though the vowel itself is classified in the same way as being said and identified as e. Each talker here has a particular detailed shape and so as again, you can see all these are differences and yet with the way that the phonetic structure is, it's not, it's the

same yet it's also different. When we take that into account and lemme go to the next slide here. We're looking at a combination of what three talkers look like. It's a bit different than, just the one voice from two slides ago but a deep neural net, what that could do is learn from the individuality that was displayed, for example, in the last slide and use it to deal with a more complex mixture of voices like what you see here. So when you ultimately we add all this information, acoustically speaking. What we want to think about for a minute here is what does a human or in this case a hearing aid wearer interpret? And also what does a machine or in this case a hearing aid interpret? So if a hearing aid were to take a snapshot for example of this kind of acoustic information and combine it with the predictive behaviors and patterns mentioned earlier in this talk, an entirely new level of processing and personalization will be readily available, for the wearer. In addition to this, adding another layer of acoustic analysis and even natural language processing, can give the hearing aid wearer, more utility than simply understanding speech.

But with that said, the goal here is to ensure that a well developed neural network is in place, for the hearing aid to access and for the hearing aid wearer to benefit from. Don very briefly talked about the importance of when you're talking about cloud computing, what can happen in real time versus offline. And there are some considerations here to recognize especially with the pros and cons of being able to process information offline compared to again in real time. Clearly a machine will have less pressure and concerns related to performance when it's not working in real time. But again, most people rely on what information is occurring at a singular moment and again, they need to have that information readily available to them if they're having a conversation. Cleaning up a signal though and if it's done later may not help you when you need it at the dinner party that you might be attending or if you're at a football game. But what can be actually helpful and beneficial is the information that's being learned and processed offline, can help those real time situations later. So if there are things that do pop up during a conversation or if there's particular types of cues that keep on occurring over

and over again, for example, in the same environment. Again, the hearing aid learn from that and then when it does come back into that similar situation after it had time to process that offline it could help the hearing aid wearer again, in real time. So overall there are still some big questions that need to be addressed and they will most likely continue to be addressed for quite some time. What we have now is a good understanding of how artificial intelligence, machines and deep learning can be applied to common use cases for hearing aid wearers and why these advances in technology, will improve the way they hear in a multitude of situation with more advances to come. And so with that I'm going to go back to Don and he will continue our discussion with sensors and brain integration and also to wrap up our talk, thank you.

- [Don] Thank you Annette. The discussion of AI and deep neural nets and machine learning really gives you an idea of how complex signal processing can look in the future as we're trying to use even more and more powerful ways of analyzing data to create future solutions. But when we turn to the topic of wearables and hearables, actually we're kinda coming back to the present day because these are things that are coming online even as we speak. And so because of that, I wanna spend a little bit of time talking about what sort of technologies you're currently seeing, coming online and what some of the implications are for those. You probably noticed that there's an explosion of the idea of using sensors in hearing aids or the term wearables or hearables or things like that. And the reason why all sudden there's so much interest in this area is pure economics. And what I mean by that is that if you wanna build something for a hearing aid, you have to assume that you're going to sell X number of hearing aids for a certain price in order to justify putting the research and development time into building a new sensor. But when you can tap into sensors that are being built by other industries, let's say Fitbit for example or other industries like that, you then can and you can borrow that technology and move it in the hearing aids, then you can access technologies that have a much lower cost to development 'cause they've already been developed. So the reason why there's so much interest in sensors right

now is that there are so many other areas of consumer electronics and even other healthcare areas that are very interested in sensors. And so our field has jumped on that trend in a very big way and the thing about sensors is that because of the volume of the number of different Fitbits being sold and other health monitoring devices that are being sold, they are low cost devices, they are small and they don't use a lot of battery. And so because of that they are the perfect sort of technology that can easily be implemented, into modern day technologies. And so if you want to know where this came from, it comes from the fact that Fitbits are so popular basically.

That's the way you can think about it. There's millions and millions and millions of Fitbits that have been sold and so that is driving this whole consumer electronics, interest in sensors and the idea is, okay, how can we move them into hearing aids? There are sensors available that could could measure a lot of different things both about the human body, including things like heart rate and respiration and things like that but also things about the environment. They can be an acoustic monitor, they can be GPS system, they can do a lot of different things and so you've seen a lot of interest in this area. Starkey as a company is one of the companies who've been out there really out in front, about talking about the role of sensors in the hearing aids. We have been doing that to a certain degree also with our hearing fitness app on our smartphone or on our Oticon ON app on your patient smartphones. It is a way in which we are monitoring the environment and giving the patient feedback about how much they're using their hearing aids and the type of environments that they're using them in. And there's a lot of other ways that sensors have been talked about being used, in the hearing healthcare field. One of the big issues that comes to mind that I think that our field is going to have to really wrestle with is the idea of scope of practice. Meaning that yes, you can build sensors in the hearing aids that can measure a lot of other things about the human body, for example but the question becomes whether or not it is within the role of the hearing healthcare professional to be measuring those things or providing devices to patients that can measure those things. And there's just a lot of

discussion going on in that area and there's no right or wrong answers but it is part of a discussion about whether or not it's appropriate for an audiologist or hearing healthcare provider to be selling devices to patients with the promise that they can measure different healthcare conditions. And in my mind and in general from the standpoint of the Oticon perspective on this, it comes down to whether or not you're measuring a clinically relevant, healthcare condition versus you're just giving good advice. So for example, if we're monitoring use time, in a hearing aid and the type of environments that a person is in and giving them coaching that they should continue to try to get X number of hours per day and in complex environments in order to stimulate the cognitive system, that's just good advice. But if we're measuring some other healthcare condition, let's say looking for some sort of arrhythmia in a heartbeat or some other healthcare condition and saying oh, we've detected such and such disorder, potential abnormality or an anomaly in the way your cardiac system is working, you should see your doctor, we've really gone well beyond what the role of the audiologist or the hearing healthcare provider probably is defined as.

And so again, there are no, there's no simple answers, we have a very strong position, from our company's perspective but that doesn't necessarily mean it has to be shared by all companies. But I think it's something that our field is going to have to really take a close look at to see just how far we as hearing care professionals and audiologist can actually be involved in other aspects of the patient's health. And so again, yes, sensors are relatively easy to put in hearing aids these days, they can monitor a lot of different things about the patient's health and the way their body is reacting and what their body is doing but then it comes down to okay, who's handling that data? Who's providing advice to the patient? How consistent is that advice? How consistent is the data? A lot of things in terms of scope of practice and liability concerns and things like that. So it is an open area that I think has to be discussed quite significantly in our field and like I said, there's no easy answers but it definitely is going to open up some realm of discussion in our field as we go forward. As I said at Oticon we have a very specific

mindset on this and that mindset is basically that there's a lot about hearing loss that we haven't solved yet. As good as hearing aids are getting, our advanced technology, the advanced technologies from other companies as good as they are getting, there's still an unmet need in the part of patients, hearing health care can be better, hearing solutions can be better, signal processing can be better. So we are very much putting our attention and our efforts into making sure that we are creating the very best, signal processing solutions for patients, in the hearing healthcare field. And so the idea of creating solutions that work in other aspects of the patient's health that's just something that we as a company are just, that's not where we wanna be. We wanna be in the field of Audiology. We wanna be in the business of creating better solutions for patients to better solve their hearing healthcare needs.

But again, this is something that is is an open decision and it's an open discussion that we should be having in our field. But I will show you a very good example to finish up our discussion about how sensors and hearing aids can be used to really create better and better solutions in the future for patients. And that is what I will call brain integration. And I'm pulling much of everything that I'll be talking about in the brain integration from what we have been doing at our research facility, Eriksholm. And so none of this is a big secret. This is all the sort of things that are up there on their website where they talk about the sort of things that are being done in the future. We're not the only company we know out there who is interested in this area but it is a very, the reason I wanna go into this area is not because these are solutions that are available now or in the very near future but it gives the hearing care provider a very good picture of what the future of hearing aid technology could look like. In order to just try to reaffirm that there's a very important role for more and more advanced solutions for patients and because the solutions are gonna be more and more advanced, there's gonna be a need for a professional body to be able to manage these devices. And that's the hearing care professionals that need to be well trained and have a great understanding of the application of these devices. So the idea with brain

integration is that can the brain give information to the hearing aid? In other words, can you collect things that are happening in the brain and use that as input back into the hearing aid to drive the way the hearing aid is operating? And that becomes a very interesting topic to bring up because one of the things that we've always dealt with and when I was younger and did a lot of more primary hearing aid research. One of the things that you always dealt with is that you if you wanted to know how a patient was performing, you basically had to ask them. You had to say, how well you understanding the speech? How much effort do you have to put in? How hard are you working?

Things like that and so you always had to have a feedback loop back from the patient, based on whatever signal processing you're doing. It basically was an oral feedback loop, they had to tell you how they were doing. Either you tested of using speech testing or whatever. There's some physiological measures that can be done but those are being done independent of the hearing aid fitting. The question that has been posed is whether or not the brain in real time and in an ongoing way can be providing information back to the hearing aid to drive what the hearing aid is doing? And that is to me is really rocket science sort of ways of thinking about the way hearing aids, can look in the future. If you can tap into the brain, tap into how much effort the person is putting forward and use that as an input to drive signal processing in the brain. And it turns out that there is definitely a viewpoint that is quite possible. There is a lot of interest in our field right now of being able to pick up the EEG signal and send that and use that as a driver to hearing a signal processing. And beyond that, it's not just the EEG that can be doing that, there can be other signals that can be used. What you see on the screen right now is a picture of a BTE hearing aid and what you notice on the earpiece, is you see some electrodes. And one of the things that has been already been established in this area is that you can actually seem to be able to pick up the EEG signal in the ear canal. That's something that has been out in the literature, it's been talked about for a while and the idea being that, well, if you can pick up some

measure of brain activity in the ear canal can that brain activity be used to significantly derive the signal processing, in the hearing aid? And so what I'll do is I'll go back to this visual example that Annette used earlier where you had this very complex situation. And let's say, the problem you're trying to solve is that the woman in the foreground, over on the right in the foreground in the gray, sleeveless top is trying to listen to the blonde woman kind of in the little bit set further back. And she has to somehow try to separate out that voice from the voice of the woman in the black sweater or some of the other sounds that are happening in that complex environment as Annette described it. This is a situation where for example, maybe beam forming is not gonna be good enough or the signal processing that we currently have in lot of different hearing aids in the marketplace, isn't gonna be enough to solve that problem for some patients with signal processing.

But if you had a very good speaker separation algorithm, based on a deep neural net let's say that you can use but you need to know which speaker it needs to be focusing on. You can separate out as many sounds as you want but you still need to know what sound that the person is listening to, is interested in listening in, then you can use that sort of input to decide to kinda drive the behavior of the signal processing in the hearing aid. Well, one of the ways you can do that is perhaps in the future, being able to monitor what the person wearing the hearing aid seems to be paying attention to. So if there's evidence in EEG or some other brain signal about what the patient is paying attention to that could be the driver to help the hearing aid decide what it should be doing at that moment in time. So that's what I mean by the this idea of a brain controlled hearing aid that you use the, just the activity of the brain, the effort, the attention, the focus, whatever you can pick up electrophysiologically, from the brain and use that directly to affect the way the hearing aid, is doing signal processing. Another way that can show up and another thing that's been looked at is actually monitoring where a person is looking. As you know that, though you've probably learned somewhere along the line, there's a big electrical potential across the eyeball,

in terms of the front versus the back and that that is a relatively robust type of signal that can be measured. Well, if you know where a person is looking that can also be used as something that can drive signal processing with a hearing aid. Knowing that they're looking in one direction or another in combination with perhaps a way that the head is moved in one direction or another. And so that's another sort of potential that could or another sort of electrophysiological potential that could play potentially help drive, the processing in the hearing aid. So again, the idea is to try to grab information from the human body and send that into the hearing aid. So this is a picture out of university of , one of the research partners that we've been involved with where they are very much digging deeply into trying to capture the some electrophysiological potentials that are being generated by the human head and use that as a way of driving hearing a signal processing based on what you can pick up in the ear canal. We're in the ear canal anyway, we have to put something in the ear canal, when we fit hearing aids to patients so why not take the opportunity to perhaps capture extra information that could potentially be found in the ear canal?

And that's what the whole idea is about. Are we close to being able to have products in our marketplace that do this? No, we're not, this is very much a look into the future. But is a sort of look into the future that I think a lot of hearing care professionals should find very interesting because this is the sort of thing that as these technologies become refined and they become more practical and they become more realistic, they can really define what the future of hearing health care can look like as far as technology. Basically, the brain can tell us a lot of things, the brain can tell us how hard it's working, the brain can tell us what is trying to pay attention to. The brain can tell us where it wants to be focused on and that if we can find ways to tap into the brain and find that information and use that to more effectively drive in real time what the hearing it is doing on a moment to moment basis, that can really set the stage for a brand new era of what hearing a technology can really mean to patients. And so the future in my mind is very bright in terms of what hearing aid technology can look like. Again, if you

wanna know more about what the future of hearing aid technology can look like, I would strongly encourage you to take a look at the Eriksholm website, www.eriksholm.com. It'll give you a really good picture of what the future of the hearing healthcare field can look like, especially from our viewpoint coming, from the Oticon viewpoint. So with that I want to thank my colleague Annette for spending time with us. If you have any questions for either Annette or myself, our emails are on the screen and I want to thank you very much for the time you spent with us and I hope you have a very nice day.

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