The Aging Perceptual System
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- - [Don] Hello everybody, this is Don Schum. I'm the Vice President of Audiology at Oticon. And I wanna welcome you to this AO session. In this seminar we're talking about the aging perceptual system. And what I wanna try to accomplish over the next hour is to talk about the effects of normal age-related changes on both the peripheral auditory system but more specifically and more completely on the central auditory system that can potentially have significant complications in terms of the ability of your patients, especially patients getting fit with hearing aids to really be able to get as much as possible out of having conversations with other people. We spend a lot of time in our field as audiologists focusing on the peripheral auditory system of sensorineural hearing loss what we know as a profession. But there's a lot that also could potentially change in the cognitive system as part of a central nervous system and so we need to be very aware, I believe, in what the implications of those changes could be also.

So the basic why of doing this session is that I believe it's incumbent upon professionals to really understand their patients in totality. So hearing care professionals have the privilege of being able to bring hearing health care to patients with hearing loss. And just like any other profession, we tend to focus on what we know best which is the auditory system and the changes in the auditory system. But the patient has more than just an auditory system, the patient is a total person. And there are age-related changes that can occur in both the peripheral auditory system, as you know, that's what we know as hearing care professionals, but it also could change in other parts of the body. And specifically, I'm gonna focus on changes that can occur within the cognitive system that just go along with the normal aging process. And I believe that if we're going to bring the highest level of care as possible to patients we really need to have a good feel to a certain level of the implications of other things that can be going on with the patients that can affect the process. So let's go ahead and move along. The specific learning objectives for this course, I want to hopefully without too much delay allow you to recognize the cognitive basis of spoken language understanding under realistic conditions. You'll see throughout the course, this course that I spend a lot of time talking about spoken language understanding as opposed to speech discrimination or speech recognition. And there's specific reasons why I do that that I'll touch on in a few moments. But most importantly I want you to really develop an appreciation for how cognitively-based having a conversation truly is and how much of the brain is involved in that process and what some of the implications of aging are? The second learning objective is to recognize how age-related hearing loss can compromise the coded neural signal sent to the brain. We all know about hearing loss, that's our bread and butter, that's the playing field that we are used to playing with. But I want to talk about some of the changes that happened in the periphery in context of the sort of information that's sent up to the cognitive system. Because the cognitive system is very dependent on getting good information from the periphery. And so I wanna talk about some of the peripheral changes in light of the need of the cognitive system to get good information.

And finally, as I've said, I wanna walk through some of the normal aging effects on central auditory processing of spoken language. And again, in this course I'm not talking about clinically significant diagnostic categories of cognitive decline such as dementia and Alzheimers. I'm talking more specifically about just the natural changes that occur throughout the decades for a person in the person's body and how they'll show up in the cognitive system. One of the things you'll remember is that when that first-time user comes and sits across the desk from you and they are on average 72 years old or whatever they are these days, that person doesn't have just an auditory system that's 72 years old, that person also has an entire body that's 72 years old, unless they've had some part replaced at somewhere along the line. And there can be changes that occur that are related to the normal aging process that affect any part of the body and the brain and the cognitive system are not spared from those age-related changes on average for patients. Of course, age-related changes just as you know, there can be a lot of variability in a population. In terms of age-related hearing loss there can still be a lot of variation in terms of age-related cognitive changes. And the hearing loss changes and the cognitive changes when they occur and the severity of changes that can occur are not related to each other. So you can have patients with good hearing but poor cognitive skill set and vice versa. And so I believe it's important for hearing care professionals just to realize that that is part of the perceptual system that we count on to help get a patient to hear and understand well, and that those changes can be significant in some cases. I wanna start by talking about the cognitive nature of speech understanding and give you just a couple of examples to really show just how cognitive speech understanding or spoken language understanding is. And I'm gonna start that process by showing this little fella. Now, I'm going to sit back and give you a few minutes to go ooh and ah and have a good, happy, warm feeling that you see, which everyone knows is the cutest puppies in the world which are Beagle puppies.

So you see this cute little Beagle puppy and I put him up on the screen not just to give you a nice smile on your face, but also because I want to have you listen to the following sentence. My daughter just got a brand new puppy and her landlord is not happy. Okay, now I want you to think about what happened when I said that sentence? My daughter just got a brand new puppy and her landlord is not happy. If you are like a lot of people, when I said that you took about a half a moment and then you broke into a little bit of a smile, a little bit of maybe even a little kind of chuckle or whatever, depending on how funny you thought that sentence was. But the point is the reason you broke into a little bit of smile or the reason you at least recognized the implications of what I said was that when I said, you know something of puppies, you know something about the way puppies could be. They could be destructive. They can chew on things. They could leave puddles all over. And oftentimes when people rent a place, that's part of the contract that they don't have animals in the place. So when I said the landlord was not happy, I did not have to say the landlord was not happy because puppies do this and this and this and this and this. You knew that and so when I said that you just immediately made all those connections about the implication of someone getting a brand new puppy when they rent a property and it meant something and you got all that. Now, if you happen to know me personally and you know that my daughter lives in a condo that I own, that she rents from me, then the implications of saying and the landlord is not happy are even deeper. Because you all of a sudden recall a conversation you had with me maybe a year ago where I talked about, oh, my daughter moved in the condo that I own, and whatever, but the idea being that when I said the landlord is not happy, I'm talking about myself being unhappy about her getting a puppy. But you get the idea that I said certain words and you decoded that acoustic signal and turned it into an utterance. But think of all the processing that you've now done on that utterance now that I've kind of talked about the process and talked about what the implications are of the landlord and the puppy and what puppies do and everything.

So you get the idea that you will end up doing a lot of processing of speech. And so the acoustic signal of speech is only the very beginning of that process. As I said, I tend to prefer talking about spoken language understanding as opposed to speech understanding, because the actual words I say, the specific words that I say are not that important, it's the meaning that I'm trying to get across to you. So when you're listening to me there's a certain idea that I'm getting across. And this is the third time that I've done this course in the last several days. And I use the same slides and made the same points, but I guarantee you I didn't say exactly the same thing every time. I'm not working off a script as you obviously can tell that I'm just talking about different ideas. And so the way I talk about it today is different than I did last Friday or last Thursday when I did earlier versions of this course. You, of course are getting the best version because I saved the best for you guys last. But the point being that I have a certain idea that I'm trying to get across to you, and the words I use, the specific acoustic signal that I'm putting out into my microphone is going over the Internet and coming out of the speaker that you're listening to are not all that relevant as long as I get the meaning across. And so the reason you dialed into this class wasn't necessarily to hear a certain acoustic utterance from me, it was to find out what it is that I wanted to tell you, and get CEUs along the way, I get that. I know why you're in class, to get CEUs. But along the way, if you're gonna sit through this you want to make sure that maybe you get something interesting to listen to or at least you got to see a picture of a cute puppy somewhere along the line. So spoken language and understanding is really, is at the heart of why we have conversations with other people. This is a drawing from a classic textbook, "Davis and Silverman". Audiologists of a certain age, like myself, were trained on the "Davis and Silverman" textbook. There were several editions of it. I was trained in the mid-1980s, early to mid-1980s as an audiologist and so this was a classic undergraduate textbook to use in audiology.

Those of you who are of significantly younger age than I am, which is the vast majority of you, I understand that, you were probably trained on other textbooks that came along the way. But this is a diagram from an early edition of "Davis and Silverman" and I think this just captures something very important that I wanna get across to you. As I said, when you and I are having a conversation or when you're listening to me give a lecture, I have a certain idea in my mind and I wanna get that idea over to your mind. That's the purpose of what we're doing. Along the way a lot of things have to happen. I've gotta turn it into a language, a construction. I then have to get my articulators to do the right thing so that you can have a fighting chance of understanding the speech sounds and the words and sentences that I'm trying to create. Then that speech signal gets sent across some medium. Normally when you're having conversation it's a face-to-face medium, less than six feet if that person's within your circle of trust, farther than six feet through a mask if that person's not in your circle of trust. But anyway, there's some sort of physical medium that it has to go through. Then it goes into the ear, the peripheral auditory system. And there's a certain amount of things, there's a certain number of things that happen in the peripheral auditory system to turn that acoustic signal into a neural code. But then it's gotta go up through all these tracks and all these stages in the ascending tracks of the central auditory system until it gets up to the cortex. And then once it gets into the cortex, the psychology part takes over. And these days we'd probably use the term, the cognition part takes over where, first of all, you have to be paying attention to what I'm saying and hopefully you are. And you've gotta start turning it into recognition of the speech elements and pulling in a lot of linguistic information to sort of put the utterance together. And then you end up with a language code and then you get meaning out of it. And then you start doing things with that meaning, you start relating to it. You start trying to remember what I'm saying. You're starting to decide if you agree with me or disagree with me. You're starting to relate it to maybe patients that you see there, whatever, but you do a lot with it. In the field of audiology, especially in the field of the hearing a part of audiology, we normally only talk about this part which is the medium in which the signal is being presented and then what happens in the peripheral auditory system, that's kind of our working area where we pay attention to.

So think about the volumes and volumes and volumes of research that you've read or trade journal articles that you've read about hearing and hearing loss and hearing aids and hearing aid signal processing and all that. The vast majority of everything that you've ever been trained about in hearing or ever read about or thought about or been presented about in lectures has been dealing with something that's somewhere falls behind between what's going on in the environment and what's going on in the person's peripheral auditory system. But all these other parts of the system are involved also. And the thing about it is that we know what can go wrong in the peripheral auditory system in the presence of age-related hearing loss. But there's also a ton of things that can also be potentially compromised throughout all these other steps in the process along the way. I'm not dealing with this side of the equation today about formulating a clear signal. But I am gonna be dealing with this side of the equation when we're talking about what happens up in the cognitive system when the speech information is turned into a code and sent up there. Give you another example of how cognitive the process is. I want you to listen to two sentences. John was talking about the growl. And the watchdog gave a warning growl. Okay, so what's the difference between those two sentences? Well, in the first sentence we would say that the final word of the sentence, growl, was almost unpredictable based on anything else in the sentence. The sentence structure up to that point in time would predict that it's probably going to be a noun there because John was talking about the something. So the signifies it's gonna be a noun. But there's hundreds of thousands of nouns and it could be, any of those things could have come from that final slot. But when I said the watchdog gave a warning something, you knew it was a noun but more importantly, you knew that it was a very short list of things that could possibly fill into that blank. The watchdog gave a warning sneer. The watchdog gave a warning bark. The watchdog gave a warning, you know, whatever.

It's not probably going to be the watchdog gave a warning giggle, right, 'cause that word doesn't make sense based on the rest of the context of the sentence. The thing about the perceptual system though is that speech understanding or spoken language understanding is extremely predictive in nature. Meaning that by the time in that sentence, the watchtower gave a warning growl, by the time you got to the word growl your perceptual system, your cognitive system had already narrowed down to a very small number of potential words that can fill in that final slot. Because it's much more efficient for the cognitive system to work in a predictive manner if it can than sit back and totally decode each and every speech sound that I create kind of right from the start, and then putting it together after the fact. If you could start to predict what I'm trying to say, then confirm that I said what you thought I was going to say, it's a much more efficient way of doing spoken language understanding and we do that all naturally all the time. There are lots of models of speech understanding out there, very computational heavy and some very theoretical, and so this is a extremely simplified view of speech understanding. But the whole idea is the idea of multiple cue processing in order to get to a level of spoken language understanding. And that means that you use both acoustic information but a whole lot of stored information that you have up in your cortex and other parts of your brain, and that in order to make meaning out of speech, right. So speech comes in, it's turned into a neural code, it goes up to the brain but it doesn't take on any meaning until the brain in the cognitive system assigns meaning to it. And in order to pull that meaning out of it you have to pull in a lot of other sources of information. Just like with those two sentences I gave you, John was talking about the growl and the watchdog gave a warning growl, early in the utterance you tend to be very focused on acoustic information 'cause you have nothing else to work with. Unless you're a mind reader you really don't know what I'm about to say. And so you're paying attention to the acoustic information. But as soon as that acoustic information starts to build into something that you can recognize you start pulling in all these other sources of information that allow you to come to an understanding of the idea that I've tried to get across.

Now, you have to continue to monitor the acoustic information because it's going to bring you some, it's gonna continue to at least bring you new information and then allows you to confirm what you thought I was going to say. But the point being that it's much more efficient if you could start pulling in and start getting into this predictive mode about speech understanding. Let me give you another example to show you how cognitive this processes is under the topic of you never really listen to me. I'm gonna give you a couple of sentences. He trows for different kinds of pitches. The pitcher feels some shoulder tightness when he trows. Okay. He trows four different kinds of pitches. The pitcher feels some shoulder tightness when he trows. Okay, now what was going on when I produced those two sentences? Well, in those two sentences I purposely mispronounced the word throws and used the word trows, T-R-O-W-S, okay. In the first sentence when I said he trows four different kinds of pitches, you are more likely to identify and recognize the mispronunciation because you're much more into that acoustic listening mode at that moment in time. In the second sentence when I said the pitcher feels some tightness when you trows, you're less likely to recognize the mispronunciation that I make. And this has been verified through a series of really interesting studies that have been done over the years, mispronunciation studies. So this is experimentally verified several times to be able to show our sensitivity to mispronunciation of speech. That when you're in that acoustic, dominant acoustic listening mode then you're aware of that mispronunciation but when you're in that confirmation mode at the end of the sentence then you're not listening as intently to the acoustic signal, you're just basically trying to confirm that I said what you thought I was going to say. And I just think it's just a very fascinating glimpse into the way the cognitive system works. But one of the things that I want you to remember is in order to do all of this cognitive processing, to do this predictive speech understanding, to recognize the implications when I said the landlord was not happy and things like that, you have to access different parts of the brain.

And in a little bit when we talk more about the central changes in the brain I want you to be thinking about that when we talk about just this rapid access to a lot of other things going on to the brain. But before we get up to the brain we have to kind of follow the natural order of things and talk about the periphery first. Now, I'm not gonna talk about peripheral changes a whole lot in terms of sensorineural hearing loss because most hearing care professionals who spend a significant amount of time fitting hearing aids, what you know and experience of sensorineural hearing loss is age-related sensorineural hearing loss. In other words, most patients who get fit with hearing aids are older and most people who are older and have hearing loss are probably walking in with kind of a mixture of mostly age-related hearing loss, maybe some, a little bit of noise induced hearing loss, but usually pretty standard stuff. Now, depending on your situation, if you're in a clinical environment where you're seeing a lot of more involved or more elaborate sort of ear cases and so you're seeing the patients and you're seeing sudden hearing losses and all those sorts of things, then that's a different kettle of fish altogether. Or if you're in a pediatric setting and you're seeing children with certain hearing disorders related to this or that. But for the most part, when we talk about sensorineural hearing loss, especially as far as fitting hearing aids, we're talking about presbycusis for the most part. That's the most common sort of condition that we're talking about. So when I talk about peripheral changes in relation to age-related hearing loss I'm mostly talking about what you always thought sensorineural hearing loss was all about. And so there's not a lot of reason to kind of dig into some of the basic stuff that you live with every day. But there is one point I wanna make over the next few minutes. And that starts with this idea that we spent a lot of time, basically the last three decades, and the reason I say the last three decades, 'cause that's been the era of multi-channel nonlinear hearing aids. Okay, so hearing aids that are designed to in a frequency-specific way, provide a different amount of gain, depending on input level to hearing aids, so multi-channel and nonlinear, okay. Most of our understanding of multi-channel nonlinear and how to fit multi-channel nonlinear, so you think about speech mapping and you think about compression ratios and things like that is driven off of a pretty simplified model of sensorineural hearing loss that talks about the relationship between the inner hair cells and the outer hair cells. And what we know is that the inner hair cells, of course, are the primary sensory fibers. They take information from the periphery, turned it into a neural code and send it on its way up to the brain.

The outer hair cells don't respond, don't send information to the brain but rather the outer hair cells primarily affect the sensitivity of the inner hair cells, so that you need three healthy rows of outer hair cells in order to get the very good sensitivity and very sharp tuning of the inner hair cells. And one of the things that we know about sensorineural hearing loss is that when you first start developing hearing loss through the mild range it's primarily a loss of outer hair cells and not inner hair cells. So what ends up happening is you still have those sensory fibers sitting there waiting to be stimulated, but because the outer hair cells are gone the stimulation of those inner hair cells is not as great. The sensitivity of those inner hair cells goes up and the tuning is not as sharp, and those are some of the hallmarks of sensorineural hearing loss. So that simplified model has worked well for us in terms of understanding how to set gain and compression in a hearing aid. But the problem is is that it doesn't really tackle what we know about changes in the auditory system. Basically the auditory system, as you know, is made up of a lot of different, the peripheral auditory system is made up of a lot of different structures and all of these structures have to be working right. You have the nerve here. You have the spiral ganglion cells here. You have the basilars membrane and Reissner's membrane. You have the stria vascularis. You have the chambers and you have the endolymph and the perilymph and these changes and all these things have to be working well in order for hearing to occur. But we spend most of our time when we talk about sensorineural hearing loss talking about it either directly or indirectly based on this model of inner hair cells and outer hair cells. Back in the dark ages when I learned to be an audiologist, back in the day as they say, I was taught there was four different types of presbycusis.

This is based on some classic work out of a Harvard Medical School researcher named Schuknecht where he talked about the changes that he saw when he did pathology work on temporal bones with people with age-related hearing loss. And he saw four types of changes in general and so he classified them as four types of presbycusis. Sensory presbycusis is what we know, that's the type of hearing loss that I've just talked about, this interaction between outer hair cells and inner hair cells. And so that's probably the most common type of effect that can occur, but any of these four types can occur. And they're not mutually exclusive, of course, you could see more than one of these types of changes in anyone's auditory system. Neural presbycusis refers to either the connections between the hair cells and spiral ganglion cells or any of the tracks leading up the auditory system, up to the brain. And he has recognized that you can see changes in neurological structures anywhere along the line that can also lead to some hearing difficulties for an older patient, and those would be age-related changes in the way the auditory system works. He talked about the metabolic type of presbycusis or he's used different terms but I've seen it summarized in terms of the term metabolic. And what he was referring to is in the endolymph and perilymph which are the two fluids that fill up the chambers of the cochlea, there's supposed to be a certain chemical mismatch between those two fluids. In other words, the balance of sodium and potassium are supposed to be different between those two fluids because that chemical balance between those two different fluids are what allows the inner hair cells to actually fire. And if that chemical balance gets thrown off then the hair cells can't fire. Okay, with that being said, what he noticed is that you can have changes in that chemical composition of the two different parts of the chambers within the inner ear, the fluid chambers within the inner ear. And that could be driven very much by changes in the stria vascularis. To me, the stria vascularis is the most valuable player within the auditory system that never gets talked about. 'Cause the stria vascularis is responsible for providing very good blood flow to the structures in the inner ear. And one of the things we know about getting older is one of the things that's very much at risk is blood flow throughout the body.

There's a tremendous number of different things that can go wrong with the human body as you get older that can cause problems with blood flow. And because of that, if you're not getting good blood flow to the very delicate structures within the peripheral auditory system you can put those structures at great risk. And so the metabolic type of presbycusis is related to trying to keep the right chemical balances within the inner ear. And finally, he talked about something that he referred to as mechanical presbycusis or has been described as mechanical presbycusis and that has to do with the movement of the membranes and the associated structures, including the spiral ligament, for example. Those things have to move in a natural way. As you know, there's a traveling wave that goes throughout the inner ear and if that traveling wave somehow doesn't have the right form because the membranes are not moving properly, then you can get a hearing loss simply because you're not getting that fluid mechanical sort of movement within the inner ear that is necessary in order to start that process of creating the neural code in the ear. So you can have all the hair cell fibers you want there, but if they're not being stimulated in the right way because of this fluid mechanical action then you can end up with some hearing loss problem with the patient. So the point I was trying to make with this discussion of the four different presbycusis is that peripheral changes can take a lot of different forms. And usually when you move beyond pure sensory changes and you go into some of these other things, then the effect of hearing loss could be much more complicated. When you take a look at the implications of these mechanical changes then you end up talking about psychoacoustic performance. And psychoacoustic performance, what I mean by it in this context is some of just the very, very core level ability of the peripheral auditory system to properly encode stimulation that's coming into it. And so, it uses not typically, we're talking about non-linguistic test materials, frequency resolution measures and the type of measure that I wanna talk about more specifically here is temporal resolution. The reason I wanna talk about it is that a lot of people talk about frequency resolution. And with sensorineural hearing loss all the time we talk about loss of fine tuning within the auditory system and masking effects and things like that that come along with that.

But one of the things that's often not described as much or talked about as much is temporal changes. And that's usually measured using something called gap detection. It could be measured a variety of different ways but gap detection is classic way of measuring it. And basically, with gap detection is you put in a signal, an ongoing signal and you create a very small break in that signal in time. And you wanna see how big of a break do you have to create in order for the person to notice that the signal stopped and then started again, okay. The reason why gap detection is believed to be very important is that, think about what the speech signal is like, right. You've all seen the speech waveform. You've seen the VU meter and the audiometer bounce around all the time. Speech is a highly modulated signal. And what I mean by that is that it changes in level rapidly all the time. And the changes are somewhat unpredictable. They're tied to the phonemic structure of what you're producing but they can change quickly or slowly or after a longer period of time or a very short period of time. Think about like an affricate or stop consonant where you're talking about very rapid changes in the level of the signal that carry information. And one of the things that has been identified is that gap detection in older patients with sensorineural hearing loss tends to be longer than for younger patients with the same amount of hearing loss. So this is some data from a little while ago but psychoacoustic data doesn't change a lot over the years. So what you're seeing up here, you're seeing along the X-axis is the amount of hearing loss that the patient had for this test at the frequency that it's been tested. I believe it's two K in this example. And up the Y-axis is the gap and how long of a gap do you need to be able to notice that something changed?

And so, smaller gaps show that you have better resolution, longer gaps mean you have poorer resolution. In the upper panel A, that's a group of older patients with hearing loss and in the lower panel B, that's a group of younger patients with hearing loss. And, on average the hearing loss was a little bit better in the younger patients than the older patients, as you can see. But if you talk about starting from right about here on up you see a significant range in which you have patients in both the younger group and the older group having hearing loss at that level. And one of the things that you see is that on average, that the average gap detection is greater in the older group than it is in the younger group and there's a lot more variability in the older group than there is in the younger group in general. And so, that shows that these age-related changes in the system can lead to a change in core psychoacoustic that we believe has a lot of implications for processing the speed signal. Okay, so the the final message that I wanna leave you with about the periphery is that in the normal situation, yeah, and that's depicted in the upper part of this drawing. You have sound coming into the cochlea and the cochlea's job is to create a neural code that gets sent up to the cortex. And this neural code normally is relatively highly resolved, meaning there's a lot of detail in it. It has a lot of detail in terms of frequency and that's what I mean by going from the green on this end to the yellow up in this end. It also is very resolved in terms of temporal properties, and I tried to depict that by showing the fineness of the gaps, of the dots in these lines. Basically you getting a very highly detailed, highly resolved neural code being sent to the cortex and then the core starts doing what the cortex is going to do. In the presence of sensorineural hearing loss in the cochlea you lose that resolution. You don't have as much bandwidth to the signal. The bandwidth that you have is not resolved as finely in terms of frequency and the signal is not resolved as finely in terms of temporal properties. So basically what you're sending up to the cortex isn't anywhere near as much information as you would be sending up in the presence of normal hearing. So then the cortex has to start working with a less highly resolved signal. So with that being said, let's start talking about what happens in the central auditory system once this information gets sent up there.

This is a quote that we use all the time when we talk about cognition and hearing. And we talk about it from our brain hearing approach to talking about hearing in the challenges faced with patients. We often say, "Speech understanding is a cognitive process, "it happens in the brain." And the reason I put that up there is that when I say that it happens in the brain, something actually happens to the brain, right. You put that information up there and then the brain has to do its job. And what we know is that basically in the presence of normal age-related changes that the brain cannot work anywhere near as efficiently as it typically did when the person was younger. And so if spoken language understanding is happening in the brain and you're pulling at different parts of the brain to do things, and that pulling in isn't happening as well, then the whole idea of spoken language understanding and effortless listening and effortless understanding starts to become compromised. This is a classic description of some of the areas of the brain and what they do. One of the things that we know is when sound comes in from the periphery it ends up in the primary auditory cortex, which is part of the temporal lobe which is you know right behind your ears, okay, or right above and behind your ears. But in order to do anything with that information, especially if you're talking about spoken language, you have to start pulling in the speech areas. And for those of you who are audiologists who were trained in speech and hearing programs, you probably remember your basic anatomy of the neurology of language understanding and remember things like Wernicke's area and Broca's area in terms of where you start pulling language functions in. So when the sound comes in here and it starts being turned into meaning, and for example, when I said the landlord is not happy, okay. If you're trying to develop an interpretation of what that sentence means and you do that automatically, it's not like you had to tell your cognitive system, okay, decode that sentence because I'm not sure what it means. It happens automatically but in order for that to happen you have to start accessing many different parts of the brain. And one of the big areas that you end up accessing a lot is the frontal cortex. The frontal cortex is the most recent addition to the brain as humans have evolved. And a lot of things happen up in the frontal cortex that are really linked to human development, things like reasoning and planning and creativity, judgment, problem solving. Those tend to be things that happen up in the frontal cortex.

So if you wanna take in an auditory stimulation and then turn it into something that's useful, just like as you're listening to me and you're kind of interpreting what this means and you're trying to remember what it means and react to it and things like that. A lot of that's happening in other parts of the brain and like I said, specifically, a lot of it happens up in the frontal cortex. But what that means is that information has to flow throughout the brain. Neurons have to connect with each other and they have to be stimulating and they have to be pulling in parts of the brain in order to create the sort of flow of turning stimulation into meaning. And that's what's potentially compromised as people get older. One of the things to remember about the brain is that it's very dependent on the status of the body in general, especially the status of things like blood flow and other metabolic processing. So if a person is getting older and are starting to show restrictions of blood flow or the restrictions in other aspects of the way of the other general health of the body, it can start showing up in terms of how efficient the brain is at doing its job. Now, the brain is given priority status in terms of blood flow in the body, but we know that as soon as you cut off blood flow to the brain or restrict blood flow to the brain, the person's in a lot of trouble and you've learned that over the years. And so the brain is extremely dependent on good, healthy blood flow. And so you'll wanna make sure that you continue to feed the brain. If the brain is not over time kept in a healthy state then the processing in the brain, the actual physical movement of information to the brain starts to get compromised. One thing that we know is that the brain gets smaller as you get older. And it used to be treated from the standpoint of that means that older people's brains don't work as well, and that's not really true. I mean, my brain, I'm 60 years old. I'll reveal that to you, I'm 60 years old and the size of my 60-year-old brain is probably smaller than it was when I was 25. So when I shake my head I can hear it moving around inside my skull. But it turns out that the size of the brain doesn't seem to be related to the functional ability of the brain.

Contrary to kind of previous notions about the brain, the brain continues to be plastic into the later decades. You can still lay down new tracks in the brain. You can still learn new skills, et cetera, et cetera, et cetera. And this idea that the brain shrinks as you get older and it gets hard and it doesn't allow you to learn new things, that's simply not a true statement anymore. There are some things that don't work as well in the brain as you get older and I'll talk about that in a moment. But one of the things that happens is that a lot of compensation can take place so that if certain ability of the brain to do its different tasks starts to be lessened because of some of the loss of efficiency about the way things work within the brain, then other functions could take over for that. In fact, one of the definitions of aging, is the loss of adaptive capacity, meaning that the effects of aging don't start showing up until the body can no longer compensate for normal changes that it's going to go through over the years. The better the person's able to compensate, the better the body is able to compensate, the less whammy the person gets by getting older. But when aging really seems to kick in is when all these sort of effects of getting older start to pile up on each other and the person can no longer adapt to those things. If we talk about the normal aging process, about just the decades passing and what changes in terms of how well the brain works? Over on the left are the list of things that we know change over time due to normal aging. And over on the right are the things that we know are preserved as a person gets older. Let's talk about things over on the right. What we mean by intelligence and long-term memory? For example, your grandmother can still remember the color of the dress she wore on the first day of school. That's not lost, that memory is not lost in normal aging. If you take a look at the list on the left, and let's set aside motor skills 'cause you know that the body just physically can't do the things that it used to do as easily as it used to. And you take a look at the rest of that list, one of the things that really typifies the things over on that list on the left is the speed and accuracy at which the body can do what it needs to do and the brain can do what it needs to do. And it's so much tied to speed. It's so much tied to the ability of just simply doing things quickly at a cortical level. The neuropsychologist, the neurobiologist in this area talk about the idea of neurological slowing. And that's one of the most important things that I want you to remember from this lecture is that in the older central system, in the older cognitive system all neurological events just take longer to happen.

And as you know, neurological events are not just a one and done sort of thing, that you have to get a lot of different neurons firing at the same time in the same way to really get to the central nervous system to work the way it's supposed to work. And if each synapse takes a little bit longer and is not as efficient, then the whole system just basically slows down and gets bogged down. So when we go back and we take a look at those things that are affected by normal aging, acuity, short-term memory, reaction time, decision speed, selective attention, all of those are the sort of things that are going be affected by this neurological slowing. And so, this is something that is important and it probably just happens as part of the normal aging process. The healthier the brain is the less likely it is going to happen but it's still something that is sort of inevitable. A lot of variation from person to person but still, it's there. The way you can start seeing these effects is by putting the cognitive system under stress.

What I mean by under stress is in order to give it a more complex sort of task that it has to do, then you start seeing how effective the cognitive system could be at this task. 'Cause remember, as you do more complex tasks you're involving more of the brain, especially like I said, the frontal lobe, especially when you have to do reasoning and judgment and things like that. And so if you start doing those sort of tasks and you start making the brain do that sort of thing, then you start to see some of the age-related differences start to show up. For example, this is a project that I was involved in back in the day when I was working as a researcher as part of a large program, a large government grant at Medical University of South Carolina on aging. And that program, project, that big NIH grant is still ongoing now 30-plus years later. And when I was there my job was to take a look at speech understanding in older patients and learn new things about speech understanding, and I was very interested in these cognitive aspects about it. So one of the test materials that myself and my colleague, Lewis Matthews used back at the time was something called the spin test. And the spin test, I gave you some sentences from the spin test earlier, the watchdog gave a warning growl. It's kind of like the only spin test sentence I always remember really quickly. But it's an example of a highly context, a highly cued sentence.

There's a lot of context in there. So that if your job is to repeat the last word of the sentence, there's a lot of information in the sentence before that last word to allow you to predict that word, as I talked about earlier. And a low context sentence and I said John was talking about the growl then it's not a very highly cued signal. If you take a look at the normative data on the spit test, you would expect that a person's high context score should be higher than their low context score because there's cue information to help you predict that last word. And so, that green arrow there is basically the normative data from the spin test of telling you what you would expect in terms of the relationship in terms of using high context cues versus low context cues. And so basically you would expect that line to be above the median. If you did not get any information from the high context items, then that line should be just straight from corner to corner. But the more it bends up towards this upper left-hand corner, the more you're using context. The median data was developed on a group of patients who are younger and age on average. And so we were interested to see whether or not aging in and of itself can account for some of the variation that patients show? So this is the data that we saw from a group of patients who were, I believe they're all above 70 if I remember the way we did the project. But in general they were older than the group that was used to collect normative data. And the normative data is reflected in this graphic by this bracketed area between these two sets of lines. That's where you would expect the scores to happen on the spin test. And any scores that fall below those bracketed areas show that the person's not being as efficient as normal in terms of using contextual information. And what we found was a significant number of patients were below that bracketed area, compared to the number who were above the bracket area who seemed to get a special ability to use context cues.

So what we took this data to tell us was that if you take a look just at older patients, there's some evidence that they're just not as efficient of pulling in that extra information in the brain and to use that context. Remember, using context requires a lot of rapid processing in the brain, and it doesn't seem to show up. Let me give you another example of the way you can test it. And this is using something called compressed speech. So compressed speech was a paradigm that was used a lot back in the '80s and '90s as a way of stressing the cognitive system. So basically what you do is you take a normally produced section of speech and then you time compress it so it's happening over a much shorter period of time. So basically what you're forcing the person to do is to do a linguistic task to decode a sentence that's presented in a much shorter time period. As you know, that's the same way if you have someone who talks very, very fast then you're sort of trying to keep up with trying to understand what they're saying and trying to remember what they're saying or interpret what they're saying or react to what they're saying or without whatever it is that you do you listen to somebody. And if they talk very fast you don't have as much time to do that. So this was a project that was done by Arthur Wingfield and his colleagues and they used compressed speech to compare the ability of normal hearing younger people with normal hearing older people. And finding normal hearing older people is a little bit tricky but you can usually find it if you look long and hard enough. So this is what the data looks like. This is speech rate, 187 words per minute which is pretty much conversational. 234 words per minute which is fast and 312 which is very fast. What ends up happening if you only looking at conversational speech the efficiency of a younger group and an older group on average are statistically the same. But as you move to faster speech presentation rates, the difference between the younger listeners and the older listeners start to really show up. And it's basically trying to show the basic reality is that if you force the cognitive system to do a lot of linguistic processing over a short period of time, older individuals just can't be as quick and efficient as that, and it all gets back to that idea which most people leave of neural slowing. One other area that I wanna talk about quickly is something called attention.

There's four different types of attention. Sustained attention is when you have to pay attention to a task over a long period of time. Selective attention is when you are monitoring more than one source of stimulation and trying to monitor them both and maybe switching attention between one versus the other. Divided attention is when you are trying to do two things at the same time, like you're trying to listen to this seminar at the same time that you're making a peanut butter and jelly sandwich for your child who's locked down with you. And finally, there's working memory, and that's your ability to keep things stored in a short-term memory store while you're working with the information like remembering the phone number or when your family's all shouting out their takeout order for this evening because you can't go out to dinner. You're trying to remember what everybody wants and you're trying to write that down and keep track of what everybody wants so that you can call in your takeout order. Those are all types of attention. And it turns out one of the things that we do know is that all of these are gonna be affected by normal aging process. Because of the loss of efficiency in terms of how well, how quickly and how organized the cognitive system can do cognitive tasks and move information around the brain, all of these issues might be potentially compromised because of the normal aging effects. At Oticon we're very interested in this concept of selective attention. We've been using EEG measures to track precisely what the brain seems to be paying attention to in the environment. And we've been able to see some very interesting abilities of the brain to be able to track more than one talker at the same time, as long as they have a very good signal to noise ratio. We haven't been diving into the age-related effects right now of that, but we do know that EEG can be compromised by age and so that's an interesting aspect of what we're doing. But it is just one of the ways of trying to dig in more and really understand better how the brain is actually doing its job over time. One of the questions you might ask if I've been spending a lot of time talking about cognitive decline in patients, and earlier I said that the rate of cognitive decline and the rate of auditory, peripheral auditory decline are basically unrelated to each other.

But you could ask that if a person has some age-related cognitive decline, does it affect their basic ability to understand speech and noise? And the answer is, yes. A former colleague of ours, Thomas Lunner, from our Eriksholm Research Center, specifically took a look at this issue. He spent a lot of his research time looking at the cognitive processing and speech understanding. It's a very big focus area of him as a researcher. And he was interested in this relation. So he tested a group of patients on a variety of different cognitive tasks, memory tasks and dual processing tasks and things that are are all designed to task the cognitive system at a higher level than normal word recognition testing and relate that to the ability of the person to do word recognition in noise. And this is one snippet of that data where he was comparing the person's ability to do speech in noise tasks as it relates to their lexical decision speed. So lexical decision speed, when you do that you you present a sentence or some other speech material to the patient. And there's a word in there where they have to decide if that word is a, for example, either sensible or non sensible, or coded as a noun versus a verb or do something else where you have to think about that word and do a different level of processing on it. Remember what I said, one of the things that happens up in the frontal cortex is you do this sort of decision making and judgment and things like that, and so that will require going up into that part of the brain and making that part of the brain do something with the information. And what he saw was a statistical relationship between how quickly you can do cognitive tasks and how efficiently you do cognitive tasks and what your core speech understanding ability in noise is? And so, as you might expect, if you're not as good at the cognitive then that it might not allow you to understand speech in a noisy environment as well because you don't have as much cognitive capacity to just simply fill in the blanks of that speech signal. And that's one of the very important implications of this whole cognitive processing is that if that's declining and you're getting a lousy code coming up on the periphery, you can't count on the cognitive system to do quite as good of a job of filling in the blanks in that in that potentially compromised code. When we talk about speech understanding in noise, and we talk about it a lot in our field, there's a lot of different things that can affect the ability of the person to understand speech in a noisy situation. Most of the things on this list are very much audiology-based, based on what we know about audibility and signal to noise ratio and things like that.

There's a couple that kind of go beyond audiology, for example, how much effort is the person investing in the task? We know that people can control how much effort they put into a listening task and the harder they try the better they do at the task. But the one aspect that I think is particularly important in relevance to this talk that I've been giving is the idea is how good is the person at piecing together a partial signal? Like I just said and we're talking about the work from Thomas Lunner, when you have a code, a neural code that's coming up from the periphery that's been compromised because of peripheral hearing loss and it gets up to the cortex, the cortex has to fill in the missing parts. And if the cognitive system cannot do that job as well because of normal age-related declines, then the effort it takes to be a listener, the amount that you get for conversations, the fatigue factor, all those things start to kick in and become more relevant because you're putting too much load on a cognitive system that can't do the job as well. If you have a very good cognitive system but a lousy peripheral auditory system, you can count on the cognitive system to fill in more. If you have a good peripheral system but a lousy cognitive system, any compromise to the signal coming up is not going to be handled as well by the cognitive system. So those two parts are kind of operating independently but they are dependent on each other in certain very important ways. One of the ways we try to talk about how this all comes together for our patients, the sort of patients that you guys see, is that we believe one good way to think about the challenges that your patients face is the loss of the ability to organize sound. Remember that when you're listening to speech, spoken language, and you're doing something with it and there's a lot of other sounds going in the environment, all those things are gonna be competing for attention and making it harder and harder and harder for you to follow and get meaning and purpose out of what it is that you're listening to.

And the combination of the peripheral auditory changes that are gonna create this poor neural code and in combination with the cognitive system not being able to work as efficiently and as fast and as effectively as it would before, basically, it's gonna leave the patient with this feeling that they get overwhelmed by sound. 'Cause the cognitive system can't do what it normally does really well which is taking a lot of input and organize it and do something useful for it. It's legitimate at this point in time to ask me whether or not you can tease apart the effects? The basic answer is, no, it's not something that you could do clinically. The sort of testing that you need to really tease apart cognitive decline versus peripheral decline, you just need a lot of specialized test equipment in order to do it in routines and that's simply something that most people in clinical environments can't do. And the second way I'd answer the question is to say, well, it really doesn't matter if you can or not 'cause we can't change either side. We can't make the periphery work any better. And we can't make the cognitive system work any more effectively. But we can build things into hearing aids, and build things into our service plans for a patient to help them understand better. So if you wanna understand a little bit more and get a little bit more insight into some of the things that we can do for patients, what I would suggest hat you do is take a listen to a class that I recorded a little over a year ago on hearing loss aging and speech understanding. And in the first part of that course there's a lot of themes that I talk about in that course that I've just talked about for the last hour, so there's some redundancy in there. But the last part of the course I talk about some of the things that you can do to perhaps offset some of these cognitive declines that patients will be running into. So if you're interested in some of the implications of what can be done, some of the ideas, I throw some ideas out in that course. Later this year in the fall of 2020, we will be recording a specific course on AO on follow-up approaches for patients, especially with a cognitive viewpoint to what we're doing.

So hopefully, you'll have the opportunity to also dial in on that course and get more information on at least our thoughts about how you might want to follow up with patients in order to deal with some of these issues. The final point I wanna make, oh I'm sorry, I jumped ahead too quickly. The final point I wanna make is something that is referred to as the mind, body connection. And the term mind, body connection is used in a lot of different ways. And the way I'm using it is in terms of patients as they're getting older, do they recognize that they're getting older? And surprise, surprise, they do. In other words, patients who are getting older know that their body doesn't work as well. And specifically, they know that the cognitive system doesn't work as well. So especially for you younger hearing care professionals out there, you might not understand what that's like, but as a person gets older they start recognizing that tasks that used to be easier are now harder, the memory is not as good, they kind of can get overwhelmed by stimulation a little bit too much. It's like they can't have a conversation with the television going. Some of that is peripheral auditory effects, some of it is selective attention approach, problems, things like that. So patients understand that and they know that they're getting older. So if it gets down to having a discussion with a patient about the sort of things that they're running into, one of the things that you can count on is the fact that they know that their system doesn't work as well. So it's not the sort of scary sort of news that you're giving to the patient that they don't already know. It's just like most hearing care professionals know that when you tell a person who's older that they don't hear as well, that they have a hearing loss, they're not all that surprised about it, even sometimes they pretend like they thought that their hearing was just fine. They understand that they're running into some problems, and they can in this context. Sometimes hearing care professionals get a little bit concerned about having this discussion of cognitive decline because they're afraid that they're suggesting some sort of clinically significant things like Alzheimer's or dementia, and that's not what I'm talking about here. What I'm talking about is just normal age-related declines and how that could make the idea of spoken language understanding harder, meaning it's harder to have a conversation with somebody in a noisy environment, hearing is just not as easy as it used to be.

When patients talk about hearing not being as good as it used to be they're not just talking about peripheral effects. They don't come in and talk about, oh, their high frequency sensitivity isn't as good as it used to be. That's not the way people experience their hearing loss. They experience their hearing loss when they're put in a communication situation that really puts pressure on their entire perceptual system to be very effective to allow them to get the information or the enjoyment or whatever it is that they're getting out of listening to somebody else talking. And patients understand that their system is not gonna be as good. But what you could potentially do is have a role of sort of explaining that at a more clinical or scientific level so they understand how the ears and the brain work together. They know that at some level, all hearing care professionals know that at some level, but hopefully out of this course you got a little bit better appreciation for why that's the case. What we know about normal age-related changes in the cognitive system and how that can compromise speech understanding because of this lack of really effective, efficient workings within the current system that some individuals might experience as they get older. I wanna thank you for your time. Hopefully, you got some ideas out of this that kind of filled out your understanding better, gave you some ideas about counseling or just the way you approach these issues. And even if that's not the case, at least you got to see that picture of a cute little Beagle puppy, and that in and of itself is almost worth an hour of time. So again, if you have any questions or comments please feel free to contact me. My email is up on the screen. And with that I wanna thank you for your time and have a very great day.

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