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From Ears to Brain: Physiologic and Cognitive Effects of Short-Term Hearing Aid Use in partnership with the American Academy of Audiology

Presenters: Erin Schafer, PhD, CCC-A, Sharon Miller, PhD

It is my honor to introduce our webinar today titled From Ears to Physiologic and Cognitive Effects of Short Term Hearing Aid Use. Today's course is presented in partnership with the American Academy of Audiology. Our presenters today are Dr. Erin Schafer and Dr. Sharon Miller. Dr. Schafer is a professor and Chair of the Department of Audiology and Speech Language Pathology at the University of North Texas where she has been a faculty member since 2005. She earned her PhD in communication and Sciences and Disorders from the University of Texas at Dallas.

As well, her research focuses on the assessment and rehabilitation of adults and children with hearing loss and auditory disorders. Dr. Miller is an Associate professor and the Director of Graduate Studies for Audiology in the Department of Audiology and Speech Language Pathology. She earned her Ph.D. and master's in Audiology and Speech Language Hearing Science from the University of Minnesota, Twin Cities. Dr. Miller directs the Brain and Behavioral Lab at UNT and the Long term goal of her research is to establish an integrative program that combines behavioral and electrophysiological measures to address fundamental questions about brain plasticity and language in adults and children with hearing loss. Please read more about our presenters in the handout and at this time I'm turning it over to Dr. Schaeffer.

Hi everybody. Thank you so much. Sharon and I are honored that you're joining us today and first we're going to start with a video from aaa. Welcome. I'm Tish Gaffney, the President of the American Academy of Audiology, and I'm here to share important information about the organization.

The Academy is dedicated to achieving recognition of audiologists as the experts in hearing and balance care and the field of audiology as an independent clinical specialty that is integral to the healthcare team. Through our partnership with Audiology Online, we're excited to offer courses like this one to help you broaden your knowledge and skills. We also offer the latest resources in practice management and evidence based clinical practice so you can grow professionally and improve patient

care. We advocate for our members in Washington and across the country to ensure that the voices of audiologists are heard and we help connect audiologists to one another through our valuable networking opportunities like our annual convention. To learn more about the Academy, make sure to visit audiology.org thank you.

Thank you Tish. And now, here are our disclosures.

And the limitations and risks.

And finally, here's our learning outcomes for today.

I do want to recognize the funding that we received for this project. It was from the Hearing Industry Research Consortium and we want to thank our audiologist our clinical audiologists here at UNT for assisting with this project and all, also our awesome AUD students, who all contributed quite a bit to the data collected in this project.

So I want to start off today with just reviewing a little bit of this research, which many of you will be familiar with. We have so much growing evidence showing that pure tone hearing thresholds relate to cognitive decline as we see aging happening. And we know that each 10dB increase and hearing loss is associated with a 16% increase in dementia risk. And that is a big deal, and it's a big deal to our patients. And the Lancet report also lists hearing loss as one of the 14 modifiable risk factors.

That should be 2024 there instead of 2004. But, yes, this is one of the modifiable risk factors for future dementia. And as audiologists, we of course can do something about that.

However, there are mixed findings regarding how much the hearing aid can help with this risk of dementia and cognitive decline. So we have different studies that I've listed here showing different

results, but we do have some positive results. For example, in two studies, there's slower decline in memory, so working memory, and more stable cognitive performance in hearing aid versus non hearing aid hearing aid users. In another study, Lynn showed a 48% reduction in cognitive decline in one of his hearing aid groups. But this hearing aid group did start out with lower baseline cognition scores and an elevated risk for cognitive decline.

When he looked at his other group who had higher baseline cognition, they did not show a reduction in cognitive decline. So again, we have these mixed findings. And so our research group was really interested in kind of expanding on this research and taking a closer look to see if we could clarify some of these mixed findings.

So we believe that there's a really complex thing happening here. Of course there is. We've got hearing, we've got cognition, we've got different cognitive aspects. So we like to use the framework for understanding effortful listening, the fuel when we're talking about this complex connection between hearing aid use and cognition. So listeners may overcome listening demands by allocating attentional resources with mental effort, which of course is influenced by a lot of different things such as cognition, motivation, their emotional state, and their perceived importance of success in that listening interaction.

So here's just a diagram of the fuel. And so there you can see the different input related demands, how attention is involved, motivation, how maybe your arousal state, so whether you have fatigue might be involved, and then how these also relate to kind of cognition and brain responses. So we're going to kind of use different aspects of this model in the research that we're going to share with you today.

So here's just a look at our recent research in our labs. So this, the goals that we had was to examine potential changes in subjective listening, acceptance of noise, cognition, emotion, and then also physiological measures after using bilateral hearing aids. Our second aim was to explore relationships among these different test measures, kind of like the fuel did, and the impact of the hearing aid use on

again cognition, motivation and these emotion measures after the hearing aid use.

So we want to share with you a pretty big study. As we said, it was funded by the Hearing Aid Research Consortium, so we wanted to use our real patients and see how potentially their cognition and different aspects were affected. So these patients came in for an audiological assessment in our clinic and they decided to order and pay for bilateral hearing aids separate from the study. At that time they were invited to participate and if they were interested, they contacted us and we scheduled study session one. That occurred before they were fit with their hearing aids.

So then they were fit with their hearing aids. They attended their normal follow up appointment in the clinic with their clinical audiologist and they wore their hearing aids for two months. They came back to see us and completed all the study measures. Again, they wore their hearing aids another two months and then they completed study session three. So again, those all three study sessions included the same test measures so we could look at performance over time.

Our participants were older, as you can imagine from this study purpose. Their average age was 70 years. We had males and females in the study and like most older adults, they reported tinnitus. Some had noise exposure and some had occasional vestibular issues. None of these patients previously used hearing aids and they were fit with different devices as selected in consultation with their clinical audiologist.

We did not have anything to do with the hearing aids that were selected. Our audiologists do an awesome job counseling our patients. So you can see they were great users. At session two, we took a look at their data logging to make sure they were actually using the hearing aids. And on average they used them about 10 hours at session two and 9.8 hours in session three.

So we were thankful for that. And if you take a look on the right here, you'll see we had a pretty traditional older adult hearing loss configuration. Sloping.

Here's an overview of the test measures that we're going to talk about today. For our subjective measure, it was the afab, the Abbreviated Profile of Hearing Aid benefit. The behavioral measures included the acceptable noise level, the NIH toolbox Cognition and Emotion battery and also another questionnaire called the Treatment Self Regulation Questionnaire. I'm going to expand on these as we go along. And then later in the presentation, Sharon will share with you some physiological data that includes auditory sensory gating to speech and non speech stimuli.

So we're going to jump right into the results and I'll kind of talk about the measures within the results slides. So the first one, as I mentioned, is this afab and I'm sure most of you are familiar with it, but an example question at the top here is when I'm in a crowded grocery store talking with a cashier, I can follow the conversation. And then they rate their perceived level of difficulty. So in this slide that I'm showing you, you can on the Y axis it's percent difficulty. So a lower rating is actually better.

And then on the bottom you can see the different subscales of the afab. So we have ease of communication, background noise, reverberation, aversiveness and global for our different subscales. Oops, going back. And you can see here that overall they rated significantly less listening difficulty in session two and three versus that baseline session one, particularly in ease of communication, background noise and reverberation. And then of course you see the same thing in the global score.

Another interesting finding was the significantly lower aversiveness rating in session three versus session two. So what you're seeing here is a slight increase in aversiveness when they got their hearing aids, so at session two. But then that settled in session three. So I want to look at that a little bit more closely in the next slide because I find it kind of interesting. So that decrease in aversiveness occurred in both groups.

And so here in this slide on the Y axis I have that aversiveness score or rating. And again, lower is better. And then now I have it broken down by the three test sessions. So again you can see, look at that low cognition group in the gray bar, lighter gray bar, how it really is the increase is driven by that group, the group with lower baseline cognition scores. And then you can see that group, it kind of resolved over time.

Whereas the baseline cognition group that was a little bit higher to start with kind of had stable aversiveness over time. So I bring this to your attention because we're going to circle back to this later in the presentation.

The next behavioral test measure was the acceptable noise level. And so this kind of gained interest about 10 years ago and maybe you haven't heard about it since then. But we find that it still relates quite a bit to hearing aid success. And if you haven't heard of it in a while, this measure consists of determining the most comfortable level that a person will tolerate or put up with when listening to running speech. And then you turn on background noise and you adjust that level to the level that they're willing to put up with.

And then you subtract those two levels on the audiometer to get the anl. So honestly, it's really like the signal to noise ratio that you're willing to put up with and listen to when you're listening to speech with that background noise. So we plotted out for you on the Y axis, that signal to noise ratio. And then on the bottom you can see mcl, the background noise level, and then the anl, which is subtracting those two scores again. So what we saw is that we really didn't have a difference in the ANLs over time, the true acceptance of the noise.

They would tolerate higher levels of speech, so that MCL and slightly higher levels of background noise. So that's good. We see that there, you know, acclimatization to this new sound, this louder

sound is happening for these particular adults based on their ratings over time.

So in particular, the MCL was a significant improvement and the BNL approached significance.

So moving on to the next behavioral test measure, these people worked hard. So this is called the NIH toolbox. It's a really great tool to look at cognition for research purposes. It consists of five different tests. So dimensional change, card sort, the flanker control and attention list sorting, working memory, another memory test called picture sequence memory, and then a processing speed.

If you combine all of these together, they represent a fluid cognition composite, or kind of like that, working memory and other executive aspects of cognition. So I'm going to show you the results of the cognition composite first, followed by the individual tests. So here on the Y axis you can see their fluid cognition, and then on the X axis across the three different sessions. So I hope you can see here that we did have significant improvements in cognition. But what I want you to see even more is the fact that when we separate these two groups that we kind of saw pop out in our data, and I mentioned this with the aversiveness, when we separate low cognition and high cognition groups.

And I did that based on the average, So I took the average and looked at everyone below the average cognition and everyone above the average. And we see, you know, you can clearly see the data that there's a significant difference in session One. So at baseline, after using hearing aids for two months and then after using hearing aids for four months, a very large difference in fact in fluid cognition. So we're kind of seeing that in our data that yes, they do improve over time slightly, but we really see that improvement in the low cognition group. And you can see on average they started at 77 and by session two already their fluid cognition improved significantly to 86 and then stayed fairly stable in session three.

So let's break this down further by looking at the individual cognitive tests that I shared with you a couple of slides ago in the table. So what you can see here is a whole lot of bars. I know that. But again, I'm showing you the uncorrected scale scores here for the fluid, I mean for these different individual cognitive tests which are listed on the x axis. And it's really interesting because what we find here is that the real differences that occurred happened in the working memory subtest.

So we didn't see improvements, for example in the flanker, the card sort and the processing speed, some of them kind of approach significance, but the significant differences occurred for those two working memory tests. So the list sorting working memory and then the picture sequence memory. And again, we kind of saw that those significant improvements were driven by that low cognition group. And while I'm showing you these uncorrected scale scores, we saw the same results for age corrected and socioeconomic corrected scaled scores. So you can look at different types of scores.

So it wasn't like some underlying factor like age was driving this finding or socioeconomic status. It really, we believe was a true thing, particularly for that low cognition group.

Moving on to the next behavioral set of measures was the NIH toolbox emotion measures. And there were quite a few of them. Again, these participants were awesome. They completed quite a few different test measures as you can see so far. So we looked at their well being, their social relationships, their stress and self efficacy, and also kind of some of their negative emotions.

And we didn't see any significant differences from the first to the second or the second to the third test session. However, positive affect and self efficacy approach significance. Perhaps if we had a larger group we would have seen some some effect. But overall their emotions didn't change much from session one to three.

And finally, the last measure that we did behaviorally was this treatment self regulation questionnaire. So why did we do this? Well, it's interesting to think about how maybe our testing might be affected by motivation. So do they want to complete the test measure? Are they motivated to use Their hearing aids, are they motivated in general related to their health?

And so we've seen in different aspects of health, particularly when we're asking the patient to do something like take their heart medication or to exercise or in our case to wear their hearing aids, it's really important to think about. So this measure measures two different things, autonomous motivation and controlled. Autonomous is you're doing it because you think it's good for you, it's personally meaningful. It aligns with your values and goals versus the controlled motivation. It's not a bad thing per se, but you're doing it because of external pressure.

Maybe your spouse is like where are your hearing aids? Or maybe for some type of a reward or you kind of feel guilty about it so you're going to do it. And even though it was just a slight improvement, we saw significantly improved autonomous motivation when using after using their hearing aids. So after using for them for a while, they were like, hey, yeah, I'm doing it because I want to. I actually want to.

But we didn't see any changes in that controlled motivation.

So for the last part of my half here, I want to talk a little bit about principal component analysis. Yes, I'm going to nerd out on you and go in a little stat. So I like this particular type of analysis because it looks at how the different variables relate. It's different than a correlation where we can look at one thing versus one thing. It actually will take a set and look at how they align and how they group.

And that's why I like it because we have all these different test measures and we might want to see how they group together and how they can maybe explain what we're seeing here in a more coherent, cohesive way. So it's not about causation, it's more about association. So let's jump right in. So the first

principal component analysis that I did was a grouping of AFAB al, the pure tone average, the fluid cognition. So those five different individual tests together and I did this before they used hearing aids.

So this was like their session one baseline data. So the first thing that we found was that preferred listening levels, so the BNL and the MCL kind of clustered together and separate from the other self reported measures. So what does that mean? It really means that preferred listening levels don't necessarily have anything to do with listening difficulty. They're two different constructs.

But what we did find was that self perceived hearing hearing difficulty was driven by hearing loss severity and the noise tolerance. So the acceptance of noise. So that subtracting between MCL and bnl. And that makes sense. So yes, of course their hearing loss was related to their difficulty.

One of the most interesting things we found though, was that cognition, that fluid cognition loaded with future hearing aid use. So what do I mean by that? So I looked at that cognition and then put in how many hours they used hearing aids in the future. So almost like that cognition was like a precursor or a predictor of whether or not they or how much they would use their hearing aids. And we know that that consistent use is pretty critical.

Now, I'm going to run the same analysis here in this next slide, but it's going to be after four months of hearing aid use. So this represents the Session 3 data. Those preferred listening levels, the MCL and BNL still clustered. Again, that's why I like the acceptable noise level measure. It's interesting and it's measuring something different than these other aspects.

Self reported difficulty, however, was now clustered with aversiveness. There's that aversiveness again, and it's no longer clustered with hearing loss. Why would that happen? Maybe because we're attempting to manage the hearing loss with the hearing aids. However, that aversiveness does not go away.

It's still kind of underlying and affecting their difficulty based on self report. Now cognition is shifting to align with actual hearing aid use, not just future intention. So again, that cognition is so critical and that baseline cognition in particular can predict the use and also affect actual use.

So what does this mean really? Well, we know that at baseline that acceptable noise level predicted difficulties in real life. I think that's important because again, ANL can be a good measure, but AFAB also is a good measure to use clinically because it can help us predict their difficulty in real life situations. Baseline cognition, possible cognition screening is important for our patients because it kind of tells us who's going to be a good decision maker about their hearing aid use. And this also highlights the importance of getting to these patients as early as possible, so fitting those hearing aids prior to the cognitive decline.

And I know you're probably saying to yourself, well, how do we get them there? But I think as we, you know, market our services, market as our skills, we need to highlight how we can be there for them prior to some of these possible cognitive declines after four months of hearing aid use. Hearing aid use aligns with higher cognition. So we really are providing something for these patients in this particular sample. So I think we're enhancing the literature showing that hearing aid use can potentially impact cognition and aversiveness again is an important measure.

It predicted future hearing aid use and then was associated with self reported difficulties. So aversiveness kind of to me aligns with suggesting additional technologies like remote microphones to address that sound aversion or talking about communication strategies to remove themselves if they're really trying to hear, you know, what's said with a communication partner.

I did one more principal component analysis and that was more related to emotion and motivation. I still included working memory on this analysis and the hearing aid use because I wanted to see how those

different things align. So this particular outcome is just after the four months of hearing aid use. I did the analysis prior to and things really didn't associate well, particularly the emotions. But after four months of hearing aid use, we saw that they really were a unified dimension, meaning that all of the positive emotions like self affect and happiness and things of those sort align together and then all negative emotions align together better after using hearing aids.

We also found that autonomous motivation clusters with working memory, emotional support and life satisfaction. So people that had better working memory had better emotional support and higher life satisfaction and sustained hearing aid use. Again, we knew this from the previous analysis, again clustered with working memory, but it also clustered with those lower negative emotions such as fear and sadness. And then social support improves quality of life. I'm sure you are not surprised by that, but that didn't necessarily translate into greater hearing aid use.

So social support being really important, but didn't necessarily explain their hours of hearing aid use.

So what are the takeaways that we know here from this other PCA is that when we're counseling the patients about the benefits of hearing aid use, we know that there's the potential, at least in this sample for higher working memory, a self driven commitment to wearing hearing aids, that autonomous motivation, better auditory experiences, possible reduced feeling of fear and sadness. So those negative emotions and greater alignment of positive emotions like increased quality of life and those decreased negative emotions. One of the great things we found in this study is about the autonomous motivation. It's important, it's important that our patients are doing this because it aligns with their values and goals and so we can support that through our counseling. We also know that that motivation is associated with cognition.

So higher working memory, better general life satisfaction and higher emotional support.

So to conclude from the different self report and behavioral measures. So here's the big key items. Hearing aid use in our sample, increased working memory, the baseline fluid cognition and aversiveness may impact actual hearing aid use. Hearing aid use may align positive Emotions increase quality of life and decrease negative emotions. And finally, that autonomous motivation will increase with hearing aid use and is associated with higher working memory and life satisfaction.

So that's my part. Now I'm going to turn it over to the fantastic Sharon Miller to share with you some really cool findings.

Okay, thank you, Erin. So up to this point, we have established that after eight weeks of hearing aid use and working with our awesome clinicians and doctoral students, that our new hearing aid patients that we saw in our clinic significantly improved on a lot of patient centered outcomes, particularly noise acceptance and in improving their aversiveness of sound. So my next question is, why do these changes occur? And so what is happening in the central auditory system that supports these behavioral improvements? And so to answer these questions, we use brain imaging or electroencephalography, EEG techniques to identify the neural mechanisms that underlie or support these changes in behavior.

And it's really important that we know what these mechanisms are that underlie these changes in behavior so that we can better design more effective training or rehabilitation protocols that target these structures or neural circuits for our patients. So in addition to all of those behavioral measures that our patients did, and they were a lot, they also completed multiple EEG sessions to look at neural coding of different types of sounds, so both speech and tones. And we did this at baseline at four weeks and then at eight weeks as well. And we did collect these in both unaided and aided conditions to see if the changes were that we saw were just in a hearing aid alone condition or if there's something more underlying in their unaided condition had changed as well. So today I'm going to focus on just the outcomes that impact a lot of new hearing aid users that relate to loudness and noise tolerance or noise

acceptance.

So I'm sure many of you here today, most audiologists have encountered patients who return after their fittings and say everything is too loud or things are too sharp, or I am completely overwhelmed by these new sounds that I'm hearing. And interestingly, though we do see often with hearing aid use, that these complaints tend to decrease over time when patients consistently wear their hearing aids. And we refer to this process as acclimatization. And so while we often think of and about acclimatization in the behavioral sense, there are likely underlying neural changes that are happening as well. And so essentially, as the auditory system is receiving more consistent auditory input, you know, as it's getting that new, that new kind of restored input, things like filtering mechanisms and attention may adapt to this new input that it's receiving.

And so this is why, you know, one of the. It's so important when you're counseling our patients to wear their, that they wear their hearing aids consistently. Because if they patient, if your patients are only wearing their hearing aids occasionally, they may not receive enough sound exposure for these adaptive neural processes to proceed. So consistent hearing aid use is really vital for acclimatization to occur.

So the neural mechanism that I'm going to focus on today that we think is related to this acclimatization process in our new hearing aid users is called auditory sensory gating, which some of you may have heard about, but it may be a new concept for many. But essentially, sensory gating can be thought of as the brain's filtering system. So every second we are exposed to tremendous amounts of sensory information, Auditory, visual, somatosensory domains, we're always, we're being inundated with stimuli. So in the auditory domain, sensory gating helps prevent the nervous system from being overwhelmed by redundant or irrelevant sounds. So clinically, stronger sensory gating, or the ability to inhibit these irrelevant redundant sounds, means that you are more efficient at auditory filtering and you have

stronger neural inhibition.

So because so many hearing aid users struggle with excessive awareness of environmental sounds, we think sensory gating may be particularly relevant for understanding how they adjust and adapt to their hearing aids.

So with auditory sensory gating, the key idea here is that gating reflects the capacity of the nervous system to differentially respond to identical redundant acoustic stimuli. So the key here is that the brain should respond less strongly to a repeated sound that carries no new information. And this is a form of auditory filtering of irrelevant inputs. This suppression of redundant or irrelevant inputs is sought to help preserve cognitive resources and free those cognitive resources up so they can focus, you can focus on more important tasks. So, in other words, when gating is functioning efficiently, fewer neural resources are spent processing this irrelevant information, which leaves more resources available for speech understanding things like paying attention or listening.

Especially in very complex environments, you have the cognitive resources that have been protected to engage in these more difficult kind of engaging tasks.

So let's look at the mechanisms of auditory sensory gating. So the underlying neurophysiology of auditory sensory gating is pretty complex. However, the basic concept is relatively straightforward. So the auditory sensory gating response is measured using two identical stimulus. So we elicit this response using pairs of identical, in our case, identical tones.

So stimulus one and stimulus two are acoustically identical. The first stimulus in the pair evokes both excitatory and inhibitory neurons in the hippocampus. So when that stimulus is presented, it is processed through the central auditory system in a fashion that excites, is both excitatory and also stimulates inhibitory neurons in the hippocampus. Then that stimulus two comes in, which is identical

and carries no new information. And because no new information is present, it is gated out because those inhibitory neurons are still active.

Okay, So a healthy sensory system, therefore, should show a reduced neural response or a smaller neural response to that second stimulus relative to the first stimulus. When this auditory suppression is weaker, what that means is that you have reduced inhibitory control and less efficient auditory filtering.

So here is just a schematic of how we measure this in my lab. So we measure auditory sensory gating using a paired pulse paradigm. It's a very common technique to measure the gating response.

Response. And so, as you can see here on the right, we present stimulus one.

Then we wait just 500 milliseconds and present stimulus two. And so then we let the brain's response come back to normal. So we wait 8 to 10 seconds, and then we present that those, that same stimulus pair, again, stimulus 1, 500 milliseconds, and then stimulus 2. So the first stimulus, stimulus 1, serves as the conditioning stimulus, and the second serves as the test stimulus. So then what we do is we compare the responses.

So we look to see how effectively the auditory system has suppressed the redundant information carried by stimulus 2. So this paradigm has been widely used to study inhibition and sensory filtering across a variety of populations. So we've looked at it in many populations in our lab as well.

So here is just another visual representation of the cortical responses that are going to result from listening to these two identical tones. So first what we do is we play in our lab. We play a thousand hertz tone, see if this works. And then we measure the cortical response to that first sound. Then we play that second sound, which is identical, and we look at the cortical response to that second sound.

So now if you look at those two cortical responses together, and this is showing you the averaged event related potential waveform to both stimulus one, which is the solid line, and stimulus two, which is the dotted line. What you can see is that the cortical response to stimulus 1 is much larger than the cortical response to stimulus 2. That reduction in amplitude is the gating out effect. So the greater the reduction or suppression of stimulus two, the stronger the auditory inhibition. And so for clinicians, you know, the important takeaway is that what we're doing is this auditory sensory gating provides an objective measure of how efficiently your patients brains are filtering out irrelevant sounds.

Did I go too far?

And so again, just looking at that representative averaged ERP waveform on the right, you can see again that the response to stimulus 2 is smaller than the response to stimulus 1. And how we measure how efficient or how great that suppression is is we look at a ratio. So what we do is we look at a ratio of the amplitude of the size of stimulus 2 to the size of stimulus 1 and we calculate a ratio. A small ratio is consistent with gating out, meaning that they really inhibited or suppressed that irrelevant information. If we see a large ratio, for example, sometimes we see ratios of 1, which means that the response to stimulus 2 is identical in terms of size to the response to stimulus one, which would mean no gating whatsoever.

That would be a 100% gating ratio. If we see a 50% gating ratio, that is consistent with stronger gating, meaning that the size of stimulus 2 was half the size of what we saw for stimulus. So again, you can think of this as a measure of neural efficiency. Stronger gating suggests the auditory system quickly recognized redundant acoustic information and reduced the unnecessary processing devoted to that process to that second sound.

So for this study, participants listened to pairs of 1000 Hz tones and and because these patients had hearing loss, we were cognizant of that and we wanted to equate for audibility. So what we did is we

had their thresholds at 1000Hz and then we presented those tones at 40dB sensation level relative to that threshold. That way we ensured that for our unaided listening conditions that audibility was controlled or consistent across all of our participants. Participants we measured this gating response at three different sessions. Baseline at session two, four weeks and then session three at eight weeks.

And we looked at their cortical or brain responses in unaided and aided listening conditions in all of those sessions. So we looked at how did sensory gating look when they were wearing their hearing aids or in the unaided condition. And this was all done passively. So participants just watched a movie with subtitles and were told to and they told to ignore the sounds going around in the background and sent. For our analysis, we were interested in the obligatory early peaks, so P1, N1 and P2 of the cortical response.

So we looked at the size of those responses and the timing of those responses or their latency for both stimulus 1 and stimulus 2 in the the every individual ERP waveform. So we looked at the individual data and what I'm going to show you in our results are the group averaged data.

So here are the results. So four months of hearing aid use, improved unaided central inhibition. So you can see what I've plotted here are the cortical averaged group data at session one, at session two, at two months, and then session three after four months of hearing aid use. And honestly, this was one of the most interesting findings on the neural side. So what jumped out at me really clearly, and I hope you can see this, is that the neural responses became much smaller in time.

So you can see, you know, in other words, when patients were, and this is testing without their hearing aids, this is unaided cortical responses that when patients were tested without their hearing aids, we observed really significant changes after using their hearing aids for four months. So these reduced responses over time are consistent with improved central inhibition. So this is not merely an acoustic effect of amplification, because mind you, this was done and these results were done without their

hearing aids. So what this is telling me is that hearing aid use induced lasting neural changes in our patients brains. And you can see the changes happened at session two and they were maintained at session three.

We had a lot of patients who asked our clinical audiologists, they said, could you retest my hearing? I think that my hearing has gotten my hearing thresholds, I think I'm hearing better. And our clinicians could look at this data and say, well, no, obviously your hearing thresholds have not changed, but your brains did. And this was really concrete evidence that that is absolutely what happened.

So just to look at the, the size of these cortical peaks. So here are the unaided early P1, N1 amplitudes to both stimulus 1 and stimulus 2. And again, as you, it's consistent with what we saw with those waveform data is that in the unaided condition, neural responses to both stimulus 1 and stimulus 2 became significantly smaller at session 3. This reduction is consistent with increased neural efficiency. So the auditory system appears to require fewer neural resources to process the same sound sounds after prolonged hearing aid use.

And so for clinicians, this provides evidence that neural adaptation does accompany successful hearing aid use in our patients.

And we observed a similar pattern for the later N1 P2 peaks of the response. So again, cortical responses were smaller following several months of hearing aid years. So taken together, these findings suggest that consistent auditory stimulation by using your hearing aids may reduce excessive cortical responsiveness, which we think potentially reflects kind of a normalization or acclimatization to auditory sound processing.

And here are the aided data. And as you can see, it looks really similar. We saw this same type of effect in their cortical data when they were wearing their hearing aids as well. So at session three, the

cortical responses were smaller in amplitude, both stimulus one and stimulus two after four months of hearing aid use. So again, just by consistently wearing their hearing aids, these patterns, these aided patterns, mirror the unaided findings.

So what this means is that hearing aid use is associated with broader changes in auditory cortical processing, rather than just changes confined to one listening condition with the hearing aid or without the hearing aid, these are long lasting changes. Neural adaptation has occurred.

And again, just looking at the amplitude data, just as in the unaided condition responses, the neural responses significantly decreased in amplitude across the sessions. And again, this pattern is consistent with the concept that the auditory system becomes more efficient and less reactive to repeated stimulation over time, even when the patients are wearing their hearing aids during the testing.

And again, the later N1 P2 peaks, same thing. So these are data are just further support the same conclusion. So across multiple ERP indices or metrics, we see evidence of reduced cortical response magnitude after prolonged hearing aid use. So taken together, again, these findings support neural adaptation and improved inhibitory function after wearing hearing aids for just four months.

So what explains these findings? So one potential explanation is something called central gain. So it is well established that with hearing loss, the central auditory system increases its neural activity to compensate for a loss of sound input from the periphery. So in other words, when auditory input is reduced because of hearing loss, the central auditory system actually overcompensates by increasing neural responsiveness. And I think that's why we're seeing in session one that such large cortical responses at baseline.

And so while this overcompensation maybe helps maintain audibility, it can contribute to hypersensitivity and difficulty filtering sounds. So our findings suggest that hearing aids can actually reverse some of these maladaptive changes by restoring auditory inputs. And by restoring those auditory inputs, we've strengthened inhibitory control. And so, you know, Erin talked a lot about our aversiveness findings and we think, I'm going to show you some of the modeling data that this, you know, central gain, we think, underlies some of the aversiveness findings that we saw. So as part of our analyses, we looked at, we did some regression and modeling to see how auditory gating strength and other patient variables predicted aversiveness outcomes in our patients.

And from a clinical perspective, I think this is a really important finding. So the strongest predictor of the, of your reduced sound aversiveness. So how, you know, we obviously want to see aversiveness go down with our patients. The strongest predictor of reduced sound aversiveness was hearing aid use. So patients who wore their hearing aids the most consistently reported less aversiveness over time.

We also found a relationship between sensory gating and aversiveness and showed that this relationship changes with hearing aid treatment. So essentially, we're seeing that hearing aid use actually may reduce the negative impacts. You know, if you have, if you're a poor sensory gator or you have poor inhibition at baseline, if you wear your hearing aids, you can actually have better aversiveness outcomes. What this also means is that patients with poorer gating may improve, but they may require greater hearing aid wear time or exposure to achieve those benefits. And that relationship is just kind of seen here.

And I'll draw your attention to the left side of the graph. Graph on the Y axis, we have predictive aversiveness, and then we have the, the unaided N1 S2 amplitude. So further to the left would be consistent with poor gating at baseline. And as you can see, that predictive aversiveness, again, higher is, is. Is worse that our patients that had the lowest hearing aid use would be, are predicted to have

poor aversiveness when they have, have poor baseline gating.

So again, individuals with poor inhibition tend to report greater aversiveness to sound. However, using your hearing aids a lot appears to reduce this negative relationship.

So again, as Erin mentioned earlier, we measure the acceptable noise level of our patients at each test session. And again, as part of this test, patients listen to a speech sound, or this case a story which is like this. We flew to Phoenix to escape the cold and arrive to the warmth and light. And they listen to that and they have, they adjust that signal until it's at their most comfortable listening level. Then when that signal is playing at their mco, we add in this background noise, And patients adjust that background noise level until it's a level that they are willing to put up with for an extended period of time.

Time. So we have shown in our lab that weaker auditory sensory gating is associated with higher acceptable noise levels or poor noise acceptance. So as you can see on the right, you're looking at gating ratios, meaning again, higher percentage, worse gating and anl, higher ANL means you have less tolerance for noise. And in listeners with normal hearing, we showed a very strong Relationship relationship that as people were poorer gaters that their anls would increase, meaning they couldn't accept very much background noise.

And so we looked at how hearing aid usage and sensory gating, how they interacted in our patients. And this I'm just briefly showing you the most interesting finding. Basically baseline gating alone in our patients with hearing loss that wore hearing aids didn't fully explain anl outcomes. What mattered was the combination of gating status and hearing aid use. So patients with poor inhibitory function, so poor gating who use their hearing aids consistently demonstrated better noise acceptance than similar patients who didn't use their hearing aids as much.

So again, this finding really reinforces the importance of counseling our patients regarding daily wear time. It helps with things like aversive and it also helps with acceptance and tolerance of background noise.

So to summarize our neural findings, we observed evidence of neural plasticity that were associated with wearing your hearing aids. So sensory gating improved cortical responses became significantly smaller and more efficient. And we saw that larger cortical responses were associated with greater aversiveness to sound or greater sound aversiveness. So we think that these findings particularly we looked at N1 quite a bit, suggest that this N1 related marker or measure, it could serve as an objective biomarker for identifying individuals who are at risk for sound intolerance or aversiveness.

So more broadly speaking, the broader message is that hearing aid success is not solely about audibility. We are seeing changes in the central auditory system that because of, because of hearing aid use that support improvements in noise acceptance and listening comfort. So consistent hearing aid use may facilitate these adaptive changes and help patients become more tolerant or accepting of noise, especially in complex listening environments.

So clinical implications, I think the key clinical implication one is obviously patient counseling. It's important to counsel patients that that initial aversion to sound is common, but that with continued hearing aid use, their brains should adapt to these new sounds. I think it's really important to monitor our patients aversiveness ratings. If our patients with larger cortical responses and poor aversiveness, they might need those slower gain increases to facilitate adaptation to the hearing aids. And it's important to know that maybe some of this early discomfort, it's important to tell patients that this can be part of that adaptation process process.

So we want to encourage consistent use and also monitor sound aversiveness during all follow up visits. Obviously, and so, you know, initial hearing aid usage may be accompanied by limited noise

tolerance. But Again, with consistent daily use of their hearing aids, we expect the cortical system will adapt to handle the amplified sounds over time. So what's next? Well, there's several important questions remain.

I've just looked at the neural data in response to pure tone. We will also have data looking at cortical gating to speech sounds. We also want to think about attention and look at how these, how these cortical gating changes when patients are paying attention to sounds. And also we want to look more into maybe doing some loudness modeling in addition to measuring aversiveness ratings. We think that getting this information will help us develop more personalized approaches to managing our hearing aid pain patients.

And with that, we are happy, Erin and I are happy to take any questions that you may have.

Seeing question Would this suggest that patients with hearing loss who are not using hearing aids and have hyperacusis could have improvements to sound tolerance patients? Yeah. So I think, I think, again, I think this central gain concept I think is really important, that when you're not using your hearing aids and you have a hearing loss, you don't maybe you're avoiding hearing aids because you think you have too much hyperacusis. I think restoring the sound inputs is the first part of that. We will have to look at how to do that safely so not overwhelm patients.

But just restoring some normal auditory inputs to these patients I think is going to be really important to helping them recover some of this aversiveness to sound.

I don't see any other.

Questions.

I'm not seeing any other questions either, but I do see a few comments about that. This was a great presentation and that's pretty cool. Cool. Thank you guys so much. Thank you.

Well, thank you so. Yeah, so thank you for attending. Just because I got some follow up if you want to close us out. Anna. Yes, no problem.

Thank you. We're getting several comments coming in. Thank you for your time today and thank you for sharing a great presentation. So I think people really enjoyed it today. So thank you both for being here.

It was amazing. I love to hear that as well. So thank you everybody for your thank you comments. This was really a wonderful presentation. And before we go ahead and end this, I'm just going to wrap it up by saying thank you for attending to our audience and please remember to complete the exam once this is over, Please wait about 10 to 15 minutes to let us to run the attendance and then log into your account, go to your pending courses, take the exam and get your live credit.

So thank you both. This was fantastic and we really appreciated having you and sharing your talent here on audiology online.