Measuring Tinnitus in a New Way: Listening Effort and Affective Processing, presented in partnership with AVAA

Presenter: Nicholas Giuliani, AuD, PhD

- [Christy] It is my pleasure to introduce our guest speaker today, Dr. Nicholas Giuliani. Today's presentation is in partnership with the Association of VA Audiologists. We'd like to thank the president of AVAA for coordinating the series. If you'd like to learn more about Dr. Giuliani, you can read about his bio on the course registration page, but at this time, I'll hand the mic over to you, Dr. Giuliani.

- Thank you so much, Christy, and thank you for asking me to do this talk today. I feel very honored to be able to do this. So, again, my name is Nick Giuliani. I am an early career researcher here at the Mountain Home VA in Northeast Tennessee. And I wanted to approach this idea of looking at tinnitus in potentially some new ways, so looking at listening effort and affective processing. So I'm gonna share with you today some background information on this. So my disclosures, you can read them here. I don't have anything to disclose. I would like to highlight that the information presented here is entirely my own, and it doesn't necessarily reflect the position of the Department of Veterans Affairs nor the federal government.

These are the learning outcomes. And jumping right in. So these statistics shouldn't be a shock to any of us. We see a lot of patients in the clinic every day with tinnitus, but approximately 10% of adults in the United States report tinnitus annually. When we look specifically at military veterans though, this number increases by about fourfold, to about 4 in 10. Thankfully, most people are not bothered by their tinnitus. However, there are some estimates that suggest approximately one and a half million people in the US experience some form of tinnitus distress. So this here is from the Annual Benefits Report. So tinnitus is something that is quite costly. And just a refresher, so when we're talking about incidents, we're talking about the number of new cases versus prevalence, where we're looking at the proportion of cases over time, usually throughout a year.

So if we're looking at the Annual Benefits Report, 17 of the last 22 years, tinnitus was consistently the number one service-connected disability that veterans were receiving compensation for. So you can see at the top there, about approximately 2.7 million veterans in 2022 alone were receiving compensation for tinnitus. In many of those 22 years, hearing loss was the second or third most prevalent service-connected disability. Some other statistics on this page is that just the compensation in 2022 alone was just over $112 billion. And something that's even even more alarming personally for me is that the average number of service connected disabilities for veterans is more than six. So if we flush these numbers out a little bit more, typically, when you're seeing a patient that has service connection for tinnitus, at least all that I'm familiar with, they receive a 10% disability rating.

And this becomes very costly, so this is right from the VA's website, where veterans can understand better what their monthly payments are gonna be. So if we take the 10%, and we multiply that payment of $165.92 times 2.7 million veterans and 12 months in a year, that winds up being almost $5.4 billion for just compensation for tinnitus, which is approximately 4% of that $112 billion figure I showed you earlier. Now, what this figure doesn't include is any information regarding the costs of interventions, so things like hearing aids, maskers, therapy, that kind of thing. Why am I talking about this? The financial costs. And when I was preparing for this talk, we were actually towards the tail end of this congressional gridlock that almost resulted in a government shutdown.

And so there are lots of things coming from the media, talks about, you know, what's gonna be cut, that kind of thing. And I do hear rumors from a lot of my veteran patients, and I can't confirm or deny these, but that they, they being the federal government, is looking at doing away with service-connected disabilities for tinnitus. Now, you know, other insurance companies are gonna look at that too, and we'll get into some of that later, and what they might be thinking is, well, sure, a lot of people have tinnitus, but if it doesn't bother the majority of them, why are we paying so much for it? And so part of my reason for wanting to look at tinnitus in some different ways is that I wanna make sure that veterans get timely compensation, so outside of the VA additionally.

So for those of us who are not veterans, who receive our care elsewhere, this might equate to us not having insurance coverage for bothersome tinnitus. And this is, in fact, a screenshot from a major insurance provider in the United States, and they talk about when tinnitus treatment is covered. So basically, they cover interventions that are, you know, done by a psychologist. And you'll notice right here, tinnitus, maskers, sound therapy, those kinds of things are not traditionally covered by many insurance companies, this one in particular. So, you know, one of my concerns is that is tinnitus potentially an easy service connection to cut to reduce expenditures? Part of the problem is, and why this might be an idea that's gaining traction with some individuals is, because with tinnitus, we're relying entirely on subjective reports.

And, again, so we don't deny veterans timely compensation. I think it's really important that we find different ways to objectively measure tinnitus. Now that being said, tinnitus is very difficult to isolate. So there is evidence for tinnitus generator sites at all levels of the ascending auditory pathways, so from the periphery to more central structures. In fact, Henry and colleagues out at NCRAR in a paper from 2014 state very clearly that tinnitus can be anywhere between the cochlea and the auditory cortex. There have been many approaches to measuring tinnitus, and each of them has their own strengths and weaknesses. So some of the approaches and their advantages, so there have been several studies, and I'm just highlighting a few ones that I thought were pretty key here, there are more out there, is the auditory brainstem response, so the ABR, Milloy and colleagues, so what they had found is that in the tinnitus group versus a normal hearing group without tinnitus, they found lower amplitude and longer latency wave one in the tinnitus group versus the normal hearing group.

Another advantage to ABR is that this is routine equipment in many clinics. We, in fact, have an ABR clinic here at Mountain Home, and it requires little to no additional training for audiologists. You know, many of us learn how to do that. And if we're not currently practicing, at least we've done it at some point. Tinnitus has also been assessed using functional magnetic resonance imaging, or fMRI. There's a study from 2012, and they found that patients with bothersome tinnitus had a reduced resting state activity between auditory cortices on that fMRI, and what the resting state activity is, so they're in the scanner, and rather than performing a task, whether that be listening or some sort of visual task, they're just asked to sit quietly.

And so they measure that activity. fMRI, one of the big advantages to that is that it has good spatial resolution, what I mean by that is that they can pinpoint with more accuracy specific areas in the brain where blood flow increases, that's the main component of an MRI, is measuring changes in blood flow to different areas in the brain. There are also have been studies that have looked at electroencephalography, so EEG, to measure tinnitus. And then a 2019 study, they found that a tinnitus group had greater mismatch negativity responses to loud deviant sounds. So firstly, MMN, so mismatch negativity, this is a paradigm that, it typically employs the oddball paradigm. So what you have is you have 80% of a stimulus that's standard, so like, in this case, a standard level, and then 20% are considered the deviance, and in this case, this would be a louder deviant.

One of the advantages to EEG is that it has really good temporal resolution. So we can tell within time after a stimulus is presented to good resolution when a response occurs. Another big advantage is that you can use EEG with some extra processing and things with many hearing prosthesis, so hearing aids, cochlear implants, that kind of thing. I'm oversimplifying that, of course, because there's a lot of artifact and other things that have to be accounted for. Now, with all those studies, there are some weaknesses, and these have been highlighted by several different researchers. So with

ABR, what they will often highlight is that their inconsistent methodologies from study to study. So just slight variability, it makes it hard to really talk about any sort of clinical utility for that measure.

Additionally, for those of us who have done ABRs, we know that wave one can be very difficult to record, sometimes it's noisy, sometimes it's not there. And we may need to purchase additional equipment to help emphasize that wave one, in this case, like a tiptrode or one of the foil-wrapped insert earphones that can, that is more, is closer to these generator sites, and record a better wave one. You could also use a ball electrode on the TM, but that is gonna have problems recruiting participants for that kind of intervention. fMRI, so it has great spatial resolution, but the problem is, is it has poor temporal resolution. So we're, again, we're measuring changes in blood flow, and that takes time to happen.

So we can pinpoint better where in the brain tinnitus, where where we think tinnitus is occurring based on blood flow. But the problem is, is the timing of it, we have, so we have poor temporal resolution. The other issue is, anyone who's ever had an MRI knows, myself included, is that they're very, very loud, and in some cases, greater than 130 dB SPL. And this can be really problematic if we're talking about measuring tinnitus for tinnitus patients because, oftentimes, tinnitus is comorbid with hyperacusis or sensitivity to loud sounds. Additionally, fMRI is using a strong, strong magnetic field, and these are not compatible with hearing prosthesis. So can't use hearing aids, cochlear implants for sure. fMRI is the most expensive.

You know, you need a separate room, you need different teams to set up the machine to take the measurements, and then physicians to analyze them and researchers to analyze them. So very expensive. And there's some conflicting evidence out there. So I mentioned that study from 2012, and they found differences in this resting state activity between auditory cortices. And then Davies and colleagues from 2014, they saw no such differences. That study, one of the big advantages is they have three times as many participants. So they were looking at 12 versus four. But, again, there's some conflicting information out there. EEG, now, like I mentioned earlier, good temporal resolution, so we can tell to a pretty good certainty where in time these responses are occurring.

But if you've ever seen like the topographical map of EEG responses, the spatial resolution is poor. You can get a broad idea of surface areas of the brain that are responding, which you can't really pinpoint, what's happening where. It does require special training and equipment. And if you've done an ABR before, you know you have to scrub the skin to get the impedances of the electrodes down. Now, imagine doing that many, many, many times more because these electrode arrays that are often placed on the scalp have dozens of electrodes. So it does take a lot of extra time, takes extra equipment, extra training. Additionally, there's some research that's looked at this, and they found that it has low sensitivity and low clinical utility in terms of being able to measure tinnitus.

So those are some of the pros and cons and what's been done so far for looking at tinnitus generator sites. But in the clinic, subjectively, I'm seeing patients that are frequently reporting that their tinnitus impacts their cognition and their mental health, so they'll often report anxiety, depression, problem sleeping, and these align with these problems that they're reporting, align with mechanisms proposed by many different studies. So what I wonder is, should we be distinguishing between the presence of tinnitus versus the distressing tinnitus or the distressing effects of tinnitus? And if we're gonna explore this further, what options are available, and what exactly are we measuring? Another motivating factor for this is, in our clinic intake form, right at the bottom of the first page, we ask questions about tinnitus.

And we're asking the patients, at least when they're new patients, to distinguish subjectively between the presence of tinnitus and whether or not it's bothersome, so whether or not it affects their concentration and whether or not it affects their ability to sleep. So what do we do? One of the things that I'm interested in measuring in tinnitus patients is arousal or affect, it has to do, it leads to affective processing. So arousal governs a lot of these responses that I'm gonna be talking about. And there's many, many forms of arousal. And in fact, arousal does fall like many good fairytale on a continuum, so too little is a bad thing, too much is a bad thing, and then somewhere in the middle is a very good thing.

This particular shape, also known as an inverted U shape, is sometimes called the Yerkes-Dodson continuum, and then what that does is that exhibits, you know, for very low arousal and high arousal, poor outcomes versus somewhere in the middle. Arousal is primarily governed by the sympathetic nervous system, which is one of the sub-branches of the autonomic nervous system. And you may recall from high school or college biology that that's the fight or flight response. So that's typically what's involved there. The autonomic nervous system also includes the parasympathetic, so the rest and digest, if you remember back on that, in the enteric system, which primarily involves digestion. The main neuromodulator and hormone that acts on the sympathetic nervous system is norepinephrine, sometimes called noradrenaline, and, again, that's a neuromodulator.

And it's produced primarily in the locus coeruleus, which is brainstem or nuclei that's located at the very top of the brainstem, and it's called locus coeruleus, 'cause that means blue spot in Latin. And oftentimes, on the, I think it's the staining studies, it'll stain blue. So to walk you through these different levels, so on the left end of the Yerkes-Dodson continuum, you know, we've got someone who's not producing a lot of norepinephrine, maybe they're disengaged, maybe even they're sleepy. But then, you know, as more is produced, they become more engaged, it's just right, at the right amount, you know, they're learning things, they're focused, they're paying attention. But on the other end, as we move into like this hypervigilant stage, is what this is referred to.

So when you're far to the right on the continuum, those people are, again, hypervigilant. And you might recognize this, this is a term that means kind of very on-edge and always expecting something to come from other directions. Those of us that work in the VA know that that is one of the critical components of diagnosing post-traumatic stress disorder. So the summary from this is, there's a arousal, there's many forms of it, and then right in the middle is a good amount of arousal, and the extremes can be, result in negative outcomes. So why are we talking about arousal? So there are many studies that have looked at this, but particularly this one from 2012, was looking at pre-sleep cognitive arousal.

So what they did is they recruited neurocognitive normal subjects, and they had 'em perform these difficult cognitive tasks, so digit task, a Stroop task, some different recognition tasks, and the symbol substitution. And they analyzed the cognitive group versus the group that was not performing the cognitive tasks. And what they found is that in the cognitive group, that sleep onset time was significantly increased. Now, it wasn't a large amount, it was only eight minutes on average, but as the authors note, the task were rather mild, only lasting about a half hour or so. Like I mentioned earlier, one of the things we frequently ask in clinic is, "Is your tinnitus, you know, interfering with these cognitive activities?

Is it interfering with your sleep?" And it's often reported as yes. And Kaltenbach and colleagues in 2019, they suggested that heightened cognitive arousal at night is linked to objective sleep disturbances and indicators of physiological hyperarousal at night and during the day. So one of the possible ways that we can quantify tinnitus distress is by examining arousal. Another thing that we can do is we can look at cognition, so, again, this kind of falls under a large umbrella here, but norepinephrine has an inhibitory effect on the auditory cortex. And inhibitory usually means it stops something, but in this case, it's a good thing. So it improves auditory attention, so the kind of prevailing idea is that it can help you focus and turn down the noise in the background so you can attend to what you wanna listen to better.

There's many studies that have looked at that. There's an interesting study from 2019, where they implanted a sensor at the LC of rats, and they would stimulate that, and then they would teach the rats to do, to perform an auditory task. And what they found is that the rats who had that LC stimulation optically learned an auditory task faster and were more accurate than the rats who did not have that stimulation. Interestingly enough, the LC receives projections from and sends projections to the dorsal cochlear nucleus, which a lot of us will recognize as really that first big nucleus in the ascending auditory pathways after the auditory nerve. It also, the cochlear nucleus receives many efferent inputs from many different structures.

And one of the prevailing ideas is that the cochlear nucleus and its responsibility in tinnitus is that there's some sort of hyperactivity going on. So the idea is that the cochlear nucleus is looking for a signal from the auditory periphery. And when it's not there, in a way, it amps up, and then that increases the gain, and then it's thought that that helps to produce or at least maintain tinnitus in those higher brainstem structures. And in fact, Theodoroff and Kaltenbach in 2019 published a paper, that, where they suggested that that LC is likely responsible for modulating and/or maintaining tinnitus. So one of the issues when we talk about cognition in tinnitus is there's not a lot of evidence that tinnitus impacts cognitive tasks.

And there's a really good study by Zeng and colleagues from 2020, and they looked at 36 different measures, and they found, on 32 of them, that the tinnitus group didn't perform significantly different than the non-tinnitus group. And they then suggested that there are these peripheral mechanisms that lead to tinnitus, but then there are these top-down processes that really influence how distracting it is, how bothersome it is. So if there aren't differences on these auditory tasks between tinnitus groups and non-tinnitus groups, well, what do we do? How do we measure this? So, again, looking more at these top-down processes rather than these bottom-up ones. And I think that listening effort might provide additional insight. One of the ways that has become very popular in measuring listening effort is pupillometry.

So why, why do we look at the eye when we're doing an auditory task? Well, so both arousal and cognitive effort, as I've shown, are promoted by norepinephrine, have been links to changes in pupil diameter. So, again, different studies are available that show this, but fluctuations in norepinephrine production across the neuroaxis co-vary with pupil size. So Rajkowski and colleagues were looking at monkeys, and they found a very strong link between pupil size and then LC, norepinephrine production and the LC. Just a little bit of a review, so the pupil dilates or gets larger in response to a cognitively demanding task, and this goes back as far as the '60s. So I can't imagine taking film camera images of these and analyzing them painstakingly as they did in 1966.

We also know that the pupil dilates when people are trying to understand speech and noise, it also dilates consistently in response to arousing sounds and images, I'll talk a little bit about what that means more later. And, again, these responses, these pupillary responses are mostly governed by the sympathetic nervous system. And another positive to looking at pupillometry is that it's pretty sensitive and reliable. Now, arousal and tinnitus, what's been done, I have not found a lot of studies that have looked into this. There is one from 2018, where they measured pupil dilations in response to positive, negative, and neutral sounds in 10 adults with chronic tinnitus. And these positive sounds could be something like a baby crying, there's someone winning at a slot machine, those kinds of things.

A neutral sound would be like a lawnmower starting, a fan-blowing. And then negative sounds can be, you know, sounds of, there's some sounds of violence, there's sounds of people vomiting. So they're the things that are designed to evoke a strong response. And what this group found is that the patients with chronic tinnitus, they had what they expected for negative sounds, which was large pupil dilations. But what they found is, for the positive sounds, those dilations were much smaller and more statistically similar to the neutral sounds. And what the authors interpret that to mean was that the people with chronic tinnitus had these dampen pupil responses to positive sounds. And these were evidence, as the author suggests, for altered affective processing of positive sounds in patients with chronic tinnitus.

And they are more similar to responses that are obtained from significantly depressed patients, so, oftentimes, they will have these blunted responses to these arousing auditory stimulant. Now there's ways that this study can be approved upon, which I'm hoping to do. They just had the tinnitus group, they weren't controlling for hearing loss, there was no mention of hearing aid use, whether or not they had used them. So there are different ways to improve upon this. So what evidence is out there for listening effort in tinnitus? How does tinnitus impact listening effort? Does it? So listening effort is a subcategory of cognitive efforts, so it's the cognitive resources that are applied specifically to a listening task. And there are many, many, many ways that have been proposed to measure this, and there are many different components of this.

So I recommend highly looking at the framework for understanding effort for listening, that's the Fuller study from Pichora Fuller in 2016, and then the McGarrigle and colleagues paper from 2014 for review on some of those topics. However, pupillometry and dual tasks are two of the more common ways that researchers have been looking at listening effort. One question that's often asked, and of me of, in particular, is, why are we gonna use these complicated physiological or behavioral measures when we can just ask a typically functioning adult how much effort they're putting forth when they're listening? It turns out there's some catches. So a study from 2018 found that when asking specifically about effort, many people don't understand that concept. So what happens is instead of rating their effort, they'll rate something that's a little bit easier to understand, so usually their performance on a task.

So they'll be like, "Well, that didn't go really well, so I'm gonna rate that as more effortful." Other participants are often hesitant to use the extremes of a scale. So if you're using, asking them to subjectively rate their effort on a scale from 0 to 100, fewer people are gonna use the zeros and the 100s, and more people are gonna be somewhere in the middle. The other thing is that these subjective tools are not really sensitive to differences between normal hearing and hearing impaired. So there's different reasons to look at these objective measures. So getting back to listening effort in tinnitus, what's been done. So it's promising, but it hasn't been all that well studied, there's not too many papers that are out there.

Degeest and colleagues have two papers, and just, again, a broad summary of those two, they used a dual task, and they found that adults with chronic tinnitus exhibit greater listening effort than the adults with normal hearing. Jull Jensen and colleagues in 2018 looked at pupil responses in tinnitus and non-tinnitus groups. And unfortunately, what they found was no significant differences in pupil dilation, which they interpreted as listening effort between the tinnitus and non-tinnitus groups. Now, those authors attributed that to fatigue. So the tinnitus group frequently reported that they were more fatigued at the end of the task, so that could have depleted cognitive resources. So there's different ways to look at that. And like I mentioned earlier, there are things that could be improved upon on these studies with really having someone who has a clinician mindset to approaching this, such as, you know, really describing the hearing loss, making sure that hearing aids are fit properly.

Additionally, many of these studies include a lot of participants that have very low subjective ratings of their tinnitus, so their tinnitus is not that handicapping or does not produce that much of a functional impairment. Okay, so another reason that we might wanna look at listening effort and use pupillometry, specifically in patients with tinnitus, is that pupillometry is really quite good at showing how listening effort changes even in the absence of decrements to word understanding. So if you recall, I mentioned Zeng and colleagues and some other studies, don't find usually significant differences between tinnitus and non-tinnitus groups. And pupillometry can often help shine a light on some of those cognitive processes that are involved. And there's some examples.

So one of the earlier ones is from Winn and colleagues from 2015, and they used vocoded speech, and there were different ways that they degraded the speech. So vocoded speech, if you don't know what this is, it's a way to simulate how a cochlear implant might sound. And they degraded the speech more and more, and what they found is that for all but the most challenging condition, participants were performing at or real close to ceiling, yet, as they degraded it spectrally more and more, their pupils dilated greater amounts, so it required more listening efforts to understand those degraded sentences versus the less degraded sentences. Another interesting study from 2018, they were looking at standard American English versus Chinese Mandarin accent.

And so they had these readers with standard American accent and then Chinese Mandarin accent read passages. And then they had participants come in and listen to these passages, and all of them could understand the passages, they were at or near ceiling performance. But when listening to the Chinese Mandarin native speaker, the pupils dilated, again, more than for the native English talker. So, again, it interpreted as evidence of increased listening effort. I have some other interesting thoughts on that, maybe to discuss at a different date. Another interesting thing, so I really like working with hearing aids, and consistently, in my graduate program and since then, noise reduction, digital noise reduction on hearing aids, we don't find that it really helps that much with speech perception, with word understanding.

However, this really good study in hearing from 2021 was looking at different amounts of noise reduction in different situations. And they found that noise reduction on hearing aids does decrease lessening efforts, so the pupils don't dilate as much when listening in a challenging environment. So all of these taken as a whole may help explain why studies like Zeng and colleagues did not report or observe any differences between tinnitus and non-tinnitus groups. Yet, we continue as clinicians to hear these subjective problems that are reported by people with tinnitus and with bothersome tinnitus. So one of the many models out there of tinnitus is the Cognitive Behavioral Model of Tinnitus Distress, and this was proposed by McKenna and colleagues in 2014.

And one of the big reasons why they developed this was because they designed it to be testable, and later, they did some advanced statistical analysis, so they did a path analysis, and found that this particular model had many strong relationships amongst other subjective inventories of tinnitus. Now, those of us who have looked at some of these different models, this is not too dissimilar from Jastreboff's neurophysiological model. So they're similar in that they're both relatively indifferent to what causes the tinnitus, but Jastreboff's model focuses a little bit more on the structures that are involved. So they like to mention the limbic system a lot, whereas McKenna and colleagues are looking at the interpretation of event, and in this case, the event is tinnitus.

So delving more deeply into this model. So what they suggest is that there's some sort of event, whether that event be hearing loss, whether it be noise exposure, and then that event leads to tinnitus-related neuronal activity, so that's in the periphery. Then some, a lot, most people are like, "Well, I hear this noise, what's going on? You know, I was at a loud concert last night, my ears feel muffled, and I hear this ringing sound." And for the vast majority of people, that's where it stops. But for whatever reason, some people go on to develop these negative automatic thoughts about their tinnitus. So the patient that comes in being like, "I think I have a brain tumor," or, you know, not really understanding what tinnitus is.

So they develop these negative automatic thoughts. and McKenna and colleagues argue that this, these negative thoughts are this key sustaining component of this particular model. And what happens then once someone gets kicked into these negative automatic thoughts, and you can see how the arrows flow around and then back to the detection, back to negative automatic thoughts, so this is a, like a negative feedback cycle or, and this leads to a lot of other complications. Now, of particular interest to me is what McKenna and colleagues talk about as conscious processes that affect the selective intention and monitoring component of the cognitive behavior model. And I think a good explanation for that or a good thing to look into is by looking at listening effort.

Now, it can be that direct path from negative automatic thoughts to problems with selective attention and monitoring, or it can go indirectly through the arousal and distress component, so in some way, there's that intermediary stop that modulates tinnitus distress. And so I've color-coded this because I think that there'll be some degrees of both of those processes present in patients with or experiencing tinnitus distress. So how are we gonna do this? Like I've suggested, and we're gonna look at pupillometry and listening effort. As an early career researcher, what I really feel compelled to do is design studies that I hope will have some impact on clinical practice, not necessarily that we're gonna be doing this on patients, but that it can inform us in some ways.

And one of the ways I like to do that is use materials that are already available. So I'm gonna be using the AzBios sentences, those are common throughout VA clinics, we use them to evaluate cochlear implant candidacy. So they're around. We're gonna do that in quiet and +5 dB signal-to-noise ratio. So we're gonna have that speech be five dB louder than the noise. This is challenging to balance when you're thinking about normal hearing versus hearing impaired. So this first leg of the journey, I'm gonna be focusing primarily on normal-hearing individuals and seeing what the responses are, and then progress more into hearing-impaired individuals, and then combining that with whether or not they have bothersome tinnitus.

So a more challenging signal-to-noise ratio for people who have normal hearing but not one that's totally gonna sink someone with hearing impairment. So arousal and affective processing, this is gonna be less familiar to most folks, but there are these two widely available libraries of sounds and images produced mostly by Bradley and Lang and colleagues in Florida. And the reason I am including sounds is because I'm wondering if this arousal that tinnitus patients might be experiencing is unique to the auditory domain, or if it persists across the visual domain as well. So that's a way that I'm kind of controlling for responses to affective sounds. The affective images are very similar in nature to the sounds, but of course, just visual.

So positive might be, you know, someone smiling, a neutral might be a picture of an iron. And then a negative image would be, like there's a picture of a needle that someone's about to inject, things that typically, you know, amp up people when they see them. And the end goal of this project is to have several measurements that we can use as a potential way to quantify not only tinnitus and tinnitus distress but different interventions. And this is some preliminary data that I wanted to share with everybody. So these are two young normal hearing controls without tinnitus, and they were recorded with slightly different paradigms. The top two, so the farthest left column for both rows are the responses to the AzBios sentences.

So the +5 is in red, the quiet is in blue, and you can see how those two separate. So that suggests, you know, I've done a reasonable job of making these more difficult. These larger scale ones, so in the middle column, I'm looking at sounds, and in the right column, I'm looking at affective images. And typically, the negative sounds and images, so that black line is higher up on the page, so larger pupil dilations, more arousing. The positive and the neutral on the bottom figure are more separated, so the positive is that magenta line, they're more similar on that top row, but, again, it shows some differentiation between those, and then a similar pattern is found for the images.

Okay, one of the other things that can influence these responses is how someone subjectively measures them. So Bradley and Lang and colleagues, when they were developing these different systems, the picture system and the sound system, they conducted a study on, you know, neurotypical young adults, and there's a scatter plot. So some, you know, most people will rate a certain sound and image similarly, you know, a similar amount of negative content or positive content. But every once in a while, there's outliers. So what one of the things that's changed between these two rows is I am analyzing them based on how the subject rated them, so I'm having them rate them as negative, neutral, or positive. So there's different things that I will need to figure out going forward on how to analyze these.

So like I mentioned, I am interested in looking at how different therapies, in particular hearing aids and noise generators, impact these measures and how they affect this Cognitive Behavioral Model of Tinnitus Distress. So there are lots of different ways that these different therapies can act on them. I've got listed here a lot of the more cognitive therapies. So they could act on a lot of different components, but we still don't really have good information on how they affect these different components of the cognitive behavioral model. So like I mentioned, I'm really interested in looking at hearing aids and how they impact tinnitus distress. And we know, a lot of us from our clinical experience, we see a patient who comes in, they have tinnitus as their primary complaint, they have some hearing loss, we fit hearing aids on 'em, and they come back, and they're raving about how their tinnitus isn't there when they're wearing their hearing aids.

So that's a really good outcome, and that's supported by the literature. So this group in 2019 found that wearing hearing aids for three months significantly decreased the tinnitus annoyance. Another group in 2011 found that sound generators or hearing aids plus tinnitus retraining therapy were effective at reducing annoying tinnitus. And importantly, this study from 2022 looked at and determined that verified hearing aids reduce tinnitus loudness, and that effect seems to remain longitudinally when compared to non-verified hearing aids, and we're gonna come back to that point in a few slides. And then Tyler and colleagues also concluded that tinnitus patients benefit from sound therapy, but there are many systematic reviews that typically find fault with many of these studies, they suggest problems such as bias, small sample sizes, et cetera.

And there's another good paper by the NCRAR group, where they were suggesting that many of these systematic reviews are applying overly strict criteria, and thus obfuscating or covering up the potential benefit of something like a sound generator. And, again, anecdotally in the clinic, you know, I fit many sound generators, and patients find that they really help with the tinnitus. They don't end the tinnitus, but they're very helpful with it being bothersome, especially in quiet places when they might be reading other things. Part of the reason that it's good to call attention to these systematic reviews and say, "Hey, we think that these are overly critical in addition to the clinical evidence," is that, like I mentioned earlier, major providers of health insurance will look at those systematic reviews, and they can be used as ways to deny payments for intervention.

So I've highlighted this as, again, this is a different major insurance provider, but they concluded that research on customized sound therapy appears to be at an early stage and that the evidence is insufficient to determine that the technology results in an improvement in health outcomes, so that means that they don't pay for sound generators. Okay. So one suggestion is that we talk about developing standard procedures for fitting sound generators and being able to quantify them. So that's one of my goals with the study that I'm starting. Some questions that we don't know the answer to yet is, you know, at what level do we set the sound generator? You know, what if that person has hearing loss tinnitus, what if they have normal hearing tinnitus, what's a good option for them?

Do we set the generator at threshold? At threshold of what, where the tinnitus is, you know, the poorest audiometric frequency? Do we set it at a certain number of dB sensation level, so above where they can detect it? And this is not addressed anywhere that I have found in the literature. And ASHA on their webpage provides several suggestions, where basically, we as audiologists, researchers, other practitioners, we develop a more standardized procedure for assessing, treating, and evaluating these devices and as they apply to tinnitus. So one of the things that I wanted to accomplish with this talk is, at least my idea for developing a procedure for verifying a sound generator, so I wanted to have a really clinically relevant part to this.

You might really like this idea, and wanna go with it, you might really hate it, but I would like to get the discussion started here. It's not particularly challenging to do, and it validates your settings, and, you know, why would we do this? We could just flip it on and say, "Can you hear it?" And then they're good to go. Part of my reason for developing this procedure is that we don't rely on first fit algorithms for hearing aids, nor do we rely entirely on patient's subjective reports, nor what the software says when we're programming hearing aids, we're relying on the real ear measures. And I think that by being able to verify that these hearing aids are working, that's gonna improve people who are researching it and the study outcomes.

So we're gonna ensure that they're providing benefit clinically and they're doing what we think they're doing, and then, hopefully, be able to show that there is some sort of benefit to that in other research studies. So I'm gonna give you my three steps that I do for this. This was, I just conducted this in a test box, so this isn't actually on someone's real ear, this is the Verifit2 that I'm using at my institution. So first thing is first, verify the hearing aids, make sure you're doing a good job of fitting them, 'cause, again, that study from 2022, that seems to be a critical component of hearing aids reducing tinnitus annoyance or distress. Step two, what I like to do is set the Verifit2 to manual control, and the original intent for this part of the software was to use it as a sound level meter.

And the way I use it is to help kind of pinpoint where the tinnitus is located in terms of pitch and its loudness. So the advantage of this is that you can see from the dropdown, you can present a warble tone at a wide range of pitches that range from 200 hertz all the way up to 12,500 hertz in 1/12 octave band steps. That's a lot more flexible than your audiometer, and the levels, you can do zero, and then 40 to 90 in five dB steps. So this isn't necessary, but my idea, so I know from the literature that the pitch, the subjective pitch and the subjective loudness of tinnitus doesn't equate to how bothersome it is. So what I mean by that is that some patients with what we would consider really soft tinnitus, so only you know a few dB SL, are really bothered by their tinnitus.

Yet patients who have, some patients who have really loud tinnitus aren't bothered by it at all. So why would I do this extra step? Perhaps we can use additional CPT codes when we do this, which leads to additional RVUs and helps with our productivity. Now, I am not a coding specialist, but, again, I kind of wanted to poke the beehive on this and get some people thinking about it. So ASHA and AAA lists the code 92625 tinnitus assessment. And what that includes is a pitch and loudness matching and then the masking component. And it is not ear-specific, but you could plug and mask the contralateral ear if they have normal hearing, or just turn off the hearing aid if you want to do it that way.

I have looked and looked and looked into this code, and there's not a lot of specifics about how to do it. So I'm like, "Hey, let's use the Verifit." The masking, it's been suggested by some, and, again, I don't see this in the literature, but others, where we're looking at a minimum masking level and/or some sort of res residual inhibition. So minimum masking level being a broadband noise that just masked the speech. And then, with the residual inhibition, playing broadband noise at a louder level, and then turning it off, and then having the patient report whether or not their tinnitus has, you know, reduced in loudness, stayed the same, or gotten worse. We can also talk about using V5020, however, I know you can't use that twice in a fitting, so you couldn't use that for the hearing aid fitting and the sound generator, but perhaps we could use the V5299 code, that tends to be kind of a catchall code, but at least we could be documenting that we're doing that in addition to a hearing aid fitting.

So how do we do this? I'm not endorsing a particular company here, I just happen to go with ReSound a lot for my tinnitus patients. And this is an example for a patient with hearing loss. So this is part three, again, with the optional part two. So I'm turning on the sound generator, and the software, the manufacturer default is 55 dB SPL, and you can see that little gray area in relation to their hearing thresholds, and that's where they predict that it's gonna come in in that person's ear. Now, again, this is in the test box, this is not a real ear, but you can see that with this simulated fitting, how much lower that, so that pink line is where the noise generator's at.

and the green line is just that speech mapping that I had done earlier. So that output is much, much lower than what the software suggests, and this is just what we teach our students in the clinic and in the classroom, it's like the software's a good starting place, but what we're relying on are the objective measures in the ear. Okay. So what I did then is that I gradually increased the level, and, again, I'm monitoring this case in a simulated measure, and I also did a bandpass filter on that. So, again, I don't have any literature that I can point to, but part of the reason I do the pitch-matching and the loudness matching is so that I can filter the noise generator, because my idea is that I don't wanna mask components of speech, I just wanna mask out the tinnitus.

That might pan out, In the end, it might not, but some of the things that it does, so if you look at, this is the output from the hearing aid with the sound generator on, so that cyan line is the full bandwidth, whereas that magenta-colored line is that band pass filtered shape. So the ending of the software in the left ear, it at 96 dB and 85 dB for the right. So much higher than that 55 that they recommend starting at. So that sound generator is detectable. You can see they're right in that two to four or three to four kilohertz range 'cause it's right at threshold in both ears. And you can also see that magenta line, that bandpass filter is very shallow.

So for someone with better hearing, it's gonna really be hard to isolate those frequency components. All right, the last thing I do here is I confirm with the patient because you wanna make sure that it's not too loud. Now, we go through all of this, and what we still do not know is we don't, like I mentioned earlier, we don't know what level to set the masker at. One of the companies out there suggest setting it to thresholds, like I had programmed in that simulated measure. But, again, there are ultimately no data-driven suggestions for how to set that masker, I would like to get a discussion going on that. How much control should the patient have?

You know, should they be able to turn it up, 10 dB, 5 dB, 15 dB, those kinds of things, should the noise be filtered, or broadband, do we put it in one ear versus the other? And do we look at developing a prescription over time? There are also many other questions that come from this. So my next steps, I'm hoping to evaluate and develop measures that I've been discussing here, and then I want to use them to evaluate the efficacy of different interventions, specifically hearing aids and sound generators, 'cause it's very easily accessed by VA audiologists. Perhaps these measures that I'm developing could address some of the concerns that are typically raised in these systematic reviews, so maybe we can get better coverage, not just in the VA, 'cause we're very fortunate, but outside the VA as well.

So like I was mentioning, the objective measures may satisfy some of the concerns that were previously raised by some of the systematic reviews, and hopefully, the hearing aids and the sound generators are gonna act on some of these components to help pull patients out of the negative automatic thoughts that begets this negative feedback cycle. Additionally, what I'm hoping to do in veterans is look at how blast exposure, post-traumatic stress disorder, and traumatic brain injury affect these different stops within that negative cycle of tinnitus distress. So thank you all very much for listening today. I would like to really thank the American Academy of Audiology for their new investigative research grant that will be funding this project, of course, AVAA and Audiology Online for asking me to do the talk.

So we can look at any questions now. These are my references, if you'd like to see them. Okay, someone asked, "I have too many TLAs in my head. So what is CBMTD?" So that is the Cognitive Behavioral Model of Tinnitus Distress, that's the one by McKenna and colleagues from 2014. Okay, so we got that one. Anyone else have any other questions? Okay, so what is the LC? So that's the locus coeruleus, that's that structure that sits atop the brainstem that is the primary supplier of norepinephrine, also called noradrenaline to the neuroaxis, to the brain, and the brainstem structures.

- [Christy] Thank you again for attending today's presentation. We hope you enjoyed this course. Please tune in next time and also the other AVAA courses in our course library. Thank you, everyone.

- Thank you.