Dr. D’Anne Rudden: Some say language is what makes us human. For others, the love of MUSIC is one of only a few qualities that set us apart from our nearest animal relatives.

No matter what side of the argument you come out on, there is no doubt that language and music are inextricably linked because each provides its own mode for organizing SOUND in the brain.

In an imaging study conducted at Johns Hopkins, researchers found that the imaged brains of jazz musicians engaged in spontaneous improvisation showed activation in the same brain areas traditionally associated with spoken language and syntax.

So, while many scientists believe that language is what makes us human, there is increasing evidence that shows us that the “brain is wired to process acoustic systems that are far more complex than speech”.

In fact, Charles Limb, an investigator in this area of study, took it one step further and suggested that “the auditory brain may have been designed to hear music and speech is simply the happy by-product.”

There are few audiologists who understand more about the ear-brain connection than Northwestern University professor, Dr. Nina Kraus.

Through a series of innovative studies involving thousands of research participants from birth to age 90, Dr. Kraus’ research has found that our lives in sound, for better (musicians, bilinguals) or worse (language disorders, concussion, aging, hearing loss), shape auditory processing.

Never having accepted a lack of technology as a roadblock to scientific discovery, Kraus has invented new ways to measure the biology of sound processing in humans that provide unprecedented precision and granularity in indexing brain function. With her technological innovations, she is now pushing science beyond the traditional laboratory by conducting studies in schools, community centers, and clinics.

Dr. Kraus, thank you SO much for being our esteemed guest on The Hearing Journal Podcast this month. In fact, I met you briefly in the early ‘90s when I was visiting universities for my master’s program in audiology and I was looking at attending Northwestern. I am such a HUGE fan!

02:37 Dr. D’Anne Rudden: You have an incredible website that I have been scouring for the past few weeks, and I want to start by allowing people to get to know you a little better. We have all seen your name, you’ve written thousands of publications. I read on your Brain Volts website that you spent your childhood under the piano while your mother, who was a professional musician, practiced. Tell us about
how that experience shaped the person you are now.

03:23 Dr. Nina Kraus: I found my way underneath the piano because it felt good to be there. I was drawn to the big sound, my Mommy was nearby, I would just bring my little things underneath the piano—one of my favorite places. I was lucky that I had a Mommy and a piano. I grew up in a household where more than one language was spoken. Italian is my first language. I learned in some very deep way that sound is very important. It is so emblematic of what sound is, and the interaction between you and another person, the sensory and motor, back and forth that the sound lets us engage in.

04:37 Dr. D'Anne Rudden: It reminds me of my favorite quote about Einstein saying, "Everything is sound. Matter is vibration slowed down enough for the eyes to see it and the senses to feel it." It makes all the sense in the world to me.

When I think of you, I think about frequency-following responses (FFRs). Your name is somewhat synonymous with that, but some people are unfamiliar with that particular line of research. Can you talk a little bit about what and how you use that information to measure the integrity of sound processing in the auditory system and the brain?

05:28 Dr. Nina Kraus: The frequency-following response has been around for decades even more than I have been around. It was used to measure as an audiologic test for the hearing threshold for low-frequency sounds. As I learned more about sound in the brain, and as one of the motivating forces in my work, I have been trying to figure out how we can measure sound processing in the brain in individual people, so we can understand sound processing better, and all of us can apply it clinically.

I figured out early on in our work at Brain Volts that you could record frequency-following response to complex sounds like speech. It is very different from other evoke-responses where you are looking at how fast it is and how big it is. It is not telling you anything about the individual sound. As you know, I love talking to audiologists because they know all about the ingredients. The sound is made up of pitch, timing, timbre, and loudness. All these ingredients are processed by our hearing brain.

How do we figure out if the brain does a good job in processing different ingredients? We know, and we've learned that the brain doesn't process these ingredients like a volume knob—that you are either good at processing sound or poor at processing sound. You are good at processing certain ingredients, and you have bottle-X processing other ingredients.

How do we access it in a human being across the lifespan? You can use the same measure in a baby and an older person with a couple of electrodes. You can play a complex sound like a speech sound, and we can measure and figure out how good a job your brain is doing by measuring different sound ingredients.

I am hoping that the listeners will not go to our magical website, but go and look for a recent publication in hearing research. We have written a second tutorial on frequency-following response that focuses on the rich amount of information that an audiologist can gather in response to a speech sound. For example, it is very complex, it has all the ingredients, and it uses one complex sound. Clinicians have
now accessed a tremendous amount of information with a granularity that we haven't had before in the clinic.

08:47 Dr. D'Anne Rudden: Is that something you see as a vehicle for clinical practitioners? If you got out of your crystal ball, would you say this is something we are headed towards clinically? Like myself, I might actually say, "Hey, let's measure your frequency-following response and see how you are doing, and how that will inform on what's happening through the periphery?"

09:17 Dr. Nina Kraus: The short answer is "Yes," and a little longer is "Yes, absolutely." Audiologists are hearing experts. How wonderful it is to be able to go to an audiologist who understands a lot about hearing and measures different dimensions of hearing. This is one additional, very powerful piece of objective information that an audiologist can do. Someday, it will become the standard of care. It will be part of the audiologist armamentarium because they are uniquely soothing to gather information, to gather tricky information, and to understand when it is being analyzed. It is a whole area where audiologists can expand and grow their practice encompassing additional information they can use to guide their hearing care.

10:32 Dr. D'Anne Rudden: We've all been aching for more clinical tools that we can use beyond the audiogram. It seems intuitive to me. I would love to see it become part of the standard level of care that we provide to people.

10:57 Dr. Nina Kraus: If anybody would like to get started, we have certain speech sounds with good norms across the lifespan. We are very happy to share all of these with anybody who would like to start tomorrow.

11:15 Dr. D'Anne Rudden: I love that there are actual norms where you can look at someone and say, "Look! You are following outside the norms, and here is what the implication is."

I want to switch gears a little bit because you have so many areas that you have on your fingers, and one of those that you are more well-known for is your work on concussions. Some of my colleagues have taken a strong interest in concussion and what it means for the patient working collaboratively with the type of concussion team. Talk to the listeners about what sound processing in the brain can tell us about concussion, and what do you see as the role of audiologists.

12:08 Dr. Nina Kraus: Audiologist is stepping up to an unmet need. As audiologists know, making sense of sound is one of the most complex jobs that we ask our brain to do. If you get hit in the head, the microsecond precision and timing that we rely on to make sense of sound can get disrupted.

Historically, concussion care has focused on balance and vision. There has been a long history of work done mostly by the audiologist documenting our military people who have experienced difficulty processing sounds especially hearing speech in noise, but you always have the complication when you are in the military often there is an ear problem—a noise-induced hearing loss.

We have several projects funded by the NIH. It's a five-year project where we are measuring all of our
division one athletes at Northwestern University—these are healthy people. We measure them at the beginning and the end of every season, and if an athlete gets a concussion, then we follow them very closely. We have discovered, biologically using the FFR that we can see the sound processing of certain ingredients. The fundamental frequency of certain elements of timing gets disrupted after a concussion. [unclear]—not only concussion signature but also a way in which the damage can resolve, and people such as trainers, physicians can have an additional piece of information that informs them when there is an athlete ready to return to play, or when there is an athlete ready to return to learn. We know and are able to conclude that hearing and noise are a compromise in athletes. More importantly, after you have been hit in the head you don't want to take a test. To be able to sit and relax impassively and have a measure taken, will give their caregiver a measure of their brain health. This is something I envision for an audiologist stepping up and becoming well-known as a part of the standard of care.

15:24 Dr. D’Anne Rudden: We don't have time left in this first segment, but we want to make sure that you strongly state your opinion. What do you think the future looks like for people with Auditory Processing Disorders? We talked about standard auditory processing, but now you've got people with disorders. What does the future look like for them?

15:57 Dr. Nina Kraus: It looks great. First of all, if you want to have additional information that informs you, if somebody is having difficulty making sense of sound, then you want to know, is sound being processed in a typical way or not? In many cases, finding nothing irregular in the brain response sound is important information. We have an auditory processing problem, but as far as the biological measures are obtained—no problem.

How comforting it is for them and their parents if you can figure in other people? Especially the kids who have difficulties and are confused because they are not understanding their auditory world well.

The harmonics is one of the particular problems that is so important for distinguishing one consonant from another. The harmonics is almost always affected by elements of timing. To be able to know is huge-able.

When you do the therapy or training...we know our auditory brain is malleable. It is wonderful for an audiologist to be able to say, "Look! You may not quite feel like your listening has not gotten much better, but your brain responses are showing some positive change." The brain has to change first before the behavior is going to change, right? So, you wait for the behavior to catch up with the physiologic response, but the audiologist is powerful with this new piece of information.

18:21 Dr. D’Anne Rudden: Wow. The future looks bright through your eyes. I am so glad to hear your voice and to have you say those things to our esteemed colleagues so that they feel bright about their place in the future of audiology.

Dr. Nina Kraus, I am so honored to have had some time with you, but don't go away because we are going to come back for a little Aftershow. We are going to dive in a bit deeper and find out some things that we don't know about you. Thank you for coming and we’ll see you in the second part.
AFTERSHOW

19:06 Dr. D'Anne Rudden: We are back with The Hearing Journal Podcast Aftershow with Dr. Nina Kraus. We dug into a lot of grey areas in the first section of our podcast this month, but I want to talk briefly about Brain Volts.

For some people who are unfamiliar with your website—this is a labor of love and a choc’ full of information not just research information but also relevant to the clinicians. Talk a little bit about Brian Volts. What can people find there? What would you encourage them to do? Is there a tour?

20:05 Dr. Nina Kraus: Please visit our website and take the tour. It is motivated by our desire to communicate with people who have different backgrounds and interests. If you take the tour, you will be able to find what you are looking for.

20:31 Dr. D'Anne Rudden: I'm going to go through the tabs for those listening and who doesn't know what it means. There's so much information on sound in the brain and how it impacts music, concussion, how bilingualism plays into things, listening in noise, aging, and autism. If you have not taken a look at it, I would highly encourage you to go to the website and dig around because it is just incredible.

21:09 Dr. Nina Kraus: You might wonder, "What are they doing in Brain Volts?" All are under the umbrella of sound in the brain. For an audiologist, sound is awesome. Sound is a part of aging, listening in noise, head injury, reading, language, and music. It is not of many things, it is sound in the brain that encompasses all of these areas.

21:42 Dr. D'Anne Rudden: I remember saying (probably to a patient) that we used to feel like the ear lives on its own little private island, and that it didn't impact or interact with anything else. But with more discovery and more research from people like you, we’re understanding the brain-ear/ear-brain connection. The only thing that we talk about is what goes from ear to brain which is the peripheral auditory system, but I find it fascinating when you said that the ear is actually listening to the brain. Talk more about it.

22:31 Dr. Nina Kraus: An audiologist focuses on the ear, but historically, we have known that we have three times as many outer hair cells than the inner hair cells. So, our efferent system, the pathway by which the brain informs the ear based on our life in sound. The sound-to-meaning connections that we make changed how our brain responds to sound for better or worse.

Indeed, the hearing brain is part of the whole system. It is not only the ear as the classic auditory pathway, but the hearing brain as being vast involving our interactions with other senses, how we feel, our limbic system, our motor system, and how we think. An audiologist is more and more aware of the importance of memory and intention to sound. All of these are part of our response to sound. In fact, it is reflected in physiologic responses that we can measure. Thus, the ear is listening to the brain.
24:05 Dr. D' Anne Rudden: Your book called Of Sound Mind is coming out in the next four months. We only have a little glimpse of what compelled you to be so passionate about what you do. Talk about what's in this book. What can we expect to uncover?

24:51 Dr. Nina Kraus: I felt a need to put all in one place the different ideas I have about sound processing in the brain, and how I have been informed by research and clinical work in our society over the years. The book is called, Of Sound Mind. It is how our brain constructs a meaningful sonic world. My target audience is Hermione Granger, a curious outsider who is interested in the powerful forces that surround us and one of these powerful forces is sound. I have learned over the years that people don't recognize what a powerful force sound is because it is invisible like gravity—another powerful force. Think about hearing and hearing in noise. People always think about the ear, but we know that moderate level sounds can damage, and can affect and disrupt our processing of sound.

We were informed through fundamental ways in biology from the works of the people done in animal models, and that is why I am trying. Originally, I was a biologist by training. I looked at our hearing world from a biological perspective. I want to bring together in a place that a curious person can read and hopefully appreciate the under-recognized force which is sound and the effect that it has on our nervous system.

There are pictures that I am working with an illustrator because there is art in science.

27:25 Dr. D' Anne Rudden: That is amazing. I don't know any woman in audiology who wouldn't want to be Hermione Granger. It is a goal that I would even go back and be like her and learn more in that respect. I think of myself as being a curious outsider even within audiology. In September—where can we get the book?

27:56 Dr. D' Anne Rudden: Any place where you buy a book. I encourage you to please search my name, Nina Kraus and Of Sound Mind. Go to MIT press in a random house. You go to their website for the book and you will see wonderful endorsements by people who have read the advance copies. MIT has put together a brief description of what the book is all about, and you can preorder.

28:35 Dr. D' Anne Rudden: Great! I guess I know what I am doing this weekend. I watched your conversation with Dr. Beck, of Music In The Brain, and somebody on social media posted, "Are you guys watching this?" I have a snapshot of the two of you on the zoom call, and I put into the thread and said, "I am going to talk to her one-on-one. What do you want to know? Give me some questions."

One of the questions came from Angela Alexander, who does a lot of work with auditory processing. She asked, "What do you think will be the long-term effects of mask-wearing on auditory processing in kids from birth to 3 years since they aren't getting audio-visual redundancy with novel speakers?"

29:38 Dr. Nina Kraus: These fall into the category of any other experience that we have in our life in sound. Our life in sound is very much affected not only by the sounds we hear whether they are muffled because they are under a mask. The linguistic stimulation you get—remember, the hearing brain is vast, it encompasses all dimensions including the audio-visual dimension which we are so tied into as a
human being. Certainly, there is going to be an effect and unlikely not a positive one on the hearing brain, but fortunately, the hearing brain is malleable for better or worse. Hopefully, we will stop wearing masks and be able to offset some of the setbacks.

This puts me at the point where I want to get across and have to make choices. We have to make choices for how we spend our time, how our kids spend their time, how the patients we work with, and how we spend our time as a society. Our life and sound bring out the fact that it shapes our brain to the extent that we can make the best choices for living and taking advantage of sound in its riches' forms—it's something we should aspire to do, in my view.

31:51 Dr. D'Anne Rudden: I think about a young person's brain, and how quickly they are able to learn and change the dynamic of having a mask-off. Do you believe that barring any kind of processing complication the brain should be able to bounce back and make those leaps forward that it would have made? Should we have not had this period where things were muffled and masked and the visuals were gone?

32:30 Dr. Nina Kraus: I've seen this firsthand when we did a study on kids with auditory processing problems who wore the Phonak Edulink, the assistive listening device, the FM device for a year. We tested the kids from the beginning to the end of the year. Some of the kids wore the device, some didn't and they were in the same classroom with the same teachers. Many of them had language problems that showed very distinctive responses in their FFRs. At the beginning of the year, many of them had inconsistent or unstable responses, so from trial to trial the response and timing were jittered. Can you imagine if the kid is hearing the same word in two different ways? Each time he hears, it helps the kid to learn. It is so beautiful to see the kids who wore these devices. So, they were tested without the devices at the beginning and the end of the year. The kids who wore the devices at the end of the year showed their responses were more stable, and their language improved to a greater extent.

33:45 Dr. D'Anne Rudden: Another testimony to why we need to be doing a different level of discovery with the patients that we are seeing clinically, and what audiologists can actually bring to the table for kids of all ages through adulthood and beyond.

We have a few more minutes but I feel like I would be remiss if I didn't take a moment to say you are a music lover, an amateur musician yourself, but what do we not know about you?

34:52 Dr. Nina Kraus: You may not know that I love to sleep. I love to move. Moving is one of life's great pleasures. I consider myself a bit of an athlete, I run or get up on my bike. Throughout this whole conversation, I am moving all the time. I do love to cook. Another thing that my 'la mama', my mommy did, she was Italian, she was probably the best cook and inspiration for me. I love to make good food and to eat it. Eating is a great pleasure. One of my three sons is a chef. He has 3 restaurants, 2 in Brooklyn and 1 in Manhattan which I suggest you check out called Hart's, Cervos, and The Fly. So, I love food. I love eating it, talking about it, mostly eating it and preparing it. It calms me down.

36:36 Dr. D'Anne Rudden: I hundred percent agree. My son is thinking about going to culinary school. During the pandemic, I am getting treated to lots of experimental food creations from my kid.
Dr. Nina Kraus: It is such a good feeling when you walk into your own home. When I'd be at work and my mother would be visiting and I'd come home at the end of a workday, I opened the door, and she had been cooking. It just feels so encouraging.

Dr. D'Anne Rudden: Dr. Kraus, thank you so much for your time, for sharing your sound mind and your incredible brain with us both in this podcast, and for all the work that you've done throughout your career. Wherever that path may take you forward, I hope you take us all along for the journey, and we will be better for it, I guarantee.

Dr. Nina Kraus: It depends on you [audiologists] for being ambassadors for our hearing brains.

Dr. D'Anne Rudden: I'm on board. I want to be an ambassador for you and our amazing hearing brains.

Thank you for being our guest on The Hearing Journal Podcast, and we will look forward to catching up with you down the road when your book comes out.

Dr. Nina Kraus: Thank you.