"The Sound Explorer" with Nina Kraus

Transcript of Communicating Brain Science Podcast

Guest: Nina Kraus, Ph.D., is a scientist, inventor, and amateur musician who studies the biology of auditory learning. She began her career measuring responses from single auditory neurons and was one of the first to show that the adult nervous system has the potential for reorganization following learning; these insights in basic biology galvanized her to investigate auditory learning in humans. Through a series of innovative studies involving thousands of research participants from birth to age 90, her research has found that our lives in sound, for better (musicians, bilinguals) or worse (language disorders, concussion, aging, hearing loss), shape auditory processing. She continues to conduct parallel experiments in animal models to elucidate the mechanisms underlying these phenomena. 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.

Host: Bill Glovin serves as editor of *Cerebrum* magazine and as executive editor of the Dana Foundation. He was formerly senior editor of *Rutgers Magazine*, managing editor of *New Jersey Success*, editor of *New Jersey Business* magazine, and a staff writer at *The Record* newspaper in Hackensack, NJ. Glovin has won 20 writing awards from the Society of Professional Journalists of New Jersey and the Council for Advancement and Support of Education. He has a B.A. in Journalism from George Washington University.

[Intro] Nina Kraus: We really work on sound and the brain. And it turns out that sound is a pervasive force in our lives. Founders of music programs have come to me and they have said, "The kids who play music are the better students." This is a really important investment in a person's life that pays dividends until we die.

Bill Glovin: That's just a small sample from this podcast with Nina Kraus, professor of neurobiology and communication sciences at Northwestern University. During this podcast, Nina refers to her extraordinary website, called the Brainvolts.northwestern.edu, as magical. And I'd have to agree. You can find it at Brainvolts.northwestern.edu.

I'm Bill Glovin, executive editor of the Dana Foundation. And this is one of our Communicating Brain Science podcasts. Not to be confused with our

Cerebrum podcasts, which focuses on the neuroscientist authors of our magazine articles. You can find all of our content, which is commercial free, at Dana.org.

We were so impressed with Nina's work and knew she would be a great guest. And we are very fortunate that she agreed to talk to us on the phone. Welcome Nina. Looking at your website, it's hard to know where to begin. One of my takeaways is that your research isn't so much about music as it is about sound, is that a correct assumption?

Nina Kraus: You are right. So if you go to our magical website, you can see panels that have topics like concussion, music, aging, language, reading, hearing and noise, autism. So we investigate many different topics, but they are all under the umbrella of sound, sound and the brain. So we really work on sound and the brain. And it turns out that sound is a pervasive force in our lives. And so affects all of these different areas of our lives.

Bill Glovin: Before we get into the nuts and bolts on research, I was watching one of the clips on the Brainvolts.com website, and it was you at the Kennedy Center's Music and the Mind event in 2018. And you opened by talking about hiding under your family's piano as your mother played. And then you're trained as a biologist, but you specialize in sound. What made you specialize in sound?

Nina Kraus: Well, I think that it was a combination of my mom was a musician and I love to play. And so there was music all the time in the house. And one of my favorite places to bring my little things was underneath the piano because it just felt so good to be with all that sound. Also, I grew up in a household where more than one language was spoken. So I learned to speak Italian probably before I learned English. And so much information is carried linguistically through sound. And eventually when I went to college, actually, I majored in comparative literature because I knew a couple of languages and I liked to read. And then I took some biology and realized, "Oh, this is for me. I really like this."

And around that time, I found a book by a Lenneberg called *Biological Foundations of Language*. And I thought, "Ooh, now this is something that is exciting to me because I can combine my interest in language and biology." So that kind of got me started on thinking about, "Well, I really loved biology and I really love sound." And I started looking at various neuroscience as a graduate student. And I loved the idea of trying to understand how the brain makes sense of sound. And one way or another I've been doing that my entire career. I began recording from individual neurons while an animal would respond to sound. And so that gave me a lot of insight into what is happening biologically in the brain.

The first lab I worked in, I was recording from individual neurons in the chinchilla, in the auditory nerve of the chinchilla. And I was investigating a phenomenon called two-tone suppression in the auditory nerve. And I was trying to explain to my mom what I was doing, and after a while she said, "Well, Nina, what are you doing?" And that really stuck with me because I felt that I had a hard time explaining to my mom how I was spending my time. And I also realized that, for me, it was really important that I do something that my mom could understand how I was spending my time, and really anybody could understand how it was spending my time. I didn't want to be doing something so esoteric that I could only speak to a handful of people.

Bill Glovin: So how does your early work with non-humans inform your work with humans, or has it?

Nina Kraus: Well it always has, because in trying to understand what is going on in the brain, one really needs to be rooted in basic biological principles. So even now, most of our work is in humans and I've always been interested primarily in questions that pertain to humans, like beginning with language, and then eventually music, because music is this wonderful model for auditory learning, for learning through sound. And to this day, we have an animal model that informs us about the different mechanisms and the different ways in which sound gets processed. So we cannot put electrodes deep inside the brain in human beings, we can only put electrodes on our scalp. So by using scalp electrodes in humans, we have to make various inferences about how individual neurons and networks of neurons are responding. But if we have an animal model, where in fact we can make comparisons between what we're measuring deep inside the brain and what we're measuring on the surface, we're able to understand better what the responses that we get from humans mean.

Bill Glovin: Without getting too far off the track, it seems that could be its own specialty when you think about the way a dog or a dolphin or an elephant or a bird or any number of species processes sound, it's really fascinating compared to how a human would, and how that sound might affect whatever the species is, how it lives in the world or exists.

Nina Kraus: Absolutely. And I have been reading whatever I can get my hands on in terms of animal communication, because we learn so much and other animals are able to communicate through sound in various ways that is so much more sophisticated than what we're able to do. It's fascinating. It's absolutely fascinating to study. Especially animals that communicate with each other socially. So birds and whales and dolphins and elephants and wolves. Animals that are social have these wonderful systems of communication that are really fascinating.

One of the reasons I love to study the brain is because we'll never understand it. And it changes constantly. And it involves so many different processes. And I feel like we do understand quite a bit about how we process sound or at least a little bit.

Bill Glovin: Getting back to humans for a second, in terms of your website, which is amazing, and all the different areas that you outlined in the opening, there is autism, bilingualism, concussion, reading, music, aging. What is the ultimate goal of your research? I saw that you got a five-year NINDS grant to study sound and concussion, and you work with athletes at Northwestern, but there's so many areas. Is there an ultimate goal that you're striving towards?

Nina Kraus: Yeah, absolutely. There are a number of goals, but we have really discovered ways of measuring sound processing in the brain in humans. And that information we are able to get from humans is enormous. So we have a biological approach that essentially involves putting a couple of electrodes on the scalp and playing sounds, complex sounds, like speech and music. And one of the fascinating things about sound is that it is invisible. And so we don't realize how much information there is and also how powerful our sound processing system is. We live in a very visually dominated world and that's because for a visual object you can see the different ingredients that make up our visual perception. You can see the shape, the size, the color of an object, and these are ingredients.

Well, it turns out that sound also has ingredients. The ingredients of sound are things like pitch and time and tambour and frequency modulation, amplitude modulation, phase. There are these ingredients in sound that are very analogous to the ingredients that we have in the visual system. But they happen very fast, they happen in time. They're constantly moving. But we can capture information which scalp electrodes. So if I just put a couple of scalp electrodes on your head and I play some speech sounds to you, I can get a tremendous amount of information about you and about how you process these different ingredients.

One of the analogies that I like to use is a mixing board. So with a mixing board, you have the faders that go up and down and the way that your brain would respond to sound, it's not going to respond well with the faders up to every single ingredient of sound. Maybe you'll process the harmonics with greater strength than the fundamental frequency, than sweeps in a frequency. So I can look at an individual person and get a lot of information about their life in sound, because if you have musical experience or you speak another language or you get hit in the head, you get a concussion, all of these factors influence how sound is processed in the brain. And we can see this, miraculously, by looking at the brain responses of an individual person.

So you asked about a head injury. Since making sense of sound is one of the hardest jobs that we ask of our brain, it makes a lot of sense that if you get hit in the head, that blow is going to disrupt this very fine grained, intricate, delicate process. And again, it does so in a very specific manner. There is a particular signature that is associated with an acute brain injury like concussion. And then eventually it resolves, usually resolves. Unless there's a bleed in the brain, you're generally not going to see any imaging information that can inform, say, a physician or a trainer about the extent of the injury. But we can by measuring the brain's response to sound, we are able to get some information about the extent of disruption. And it's something that we can follow over time and help in eventually making decisions about when an athlete is ready to return to work or return to the classroom, return to play. So one of the goals is to have an objective metric to measure the impact. If you will, of concussion on the brain.

Bill Glovin: In that same vein, in our next *Cerebrum* magazine, we are going to be featuring an article by Frank Lin at Hopkins on hearing loss and its effect on dementia, which has been a growing area. But that brings me to the idea that sound, and all the therapeutic value it may have, do have an autism component. There's, of course, depression. Does it help with that? We talked a little bit earlier about Adam Gazzaley and his collaboration with Grateful Dead drummer, Mickey Hart, who has invested a lot of time and money exploring the therapeutic potential of rhythm. And that grew out of Hart's interest in his grandmother's reaction to her Alzheimer's disease and her relationship to music. So it just seems like are we just scratching the surface on the therapeutic value of sound at this point?

Nina Kraus: Yeah, we really are. The science, it's interesting, but it is important to me to the extent that it can make medicine better. It can make education better. I see a tremendous potential here. You talk about aging and

Alzheimer's, music is something that a person will respond to even when all of the other systems in the brain have failed or have become diminished. This is because music involves, actually, sound processing involves, evolutionarily ancient areas of the brain and many different areas simultaneously. So it is a portal into a person's being. Especially important when other aspects of life and function become impaired.

Now, this is the impact of listening to music and listening to music that you have listened to before in your life. And that's a different effect from, for example, in aging, if you actually play a musical instrument or you have played a musical instrument during your life, that has an enormous effect, positive effect, on sound processing in the brain and not just for music, but for conversations and for conversations and challenging settings like noise. One of the common complaints of an older adult is difficult to hearing a noise.

But in addition, one of the aspects of neural activity is that as we get older, certain responses to sound will slow down. But if you have had musical training, even if you stopped, but you have had musical training, and of course, if you continue to play music, what we see is a brain, in terms of the response to these different sound ingredients, we see a brain that looks biologically much younger in an older person who has a history of making music. And that is the actual making music, we're not talking about listening to music.

Bill Glovin: That may be a reason that a lot of jazz players seem to live into their eighties and nineties. It seems more than a coincidence.

Nina Kraus: Absolutely. And I see this again and again. Not only jazz players, but many musicians. Went to a fabulous performance of Arthur Rubinstein when he was 80 something, and it was fabulous. I'm interested in learning through sound, right? And recording from individual neurons, I'm interested in the biological basis of language and how we can better understand what happens in the brain with the languages that we speak. But ultimately, there is this question of, "What happens in the brain when we learn through sound?" And music, it turns out, is just the jackpot for auditory learning. The hearing brain is vast. The hearing brain encompasses what we know, how we move through sound, how we feel and, of course, how our various sensory input gets processed.

So I call this our cognitive sensory motor and reward framework for thinking of sound processing. Because really, when we process sound... I mean, just think about listening to the sound of somebody who you know well, you listen to the sound of their voice. There is a lot of what you know about that person, sound inherently is movement, it's a movement of air molecules, and making sound means that you're going to move and combine this information with what you're getting from your other senses. All of this together is a hearing brain. It is very affected by how we learn. And music is this wonderful model for auditory learning because it engages all of these different dimensions, the cognitive, the sensory, the motor, and the reward networks all at once.

Bill Glovin: You know, in 25 years of us doing articles that are mostly authored by neuroscientists, far and away the one that has been most accessed has been an article on bilingualism that happened, I don't know, 18 years ago. It's amazing. And that, for some reason, resonates in the neuroscience world more than anything by far. So I think there's lots of interest in this, especially in that realm of bilingualism, which is part of your website as well.

Nina Kraus: Certainly. Most people outside of the United States speak more than one language. And there are many people in the United States who speak more than one language. I'm looking at sound processing of these different ingredients. By the way, if anyone is interested in looking at our biological approach and understanding it a little bit better, on our website, on the homepage, there is an icon that says Demonstration of Our Biological Approach. And it's a little movie that explains in a minute or two the process and how we think about capturing these different ingredients in sound and how they are affected by the languages we speak, the music we make, the linguistic deprivation we may experience, the head injury we may have.

So you can think of music-making and bilingualism as forms of enrichment through sound. Yet the way that they impact the different sound ingredients, and the way in which the brain processes sound is different. Musicians have tremendous strength in how the brain processes harmonics, FM sweeps, timing. And it turns out that these are extremely important. These are the building blocks of words and languages and consonants. So you can understand better the relationship between literacy and language skills and musicianship because of the common ingredients. On the other hand, if you're a musician or bilingual, bilinguals have responses to sound that are very strong in the response to the fundamental frequency, which is the pitch on the sound.

So it is a pitch that enables me, for example, to pick out your voice, amidst a bunch of other voices. So it really helps me form what we might call an auditory object, right? Because auditory objects, things that make sound, have a pitch. And if you're very, very strong at processing the components of sound that go into creating the sensation of the pitch, that can certainly affect how you perceive the sounds around you. And these two aspects of enrichment, musicianship and bilingualism, have a lot to do with making sound to meaning connections. They are enriched through sound, and yet their effect on the nervous system is quite distinct.

Bill Glovin: Now, I need you to put on your outreach hat for a second. And I'm talking specifically about an article that you co-wrote for *The Scientist* entitled, “The Argument for Music Education.” It seems that arts education is always the first thing that is threatened by funding deficiencies. And in this economy, it will probably be ratcheted up. Can you briefly make the case as to why it's so important and needs to continue?

Nina Kraus: Oh my goodness. So this is such an easy argument to make, and I am mystified that one has to actually make an argument, that this isn't more obvious. We've been studying at Brainvolts sound processing in the brain for decades. And we've studied thousands of individuals across the lifespan. But some of the work that has been especially interesting and revealing is that founders of music programs have come to me and they have said, "The kids who play music are the better students." And it is so obvious to them. The founders of different music programs, one was the Harmony Project in Los Angeles, and the other was in several Chicago public schools.

These founders came to me and they said, "We know these kids are thriving. What is going on in their brains?" And so we really worked at trying to figure out what was going on in the brain. And then we wanted to see if you have the most powerful scientific design, which is a longitudinal design, and you take two groups of kids, you match them for sex and for reading ability and for every possible thing that you can think of and you follow them longitudinally year after year after year, and you see what is the impact of music in the kids who play music in comparison to kids who don't play music and who often do other enrichment activities, but particularly what is the effect of making music on sound processing in the brain?

We've done this in the Harmony Project, where we followed over three years second grade, third grade and fourth graders. In Chicago, in a number of public schools, we followed adolescents all through their high school career. So first as freshmen, then sophomores, then juniors and then seniors, so the same kids, over this period of time. Some of them engaged the music and others engaged in other forms of enrichment, we found that it takes a while to change the brain.

After one year of music making, we actually didn't see any fundamental changes in how the brain processes sound. It was only after two years and more. And we saw that the elements of sound processing, the ingredients that we know are really important for learning to read, how well the brain processes the harmonics, FM sweeps, how stable the response is from when you hear a sound the first time and the second time, is your brain responding consistently, all of these factors we saw become enhanced in the kids who played music while they also improved in their literacy skills and in their ability to hear sounds and noise.

Which is... We live in a very noisy world and kids need to be able to learn in a noisy classroom and understand each other in a noisy playground. And we found that there was a strengthening of the ingredients of sound in the brain, and they were related to reading and to academic achievement. In this article that you talk about, the arguments for a music education, we make what is called the indirect argument, which is that music boosts brain and cognitive functions that are important for learning. And we see that it does through sound processing in the brain, that ingredients strengthened by making music are those that are needed for language and literacy and hearing a noise.

The other arguments are the incentive argument, which basically ties the benefits of music training to educational outcomes like graduation rates. And there've been a number of studies that have shown that kids who make music are less likely to drop out of school and to graduate. Especially in low income areas, areas where kids don't have a lot of resources economically. And we have the indirect argument, the incentive argument, and what we call the intangible argument. And that is, many profound neurodevelopmental benefits are hard to quantify. And here we're talking about the limitations of science. It is hard to reduce many of these neurodevelopmental benefits to a set of data points and parameters.

How do you really measure a child's social engagement? Their satisfaction, their friendships, the confidence that they get from playing their instrument in front of everyone? All of these things lead to helping a child become a more productive member of society. And to me, taking all of this information together, and this is not only work that we have done, but so many others across the globe, there is a lot of converging evidence that the music education or playing a musical instrument is really good for the brain and for development and for us throughout our entire lives. I would say that that music education supports child development, actually human development, in its most holistic sense.

Which gets to, what I might call, my scientific gut feeling. People view gut feelings with skepticism, but yet at a certain point as a scientist, you realize that you've been studying your field for many, many years, and it isn't the outcome of a single study, it is the outcome of many different factors that make you have an opinion, like the opinion that I have, which is that music supports human development in its most holistic sense. This is my scientific gut feeling. This is a really important investment in a person's life that pays dividends until we die.

Bill Glovin: I hope school administrators and funders are listening, because you make a very persuasive argument there. I think that's a great place to end. And I can't thank you enough. I saw that you've done at least 35 of these podcasts. So you must be a little bit tired of talking about this, but we so appreciate you giving us some time and your insight.

Nina Kraus: Bill, I never get tired of talking about this. And every conversation is different. It's fun to talk to you, Bill. Your questions have been awesome. Thank you.

Bill Glovin: I appreciate that. And I had a lot of fun as well. Again, thanks a million. And I hope one of these years, I get to meet you in person at a SFN conference or something. But much appreciated.

Nina Kraus: Thank you.

Bill Glovin: That's Nina Kraus, professor of neurobiology and communication sciences at Northwestern University. We hope you enjoyed her thoughts on the importance of sound in almost every aspect of our lives. You can find all our content at Dana.org. This podcast is sponsored by the Dana Foundation in New York City and comes to you commercial free. Have a great day.