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Brainvolts and Nina Kraus

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1. Even though this is an interview about Brainvolts (https://Brainvolts.northwestern.edu) and not Nina Kraus, I have a few questions about Nina Kraus since it's challenging to separate Nina Kraus from Brainvolts. I notice that your background is biology and not auditory neuroscience. Would you care to comment on the strengths and perhaps challenges of coming "from another field of study"?

Sound and what the brain does with it is a *huge* topic. It involves fields from biology to physics to neuroscience to philosophy. I like to think of myself as a 'Renaissance Man' in my approach to science. As a scientist, my most satisfying experiences are my relationships with people from a gamut of perspectives interested in sound and the brain. I'm talking about teachers, musicians, physicians, athletes, parents... The exchange of ideas goes both ways. The Brainvolts website illustrates this. The projects listed on the home page include music, concussion, bilingualism, reading, listening in noise, aging, autism, neuroeducation, and technologies. Our tentacles reach into many fields.

2. Which came first, the chicken or the egg? Or, more specifically, did your interest in music facilitate your interest in the study of the brain, or did your interest in the brain, facilitate your interest in music?

Music has always been part of my life. I grew up in a musical family, my children play music, and I'm married to a musician. But, while the music came first, it is really *sound* that got me into brain research. Sound anchors the work we do at Brainvolts. In fact, Brainvolts was around for many years before we added a music component. Somewhere along the way, I realized music is a fabulous model for thinking about sound and the brain. Learning through sound involves the whole brain. It involves the other senses. It involves thinking. It involves feeling. It involves moving. What better than music involves all those components? From my view as a neuroscientist, music is the jackpot for studying our vast hearing brain (see figure). With what we have learned about music making's effect on the brain, I am grateful my parents made it a part of my life growing up. I keep making music—piano, guitar, drums, harmonica, singing harmony—not especially well, but with great joy. It also happens to be good for my brain.

3. Of the many parts of Brainvolts some, at least on the surface, are obviously connected such as bilingualism and reading or aging and hearing in noise. Others seem unconnected, music and autism, for example. What, if anything, is the thread that ties everything together?

The overarching theme of Brainvolts is sound and the brain. From that point of view, everything we do is connected. For example, I mentioned before that our arms reach into many arenas. One way to think about this is through the idea of healthy and hurting brains and their relationship to sound.

Within the unifying theme of sound and the brain, there is ample room for some interesting excursions. One way I frame my thinking about sound is as a mixing bowl with a multitude of ingredients. For example, sounds have pitch and timbre and timings. In addition, sounds contain amplitude and frequency modulations, temporal envelopes, reverberations, and dynamics. All of those sound ingredients must be processed by the auditory brain, but not every brain encodes them in the same way.

Healthy brains and hurting brains may dial up or dial down the encoding in specific ways. Crucially, there is not a single big volume knob that is turned up in a bilingual, for example, or turned down in someone with autism. Which sound ingredients are enhanced in the brain of a musician or an athlete, or a bilingual? Which ingredients decline with aging or with autism, or with dyslexia? The overlap or independence of the affected ingredients is fascinating to me. For example, playing a musical instrument enhances a handful of sound ingredients, notably harmonics and timing. But, Lo and behold, those sound ingredients are exactly the ones that are diminished in poor readers. Understanding the correspondence between music and language gives us a clue about why music is so effective at helping kids out in the classroom.

4. If I understand the history of your lab, it seems that there is a relatively recent interest in athletes and concussions. How do you feel that the study of this area informs your study of other areas of interest at Brainvolts?

The study of athletes and concussions falls squarely in the healthy brains / hurting brains idea. Making sense of sound is one of the hardest jobs we ask our brains to do. So it makes sense that getting hit in the head can disrupt this delicate process. The exquisite precision with which sound ingredients are encoded in the brain can tell us a lot. There is a long history of using sound processing to inform neurological conditions like hydrocephalus, cerebral palsy, brain tumors, meningitis, and more. The auditory brainstem response (ABR) has historically proven to be a powerful lens into the function of the brain. We reasoned a concussion would likewise leave a mark on the hearing brain. The ABR is generally unaffected by concussion but the frequency following response (FFR) is. We discovered a telltale FFR signature in the brain of children and adults who have suffered a concussion. Moreover, there is an often-overlooked difficulty hearing in noise following a concussion. I hope audiological care will soon become a routine part of concussion management.

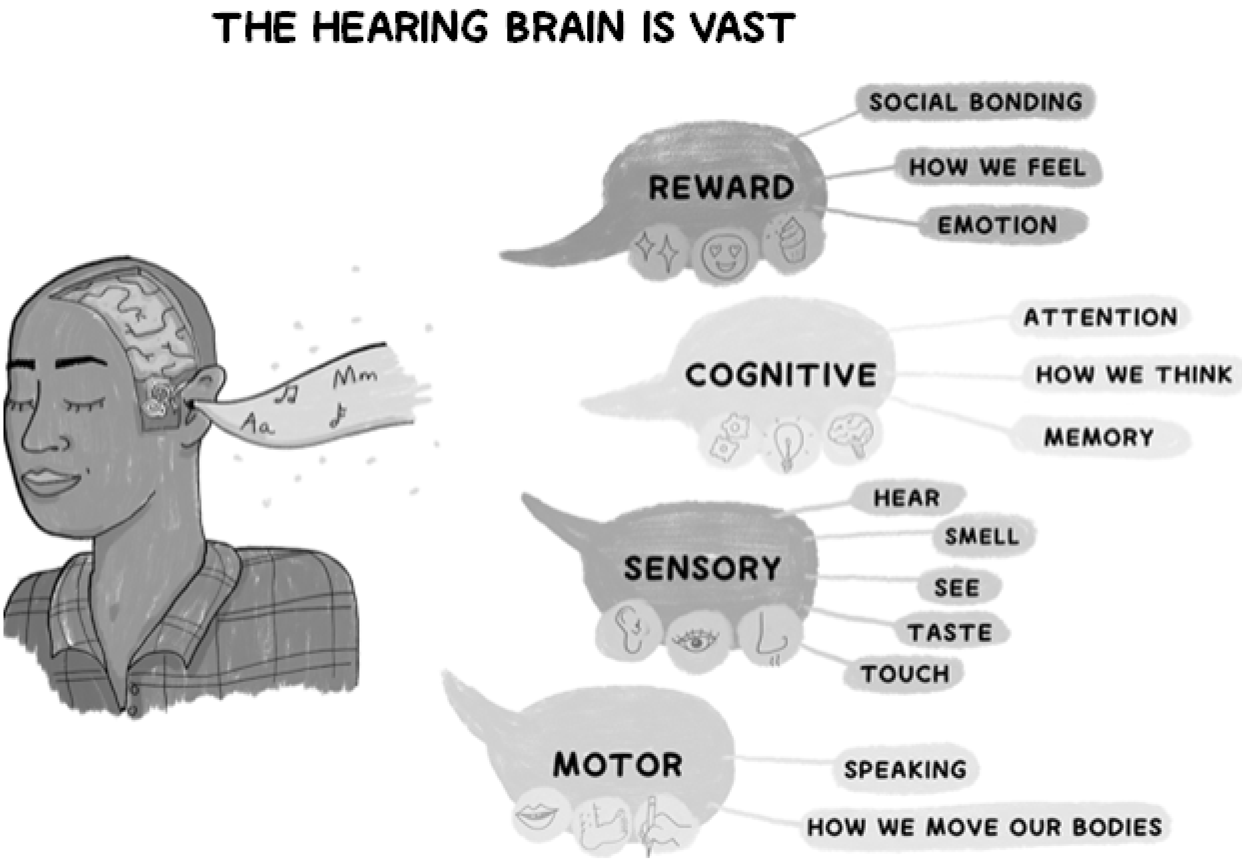
On the flip side, a healthy athlete has a well-tuned sound processing infrastructure, likely honed by the need to communicate with teammates and coaches in suboptimal listening conditions. This is reminiscent of the brain tuning that comes about from playing a musical instrument or speaking two languages. Thus, a boon to the listening brain is an unsung advantage of being in good athletic shape.

5. At Brainvolts, you and your students have studied both animal models at the level of the single neuron as well as aggregate neural activity in humans. Can you expand on some of the techniques you have used, and if any of these techniques would be useful in a clinical audiology setting.

Yes, we’ve looked at single neurons and multi-unit activity using microelectrodes in an animal model. This is fantastic for digging into mechanisms and understanding how the brain processes sound ingredients like pitch, timing, and timbre at the cellular level. But, for me it is important that we never stray too far from approaches that can be used in humans. That is how we arrived at the frequency following response. It works for everyone. In our experimental animals, all the while we were recording from neurons deep in the midbrain or auditory cortex, we were simultaneously recording aggregate activity from the scalp—basically a guinea pig version of the FFR you would collect from a human in a clinic. It kept us grounded.

One thing that often gets lost is that the hearing brain is vast. The midbrain is in the middle of the action (and plays a key role in the FFR). The midbrain is at the crossroads of a rich, distributed, bidirectional system, a site of two-way exchange of information traveling from the ear to the brain and back to the ear. The FFR can reveal the imprint of our lives in sound when you keep in mind that it’s not a “low-level” response. Instead, it’s an “all-level” brain signature of our *vast hearing brain* (see figure).

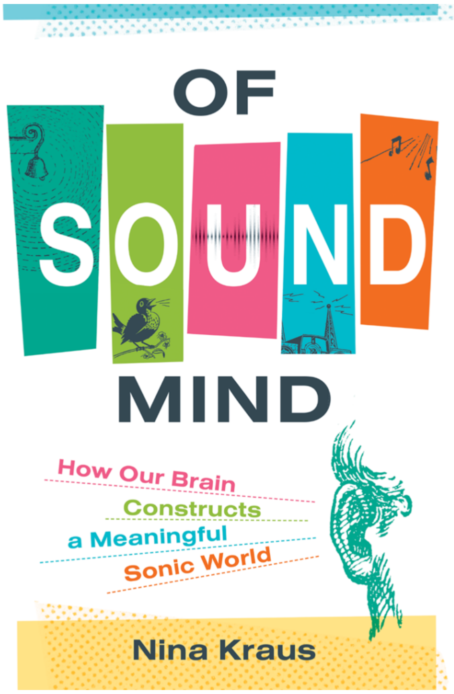
Brainvolts has published tutorials on how to harness the FFR to gauge how the brain encodes the rich array of ingredients in sound. I would like to invite everyone to check out our website at https://Brainvolts.northwestern.edu, where you can download our tutorials and most of our 30-plus year history publications. While you are there, please have a look around. The Brainvolts website is a labor of love; please start by taking the website tour at the top of the home page to find what you're looking for.



The hearing brain is vast. [Kraus N & White-Schwoch T, Unraveling the biology of auditory learning: a cognitive-sensorimotor-reward framework. Trends in Cognitive Sciences, 2015]

6. Now… this is a loaded question because I already know the answer, but it sure would be handy to have a lot of this information in one place in a book….. any plans for a book?

What a timely question! My book *OF SOUND MIND - How our Brain Constructs a Meaningful Sonic World* will be published by MIT Press and Penguin, Random House, in September. (And see the book review in this issue of CanadianAudiologist.ca).



My target audience is Hermoine Granger, a curious outsider interested in the unseen forces surrounding us, like sound.

In ***OF SOUND MIND***, I make the case that the sounds of the world around us—and what sounds we're exposed to throughout our lives—impact the development of our brains, the abilities and weaknesses we develop, and even who we are as human beings. Drawing from decades of studying the interplay of the brain and sound, I show that the processing of sound drives many of the brain's core functions. Hearing a cry or a word or a bird call or a chord brings forth different, specific reactions in each of our brains, and how we engage with those sounds, tune them up or down, in or out, is a lifelong process that changes the brain along the way.

The brain and sound each inform the other from the moment we are born through old age. The vast "sound mind" is inextricably woven into our thoughts, movement, and feelings. I explain how sound-brain teamwork influences our lives on many levels. Among the topics in the book:

- How the brain connects sound with meaning and how our sonic memories are formed
- Why there is more to keeping a beat than playing music or holding our own on the dancefloor. Rhythm has a deep connection to language and our biological systems and how they function
- How music has a profound effect on our brain's ability to process sound, and why musicians—defined here as anyone who has played an instrument regularly at any point in their lives—have measurably better sound minds for decades

- Why athletes are also better able to hear specific sounds in rooms full of noise, and how their brains tune sounds in and out differently from the way musicians do
- Why bilingual people are better able to hear and distinguish sounds throughout their lives; the effort of learning two languages gives their brains a distinct advantage in other listening roles
- How the way the brain processes (or does not process) sound can lead to an accurate diagnosis of concussion—a challenging diagnosis to make—or of other brain injuries, and then also play a role in the treatment
- What strategies can be used to practice distinguishing speech in noise (the most challenging hearing struggle as people age), and why this is a critical area of study when hearing difficulties can lead to many other health problems
- Why the increased noise of our 21st-century lives—traffic, machinery, the use of headphones, and even electricity humming through our computers and appliances—takes a toll on our sound minds and nervous systems, even when the noise level is modest
- How sound in the human world can negatively impact the natural world around us—from decreased bird songs to lost whales—and why we disrupt the fabric of nature at our peril.

I hope the book makes people more aware of the enormous impact that sound has on our lives, our consciousness, and who we are.