Transcript of Cerebrum Podcast—Why Do We Love Music?

Guest: **Robert Zatorre**, Ph.D., is a cognitive neuroscientist at the Montreal Neurological Institute of McGill University. His laboratory studies the neural substrate for auditory cognition, with special emphasis on two characteristically human abilities: speech and music. He and his collaborators have published about 300 scientific papers on topics including pitch perception, auditory imagery, brain plasticity, and musical pleasure. In 2006 he became the founding co-director of the international laboratory for Brain, Music, and Sound research (BRAMS), a unique multi-university consortium dedicated to the cognitive neuroscience of music. He tries to keep up his baroque repertoire on the organ whenever he gets a chance.

Host: **Bill Glovin** serves as editor of *Cerebrum* 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.

Bill Glovin: Who doesn't like music? From the time we are in our mother's wombs, to religious prayers, to every kind of celebration, music is an integral part of our lives. But each of us responds to music in a different way. Some enjoy singing while others are tone deaf. Some prefer hip hop to Mozart. Some can master playing a musical instrument, while others, no matter how hard they try, cannot.

Hi. I'm Bill Glovin and welcome to the *Cerebrum* podcast. To try to sort out some of how the brain processes all these things, we asked Robert Zatorre to write a *Cerebrum* article about it. His article, "Why Do We Love Music?" can be found at dana.org. Robert, who is on the phone with us, is a cognitive neuroscientist at the Montreal Neurological Institute of McGill University, in Canada. His lab studies auditory cognition. He and his collaborators have only published about 300 scientific papers on topics like pitch perception, auditory imagery, brain plasticity, and musical pleasure.

In 2006, he became the founding co-director of the International Laboratory For Brain, Music, and Sound Research, a unique, multi university consortium. And he even tries to keep up his baroque repertoire on the organ whenever he gets a chance. Welcome, Robert. I know that you gave a TED talk and started with a personal anecdote about how music changed your brain. Let's begin with that.

Robert Zatorre: Hi, Bill. Yes, this is just a very personal experience that I had as an adolescent, that really brought home to me the power of music. I remember this very clearly. Like most people my age, I was listening to heavy metal music and that sort of thing, and one day, for some reason, someone gave me a recording of music by the Hungarian composer Bela Bartok. And I had never heard of Bartok. I knew nothing about classical music, and I just put this on, and I was completely blown away by the patterns of sounds that I was experiencing. I had never really heard anything like it. And I had a very deep emotional response. I had chills down my spine and it was really quite extraordinary. And from that moment on I decided that this was something really important that I wanted to understand, both from an artistic point of view, but also maybe scientifically.

Bill Glovin: Before we get into the nuts and bolts of how music may change the brain, can we start with the kind of technology you use in your research, and also about the evolution of that technology, let's say, over the last decade?

Robert Zatorre: Yes. We use several different kinds of methods and we've been very, very fortunate that over the past decade, or two decades really, technology has advanced tremendously. So, a lot of our work uses brain imaging techniques. And mostly this entails magnetic resonance imaging, or MRI, and the advantage is that we can scan healthy volunteers. It's a procedure that is really free of any risk, and we can see the patterns of brain activity in those volunteers while they're doing something that interests us, such as listening to music or even performing music on an instrument.

The other techniques that we use are also equally important. So, recently we've been doing work with magnetoencephalograph, which is a very interesting technique because it always us to look at brain oscillations, whereas the MRI technique does not. And, finally, in the very recent few years, we've been using brain stimulation technology, and this is a way to actually create activity in the brain, either excitation or inhibition, and it always us directly to manipulate brain function while a person is carrying out some task. So, all of these techniques together really give us tremendous insight that just would not have been possible, say, 20 years ago.

Bill Glovin: When you say brain oscillation, can you tell us exactly what that is?

Robert Zatorre: Yeah. So, the neurons in your brain, the nerve cells, when they're active they tend to be active with a certain rhythm. So, a certain subset of neurons might be all firing in synchrony, let's say at four times a second. Whereas another set of neurons in a different part of the brain might be active at let's say 10 times a second. And so, with the MEG device we can actually look at those different oscillatory patterns and see what the relationship is between them and how they change, for example, as you are perceiving a sound or as you learn to perform some particular task.

Bill Glovin: For listeners who may not have read the article, is there an area in the brain that mainly processes music?

Robert Zatorre: No, I don't think so. Not everybody agrees with my point of view, but I like to say, when I'm asked that question, that the part of the brain that handles music is everything from the neck up. Because music is so complex that it engages all of our most higher-order, cognitive mechanisms. So, if you think about something really simple, that a child can do, like recognize a tune and maybe bounce around to it. Any four-year-old can do that. But that's a very complex set of actions that's involved there because you have to, first of all, take the sounds that are coming in through your ear, separate them out into the different components, the melody or the rhythm, or the harmony, separate them from any background sounds that might be present. You then have to have a memory system that allows you to recognize if that pattern has been heard before or not, and it may not be the identical pattern, right? It could be a new version of an old song, but you still recognize it without any trouble.

And then you have to activate your motor system, let's say if you want to sing along or you want to dance to it, you have to convert those sound patterns into something that the motor system can act upon. And on top of a lot, you might feel a great deal of pleasure as you're doing this. That means that you're engaging all of the pleasure circuitry, the reward system. So, really, right there you've got at least 80% of the brain that's already been engaged by something extremely simple that we're not even talking about, let's say, highly trained musicians. We're just talking about an everyday activity that almost any normal human being can engage in.

Bill Glovin: The auditory cortex is something I think I've seen you mention. How does that tie in?

Robert Zatorre: Yes. So, the auditory cortex is particularly important in many aspects of music because it is the part of the brain that first receives the inputs from the ear. So, if you have a sound, it's coming in through your ear, it will go through several stages of processing, first in the brain stem, then in the midbrain, then the thalamus. But eventually it gets to the cortex. And so, the auditory cortex is that part of, technically the cerebrum, that not only responds to sounds, but also figures out the relationships between sounds.

So, to give you an example, if I were to play two tones for you on a piano, let's say a C followed by an E-flat, that would sound like a minor third. Now you don't have to be a musician. If you're a musician, you would be able to say that that's a minor third. But even if you're not a musician you might recognize that as a particular sound quality. Now that is already a product of the auditory cortex because the first sound has to be represented as some kind of pattern in brain activity. And then the second sound has to be represented as another pattern. And then, importantly, the relationship between those two sounds has to be figured out.

And so, that's what our cortex does in a very kind of a seamless way. It figures out all of those relationships such that you can recognize a pattern of sounds really very, very quickly, and you can then remember it for some period of time. Similarly, for rhythms. The durations of a particular set of tones, and it's not just the durations but also, again, the relationships between them. So, when we talk about rhythm we're often talking about the meter of a piece of music. If you have a certain beat you'll have a repeating pattern, let's say, every four sounds, which is like in a 4/4 meter. That, in a sense, that doesn't exist in the sound itself. It's a property of the brain that it's able to notice that every fourth sound is somehow related because it's on the beat as opposed to being off the beat. And that's something that has to be computed by the brain, and it does involve the auditory cortex along with other structures that are connected to it.

Bill Glovin: Is there a sense ... Well, before I even get into that, I want to thank you for mentioning Cerebrum before. It's a nice plug for our journal. There's so many avenues I can do down, but one thing that stuck me was in the article you never alluded to the amygdaloid, the part of the brain that has been linked to emotion and consciousness. And, in fact, a fellow named Joe LeDoux, the director of the Emotion Institute of NYU, who wrote an article for us, plays in a band of neuroscience academics called the Amygdaloids. This is long way of asking if there is a link between music and the amygdaloid?

Robert Zatorre: Sure. There are definitely responses that occur in the amygdaloid complex through music. It's somewhat controversial as to exactly what that activity means. So, on the one hand, someone like Professor LeDoux would probably emphasize the negative emotional state that might be associated with the amygdala's response, notably the fear response, of course, that he's studied extensively. And there is some evidence that, for example, fear-inducing music might engage the amygdala. Also, people who have damage to the amygdala, when they're played scary music, like music from a horror movie, don't particularly find it scary.

So, on the one hand, they're that. On the other hand, we have found, for example, that when you perceive very pleasurable music, the amygdala is inhibited. So, there's actually less activity in that structure, which might go along with the idea that pleasure is also involved in calming, or some kind of state where you are less likely to be in a negative mood state. But, finally, there are also some investigators, colleagues of ours, who have found that the amygdala might respond when there is a very strongly emotive music, even if it's pleasurable.

So, if you listen to something that's extremely rhythmic and full of energy, maybe something played by that band, for example, you might actually get a response from the amygdala, even if people say that it's pleasurable. So, I guess the jury is still out on exactly what its function is. It's clearly linked to some kind of emotional response. Maybe to the intensity of the response, or maybe to arousal, and obviously we need to understand more about it. But I guess the answer, in short, is yes, it certainly plays a role, but we don't entirely understand what that role is.

Bill Glovin: In our first 10 minutes of conversation you've mentioned the word 'controversy' twice. Are there a lot of controversial issues in this type of research?

Robert Zatorre: Well, there are. I don't think it's unique to this particular area. I think it is perhaps a function of it being a very new area. So, you know when I started working on this way back in the 1980s, there was no such field as cognitive neuroscience and music. It really didn't exist. It was a few lonely individuals, myself included, who were trying to hack away at it, and we didn't even necessarily get a lot of strong support early on. But we persisted. So now there are more labs that are working on this, particularly quite a few groups in Europe, and quite a few in Canada, actually. And a few very good labs in the USA as well.

And so, because it's a new area and there are different groups working on it from different approaches, the findings aren't always necessarily perfectly aligned, but I think that's how science proceeds. A lot of people are concerned about sometimes the results of experiments not being perfectly consistent, but it seems to me that that's how we make progress, is by comparing our results and saying, “Okay, well, what did you do?” “Okay, I did this, and I found that.” “Well, I did this other thing and I found something else. Let's figure it out.” And, although there's controversy, I also think there's an excellent kind of esprit de corps that goes along with this field, and we have our meetings every couple of years and we hash it out and then we eventually, I think, come to a better understanding. So, it's kind of a lot of fun, frankly, that there is some controversy, because it means that we have work to do and it's really interesting work and it's at the edge of something that we're not quite understanding fully and that makes it scientifically very exciting.

Bill Glovin: Is there sort of an end goal in terms of what you're trying to achieve or understand?

Robert Zatorre: That's a very interesting question. I think perhaps the end goal might seem grandiose, but the way I think of it is that we're using music to try to understand all of those complex cognitive functions that the brain is capable of. And so, in that sense, the end goal is to really understand how the brain enables us to have our rich, cognitive and emotional world. And because music exploits many of those highly complex functions that we are endowed with, it serves as an excellent tool to really understand brain function, and then what's really interesting is that it then feeds back onto our understanding of music. And I firmly believe that, having a better understanding of how it is that the brain enables us to have music, it gives us a deeper understanding of music itself.

Bill Glovin: I think one key question might be, can music change the anatomy of the brain? Or do you believe it can?

Robert Zatorre: Yes, it can. And we have evidence of that. Of course, it's not just music. Lots of different kinds of skills might change the anatomy of your brain. Basically, the brain adapts to the requirements of any particular demand that you make on it. Particularly over long periods of time when you have extensive practice. So, in the case of music, for instance, it's especially a good model to look at what we call brain plasticity because you can have someone that spends several hours a day for 20 years of their life doing one thing, which is, say, playing the violin. That's the kind of thing that would be impossible to study in the laboratory. I can't imagine trying to bring in experimental participants and asking them to do something for two hours a day, for 20 years. That's insane and impossible. But I can study those people and I can then look at them at different stages of their training. And then with brain imaging, we can not only look at function, we can also look at brain anatomy.

And we we've done experiments like that. For example, with my collaborators, we've looked at the connections between the left and the right motor cortex in the brain. These are the parts of the brain that control the fingers. And what we find is that there are stronger connections between those two regions in people who have learned to play an instrument. Presumably because it requires coordination of the fingers, if you're playing a keyboard instrument, for instance, you have to coordinate the movements of your right fingers and your left fingers.

But also, very interestingly, the degree of change in that structure, in that connection between those two motor regions, is much stronger when the training begins early in life, like around age five, six, seven, than if it begin later in life. And so, this tells us that plasticity is more evident when you are young than when you're older. Of course, this has been known for a very long time, but here we see a very good example of it in practice. And it also explains why usually highly, highly proficient musicians, people who are performers, who make their living professionally as musicians, most of the time ... not always ... but very often, they have begun their musical training quite young.

Bill Glovin: About a month ago I was lucky enough to have Pat Metheny on this podcast. And I'd like to ask you the same question that I asked him. Why do some people gravitate to music while others don't?

Robert Zatorre: As I mentioned in the article, there are different scholarly approaches one can take to address these questions. So, if you're a sociologist, for instance, you might look at the social environment that a person grows up in, which might explain part of what makes someone more likely to become a musician. But from the neuroscience point of view, what we're finding is that there are actually interesting differences in the way that the brain is connected, the different parts of the brain are connected to each other. Which might give rise to a greater or lesser responses to music.

So, we've been studying a small subgroup of people that are particularly interesting to us. We refer to them as people with musical anhedonia. So, anhedonia is a word that means lack of pleasure. So, these are people who simply don't get much pleasure from music. And there's nothing else wrong with them. They don't have any disorder as such. They simply don't respond to music. They respond to everything else that everyone finds pleasurable. So, it's not like they're depressed. And they perceive music normally. They just don't have much emotional response to it.

And when we look at their brains, we find something very interesting which is that the auditory cortex that we mentioned before, that perceives the sounds, and the reward system which involves structures that have to do with pleasure, those two systems are much less interconnected than usual. Which means that the person can perceive the sound, but that sound doesn't somehow get transferred into the reward system and therefore the person doesn't really feel much emotional engagement with it. On the other hand, other avenues of input to the reward system are intact. So, a person might enjoy a good meal as much as anyone. Or they might enjoy social interactions as much as anyone. Or they might enjoy movies or visual arts, or whatever.

So that is one way that people differ in terms of how much they gravitate to music. And interestingly, we also found not only that there are people with what we call musical anhedonia, but we also found people with what we call musical hyperhedonia and I would probably be in that category. And when we study the brains of those people we find that they have more interaction, more connectivity between the auditory region and the reward region. So, it's as if they have an enhanced emotional response compared to the average. So, there's a wide continuum in the general population, and some people are particularly strongly responsive to music, some less so, and some not at all.

Bill Glovin: Can you explain maybe in a little more detail about the reward system and how it ties in?

Robert Zatorre: So the reward system has been studied for many decades in neuroscience, and until very recently it was almost exclusively studied from the kind of biological point of view, in the sense that it would be studied, for example, in a rat where you give the animal food, you make it hungry and then you give it food, and then you look at what's going on in its brain, and there are certain regions, there's one in particular known as the striatum, which responds very strongly. It sends out dopamine signals when the food arrives.

So, for a long-time people said, “Well, this is the system that is there to signal biologically important events." So, if you're hungry and you eat, you get this response which is highly pleasure, and that allows your survival. Similarly, a same reward system is also active with sexual activity. And that, again, makes sense, because sexual activity is hugely pleasurable for most people and that is how the species reproduces. So, if we didn't have that system we might not reproduce and therefore the species would die out. And so, that's the context in which the reward system has been largely studied. And there's a lot of excellent research on that.

But a few years ago, we thought, well, okay, music is highly pleasurable. But it's not, strictly speaking, necessary for survival. And it's not even like a substance. So, the reward system is also very responsive to certain drugs, like amphetamines for example, or cocaine or even nicotine. So, in those cases, I mean, that's why those drugs can be highly dangerous is because it's a direct chemical signal into the reward system and that can get you hooked. But music is not a substance. Music is not strictly necessary for survival the way food is. You won't die if you don't get music. You might be unhappy, but you won't starve to death.

And so, we started doing some experiments to see, well, does music depend on that same system or does the pleasure come from somewhere else? And we found, indeed, that quite a few series of experiments that we've done now, the reward system is engaged by pleasurable music, and that dopamine is released when you experience pleasurable music. And so, this links up this whole biological system which evolved for survival in a biological sense. Our way of thinking about is that in the human brain at least, it is now interconnected with other systems, notably, penetralia systems, and our ability to make predictions, our ability to hear sounds and anticipate the patterns and the sounds that are going to come up.

As you're hearing one sound, you anticipate what the next sound will be. If you're listening to a chord progression, you know roughly where it's going to end. And that whole system is linked to the reward system in such a way that we get both the intellectual response, which is the ability to make anticipations and perceive those patterns, and we also get the emotional response which is the pure pleasure, the physical pleasure, even those chills down the spine that I mentioned at the beginning of the interview. That's a product of the reward system.

So, music is a remarkable feature of the human brain, I think, because it links together, in one sense, the most highly evolved parts of the brain, the areas of the brain that most differ between us and other species, it links those regions with the reward system which in a sense is one of the ones that's more preserved in phylogeny, in the sense that our reward system functions not so dissimilarly from that of other animals. I find that to be a very fascinating concept that needs refinement of course, but I think it's a good hypothesis to work on.

Bill Glovin: So, the reward system suggests pleasure, and you've also talked about the idea that sound can produce fear. Is there a connection between music and pain?

Robert Zatorre: There is. I personally have not worked on that, but there are a few groups that have been looking at it. So, music has been used as a kind of analgesic in some cases, and does seem to help. I think people are still trying to work out what the mechanism is. Is it a kind of a distraction type of thing where it's a general calming, or is there a natural inhibition of the pain mechanism? There's some evidence for both of those ideas. And I think the importance of studying something like the reward system is to get a better handle on how it is that music engages our emotions, because if we can do that, we might be able to harness that knowledge in specific ways that might have direct applications.

So, pain control is one of them. I think the idea of mood control is another one. In a sense people do this already. People modulate their mood with music. Everybody does that, right? You may have had a rough day at the office and you come home, and you listen to something soothing. On the other hand, if you're really bored, you might want to listen to some very upbeat music. So, you can up regulate or down regulate your mood with music and this is hardly anything new. I mean, if you're a mom and you have a baby and it's crying, you calm it down. How do you do it? By singing a lullaby, right? And this is something that people do in all cultures around the world.

On the other hand, if you want to wake the baby up, you might sing it a lively tune. So that's kind of already our folk knowledge. People understand this intuitively. But if we can really understand the brain mechanisms behind it, we might be able to come up with direct therapies for populations that might need help. So maybe depressed patients, or maybe patients with Parkinson's disease who have large motivational problems. There are many potential applications that might emerge from this knowledge.

Bill Glovin: Yeah, we've heard about Alzheimer's patients who can recollect songs from their youth and it kind of suggests that music is stored in a place in the brain that is unique. Because they can't remember lots of other things. So, it could have a therapeutic potential. Is that something that you look at, in terms of disorders and how to treat them?

Robert Zatorre: Yeah, so that's a very active area of research. It's not one that I personally have worked on, not with dementia anyway. But it is an active area of research for the reasons you indicate, which is that there are some very compelling instances of people who, while otherwise really quite demented, will respond to music. The part of the story that we don't entirely understand yet is why it is that some patients do respond that way, whereas others really just don't respond that way at all. So, it is not the case that every single Alzheimer's patient will remember the songs of their youth. Some will and have a huge emotional response, others will be completely indifferent. And so, we don't really understand that heterogeneity, those differences, in the responses, and until we do it'll probably be more difficult to develop some direct applications. But this is exactly why we need to pursue the research. So, it is an exciting time in that sense, that we're on the cusp of really having some breakthroughs.

Bill Glovin: When I sent your article to my advisory board, which is made up of prominent neuroscientists, they loved it, and some of them came back with questions and I promised I would ask at least a few of them. So, one of our board members, John Morrison, who directs the California National Primates Research Center at

UC Davis, and is editor and chief of BrainFacts.org, asks, “When Dylan won the Nobel Prize for literature, the committee made a point of awarding it to him as a song writer, not as a poet. If you read Dylan's lyrics, they have nowhere near the impact of the song. Same is true for Springsteen and many others. So how do lyrics fit in, particularly to the reward system?”

Robert Zatorre: That is a very interesting question. It's not one that's been addressed very much experimentally. It's certainly one that we would like to get our hands on. It's absolutely true the if you simply read lyrics of many songs, they have no emotional impact. And yet when you sing them, they suddenly become impactful. But if you just play the tune, without the words, they may not be quite as impactful as they would be together.

So there's some kind of interesting interaction between the content of the words and the musical features themselves, both the melody and the rhythm and the way that the rhythm enhances the structure of the text, emphasizing certain syllables over others, the way that the harmonies might change to make you subtly reinterpret the way that the text works. So, there's some unique interaction going on there and it's interesting, too, because if you look across cultures, almost all cultures have singing. Whereas not every single culture necessarily has instrumental music. So, it seems like singing is very basic, something that is very much a part of being human. So, I think that's one of those areas that's ripe for further study. Because there's definitely something quite interesting going on.

Bill Glovin: When we started out you mentioned that you listen to metal and then you had an epiphany when you heard Bartok. And the sort of brings up the idea of music and culture, and I know that's not an area that you study, but the evolution of music is fascinating, especially when it comes to the use of rhythm. Is that ... this might be a science fiction-type of question ... but is music still evolving and is it going to go somewhere where we can't even perceive at this point where that point might be?

Robert Zatorre: Yeah. I'm not probably the right person to address that question because I'm not a musicologist and don't claim to be. From what I understand, music, and really all art forms, typically evolve culturally over time due to many different circumstances. Sometimes it's because of a technological innovation. So, the first time ancient humans figured out that they could blow through a reed and make a pleasant sound from it, that changed the course of music. Until then, they would have made music by their vocal tracts by singing, or by clapping perhaps.

But at some point, they figured out that you can make flutes. And we know from archeology, for instance, that there are bone flutes that have been discovered that are 40,000 years old that have holes drilled into them made out of the bones of storks, for example, or long-legged birds. So, this means at some point human beings figured out that they could make different kinds of sounds using a new technology. So that drives change in music.

Other times it's because of cultural exchange. So you might one group of people who have one particular type of musical expression, and then they come into contact with another group of people who have a different kind of musical expression, and then if they don't kill each other ... which often happens ... they might come up with a new musical form. And I think there are many historical instances of that happening, many types of music that are the product of cultural fusion.

So, yes, so music evolves for sure. I think I would go back to the idea that what we hear early in our lives sets the stage for how we interpret sounds later on, and this is really the same thing for speech sounds as it is for musical sounds. So, as you're exposed to sounds, you figure out the relationships between them and you come to understand the syntax, the patterns, and how those patterns typically play out. And so, for cultural evolution to happen, someone has to then come and break a little bit with those patterns.

And so, you often have individuals who might be quite creative and come up with new patterns that hadn't been experienced before, and it might take a while for them to catch on, but as a new generation hears those new patterns, they might have a more flexible brain and be able to understand what's going on. Whereas the older generation may stick with the older patterns. But eventually they'll die off and a new generation comes in and that's also another way that cultural evolution happens.

Bill Glovin: This is such a fascinating topic. We could go on all day. But I think that would be a great place to end. And I can't thank you enough for the article and for taking the time to participate in our podcast. And for people who are listening and might want to look at the article, you can find that at dana.org and, again, this is a *Cerebrum* podcast and our guest has been Robert Zatorre. And thank you, Robert, very much.

Robert Zatorre: Thank you very much, Bill. I really enjoyed our discussion and I want to thank the Dana Foundation, as well, for having allowed me to write that piece.

Bill Glovin: And thank you for listening. You can find this and all our other *Cerebrum* articles and *Cerebrum* Dana podcasts at dana.org, including a recent podcast that covers the creative process and how it relates to music, with master composer/guitarist, Pat Metheny. I'm Bill Glovin at the Dana Foundation in midtown Manhattan. As Dennis Miller used to say on Saturday Night Live, "That's the news, and I'm outta here."