by Donald A. Hodges and Robin W. Wilkins

How and Why Does Music Move Us?

Answers from Psychology and Neuroscience

Abstract: What scientific evidence can music educators share with their community stakeholders concerning how and why music moves us so powerfully? Five key points derived from recent psychological and neuroscientific findings are (1) Network Science is a new technique that allows researchers to examine the brain's interconnectivity as people listen to music; (2) the Default Mode Network is a set of interconnecting brain networks that are involved in conscious awareness, self-reflection, and autobiographical memories and emotions; (3) when people listen to preferred music, there is dynamic interconnectivity in the Default Mode Network, linking music to self-awareness, along with associated personal histories, core emotional memories, and empathy; (4) musical training leads to numerous changes in the brain that have implications for music learning; and (5) scientific evidence supports the powerful role that music plays in enhancing quality of life.

Keywords: brain, Default Mode Network, network science, neuromusical research, peak experiences

What can psychology and neuroscience research teach us about the value of music?

What scientific information can music educators share with parents of their students, administrators, school board members, and community leaders about the powerful role of music in our lives? Imagine, if you will, the closing concert in a weeklong celebration of music at a typical high school. The band and jazz ensemble have already performed, and the choir and orchestra will perform shortly. Between these presentations, however, the audience hears a brief talk given by a psychologist and a neuroscientist. Let's listen in as the principal introduces them.

Principal Bryant: "Ladies and gentleman, the moving performances you just heard may naturally raise some fundamental questions about how music is processed in the brain. To provide some answers, I've invited Dr. Valerie Reynolds, a neuroscientist, and Dr. Steven Reynolds, a cognitive psychologist, to share with us some recent scientific evidence that may help explain our strong responses to music. They will also show some images of recent brain research. Dr. Valerie is an accomplished violinist, and Dr. Steven is an avid singer and guitarist. They are also the proud parents of Jenny Reynolds, a cellist

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in our school orchestra. Please welcome Drs. Valerie and Steven."

Steven: "Thank you, Mr. Bryant. As you think about these young people performing so beautifully, and other meaningful musical experiences you may have had in your life, you may be wondering, 'How and why does music move me so much? Why do human beings all over the world and throughout time find such deep pleasure and meaning in music?' Valerie and I will do our best to give you some current information emerging from the cognitive neuroscience of music. In the interest of time, we're going to do this in five brief segments. We'll talk about a new brain-imaging analysis method called Network Science, brain areas called the Default Mode Network, an exciting brain-imaging experiment involving the effects of music preference on the brain, and music learning's effect on brain structure and function. Finally, we'll weave these four strands together into a more complete picture of why music so powerfully moves us as it affects quality of life. Here is Dr. Valerie."

Network Science

Valerie: "To begin, brain-imaging experiments in general, and those concerned with music in particular, have improved tremendously in the past few decades. Researchers have discovered which parts of the brain are active during a variety of musical tasks, such as listening to or performing brief excerpts. They have learned that everyone has the possibility of meaningful musical experiences and that those who study music seriously show significant changes in both brain structure and function,[1] which we'll discuss later. However, there is a significant limitation to traditional approaches: The brain does not function by tiny areas acting in isolation, but rather as an integrated, interconnected system. Because people's responses unfold while they are experiencing music, neuroscientists needed a way to investigate the whole brain while a listener enjoys an extended musical selection. Fortunately, a very recent development called Network Science[2] allows us to do both those things; now we can investigate dynamic interconnectivity in the brain as listeners hear complete songs.

"By measuring brain activity throughout the whole brain, including interconnections among the front-back, top-bottom, and left-right sections of the brain, we can construct a connectivity map that represents how the brain communicates within itself from moment to moment. A voxel is a tiny, three-dimensional piece of brain tissue comparable to a pixel on a television or computer screen. It contains about 5.5 million neurons and 50 billion synapses, which are the connections between neurons. Using a network science approach, researchers constructed a brain connectivity map consisting of approximately 21,000 voxels monitored during five minutes of music listening.[3] They determined the strength of these connections, measured between each voxel across time, and eliminated the weaker connections. Retaining the strongest connections between voxels throughout the entire brain provided a connectivity map of the brain during real-time music listening."

The Default Mode Network

Valerie: "Relevant to the effects of music, I want to describe the Default Mode Network—DMN for short. As shown in Figure 1, the DMN is a set of interconnected regions in the brain that becomes less active when you are paying outward attention to something but is more engaged when you are focusing inward, such as during introspection or mind-wandering.[4] Neuroscientists often call it 'the resting state.' We think that people move in and out of the resting state throughout the day. For example, maybe one minute your mind is adrift and you're reflecting on your life and feeling overwhelmingly grateful or perhaps the opposite, a sense of profound loss. While your mind is wandering, you may suddenly in the next minute have to redirect your attention to an external task.

"The DMN emerges in infancy[5] and continues to develop throughout the life span.[6] It supports levels of consciousness or awareness, and in the case of self-awareness, the DMN is involved in the reprocessing of autobiographical memories and self-relevant emotions. This experience is something I like to think of as 'mulling over.' It is also active while one ruminates on hopes and dreams. The DMN is thought to help us imagine or understand the feeling states of others.[7] Support for these ideas comes from the fact that the DMN is impaired in individuals with Alzheimer's, schizophrenia, autism, and other cognitive conditions that involve a loss of self-awareness."[8]

FIGURE 1

The Default Mode Network. This is a view of the brain looking down from the top. The colored areas are regions that cooperate with each other during times of introspection. Colors indicate the degree to which the area serves as an important conduit of neural information, with red areas being more critical than yellow.

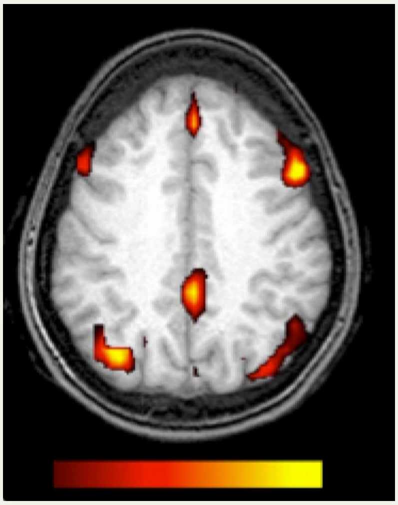

Image by Robert Kraft

A Network Science Music Experiment

Steven: "In a study involving music and the DMN, researchers had young adults listen to entire songs or extended excerpts from different musical genres.[9] Participants reported preferences for a specific type of music—country, classical, rock, or rap/hip-hop—and identified a personal, all-time favorite piece as well. The researchers had them listen to a set of randomly presented songs from each of these genres as well as an unfamiliar selection of Chinese opera. You may recognize some of these songs. [Steven plays a few seconds of "I Wanna Rock 'n' Roll All Night" by the band KISS, "O.M.G." by the singer/songwriter Usher (full name Usher Terry Raymond IV), and the beginning of Beethoven's Symphony no. 5.] In addition, each person listened to his or her self-reported, all-time favorite song or piece of music.

"Because this was the first time researchers had used network science to analyze brain responses while listeners heard entire songs, they discovered information previously unobtainable. The primary finding was that when these young adults listened to music, their brains showed increased connectivity in the DMN, as shown in Figure 2. In particular, preferred and favorite music elicited increased connectivity to the frontal part of the brain. This indicated that listening to favorite music engaged the part of the brain involved in higher-order thinking, which can involve such cognitive functions as understanding, analysis, and evaluation.

"Another finding was that it was not the genre of music or whether the music had lyrics, but, more important, whether the person liked it, that changed the patterns of brain functional connectivity. Analysis revealed that when a person listens to music he or she prefers, the brain increases connectivity within the Default Mode Network. This supports what people often report: They find themselves considering unsolicited personal thoughts while listening to music that they like. They are essentially 'looking in'—ruminating on personally relevant memories and emotions—rather than 'looking out'—paying attention to external events.

"Because it is involved in rumination, where new ideas can be formed, it has been suggested that the DMN might influence aspects related to creativity, abstract thought processing, and cognitive flexibility. It helps us connect

FIGURE 2

The Default Mode Network during Music Listening. Colored portions link together in a distributed communications network. Note that frontal regions of the brain (red arrows) are part of the network when listeners like the music and are missing when they do not like the music. Red color indicates consistent involvement of these regions among music listeners; purple indicates less consistency.

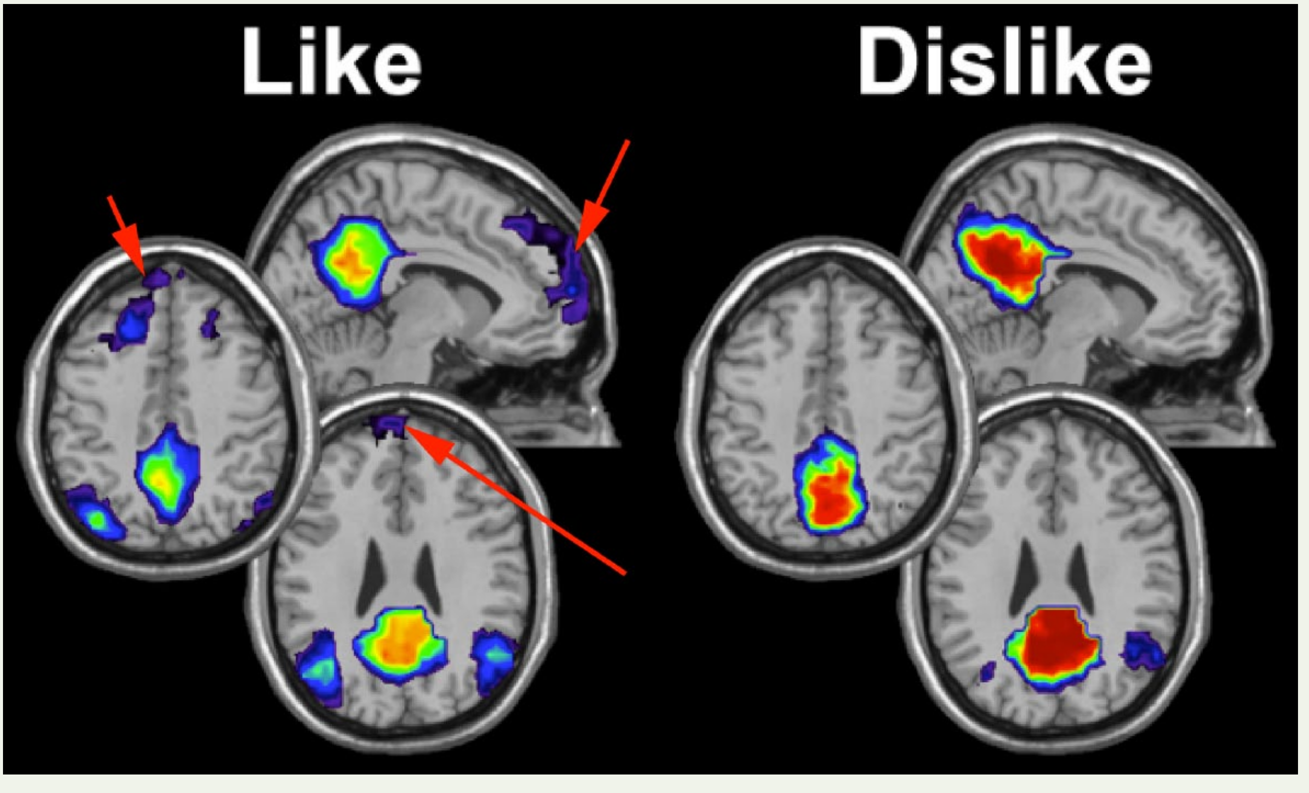

Image by Robin W. Wilkins

smaller bits of previously disconnected pieces of information, such as puzzle pieces, to create a new idea or concept. Furthermore, some researchers consider this network related to identity formation, social learning, and personal decision-making. While more research is needed, the close association between the DMN and music may explain why people identify themselves, even as young children, so strongly with certain genres or favorite pieces of music."

Music and Brain Function

Valerie: "A number of years ago, the notion that music makes us smarter garnered a great deal of press. Recent findings provide a more nuanced perspective. Certainly, we see that music learning modifies brain structures and functions. Adult musicians, especially those who started studying seriously before the age of seven, show changes in numerous brain regions and improved functioning for music processing. What you see up on the stage tonight are young people who are engaging in intensive mental and neurological feats to sing or play their instruments. Performing music is a whole-brain activity, with neural pathways connecting multiple regions throughout the brain. As you look at the next four images (Figure 3), you will see colorized pathways in the brain of a professional clarinetist. In Figure 3a, we see her brain as if looking at it from the back of her head. The purple strands show neural pathways connecting the top and bottom of the brain; the green strands are neural pathways running primarily side to side. Next (Figure 3b), we see an image of her brain taken from the left side. The red band in the center is her corpus callosum, the major neural pathway connecting the left and right sides of her brain. Based on data from several studies, it is likely that she has millions more fibers in her corpus callosum than those who have not studied music.[10] In Figure 3c, we see her brain from the top. Neural pathways connecting the front and back parts of her brain are shown clearly. Finally, in the last image (Figure 3d), we see the same red band on the left side of the image as in a previous slide; this is her corpus callosum. The blue strands arising out of her head show neural pathways running from the core of her brain to the top. Researchers have demonstrated differences in neural pathways between highly trained musicians and those without training. Furthermore, there is a strong relationship between the amount of time practiced during childhood and adolescence and structures in the brains of adult musicians.[11] From a neuroscientific perspective, then, musical training can cause significant and lasting changes in the brain. However, those changes do not necessarily translate into better performances in other domains, as Steven will explain."

Steven: "From my perspective, the answer to the question, 'Does music make you smarter?' is 'no, maybe, and yes . . . depending.' [*Laughter.*] What I mean by 'no,' is that we do not automatically become smarter simply by listening to music. It is true that students such as these [*motions toward band, orchestra, choir, and jazz ensemble*] on average have higher grades than those who do not participate in music.[12] However, research is still ongoing to understand what is transpiring in the brain that might influence academic performance. It is probable that these findings about music and academic skills are in large part a result of children coming from homes where the parents support education, provide their children with opportunities such as attending concerts, and teach them good time management skills, responsibility, perseverance, and so on.[13]

"The 'maybe' answer comes from work on what is called near and far transfer.[14] That is, those with musical training tend to do better on near transfer tasks that are similar to music, such as auditory discrimination in language.[15] They are less likely to perform as well on far transfer tasks that distantly relate to music. The 'yes' answer is that, as Valerie demonstrated in the previous slides, there are distinct brain changes in adult musicians compared to those without formal training, and this leads to improved performance on musical tasks. Some of these changes occur in the auditory cortex, the corpus callosum, the cerebellum (responsible for integrating sensory input into motor output), the gray matter (the outer wrapping of the brain involved in sensory, motor, cognitive, and emotional processing), the white matter (the inner core involved in transmitting messages throughout the brain), sensorimotor cortex (where incoming sensory information and outgoing motor actions are processed), and multimodal integration areas (where information from the senses is integrated into a coherent whole).[16] These changes generally lead to more efficient functioning, that is, faster and more accurate performances on musical tasks. Because some musical tasks may share components with other domains such as language, it is possible that becoming musically proficient may confer benefits to performance in other domains. For example, at-risk children who received two years of musical training improved significantly in neural processing of speech sounds when compared with those who did not receive the training or who only had it for one year."[17]

Intense Musical Experiences and Quality of Life

Steven: "To move away from how music might influence other domains and return to core musical experiences, we want to finish with an examination of what these powerful, emotional experiences have to do with quality of life. In doing so, we will be weaving psychological and neuroscientific experiences into a coherent viewpoint.

"In the 1960s, psychologist Abraham Maslow wrote about *peak experiences*. These are intense, transcendent, intrinsic experiences that are critical in achieving self-actualization or in progressing toward becoming who we are meant to be—our best, most complete selves. Maslow found that music is one of the most common ways for people to have peak experiences.[18] Nearly fifty years later, Swedish psychologist Alf Gabrielsson surveyed more than 1,300 people, asking them to describe 'the strongest, most intense experience with music' they

FIGURE 3

Communication Pathways in the Brain

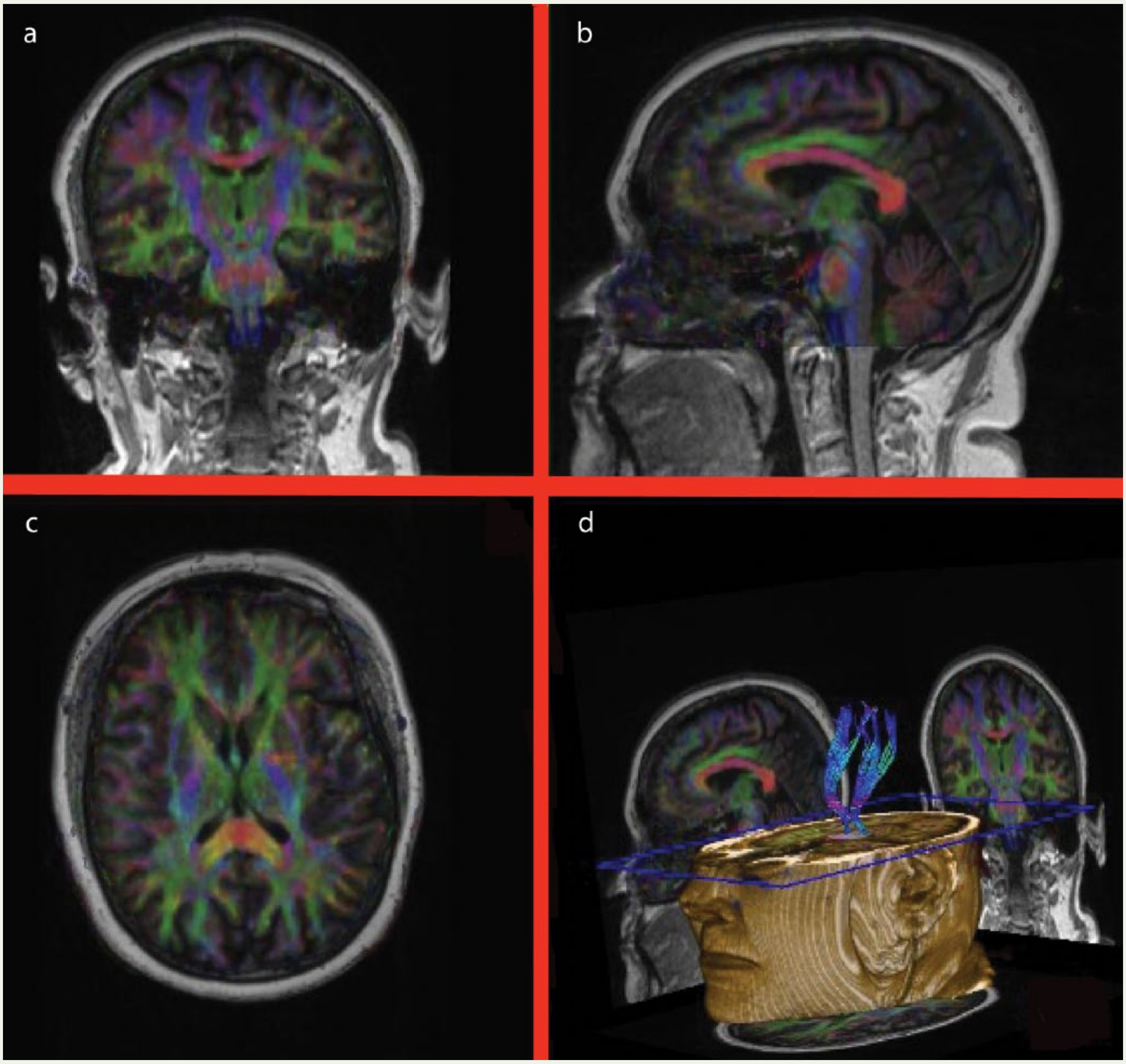

Image by Robin W. Wilkins

could recall.[19] Responses ranged from physical responses such as weeping or hair standing up on the back of the neck, to the elicitation of important memories that were highly emotional and personally important. These descriptions bore a very strong resemblance to Maslow's concept of peak experiences.

"More recently, another group of researchers conducted in-depth interviews concerning intense musical experiences. They concluded that intense musical experiences can lead to enduring changes in one's personal values, perceptions of the meaning of life, social relationships, and personal development.[20] Intense musical experiences can 'help us to realize our true inner selves in order to live a more authentic, fulfilled, and spiritual life.'[21] Finally, psychologist Adam Croom[22] discussed the role of music in five commonly recognized factors that are characteristic of human flourishing or well-being: (1) positive emotion, (2) relationships, (3) engagement, (4) achievement, and (5) meaning. For each of these five factors, he identified relevant research, including neuroimaging studies, that shows music's potential for enhancing the human experience. Croom concluded that 'musical engagement can positively contribute to one's living a flourishing life.'[23] In sum, evidence confirms the notion that music is a common way for people to have very powerful, emotional experiences that are transcendent, help shape each person in unique ways, are long lasting, and that lead to an enhancement of quality of life."

Valerie: "The field of neuroscience is developing so rapidly that we are now capable of examining the brain to study aspects of mental experiences in ways we never dreamed were possible. For example, philosophers have thought about the nature of musical experiences for several thousand years, but recently neuroscientists are joining the discussion.[24] I want to talk briefly about something called *neuroaesthetics*—the investigation of brain systems involved in aesthetic experiences.[25] Because definitions of an 'aesthetic response' can vary and because music is represented in diffuse patterns spread throughout various regions of the brain, there is no specific 'music aesthetics network.' However, in addition to the DMN, neuroscientists have identified other brain mechanisms involved in significant musical experiences that are associated with reward, memory, self-reflection, emotion, and sensorimotor processes.[26] After conducting a meta-analysis of ninety-three neuroimaging studies involving visual art as well as music, neuroscientists concluded that aesthetic processing primarily involves positive/negative judgments, such as like/dislike or pleasant/unpleasant, and that this is an adaptation of our appraisal of things that provide survival value, such as food or potential mates.[27]

"One way to organize neuroaesthetics findings as they apply to music is to consider brain-imaging experiments that support each of music educator Gerard Kneiter's five characteristics of an aesthetic experience—focus, perception, cognition, affect, and cultural matrix.[28] Focus, or paying attention to the music, unfolds in a timeline of neural responses that begins with auditory brainstem responses that occur within a few milliseconds. Positive/negative judgments[29] and identification of musical genre[30] can occur in less than an eighth of a second. Researchers found evidence of focused attention over time when performances of Bach by professional pianists caused a sharp decrease of blood flow in specific areas of the brain.[31] Music perception[32] and cognition[33] engage many brain regions, with specific aspects such as pitch and rhythm processed in distinct areas.

"Musical emotions are also broadly represented in the brain, with many different structures involved.[34] So-called feel-good neurochemicals such as dopamine[35] and serotonin[36] are released during musical experiences, leading to intensely pleasurable feelings. By 'cultural matrix,' Kneiter meant that music does not occur in a vacuum; rather, it occurs within broader sociocultural contexts. A number of studies have demonstrated that culturally familiar and unfamiliar music elicit activations in different brain regions.[37] Neuroaesthetics is a relatively new field, and we should expect to see much progress in coming years that will help us better understand how we process aesthetic experiences with music in the brain."

Steven: "To recap briefly: From our discussion so far, we can draw five important conclusions:

- First, using the new techniques of network science, we can examine the brain's interconnectivity as it processes extended musical experiences.
- Second, the Default Mode Network is a set of brain networks that deal with conscious awareness, self-reflection, and autobiographical memories and emotions.
- Third, in the particular experiment described previously, we saw that when people listened to their preferred music, there was dynamic interconnectivity in the Default Mode Network, linking music to self-awareness, along with associated personal histories, core emotional memories, and empathy.
- Fourth, musical training leads to numerous changes in the brain. While these modifications definitely influence musical processing, they may or may not lead to improved performance in other domains such as language arts or mathematics.
- Fifth, a considerable amount of psychological and neuroscientific evidence supports the powerful role that music can play in enhancing the quality of life.

"What this means to us can be summed up nicely in a brief quote from Sister Wendy Beckett. Sister Wendy is known for her video series on the history of art. When a BBC interviewer asked her what we gain from engaging in art experiences, she answered immediately and succinctly, 'We can become more fully human.'[38] Transposing this to music, perhaps we can say that one of the most significant values of music is that it can provide us with insights into the human condition. No matter the differences of age, gender, ethnicity, socioeconomic status, or any other real or perceived variable, at heart we are united by the fact of being human. Music has the capacity to tap into this central aspect of our humanity to reveal, explore, and share what it is that makes us both corporately the same and yet individually unique. Furthermore, musical experiences appear to connect brain structures that play essential roles in our development and well-being, especially when we are being thrilled to the core, lifted to new heights, or experiencing transcendence over everyday concerns as we sing, play, create, dance, or listen to music. In conclusion, all of this evidence points to a scientific explanation for how and why music moves us."

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