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Implications of Music and Brain Research

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IMPLICATIONS OF MUSIC AND BRAIN RESEARCH

This introductory article offers an overview of neuromusical research and articulates some basic premises derived from this research.

BY DONALD A. HODGES

In recent years, we have witnessed an explosion of information about the brain. New imaging techniques have given neuroscientists the tools to peer into the brain in ways unimaginable just a few years ago. What they are learning is revolutionizing our understanding of this incredible neural machinery, and now they are able to ask—and answer—questions that will eventually unravel many mysteries of the mind.

Among these mysteries is music. Why are human beings musical? How does music processing take place in the brain? Are there strategies we could uncover that would allow people to learn music more efficiently? Is there an optimal time for learning music? How is it that some cognitively impaired individuals can be so musically proficient? On and on go the questions we would like to have answered.

For many music educators, obtaining information about recent discover-

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ies involving music and the brain may be difficult. This is so because the reporting of neuromusical research is often polarized: either it appears in scientific journals in language that is too difficult for nonscientists to easily read and understand, or it appears in the popular press in such a watered-down fashion that actual facts may be distorted or obscured. The intent of this special focus issue of the *Music Educators Journal* is to provide current neuro-

musical information in a way that is at once accurate and accessible to music educators.

To that end, the articles in this issue provide a broad overview of many important topics, along with considerable detail and many reference lists to guide the reader in further exploration. We begin with "Music and the Baby's Brain: Early Music Experiences." In this article, Donna Brink Fox reviews the literature on infant and early childhood music with respect to brain development. Perhaps surprising to some, but probably not to those actively working with young children, is the idea that many adult-like responses to music are already apparent in infants. Cross-cultural studies are confirming that even if music is not a universal language (in the sense that we do not automatically understand the music of unfamiliar cultures), music (like singing lullabies or responding affectively to music in the surrounding environment) is universal. Based on her review of the neuroscientific literature, Fox offers support for several key ideas in early childhood music education, such as the fact that active engagement, not passive listening, spurs brain development. She concludes by giving exam-

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ples of ways in which we can collaborate with others to create the healthiest, most effective climate for the musical development of young children.

The next article, “EEG Studies with Young Children,” continues by looking at brain activity in preschool and elementary school children. Here, John Flohr, Dan Miller, and Roger deBeus explain electroencephalogram (EEG) techniques and how they have been applied to the study of musical behaviors in children. Some of the research supports the similarity of activation patterns in children and adults, but other studies identify ways in which the developing brain is different from the adult brain. Though we don’t yet know the precise characteristics of the “window of opportunity” for learning music, research investigators are moving toward a more complete understanding of them.

In “Does Music Make You Smarter?” Steven Demorest and Steven Morrison take up a very timely topic. The notion that exposing children to music increases their brain power is perhaps the best example of how music educators can get caught between what is reported in the popular press and what is actually reported in scientific journals. Demorest and Morrison review the various aspects of this issue and present a balanced viewpoint based on a careful reading of the literature. To serve our students well, we need to look at the research honestly and dispassionately.

“A Virtual Panel of Expert Researchers” presents excerpts from interviews with four senior researchers—Andrea Halpern, Larry Parsons, Ralph Spingte, and Sandra Trehub. Individually and collectively, they share important ideas for music educators. Perhaps one of the most important ideas they communicate is that serious scientists are taking music seriously. These researchers have devoted a major part of their careers to understanding musical behavior. To them, music is not a frivolous sideline, but something that is at the core of what it means to be a human being. We can take encouragement from their dedication to studying that which is so important to us.

Premises Derived from Neuromusical Research

- The human brain has the ability to respond to and participate in music.
- The musical brain operates at birth and persists throughout life.
- Early and ongoing musical training affects the organization of the musical brain.
- The musical brain consists of extensive neural systems involving widely distributed, but locally specialized regions of the brain:
 - Cognitive components
 - Affective components
 - Motor components.
- The musical brain is highly resilient.

Neuroscientists have studied sound production and processing in animals; they have studied fetal responses to music, as well as responses among the elderly, including those having Alzheimer’s disease or other cognitive dementias. Neuroscientists have also examined special populations, such as prodigies or those with savant syndrome or Williams Syndrome. Responses of naive listeners have been compared to those of expert musicians. From all these approaches, a number of important concepts are emerging. While not all these findings have direct applications to the daily practice of music education, collectively they do have much to offer our profession.

An Overview of Neuromusical Research

Here is an introduction that provides a more detailed look at music and brain research than that provided by the popular media. Highlights of recent neuromusical studies are presented, and basic premises derived from the studies are articulated. The sidebar summarizes these premises.

The human brain has the ability to respond to and participate in music. Music, like language, is a species-specific trait of humankind.¹ All human beings—and only human beings—have music. Neurologist Frank Wilson says that he is “convinced that all of us have a biologic guarantee of

musicianship.”² Wilson does not mean that all of us are guaranteed to become musicians on par with Mozart, but rather that we all have the capacity to respond to and participate in the music of our environment. Music, then, is one of the hallmarks of what it means to be a human being.

Much of the literature that supports this notion comes from anthropologists who tell us that “all people in all times and in all places have engaged in musical behaviors.”³ Based on the neuroscientific literature cited throughout this issue, we can say that mounting and incontrovertible evidence supports the ubiquity of human musicality. Further, we can say that a musical brain is the birthright of all human beings.

Clearly, the idea that all human beings are musical has enormous implications for music education. A music education should not be reserved for those “with talent,” nor should it be restricted to those who can afford it or whose parents deem it important. All members of our society, from cradle to grave, stand to benefit from being musically involved.

It is true that many animals have sound-producing and -processing capabilities. They process sound as it occurs across time, ascribe “meaning” to this sound, and adjust their behavior accordingly. A cat responding to a barking dog, for example, is an animal processing sound.

Although we tend to anthropomorphize animal behaviors—and to be sure, we can probably never know exactly what is going on inside an animal's brain—it is safe to say that the vast majority, if not all, of animal sound-making has to do with such things as territoriality, signaling, courtship, and mating.⁴ In other words, although we refer to *birdsong*, it is not likely that birds or other animals sing for musical or aesthetic pleasure.

Early research indicated some remarkable musical feats, such as certain birds being able to distinguish between different composers. However, more careful investigation indicates that animals rely on absolute frequency analysis⁵ rather than on relative pitch as we do.⁶ Thus, while various animals can be trained to choose between two songs, they fail miserably if those songs are transposed. By contrast, even among those humans with absolute pitch, our sophisticated musicality is possible, in large part, because we deal with pitch relationships. “Yankee Doodle,” for instance, is recognizable to us when begun in any key.

There are other cognitive limitations among animals as well. For example, musical forms ranging from simple verse and chorus alternations to lengthy symphonic movements can be processed by humans because of their ability to retain musical information for long periods of time. If any animals are musical, dolphins are the most so. But they can recognize the second A section of a simple ABA form only if each section is no more than two seconds long.⁷

One might reasonably ask whether giving animals human musical tasks is fair; after all, we can't understand many of their vocalizations. However, the point of this line of research is really twofold. First, we can begin to trace the development of auditory and cognitive mechanisms from an evolutionary standpoint. This type of information can be used to offer a plausible explanation for the evolutionary basis of human musicality.⁸ Second, we can begin to look for the additional brain mechanisms unique to humans that make our musicality possible.

The musical brain operates at birth and persists throughout life.

The fact that babies respond to music at birth (and, in fact, in the womb during the last three months before birth) gives strong evidence for the existence of neural mechanisms that seem ideally suited for processing musical information.⁹ This topic is covered more fully in this issue's articles on “Music and the Baby's Brain” and “EEG Studies with Young Children.”

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At the other end of the life spectrum, a group of retired nuns has offered to donate their brains to science.¹⁰ They are being studied constantly as they age. The first outcomes of the project reveal that (a) the more learning one has in childhood, the less likely one is to be debilitated by Alzheimer's disease or other forms of cognitive dementia, and (b) the common adage “Use it or lose it” is sound advice. Even as they progress into their eighties and nineties, these women are encouraged to learn new skills. Learning to play a musical instrument, or a different one if they can already play one, is frequently advised by the neuroscientists.

The clear implication for music educators is that neuroscientific research supports an emphasis on lifelong learning in music. Our profession needs to continue to expand beyond the confines of K–12 music education.

Indeed, it may be in this underexplored area that we will find the most opportunities for new growth.

Early and ongoing musical training affects the organization of the musical brain. There are growing indications that those who study music, particularly beginning at an early age, show neurological differences compared to those who have not had such training. Frédérique Faita and Mireille Besson demonstrated that musically trained subjects had stronger and faster brain responses to musical tasks than untrained subjects.¹¹ (See this issue's article “EEG Studies with Young Children” for additional studies.) Brain imaging data demonstrate that the primary auditory cortex in the left hemispheres of musically trained subjects is larger than that of untrained subjects.¹² This difference was exaggerated for those with absolute pitch or those who started their musical training before age seven.¹³ Moreover, for the musically trained, the arrangement of the auditory cortex is much like a piano keyboard, with equal distance between octaves.¹⁴

The area of the motor cortex controlling the fingers increased in response to piano exercises, both actual and imagined.¹⁵ The auditory cortex, which responds to piano tones, was 25 percent larger among experienced musicians; the effect was greater for those who started studying music at an early age.¹⁶ Finally, compared to nonplayers, string players have greater neuronal activity and a larger area in the area of the right motor cortex that controls the fingers of the left hand.¹⁷ Again, these effects were greater for those who started playing at a young age.

Although there are apparent implications for music education from these data, a note of caution must be inserted. First, probably anything we do in early childhood has an effect on brain organization. It is likely that comparisons between chess players and nonchess players, or between high level mathematicians and those who can barely add and subtract, for example, would also show differences. Second, it is not at all clear whether there are transfer effects. That is, it is not



Photo courtesy of Jim Kirby

Early and ongoing musical training affects the organization of the musical brain.

certain that music education necessarily improves performance in other modes of cognition. This question is discussed in this issue's articles "A Virtual Panel of Expert Researchers" and "Does Music Make You Smarter?"

The musical brain consists of extensive neural systems involving widely distributed, but locally specialized regions of the brain. One of the more visible topics of research in the 1970s dealt with differences between the left and right sides of the brain. Naïve interpretations of research data led to such notions as "musical knowledge is in the right side of the brain." We now know that it is not that simple. Reviews of research literature indicate that results can be highly varied depending on subject variables (like how much and what kind of training subjects have received), stimulus variables (like computer-generated tone pipes versus "real" music), and task variables (like what the subjects are asked to listen for).¹⁸ Furthermore, many would contend that two-second sound bites (a requirement for much of this type of research) do not adequately represent music and that using amusical fragments doesn't tell us much about what happens when people hear a Mozart symphony, for example.

These considerations do not preclude the possibility that there are differences in the ways the two hemispheres process music. For example, a portion of the right auditory cortex has been implicated in the retention of rhythmic patterns.¹⁹ (Interestingly enough, data from the same study did not support a link between left hemisphere timing mechanisms and musical rhythm, something that had been previously proposed.)²⁰ The right hemisphere was also more strongly implicated than the left hemisphere in music instrument timbre recognition.²¹

Reviewing the bulk of neuromusical research literature leads to the conclusion that music is not just in the right side of the brain, but is represented all over the brain. One of the major findings in a recent study was that musical processing is spread throughout the brain—front/back, top/bottom, and left/right.²² Furthermore, selectively changing the focus of attention radically alters brain activation patterns.²³ Thus, rather than focusing on a simplistic left-right dichotomy, it may be more accurate to think of musical processing as involving widely diffuse areas of the brain.

It can be said that the musical brain is modularized. That is, musical expe-

riences are multimodal, involving at the least the auditory, visual, cognitive, affective, memory, and motor systems. Beyond that, each component of music processing and responding is likely to be handled by different neural mechanisms. This idea is consistent with what is known about language, but with language the linkage between function and location is more clearly delineated than it is for music. Scientists using modern neuroscientific techniques are beginning to identify specific structures in the brain that carry out specific musical tasks.

Cognitive Components. A number of studies have indicated that music processing involves functionally independent modules. In a 1998 study, neural mechanisms for melodic, harmonic, and rhythmic error detection were found to be independent from each other.²⁴ Also, music reading activated an area on the right side of the brain parallel to an area on the left side activated during language reading. A 1997 study showed that familiarity with music, timbre recognition, and rhythm perception activated different regions of the brain.²⁵ In a 1988 study, it was found that the electrical activity of sophisticated music listeners is different from that of naïve listeners.²⁶ Based on a 1991 study, the brain appears to use working memory for music; working memory refers to the process of comparing incoming musical information to stored information.²⁷

Affective Components. Although emotional response to music is perhaps one of the most important topics of research, it is also among the most difficult to study. There is a lack of knowledge about this central aspect of the musical experience. A recent study indicated that different neural structures were activated in response to positive and negative emotions.²⁸ Furthermore, these structures, located mostly in the right hemisphere, are dissociated (that is, separate from) neural correlates of various emotions and function apart from other music perceptual processes. Music medicine research is making effective use of music to reduce fear and anxiety in surgical and pain patients.²⁹ Experiments show that hearing music affects

the biochemistry of the blood, which in turn may cause affective changes. For example, physicians are able to reduce drug dosages and speed up recovery times by using music in certain medical procedures. In other words, music is not just a psychological distractor; rather, it elicits actual physical changes in the system. (It should be noted that research on emotional, mood, and feeling responses is much less developed in psychology and neuroscience than research on topics such as learning and sensory perception.)

Motor Components. The connection between music and movement is fundamental to both expressive and receptive modes. Music making (expressive mode) is clearly a bodily kinesthetic experience. Neurologist Frank Wilson recognized this when he called musicians "small-muscle athletes."³⁰ In one study, professional pianists underwent brain scans while performing Bach on the piano.³¹ Among the results was a clear demonstration that motor control systems were highly activated during performance. At the same time, other regions of the brain were strongly deactivated—in effect, switched off—which is a hypothesized indicator of focused concentration.

Abundant research data indicate that there are both physiological and physical responses during music listening (receptive mode). Physiological responses include changes in heart rate, blood pressure, and a host of other systems.³² All of us have experienced physical responses to music such as foot tapping or head nodding. Researchers are using this natural response to music in a process called "Rhythmic Auditory Stimulation" to enable Parkinsonian and stroke patients to regain walking and motor skills.³³

These brief sections on cognitive, affective, and motor components only skim the surface. But perhaps the discussion is sufficient to support the contention that music is modularized in the brain. The literature on "amusia," loss of musical function due to destruction of brain tissue, gives further evidence of modularity. In these cases, individuals who have suffered

destruction of particular brain tissue correspondingly lose specific musical abilities.³⁴



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The musical brain is highly resilient. Music persists in people who are blind, deaf, emotionally disturbed, profoundly retarded, or affected by disabilities or diseases such as Alzheimer's disease or savant syndrome. Regardless of the degree of disability or illness, it is possible for the individual to have a meaningful musical experience. Any music therapist could easily testify to the residual power of music. The research literature on amusia reveals that destruction of brain tissue may eliminate a particular musical function (e.g., ability to track rhythms), but it does not eliminate music entirely. Another fascinating example concerns individuals with Williams Syndrome. These cognitively impaired individuals have average IQs of 65–70, yet they often have remarkable musical abilities.³⁵

Ongoing and Future Research

Although hundreds of research studies fall under the category of neuromusical research, this is still a small amount compared to the study of language, for example. In that sense, it is a little premature to make broad, sweeping statements that have direct bearing on the daily teaching of music. Certainly, however, there is

every reason to believe that continued efforts along these lines will provide significant applicable benefits in the future.

There is one more idea that has profound implications for our profession: Neuromusical research supports the notion that music is a unique mode of knowing. The literature clearly supports the notion that music is dissociated from linguistic or other types of cognitive processes. Therefore, it provides a unique means of processing and understanding a particular kind of nonverbal information. By studying the effects of music, neuroscientists are able to discover things about the brain that they cannot know through other cognitive processes. Likewise, through music we are able to discover, share, express, and know about aspects of the human experience that we cannot know through any other means. Musical insights into the human condition are uniquely powerful experiences that cannot be replaced by any other form of experience. It is to a deeper understanding of this core value of music that neuromusical research will continue to make its most important contributions.

In this special focus issue, we are attempting to represent the current state of neuromusical knowledge. It is our hope that music educators will find these articles readable and informative. Because the field is changing rapidly, it is important for music educators to keep abreast of new findings. In time, the picture will become clearer and clearer, and our profession will benefit greatly from what is learned in this emerging field.

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