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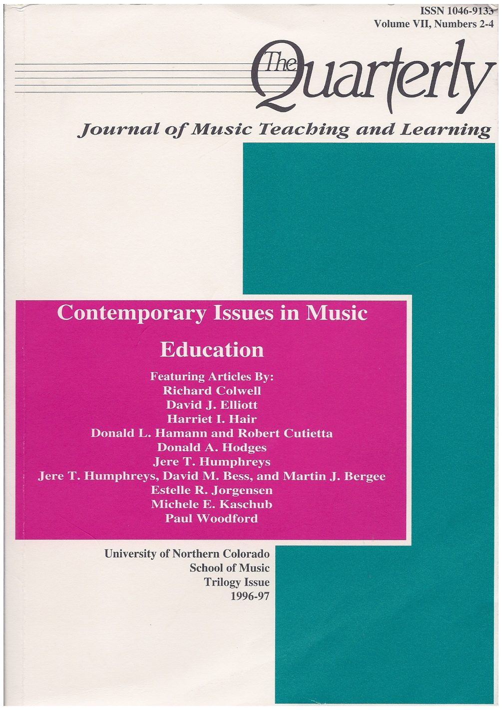

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What Neuromusical Research Has To Offer Music Education[1]

By Donald A. Hodges

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One area of music research that has received increasing attention over the past twenty-five years is the study of music and the brain, or neuromusical research. Although the earliest studies can be traced back more than 100 years (e.g., Proust, 1866), there was a surge of interest in the 1970s with a focus on "music and the right brain." Contemporary research, though far from giving us final or complete answers, is providing many new and exciting findings.

Neuromusical Research in Perspective

What does neuromusical research have to offer the music education profession? Before making direct applications, I believe there are at least four fundamental issues that need to be explored. These four issues are organized under the following headings: Magic versus Mystery, Restrictions and Limitations of Neuromusical Research, Basic and Applied Research, and Short-term versus Long-term Gains.

1. Magic versus Mystery

Gaston (1968) made a point of distinguishing between magic and mystery. By this he meant that since music is a form of human behavior, it must obey the laws and principles of the universe. Music is not magical, in the sense that it operates in any way beyond natural laws. It is, however, mysterious in that we do not yet understand many aspects of this phenomenon.

Why do I bring this up? Simply because we in music education are keenly aware of the power of music to affect people's lives. In our enthusiasm to convey this power to others, we sometimes resort to hyperbole and make exaggerated claims or statements. For instance, at one time in the 70s it was common to hear that without music instruction the right side of our brains would atrophy. We need to strive for language that preserves our sense of awe and wonder at the power and beauty (i.e., the mystery) of music, without overstating the case (i.e., resorting to magic). Finding a language that accurately communicates our best understanding is critical.

2. Restrictions and Limitations of Neuromusical Research

It is important to have some understanding of the restrictions and limitations of research in general, and of neuromusical research in particular. Research is certainly not a panacea for all ills. Total reliance on research for our profession is neither possible nor desirable. Neuromusical research has its own special restrictions and limitations. Obviously, there are certain restrictions on what can be done with the brains of human subjects. While we might do ablation studies (cutting away portions of brain tissue) on mice, we cannot do the same to humans.

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Likewise, there are limitations in the technology available. The current state of technology does not allow for the study of most musical behaviors in a natural setting. For example, EEG equipment (an electroencephalogram which is used to measure electrical activity of the brain) is so sensitive that eye blinks must be factored out; for this reason, it is not possible to gather EEG data while playing a musical instrument. Once, while describing a recent PET (positron emission tomography which monitors brain activation) experiment on pianists, students were critical of the artificiality of the experiment (particularly the fact that the pianists were performing while lying on their backs). It was necessary to explain that this study was ground-breaking; for the first time researchers were able to look into the brain of a musician while actually performing. In time, the equipment used in this study will seem as out-moded as a Model-T Ford, but for the time-being it represents real progress. The point is simply that we need to keep a broad perspective; neuromusical research has much to offer, but it must always be considered in the context of a bigger picture.

3. Basic and Applied Research

In the simplest terms, *basic research* refers to the seeking of knowledge for its own sake or for the purpose of knowing and understanding more about a given phenomenon. For example, efforts to understand the physiological processes involved in the male vocal apparatus during the period of vocal change would be classified as basic research. *Applied research* is aimed toward a direct application, in our case to a music teaching-learning situation. One might wish to compare two approaches to dealing with the cambiata — one that restricts vocalization during the vocal change and one that emphasizes full-range vocalization.

The two forms of research are related in that basic research provides a foundation from which applied research can be launched. Lewis Thomas wrote a brief commentary on the history of medicine (1979), that provides a good example. His thesis was that for most of its history, medicine was practiced in a trial-and-error fashion and often was unable to ameliorate pain or bring about healing. Mostly this was due to lack of understanding of the fundamental processes of the body and of disease. Use of the scientific method (near the end of the 19th century) began the systematic march toward explicating the mysteries of the body. After describing some of the rapid advances made from the 1930s on, Thomas is emphatic in the necessity of basic research as a prelude to applied research. "But it needs emphasizing that it took about fifty years of concentrated effort in basic research to reach this level" (1979, 162). "It was basic science of a very high order, storing up a great mass of interesting knowledge for its own sake, creating, so to speak, a bank of information, ready for drawing on when the time for intelligent use arrived" (1979, 164).

The relationship between basic and applied research as described in the previous paragraph is the ideal. In our profession, there is all too often a lack of basic research on fundamental processes of music teaching and learning, such that applied studies are frequently conducted without sufficient knowledge of the underlying processes. The primary music education research journals generally publish only applied research. This circumstance necessarily promotes applied research at the expense of basic research.

In the case of neuromusical research, it is clear that a considerable amount of basic research is needed before we will have anything approaching a good understanding of the phenomenon of music in the brain. Although there is no reason applied studies cannot be done now — in fact one could argue that to wait until we have a full understanding of the musical brain would mean that we would never be at the point of conducting applied studies — my own sense would be that we should put more efforts

into basic neuromusical research at the outset. This will lay a stronger foundation for well-grounded applied studies in the future. The downside of doing applied studies without the necessary basic research is that we flounder around trying this and that without having a clear agenda established.

4. Short-term versus Long-term Gains

The obvious follow-up to the foregoing discussion of basic and applied research is that we must be patient enough to wait for basic research to provide fundamental understandings of neuromusical behavior. To be sure, we must continue to publish applied research, and wherever possible applied neuromusical research ought to be pursued. Neuromusical research showing the implications of mental rehearsal — that mental rehearsal may stimulate the brain much as does "real" practice — is one example. However, the best and most secure way toward complete understanding may lie in support for and recognition of long-term, basic research.

Strategies for Neuromusical Research[2]

Over the years a number of research strategies have been used in an attempt to explicate the phenomenon of music in the brain. Each strategy has its own kind of information to share, and each has corresponding strengths and weaknesses. The topics to be covered in this section include animal research, fetal and infant research, research with brain-damaged individuals, hemispheric asymmetry research, EEG and ERP research, research using brain imaging techniques, emotion research, and neuromotor research.

Animal Research

Studying the ways animals process sounds gives neuroscientists useful information about human sound processing. Most animals have devices for detecting, analyzing, and responding to sounds. Once a sound has been detected, the animal analyzes it for "meaning," and this meaning shapes behavior. A house cat demonstrates this when it comes running into the kitchen at the sound of the can opener. When humans listen to music, the process is much the same: we analyze the sound for meaning and that meaning shapes our responses.

Although there are many similarities, there are also significant differences between animal and human sound processing. Animals operate on absolute frequency detection and they are essentially incapable of tracking pitch relationships (D'Amato, 1988). Human beings rely much more strongly on pitch relationships (Trehub, Bull, and Thorpe, 1984). Similarly, animals are unable to retain pitch and rhythm patterns such that they could recognize the return of A in an ABA pattern (Warren, 1993). Such tracking of form is obviously a hallmark of human musicality.

We imply that some animal vocalizations are musical when we use words like birdsong and whalesong. But most animal sound-making is about things like courtship or territoriality, rather than about aesthetic expression. We can never say for certain, of course, that animals don't "appreciate" or "enjoy" their sound making, but the full experience of music does seem to be a particularly human trait.

Fetal and Infant Research

Although research on fetal responses to music is limited and susceptible to over-generalization, it is a useful area. In the simplest terms, a fetus cannot learn about the outside world through vision, taste, touch, or smell. It can, however, respond to sounds. While it would be easy to overstate the case for what a fetus can "learn" in the womb, there is abundant evidence showing that the human fetus is aware of and responsive to sounds, including music (Deliège and Sloboda, 1996; Shetler, 1985 and 1989).

Research with infants shows that they come equipped with sound detection and analyzation mechanisms. Soon after birth, babies can orient toward sounds and soon after that can pick out the sounds of the mother's voice (Trehub and Trainor, 1993). A significant amount of the interactions between a newborn and its caretakers is based on two-way sound manipulations. The caretakers sing lullabies and talk "babytalk" and there are musical crib mobiles and toys. "Motherese speech," a term psychologists have coined to refer to the type of babytalk typically spoken to infants, emphasizes pitch, timbre, dynamic inflections, and rhythm patterns in order to convey meaning. Clearly,

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the baby cannot interpret the meaning of words. Likewise, the baby learns early on to communicate by manipulating these same "premusical" elements.

The point of this brief discussion on fetal and infant research is not to exaggerate the case for infant musicality. Rather, it is to suggest that these behaviors are exhibited primarily because of inherited mechanisms. While learning takes place from the outset, babies do not need systematic, formal instruction in order to respond to music, speech, and other sounds.

Research with Brain-Damaged Individuals

Amusia

A wide variety of brain-damaging conditions can provide useful information toward the understanding of musical behavior. One classification involves individuals who have suffered from a stroke, tumor, or some other form of brain damage. Aphasia is a term given to the loss of linguistic skills due to brain damage; amusia refers to loss of musical skills. Both terms are umbrella terms in the sense that they include a wide variety of deficits. Under aphasia, there are individuals who cannot speak (Broca's aphasia), or understand speech (Wernicke's aphasia), or read (alexia), or write (agraphia). By matching up specific deficits with precise anatomical sites, neuroscientists are beginning to map function onto location.

Linkages between various types of amusia (e.g., inability to track rhythm or pitch, or to sing, etc.) and precise anatomical locations are not nearly as well established as for aphasia. There are at least several reasons for this. First, one might suppose that most physicians treating brain-damaged patients do not test for musical deficits, thus far fewer case studies have been reported in the literature. Second, it may be supposed that linguistic skills are much more homogenous among the general population than musical skills. The result is that while quite a number of amusia articles have been written, there is nothing yet approaching a delineation of a musical neural network. Finally, some of the earlier studies are not so refined in their discussion of anatomical locations, and there is a decided lack of protocol in studying amusia. Wertheim and Botez (1961) provided an assessment battery for amusia, but there is no indication that it has been widely used.

Although we await a more definite picture from this line of research, there is one extremely valuable outcome already. There are enough studies involving an investigation of both aphasia and amusia to identify three categories (Marin, 1982): (a) some patients suffer from aphasia but not amusia, (b) another group suffers from amusia but not aphasia, and (c) a third group suffers from both aphasia and amusia. This indicates that music and language are dissociated; that is, they are represented by different neural mechanisms. Group C individuals may be those whose lesions are large enough to involve both language and music, or it may be that language and music activate the same neural areas for certain aspects of processing.

Prodigies, Musical Savants, Williams Syndrome

Prodigies, musical savants, individuals with Williams Syndrome, and other "special cases" (e.g., persons with musicogenic epilepsy, a condition in which certain musical experiences can cause seizures) also provide invaluable information. While no one could doubt the role of learning in the case of prodigies — Mozart, after all, wrote and performed Viennese classical music as a child, not Javanese gamelan music — it is difficult to account for their precociousness unless one hypothesizes neural structures primed for music.

Musical savants (Miller, 1988) and those with Williams Syndrome (Finn, 1991), though different in many respects, share some characteristics. Most notably, both are cognitively impaired, yet show a proclivity for music. If a person has musical capabilities and yet is unable to read or write, or

perform the simplest of mathematical calculations, once again, we must posit the presence of neural structures allowing for musical behaviors.

Alzheimer's Disease

Research with Alzheimer's patients gives further indication of dissociation between language and music. Individuals with prior musical backgrounds may retain procedural skills (e.g., singing or playing an instrument) in spite of declining linguistic fluency (Crystal, Grober, and Masur, 1989). In at least one case, an Alzheimer's patient was able to sing the words to familiar songs even though she could no longer communicate via language (Johnson and Ulatowska, 1996).

Hemispheric Asymmetry Research

The role of the two hemispheres in cognition is one of the more controversial issues. Some neuroscientists stress differing contributions, while others emphasize integration and cooperation. Although data come from a variety of research strategies, dichotic listening tasks have been most frequently employed, and this technique has itself come under considerable criticism. In a dichotic listening task, the subject hears two different musical "bits" presented simultaneously to each ear. The subject then identifies, from a choice of four items presented sequentially, which was heard. The underlying theory is that the right hemisphere is more strongly implicated in processing information presented to the left ear, and vice versa, because the auditory pathway from the inner ear to the opposite-side hemisphere is stronger and faster (Lipscomb and Hodges, 1996). Results, however, are influenced by the subject's musical background, the particular stimuli used (e.g., real musical phrases or "amusical" tone pips), and the specific task (e.g., listening for global versus local features).

Although a popular misconception places music exclusively in the "right brain", while others (e.g., Sergent, 1993) discount as invalid any findings from dichotic listening techniques, a more moderate mid-position may be the most reasonable view to take. Taking this approach, music processing is seen to involve many regions of the brain working cooperatively. Some processing may take place subcortically (that is, before reaching the hemispheres), the left hemisphere may take a greater role in analytical processing, and the right hemisphere may be more important for a sound gestalt.

EEG and ERP Research

Even at rest, the brain produces electrical currents that can be measured. An EEG measures the summed activity of millions of neurons lying under the skull. Interpretation of brain maps based on EEG readings is extremely complicated. At present, it may be safest to say that researchers are able to identify differences between those with varying amounts of musical training.[3] For example, Johnson and others (1996) found significantly higher EEG coherence values (an indication of the degree of cooperation within and between the hemispheres) among musically-trained subjects when compared to those with limited training.

Auditory event-related potentials (ERP) show how the brain responds in the microsecond intervals following the presentation of a novel stimulus. For example, in one set of tasks, the subject might hear a series of like tones, with a different tone randomly interspersed. The ERP would monitor the brain's response to the different tone. Using familiar and unfamiliar melodies, Besson and Faita (1994) found that musically-trained subjects had stronger and faster responses than untrained subjects.

Research using Brain Imaging Techniques

Using SQUID (superconducting quantum interference device) Williamson and Kaufman (1988) demonstrated that the primary auditory cortex is mapped for complex tones in such a way as to resemble a piano keyboard. That is, from one octave to another is equidistant.

MRIs (magnetic resonance imaging) provide precise details of anatomical locations. MRI data have indicated that the primary auditory cortex in the left hemisphere is larger for musically-trained subjects than untrained (Schlaug et al, 1994). This difference was exaggerated for those with absolute pitch or those who started their musical training before age seven (Schlaug et al., 1995).

PET scans provide information about brain activation by injecting radioactively-tagged water into the bloodstream. Since the brain,

New imaging techniques are beginning to give reseachers the tools to investigate the brain in action.

even at rest, requires oxygen (brought by the blood), and the areas most active require more oxygen, PET gives detailed information about which parts of the brain are most engaged in a given task. Interpretation involves subtracting the PET data of one task from another. For example, in one study (Fox et al, 1995), pianists were studied in three conditions: rest, playing scales, and playing Bach (the opening of the third movement of the Italian Concerto). Subtracting "rest" from "scales" and scales from "Bach" revealed the brain at work while playing the piano.

In the aforementioned experiment, results indicated that playing scales preferentially activated the left motor systems, while playing Bach activated right motor and parietal (sensory processing) areas. Presumably, Bach recruited right hemispheric areas because of the additional expressiveness (i.e., emotional content) not required for scales. Results also clearly indicated that certain neural circuits were deactivated (i.e., less active than at rest), while others were activated.

Finally, a surprising finding was that nearly all the most active areas were motor systems. One might suppose that removing motor activation by subtracting scales from Bach might reveal other active structures (e.g., those involved in higher thinking or feeling). One way of accounting for this finding is that everything a performer "thinks" and "feels" about the music must be translated into muscle movements through hours and hours of practice, if these ideas are to be shared with the audience. On the recital stage, the performer's brain is busy monitoring and coordinating all these myriad movements; other mental activity would be distracting. This may be why the most effective performances are those that seem "natural" — that is, when the body is free to do what it has been trained to do.

New imaging techniques are beginning to give researchers the tools to investigate the brain in action. From the relatively few studies completed so far, it is abundantly clear that musical experiences are highly complicated events, involving many different parts of the brain in intricate cooperation.

Emotion Research

Neuromusical research into emotional responses to music is quite limited. For clarity of discussion, particularly in such limited space, it may be helpful to think of emotion in three ways (Buck, 1986): *Emotion I* involves homeostasis (maintenance of body stability) and adaptation and can be measured by monitoring physiological changes. *Emotion II* involves spontaneous expressive tendencies and can be measured by direct observation of external displays, such as postures and facial expressions. *Emotion III* involves subjective experiences and is often monitored by self-report.

While there is considerable research on physiological responses to music (see Bartlett, 1996), most (e.g., studies about heart rate or breathing rate responses) does not qualify as neuromusical research. One aspect of Emotion I, psychoneuroimmunology, is the study of relationships between mind, brain, and the immune system. This is proving to be an important branch of study in the field of music medicine (physicians using music as part of medical treatment). While the results are somewhat mixed, as is to be expected in any complicated interaction, there is a growing notion that music can elicit changes in such biochemicals as endorphins, cortisol, ACTH (adrenocorticotropic hormone), interleukin-1, and secretory immunoglobin A (Aldridge, 1993). Spintge and Droh (1992) have studied the effects of music on more than 90,000 surgical and pain patients. In general, they can often reduce the drug dosage and subsequent recovery period in half.

Neuromusical research done in Emotion II, spontaneous expression of emotion, is quite limited. Only one, somewhat controversial approach — that involving a Clynes sentograph (Clynes, 1977 and 1982) — might qualify. A sentograph allows for the quantifi-

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cation of finger pressure exerted in button pushes used to express emotions or music. The subject pushes on a button (basically a strain gauge linked to a computer) fifty times or more to express an emotion word such as "joy." The computer averages these "sentic" expressions into one essentic shape, with distinct shapes representing different emotions. Clynes has found no differences in these shapes based on gender, race, training, or cultural background. Likewise, he has had trained musicians create essentic forms while "thinking" specific pieces by well-known composers. Once again, he found such consistency that he can identify unique essentic forms for Bach, Mozart, Beethoven, and many others.

Clynes has confirmed these essentic forms with EEG readings and theorizes that music has the emotional effect on us that it does, in part, because the essentic forms of music map onto the essentic emotional forms wired into all human brains; the better the composer, the better the match. As indicated, this approach is somewhat controversial due primarily to the lack of replications done by researchers other than Clynes.

Emotion III, subjective experiences, seems to fall outside the realm of neuromusical research for the time being. Primarily, these responses are studied by self-report. Although brain imaging studies of emotion are beginning to appear in the literature, none have been reported in connection with music.

Neuromotor Research

Neuromotor responses to music can be divided into two categories: expressive (making music) and receptive (responding to music) motor activity. Research on expressive neuromotor responses can be illustrated by two related experiments. In the first (Pascual-Leone et al., 1994), one group of subjects viewed random numbers displayed on a computer screen and typed in corresponding keys as quickly as possible. Their reaction times and cortical maps remained unchanged. A second group executed the same procedure, only there was an embedded pattern in the numbers they viewed. During the time they were gradually becoming aware that there was a pattern, their reaction times grew shorter and their cortical maps increased. As soon as they figured out that there was a pattern, their reaction times switched to anticipation times and their cortical maps returned to normal. This gives evidence of brain changes due to learning. It may also indicate that once learning has taken place, the primary motor cortex may operate more efficiently by passing control onto lower brain regions.

In a follow-up study, Pascual-Leone and others (1995) divided subjects, none of whom had played the piano, into three groups. One group practiced a specific five-finger exercise for a given amount of time, the second group practiced random patterns for the same amount of time, and the third group did not touch the piano and only practiced the five-finger pattern mentally for the same amount of time. The researchers found that the area of the motor cortex controlling these five fingers had tripled in size for the first and third groups but not for the second group. This indicates that the brain changes in response to specific learning experiences and that mental rehearsal stimulates the brain much as "real" practice does.

The effect of long-term musical training was demonstrated by Elbert and others (1995) who discovered that a region in the right motor cortex, representing the fingers of the left hand, was larger among violinists than among non-violinists. The earlier the subject started playing the violin, the greater the effect. Researchers have also begun to look into the biomechanics of musical performance (e.g., Moore, 1992). These studies of expressive neuromotor responses provide support for neurologist Frank Wilson's (1986) conception of the musician as "small-muscle athlete."

Receptive neuromotor responses are familiar to everyone. As indicated by dancing or tapping one's toe to a band marching by, music can elicit strong physical responses.

In certain circumstances, researchers can harness this natural reaction. Thaut and others (McIntosh, Thaut, and Rice, 1996; Thaut et al., 1993;) have used music, particularly tempo and rhythm aspects, to assist Parkinsonian and stroke patients to regain walking facility. Sacks writes eloquently of the power of music to "awaken" catatonic patients. "This power of music to integrate and cure, to liberate the Parkinsonian and give him freedom while it lasts ('You are the music while the music lasts,' T. S. Eliot), is quite fundamental, and seen in every patient" (1983, 294).

These brief discussions give only a glimpse of the current status of neuromusical research. All the new and fascinating findings aside, what does neuromusical research have to offer the music education profession?

Implications for Music Education

Keeping in mind the four general discussions placing neuromusical research in perspective (Magic versus Mystery, Restrictions and Limitations of Neuromusical Research, Basic and Applied Research, and Short-term versus Long-term Gains), there are some benefits to be had from this line of research. One way to synthesize these benefits is by moving toward the creation of a model of the musical brain.

Toward a Model of the Musical Brain

Synthesizing neuromusical research leads to a model of the Music Brain with these features:

- *All human beings are born with a Musical Brain.* Wilson states this emphatically when he says that "all human beings have a biologic guarantee of musicianship" (1986, 2). Besides supporting this notion with neuromusical research, one can easily look at the anthropological literature. Anthropologists tell us that human beings have always and everywhere engaged in musical behaviors. Blacking (1973) said that music, like language, is a species-specific trait of humankind. All human beings — and only human beings (at least to the high degree that we do) — have language and music. They are hallmarks of what it means to be a human being. To be musical is to be human and to be human is to be musical.

  To say that all human beings are inherently musical does not mean that all have the potential to become outstanding performers. Rather, it means that we all have the wherewithal to respond to the music of the surrounding culture. Music therapy literature is replete with studies documenting the responsiveness to music among individuals in all handicapping circumstances. While musical behaviors, like any form of human behavior, must be distributed across the population such that there are a wide range of potentials, there are no indications of its missing altogether.
- *The human Musical Brain is different from other animal brains.* Only humans have music — what we call bird*song* is more communication than music — because only humans are capable of tracking musical elements such as melody, harmony, rhythm, form, and so on. Studying animal sound processing teaches us much about our own sound processing and helps us to define what "extra" neurological resources we have that allow for music.
- *The Musical Brain operates at birth.* The fact that babies respond to music immediately (and, in fact, in the womb during the last three months before birth) gives strong evidence for inherited neural mechanisms devoted to music.
- *The degree to which the Musical Brain is lateralized is still being debated.* Currently, the safest position to take may be that the left hemisphere processes information in more sequential, analytical ways and the right hemisphere in more holistic, intuitive ways. The degree of laterality may depend on the subject (e.g., training), the stimulus (e.g., the kind of music being used), and the task (e.g., listening for global or local features).
- *The Musical Brain consists of an extensive neural system (or systems) involving widely-distributed, but locally-specialized regions of the brain.* Music is not only in the right side of the brain; rather, it is represented all over the brain. Musical experiences are multimodal, involving auditory, visual, cognitive, affective, motor, and memory systems.

- *The Musical Brain has cognitive components.* Modern neuroscientific techniques (e.g., EEG, ERP, MRI, SQUID, PET) are beginning to identify structures in the brain that carry out specific musical tasks (e.g., absolute pitch in the left temporal lobe) and to look at musical processing (e.g., the electrical activity of sophisticated music listeners is different from naive listeners).
- *The Musical Brain has affective components.* Music medicine is making effective use of music to reduce fear and anxiety. Essentic forms, as identified through the sentograph, show links between music and emotions.
- *The Musical Brain has motor components.* The connection between music and movement holds for both expressive (e.g., musicians as small-muscle athletes) and receptive (e.g., music energizing Parkinsonian and stroke patients) modes.
- *Early and ongoing musical training affects the organization of the musical brain.* Musically-trained subjects exhibit significantly higher EEG coherence values when compared to controls with limited musical training. An area of the left temporal lobe concerned with sound processing (the planum temporale) is larger in musically-trained subjects than in untrained subjects; this is especially true for those who started studying music before the age of 7 or who have absolute pitch. Motor cortex areas controlling the fingers increased in response to piano exercises, both actual and imagined. Finally, string players have greater neuronal activity and a larger area in the right primary somatosensory (body mapping) cortex that controls the fingers of the left hand than non-string players. Again, these effects were greater for those who started playing at a young age.
- *The Musical Brain is highly resilient.* Music persists in people who are blind, deaf, emotionally disturbed, profoundly retarded, or afflicted with any number of disabilities or diseases (e.g., Alzheimer's disease, savant syndrome, etc.).

This model of a musical brain has rich implications for music education. Some aspects have pedagogical implications, such as the notion of mental rehearsal or the support for early childhood music education. Other aspects might serve to buttress philosophical arguments.

Neuromusical Research Supports Music as Intelligence

By now, most music educators are perhaps aware of Gardner's (1983) theory of multiple intelligences. He suggested that rather than thinking of human intelligence as something represented by a single I.Q. number, we should consider a pantheon of intelligences, including linguistic, musical, spatial, logical-mathematical, bodily-kinesthetic, intrapersonal (access to one's own internal world), and interpersonal (ability to notice and make distinctions among other individuals, especially their moods, temperaments, motivations, and intentions) intelligence.

Those who consider these the "sacred seven" intelligences should be aware that Gardner himself states that there may be more or fewer. The seven thus far identified were selected because they meet all eight of the criteria of an intelligence established by Gardner:

1. potential isolation by brain damage.
2. the existence of idiot savants, prodigies, and other exceptional individuals.
3. an identifiable core operation or set of operations.
4. a distinctive developmental history, along with a definable set of expert "end-state" performances.
5. an evolutionary history and evolutionary plausibility.
6. support from experimental psychological tasks.
7. support from psychometric findings.
8. susceptibility to encoding in a symbol system.

Although only 1, 2, and possibly 5, are relevant for this discussion, all eight can readily be substantiated for music (see Hodges and Haack, 1996). Previous discussions have provided support for numbers 1 and 2 for music. It is also possible to account for music from an evolutionary standpoint (Hodges, 1989 and 1996a). We live in a universe with many evident periodicities (e.g., phases of the moon, light-dark cycles, etc.) and there are over 100 oscillators in our bodies; it makes

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sense that we are able to track rhythms. Other ideas focus on:

- mother-infant bonding. As indicated previously, mothers and infants share with one another by manipulating the musical elements (prosody) of speech. Notice that what is being exchanged initially is feelings, not the meanings of words.
- acquisition of language. Rhythm plays an especially crucial role in language acquisition. Newborns move their limbs in rhythm to the speech they hear around them (Bohannan, 1983). If they hear a different language, their rhythms will subtly change. Rhythmic activities in the acquisition of language are so important that they form the basis for acquiring cognitive expectancies and for interrelating cognition and affect (Stern, 1982).
- social organization. Music may have played a strong role in helping human beings to organize socially (Roederer, 1984; Stiller, 1987). Music helps us to express who we are as a people; each social group gains identity, in part, through music. In *How Musical is Man?* Blacking (1973) counterbalances the first and last chapters. The first chapter, "Humanly Organized Sound," describes how all human beings organize sounds into a meaningful entity called music. In the last chapter, "Soundly Organized Humanity," he describes how the sounds we create, in turn, create and shape us. Of course, the most important evolutionary reason for music may be that music provides a unique way of knowing.

Another way to characterize these multiple ways of knowing is the phrase "human knowledge systems." A human knowledge system can be defined as a means for knowing, expressing, sharing, and understanding one's inner world, the outer world, and interactions within and between the two. Through the process of evolution, we have developed a variety of knowledge systems, each of which is a unique and equally valuable way of knowing.

It is obvious what kinds of things we can know in the linguistic and mathematical domains. But, more to the point, what can we know, express, share, or understand through music? Among the myriad possibilities, surely the focus must be on feelings or emotions. If we wanted to express ideas about time and distance as they relate to an understanding of the universe, we would resort to the power and economy of mathematics. However, mathematics may not be so useful if we wish to express joy; then we might turn to the power and economy of music. This discussion would take us too far afield if we take time to elaborate on this theme, so let it suffice for now to recognize that human beings are biologically equipped to experience many things of value, primarily feelings, through music.

Neuromusical research will continue to provide support for music as a human knowledge system (or as an intelligence, if that language is preferred), and the possible benefits might be illustrated by two examples. In recent years, American society has seen significant changes with respect to the effects of high-fat diets and smoking. We now have available a variety of low- or no-fat foods and access to non-smoking flights, hotel rooms, and so on. While many individuals may continue to eat fatty foods or smoke, they do so in the face of nearly incontrovertible evidence that these are not healthy habits. All the moralizing and "nagging" has done far less to bring about changes than a body of scientific data.

I do not mean to suggest that neuromusical research will someday be able to "prove" that music is "good" for you. Rather, I am suggesting that neuromusical research may be useful in supporting the important role music plays in human life. To the extent that we

are beginning to document neural mechanisms for music, we are saying that music is as biologically inherent in the human system as language. If we are genetically predisposed for musical behaviors, there must be a reason. Just as societal changes have come about in diet and smoking through research, it may be that society will become more strongly supportive of music because of neuromusical research.

Finally, neuromusical research may, in time, provide support for various curricular notions. We are moving toward a time where psychologists and neurobiologists are beginning to work together in a field called cognitive neuroscience. Soon cognitive theories of music and neuromusical research will come together to provide us with more useful models of musical behavior. The previous review of research indicated that musical experiences change the organization of the brain, that the earlier these experiences take place the better, and so on. Just as applications are beginning to be made in music medicine (e.g., enabling stroke patients to walk again, reducing fear and anxiety in surgical patients, etc.), we may, in time, have specific pedagogical strategies solidly grounded by research in the cognitive neuroscience of music. In many cases, neuromusical research may merely confirm already established practices; in some cases it may indicate ineffective or incorrect practices, or we may derive entirely new pedagogical strategies. In the meantime, it is hoped that the music education community will be supportive and patiently look to a time when neuromusical research will pay off in significant ways.

Notes

1. This article is based on information presented at the MENC national convention in Kansas City (April, 1996). While the presentation was highly visual, those illustrations have been omitted here. Conversely, I am including here a more focused discussion of implications of neuromusical research for music education, which was not part of the MENC presentation.

2. Due to space limitations, the discussions in this section are necessarily truncated. Those who wish to read more complete discussions can find them in Neuromusical Research: A Review of the Literature (Hodges, 1996b).

3. The terms "musician" and "nonmusician" are frequently found in the literature. In the sense that all human beings are capable of responding to the music of their environment, there is no such thing as a nonmusician. The implication of the common usage, however, is that some individuals have limited formal training in music, while others have considerable amounts.

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