A VIRTUAL PANEL OF EXPERT RESEARCHERS

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This article presents the observations of a virtual panel of research experts who have conducted significant research on music and the brain. Their answers to questions posed by the moderator (the author) give unique insights into their findings and conclusions. This panel comprises real people who have given permission for their observations (originally given in separate interviews with the author) to be presented in this format. They include Andrea Halpern, a cognitive psychologist at Bucknell University in Lewisburg, Pennsylvania; Larry Parsons, a cognitive neuroscientist at the University of Texas Health Science Center in San Antonio; Ralph Spintge, a medical doctor and researcher at the Sportkrankenhaus in Ludenscheid, Germany; and Sandra Trehub, a developmental psychologist at the University of Toronto in Toronto, Canada.

Moderator (Donald Hodges): To begin this panel session, I'm going to introduce the members of the panel and ask them to comment briefly on the nature of their work. To the far left, we have Dr. Lawrence Parsons, a cognitive neuroscientist at the Research Imaging Center at the University of Texas Health Science Center at San Antonio. He has collaborated with several colleagues on studies of brain imaging aimed at understanding the neural systems that support musical performance and comprehension. He is also attempting to better elucidate the effect of music on subsequent spatial task performance. Dr. Parsons, how would you characterize your principal findings?

Larry Parsons: Our brain imaging study of the performance of a memorized piano piece for two hands gave us our first glimpse of whole-brain activity during pure musical performance.[1] By comparing this musical performance (of Bach's "Italian Concerto") to a performance of two-handed scales, we observed that certain brain areas are active specifically for music performance. These are the auditory association areas in the right temporal cortex, the left lateral cerebellum, and the right supplementary motor areas. Surprisingly, performing music caused many of the players' other brain areas to be deactivated. Many of the deactivated cortical regions are associated with the processes of self-consciousness, judgment, goal setting, rationality, and so on. Their deactivation appears to be associated with a mental state of full conscious absorption during playing that musicians report to be related to superior performance.

Our brain imaging study of musicians' comprehension of some of the principal components of music enabled us to isolate subsystems in the brain that specifically support melody, harmony, and rhythm.[2] University music professors were asked to detect errors in an instrumental performance of an unfamiliar Bach chorale as they read its score. For each brain scan, a different kind of melodic, harmonic, or rhythmic error had been implanted in the performance. To summarize, processes we observed in both cerebral hemispheres supported score-reading and listening for melody, rhythm, and harmony. Melody activated each hemisphere equally, whereas harmony and rhythm activated more of the left than the right hemisphere. We found that widely dispersed, interconnected parts of the brain were used during close selective attention to different aspects of a piece of music. Often, harmony, melody, and rhythm activated different subareas of the same major brain area. Among other specific results, we found that an area in the right half of the brain interprets written notes and passages of notes. This area corresponds in location to the area in the left half of the brain known to interpret written letters and words.

Moderator: Thank you. We will return to your work on music and spatial reasoning a little bit later. Seated next to Dr. Parsons is Andrea Halpern, a cognitive psychologist at Bucknell University. One of her research interests has been how people of various ages and musical backgrounds perceive and remember music. She is also interested in which areas of the brain may be involved in musical processing, especially in auditory imagery. Dr. Halpern, how would you characterize the principal findings of your work?

Andrea Halpern: In a series of studies with Robert Zatorre, I have found that many of the brain areas active when we perceive music are also active when we imagine music.[3] These include some areas of the brain responsible for processing auditory information. So, the idea that we can "hear" a song in our heads has physiological legitimacy to some extent. Of course, as we rarely confuse actual perceived music with imagined music, it is not surprising that imagery and perception are unique to some brain areas. For instance, the primary auditory receiving area is active only when music is actually heard. And some areas associated with memory structures are active only when the individual imagines music, because using one's imagination typically puts more of a burden on memory than perception does.

Moderator: What can you tell us about the phenomenon of musicality in the human brain?

Halpern: My physiological research has not specifically looked at people with greater and lesser degrees of musicality. However, I have looked at differences between nonmusicians and highly trained amateur musicians as they perform memory and perception tasks, as well differences that may occur in the context of cognitive aging. Musical training seems to increase one's sensitivity to the musical idiom in basic ways, such as improving a listener's ability to detect changes in interval, rhythm, or mode between a just-heard melody and a similar comparison melody. However, even nonmusicians are attuned to basic musical regularities, and this sensitivity remains stable or can even grow during older adulthood at the same time that performance on some other types of memory tasks can show age-related declines. This suggests that the parts of the brain that learn about the regularities of one's environment (music being one of those regularities) are relatively intact in healthy aging and can be used productively.

Moderator: Thank you. And now we turn to Sandra Trehub, a developmental psychologist at the University of Toronto. She has conducted numerous experiments on infants' perception of music and on the role of music in infant care. Dr. Trehub, would you describe your work for us?

Sandra Trehub: The findings of my research on infants' perception of music are consistent with a biological basis for music listening and with the nature of music itself. On the whole, infants perceive melodies in much the same way as adults do even though the adults may have had extended formal or informal exposure to the music of their culture. For example, adults and infants have robust memory for the pitch contours and rhythms of novel melodies but relatively poor memory for other details. Infants as well as adults readily remember melodic or harmonic intervals that are consonant (tones related by small-integer frequency ratios) but have difficulty remembering intervals that are dissonant (tones related by large-integer ratios). Moreover, adults and infants have better memory for scales based on unequal steps (such as the major scale) than those based on equal steps (such as division of the octave into seven equal steps). Interestingly, consonant intervals such as octaves, perfect fifths, and perfect fourths are universal or nearly universal, as are unequal-step scales.

My research findings indicate that singing to infants in the course of caregiving is universal. Moreover, there is a special genre of music for infants that consists of lullabies (universal) and play songs (in some cultures, the singing of play songs begins only in the toddler period). Despite the diversity of musical styles across cultures, lullabies are recognizable as lullabies everywhere, even by naive listeners. And not only is there a distinct genre of music for infants; there is also a distinct manner of singing to them. Finally, infants are especially responsive to infant songs and to the unique manner used to sing them.

Moderator: And what does this research tell us about music and the brain?

Trehub: It leads me to believe that our music perception skills result in large part from the nature of the human auditory system, which obviously includes the auditory cortex. I believe that the structure of music across cultures also owes much to the nature of the human auditory system. In other words, the music of any culture is not merely a matter of convention; nature makes important contributions.

Moderator: Seated next to Dr. Trehub is Ralph Spintge, who is a pain specialist, an anesthesiologist, and the executive director of the International Society for Music in Medicine. A physician in Ludenscheid, Germany, he has gathered data concerning the effects of music on stress response, pain, and sleep on more than 120,000 surgical and pain patients. Dr. Spintge, what can you tell us of your major findings?

Ralph Spintge: The main findings from clinical research and from treating our patients since 1977 are twofold. First, selected music significantly decreases the psychological and somatic stress response to acute stressors and acute pain in various medical settings such as surgery, dentistry, labor and childbirth, and intensive care. Second, specifically designed music significantly decreases chronic pain in patients suffering from syndromes such as musculoskeletal pain, low back pain, headache, and rheumatic pain. Listening to selected music mediates pain because music can stimulate the release of pain-controlling hormones such as endorphins and can enhance normal physiological rhythmicity.

By using music in these ways, we have observed a reduction of costs associated with the length of treatment in intensive care units (ICUs) and general hospital stays, a decrease in the quantity of drugs needed, and improved patient compliance in following the treatment plan.

Moderator: Since our audience consists of music educators, what should they know about music and the brain?

Trehub: Perhaps music educators should know that, although some unlearning may occur, we're born with implicit knowledge and general skills. Music educators can give us explicit knowledge (such as the names of particular notes and intervals) and teach specific skills relevant to our musical culture.

Halpern: Following from my previous comment about cognitive aging, I suggest that exposure to music and music training can be valuable to students of any age. We might consider encouraging senior citizens to study music more than we do now. Even if not every senior has the physical capacity to master the fine motor skills of instrument playing, those who have the interest can probably benefit from instruction in critical listening skills, theory, and history.

Moderator: Are all human beings neurologically engineered to be musical in the same sense that all of us are genetically predisposed to be linguistic?

Parsons: Yes. Most of the relevant evidence I know of from anthropology, biology, psychology, and so on seems to support this hypothesis.

Spingte: Looking at our consistent results in patients whose ages range from the premature infant to the elderly, I would think that musicality is genetically determined. I am sure that music has a specific evolutionary significance insofar as societies can survive only with or through music. In my opinion, the social function of music cannot be matched by any other cultural achievement in the history of mankind.

Trehub: I believe that all human beings are equipped by nature to be musical although, like other skills such as athletic or intellectual skills, the underlying substrate, or potential, is likely to be normally distributed. This means that a few individuals have extremely high or low levels of skills and that most people fall within a general intermediate level of skills. Thus, unlike some other scholars who argue that anyone can become a musical genius with appropriate training and diligence, I maintain that exceptional levels of skill require contributions from nature as well as nurture. Nevertheless, appropriate training and practice can lead to considerably higher levels of musical skill than we currently see in the general population.

Moderator: If this is so, how would you account for human musicality from an evolutionary standpoint? Why does music seem to be so prevalent in the human species?

Trehub: Music isn't simply prevalent; it's as universal as language is. Nevertheless, its evolutionary advantage remains unclear.

Parsons: The biology of music is poorly understood. Among animals, only two species, songbirds and humpback whales, possess the capacity to recombine learned sounds into many different sequences and produce large repertoires of affective nonsymbolic songs. Recently, theorists in animal communication have compared these animals' capacity to create sequenced sound with humans' ability to create music.[4] Moreover, it has been suggested that this capacity resembles the combinatorial creativity that underlies language ability, which only humans possess. Because both music and language are apparently universal human capabilities, it is possible that music is an evolutionary precursor to language. This speculation about the evolution of music is compatible with the hypothesis that music confers an adaptive advantage by virtue of strengthening social bonds.

Moderator: Do you think that there are neural networks specifically devoted to music?

Spingte: Our research on the autonomic system clearly shows that functional neural networks are the basic organizing structure of all vital brain activities. For instance, there is no "respiratory center" in the brain, only a neural network that can change size and localization. The governing principle is called "neurovegetative rhythmicity" and is also known as "autonomous nervous system rhythmicity." I think it is exactly here that we can find the "missing link" between physiology and music--it is rhythm. The functional rhythmic variability of physiological systems can be described through mathematical algorithms. (As I understand it, mathematicians nowadays are on the way to describing music with algorithms derived from chaos theory and nonlinear mathematics.) However, describing a subject and understanding a subject are two different things. I am sure that music itself can never be completely quantified, because musical meaning cannot be quantified. It is personal and always will be.

Trehub: It is unclear whether there are neural systems specifically devoted to music or whether systems for auditory pattern processing can serve both speech and music processing. We often forget about prosodic (intonation, stress, and pauses) and paralinguistic (pitch level, speaking rate, and vocal timbre) aspects of speech, which carry information about the speaker's attitude, feelings, and intentions.

Parsons: The current evidence from studying brain-damaged patients and individuals with healthy brains suggests that neural networks specifically devoted to music exist. However, determining whether a brain area supports only one activity such as music comprehension entails proving that an infinite number of other activities are not supported by that area. This issue is perhaps illustrated in comparing and contrasting the biology of music and the biology of language, which has been the most fruitful framework for the study of music and the brain. In general, the structure of music and our use of it are similar in key respects to the way we structure and use language. Close comparisons between the biologies of music and language are important for understanding the biology of music and for understanding the biology of language.[5] By understanding where in the brain the separate aspects of music are represented, we can understand better which neural mechanisms are specific to music, which ones are specific to language, and which ones are common to both. Knowing that a neural mechanism can operate only on music, only on language, or on both imposes important constraints on how we explain the details of large-scale and small-scale neural circuitry.

Moderator: If there are neural networks devoted in whole or in part to music, is there a "music center"? Or does music seem to be represented by a more widely distributed, locally specialized neural network?

Halpern: I am conservative on the modularity issue. While it is true that musical processing has sometimes been shown to involve structures in the right hemisphere more than in other domains of processing, we also have to remember that many musical tasks use both sides of the brain. As we eventually find brain areas especially active in musical tasks, I believe it will be more profitable to analyze what particular characteristics of musical tasks may be important in activating an area rather than drawing conclusions about musical tasks in general. As a cognitive psychologist, my bias is to assume that brain specialization revolves more around processes than materials. For instance, it makes more sense to me that some part of the brain would specialize in pitch judgments, no matter whether that pitch information comes in via music (as would often be the case), via language, or even via environmental sounds.

Parsons: All evidence from brain-damaged patients and brain-imaging studies of healthy persons strongly points toward the view that music is supported by a distributed set of brain areas, each performing elementary information processing operations. This prediction is consistent with the observation that some individuals are better at specific components of music, such as tone recognition, melodic structure, movement, the ability to play an instrument well, and the skill of dramatizing oneself and playing in public. This view of how music is processed is consonant with the widely held belief that, in general, complex human behaviors are enabled by interactions between multiple regional and local circuits, each of which supports a particular elementary cognitive computation.[6] Music is certainly a complex stimulus and can produce a complex cognitive, emotional, and perceptual motor state. Such a complex stimulus activity can be expected to rely on some mechanisms that may have originally evolved for other purposes.

Moderator: There are several examples in the literature that address morphological differences between the brains of musicians and nonmusicians. Do you think musicians are born this way, or do you think that these differences reflect the influence of musical training?

Trehub: Current evidence does not permit a separation of the effects of innate factors and exposure, but there is considerable evidence of changes in the brain that result from various experiences, especially when they occur early in life.

Parsons: The reports of morphological differences, such as the larger left planum temporale in musicians, have been disputed by other scientific reports, so that these findings must still be considered tentative. Furthermore, there is not enough evidence in hand to decide scientifically whether such possible morphological differences are hardwired or learned. In general, the most widely accepted account of such issues is that an individual's variation in a specific faculty is initially hardwired into a neural structure, but it must be appropriately stimulated or trained to achieve its full potential. Based on this view, the morphological differences that have been reported appear to result from some combination of hardwiring and training.

Moderator: What differences are there in left and right hemispheric processing in general, and what implications do you think they have for music processing in particular?

Parsons: The classic view of hemispheric specialization is that the left hemisphere specializes in language and analytical processing and dominates self-conscious awareness and that the right hemisphere specializes in processing intuition, spatial relations, music, emotion, and global aspects of perception. This view is being modified by recent findings indicating that the left side of the brain is characteristically more inventive and interpretative and that the right side is more literal and truthful.[7] Another new view is that each hemisphere possesses complementary mechanisms for information processing, with the left hemisphere processing microstructure and the right hemisphere processing macrostructure.[8] New brain-imaging research in our laboratory indicates that deductive reasoning is supported primarily by right-hemisphere processes and that probabilistic reasoning is supported by left-hemispheric processes.[9] These findings modify the view that the right hemisphere is nonrational, and they are consistent with the new theory that the two hemispheres possess complementary information-processing mechanisms. Neuroimaging studies in music generally indicate that music performance and comprehension are supported by neural mechanisms distributed across both hemispheres. The elementary processing mechanisms that support the different components of music will need to be integrated into a coherent framework that will include the other new findings mentioned.

Moderator: There has been much coverage in the press lately stating that "music makes you smarter." To what extent do you agree or disagree?

Parsons: We have also studied the well-known "Mozart effect" in which passively listening to music appears to enhance individuals' performance on spatial reasoning tasks that follow immediately.[10] Our study attempted to answer the questions of whether the enhancement of spatial ability is caused by music as a whole or if it is primarily due to one or more musical components (tone, melody, or rhythm); whether enhancement could be found using analogous components in other modalities, such as a rhythmically patterned visual stimulus; and whether other kinds of spatial tasks were enhanced by such stimuli. We found that only rhythm, not melody or tone, produced enhancement. In addition, enhancement was found for the rhythmically patterned visual stimulus, suggesting that the effect is not limited to tonal stimuli. Finally, enhancement does not appear to affect all spatial abilities, only those that involve mental rotation, an operation that transforms spatial structure over time.

There is no scientific evidence I know of that indicates that performing or listening to music improves one's overall intelligence. However, there is some evidence from Rauscher and colleagues and from our lab that passive listening to music may temporarily enhance performance on spatial ability tasks, specifically those involving mental rotation.[11] Recent preliminary evidence also indicates that training in music performance before puberty may be associated with permanent enhancements of verbal memory.[12] (The period prior to the onset of puberty is also the critical period for language acquisition.) These findings need to be able to stand up to independent replication and further inquiry.

Halpern: There has been an extraordinary and, in my experience, unique crossover of the music cognition world into the popular press world. Unfortunately, something has been lost in the translation. There is absolutely no evidence that "music makes you smarter" in any global sense of that word. A spate of researchers has recently examined the more circumscribed question of whether brief exposure to music can lead to short-term enhancement of certain spatial skills. These studies have been quite variable in quality, so it is hard to draw strong conclusions at this point. However, the most promising take on this literature is that short-term exposure to some kind of rhythmic pattern--not necessarily music in general, nor Mozart in particular--may temporarily enhance performance in certain three-dimensional spatial tasks. More research is necessary to verify enhancement and, if it is confirmed, to investigate plausible neural mechanisms for this association.

Trehub: Much of the "music makes you smarter" literature is scientifically unsound, particularly the "Mozart effect" in its various guises. I am particularly wary of studies pointing to temporary improvements in spatial-temporal reasoning that result from brief exposure to a Mozart piece. These studies, which have been widely reported in the popular press, have fueled a variety of commercial endeavors, such as the "Mozart effect' recordings now being sold in record shops. Yes, compared to a period of listening to silence or a tape with minimalist music, listening to the Mozart sonata that produced the effect documented by Rauscher and her colleagues can lead to short-term performance enhancement on various mental paper-folding problems.[13] But, other researchers have shown that comparable enhancement can result from listening to other auditory materials, including a piece by Schubert or a recording of a Stephen King story.[14] The crucial factor is the listeners' preference. Those who prefer a story to music perform better with the story, and those who prefer music do the reverse. In short, the enhancement most likely stems from changes in mood or arousal, which arc known to influence cognitive processing. This bleak picture does not rule out the possibility that long-term effects in other realms, including academic skills, can result from some aspects of systematic musical training, but that's another matter altogether.

Spingte: "Music makes you smarter" is an exaggeration that is disastrous to the field of music medicine, because this statement is perceived by the public as "just listen to music and you get smarter." That is nonsense. However, music can enhance attention, focus, and motivation. In this sense, it can be part of a general educational concept. In Germany, music education is an integral part of schools at all levels.

Moderator: Our time is up, so we will have to stop. I want to thank all of you for sharing your expertise with us. It is obvious that the music education community has a great deal to learn from neuromusical research. We will follow new discoveries with enormous interest as mysteries of music and the brain begin to unfold.

Notes

1. Peter Fox, Justine Sergent, Donald Hodges, C. Martin, T. Jerabek, T. Glass, H. Downs, and J. Lancaster, "Piano Performance from Memory: A PET Study" (paper presented at the Human Brain Mapping Conference in Paris, July 1995).

2. Lawrence Parsons, Peter Fox, and Donald Hodges, "Neural Basis of the Comprehension of Musical Melody, Harmony, and Rhythm" (paper presented at the Society for Neuroscience Meeting in Los Angeles' November 1998).

3. Andrea Halpern and Robert Zatorre, "When That Tune Runs through Your Head: A PET Investigation of Auditory Imagery for Familiar Melodies," Cerebral Cortex 9, no. 7 (October-November, 1999): 697-704; Robert Zatorre and Andrea Halpern, "Effect of Unilateral Temporal-Lobe Excision on Perception and Imagery of Songs," Neuropsychogia 31 (1993): 221-32; Robert Zatorre, Andrea Halpern, David Perry, Ernst Meyer, and Alan Evans, "Functional Anatomy of Musical Processing in Listeners with Absolute and Relative Pitch," Proceeding of the National Academy of Sciences 95 (1998), 3172-77; Robert Zatorre, Andrea Halpern, David Perry, Ernst Meyer, and Alan Evans, "Hearing in the Mind's Ear: A PET Investigation of Musical imagery and Perception," Journal of Cognitive Neuroscience 8, no. 1 (1996): 29-46.

4. Peter Marler, "Origins of Music and Speech: Insights from Animals," in The Origins of Music, edited by Nils Wallin, Bjorn Merker, and Steven Brown (Cambridge, MA: MIT Press, 1999).

5. Aniruddh D. Patel and Isabelle Peretz, "Is Music Autonomous from Language? A Neuropsychological Appraisal," Perception and Cognition of Music, edited by Irene Deliege and John Sloboda (London: Psychology Press, 1997), 191-215.

6. Michael I. Posner, Steven Petersen, Peter Fox, and Marcus Raichle, "Localization of Cognitive Operations in the Human Brain," Science 240, no. 1627 (1988): 1627-31; Lawrence M. Parsons, Peter T. Fox, J. Hunter Downs, Thomas Glass, Traci Hirsch, Charles Martin, Paul Jerabek, and Jack L. Lancaster, "The Use of Implicit Motor Imagery for Visual Shape Discrimination Is Revealed by PET," Nature` 375, no. 54 (1995): 54-58.

7. Michael Gazzaniga, "The Split Brain Revisited," Scientific America 279, no. 1 (July 1998): 50-55.

8. Richard B. Ivry and Lynn C. Robertson. Two Sides of Perception (Cambridge, MA: MIT Press, 1998); Mark J. Beeman and Christine Chiarello, "Complementary Right- and Left-Hemisphere Language Comprehension," Current Directions in Psychological Science 7, no. 1 (February, 1998): 2-8.

9. Lawrence Parsons and Daniel Osherson, "New Evidence of Distinct Right and Left Brain Systems for Dedicated versus Probabilistic Reasoning," in press.

10. Lawrence Parsons and Michael Martinez, in preparation.

11. Frances Rauscher, Gordon Shaw, and Katherine Kay, "Music and Spatial Task Performance," Nature 365, no. 14 (October 1993): 611; also Lawrence Parsons and Michael Martinez, in preparation.

12. Agnes Chan, Yim-Chi Ho, and Mei-Chun Cheung, "Music Training Improves Verbal Memory," Nature 396, no. 6707 (12 November 1998): 128.

13. Rauscher et al., "Music and Spatial Task Performance," 1993.

14. Kristin Nantais and Glenn Schellenberg, "The Mozart Effect: An Artifact of Preference," Psychological Science 10, no. 4 (July 1999): 370-73.