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The human knowledge system: Music and brain coherence

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Abstract

Purpose—This paper explores the relationship between music and learning in the mind/brain.

Design/methodology/approach—Taking a consilience approach, this paper briefly introduces how music affects the mind/brain, then moves through several historical highlights of our emergent understanding of the role of music in learning; for example, the much-misunderstood Mozart Effect. Then the role of music in learning is explored from a neuroscience perspective, with specific focus on its potential to achieve brain coherence. Finally, using a specific example of sound technology focused on achieving hemispheric synchronization, research findings, anecdotes and experiential interactions are integrated to touch on the potential offered by this new understanding.

Findings—Listening to music regularly (along with replaying tunes in our brains) clearly helps our neurons stay active and alive and our synapses intact. Listening to the *right* music does appear to facilitate learning, and participating more fully in music-making appears to provide additional cerebral advantages. Further, some music supports hemispheric synchronization, offering the opportunity to achieve brain coherence and significantly improve learning.

Originality/value—This paper brings together diverse research to demonstrate the potential of music to affect mind/brain learning. Further, it introduces and discusses a specific example of sound technology to achieve brain coherence.

Keywords Music, Learning, Brain Coherence, Hemispheric Synchronization, The Mozart Effect, Transfer Effects

Paper type General review and Conceptual paper

Introduction

When Charles Darwin wrote his *Autobiography* in 1887, he was moved to say,

> If I had to live my life again I would have made a rule to read some poetry and listen to some music at least once a week; for perhaps the parts of my brain now atrophied could thus have been kept active through use (Amen, 2005, p. 158).

Today there's no doubt that the brain atrophies through disuse, that is, neurons die and synapses wither when they are not used (Zull, 2002), but would listening to music once a week have kept more of those neurons and synapses active and alive? And if so, what if we *participated more fully* in music-making? How could we maximize our learning?

This paper briefly introduces how music affects the mind/brain, then moves through several historical highlights of our emergent understanding of the role of music in learning; for example, the much-misunderstood Mozart Effect. Then we will explore the role of music in learning from a neuroscience perspective, with specific focus on its potential to achieve brain coherence. Finally, using a specific example of sound technology focused on achieving hemispheric synchronization, we integrate research findings, anecdotes and experiential interactions to touch on the potential offered by this new understanding.

The approach of this exploration through the literature—peppered with anecdotes and experience—is one of consilience; specifically, the integrating of knowledge from a variety of fields to discover a common groundwork of explanation (Wilson, 1998). Among others, this paper considers the findings of psychologists, physicists, neuroscientists, musicians, educators, biologists, engineers and medical doctors.

Brain coherence is considered the orderly and harmonious connectedness between the two hemispheres of the brain, in other words, when the two hemispheres of the brain are synchronized, thus the term hemispheric synchronization. Borrowing from physics, when the brain is in a coherent state, systems are performing optimally and virtually no energy is wasted.[1] This, then, would be considered an optimal state for learning.

While specialization and selection occur in various parts of the brain, they do not occur independently (Levy, 1985). As will be demonstrated, one of the "jobs" of music in the process of evolution and growth is to increase the interconnections between the two hemispheres of the brain. We begin.

How music affects the mind/brain

Music and the human mind have a unique relationship that is not yet fully understood. As Hodges forwards,

> 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 other means. Musical insights into the human condition are uniquely powerful experiences that cannot be replaced by any other form of experience (Hodges, 2000, p. 21).

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[1] The terms coherence and entrainment are often interchanged. However, entrainment is a *form* of coherence used to describe the state achieved when two or more body systems are synchronous and operating at the same frequency. For example, in Heart Math the term entrainment is used to describe this relationship between the respiration and heart-rhythm patterns.

While the effect of music on the critical aspects of learning, attention and memory may be a relatively new area of focused research, the human brain may very well be hardwired for music. As Weinberger, a neuroscientist at the University of California at Irvine, says: "An increasing number of findings support the theory that the brain is specialized for the building blocks of music" (Weinberger, 1995, p. 6). Wilson, a biologist, goes even farther as he states, "...all of us have a biologic guarantee of musicianship, the capacity to respond to and participate in the music of our environment" (Wilson, as cited in Hodges, 2000, p. 18).

Sousa (2006) forwards that there are four proofs that support the biological basis for music: (1) it is universal (past-present, all cultures (Swain, 1997)); (2) it reveals itself early in life (infants three months old can learn and remember to move an overhead crib mobile when a song is played (Fagan, et al., 1997), and within a few months can recognize melodies and tones (Weinberger, 2004; Hannon and Johnson, 2005)); (3) it should exist in other animals besides humans (monkeys can form musical abstractions (Sousa, 2006)); and (4) we might expect the brain to have specialized areas for music.

Exactly where this hardwiring might be located would be difficult to say. For example, even though there is an area in adults identified as the auditory cortex, visual information goes into the auditory cortex, just as auditory information goes into the visual cortex. That is why certain types of music can stimulate memory recall and visual imagery (Nakamura *et al*., 1999). Further, the auditory cortex is not inherently different from the visual cortex. Thus, "Brain specialization is not a function of anatomy or dictated by genes. It is a result of experience." (Begley, 2007, p. 108) This process of specialization through experience begins shortly after the time of conception, selecting and connecting. Many of the interconnections remain into adulthood, or perhaps throughout life. While these connections are not exercised in most adults—they are more like back road connections—when the brain is deprived of one sense (for example, hearing or seeing), a radical reorganization occurs in the cortex, and connections that heretofore lay dormant are used to expand the remaining senses (Begley, 2007).

In the early phases of neuronal growth (during the first few months of life), there is an explosion of synapses in preparation for learning (Edelman, 1992). Yet beginning around the age of eight months through sixteen months, tens of billions of synapses in the audio and visual cortices are lost (Zull, 2002). Chugani says that this explosion is concurrent with synaptic death, with experiences determining which synapses live or die (Chugani, 1998). As Zull explains, before eight months of age synapses are being formed faster than they are being lost. Then things shift, and we begin to lose more synapses than we create (Zull, 2002). The brain is sculpting itself through interaction with its environment, with the reactions of the brain determining its own architecture.

This process of selection continues as the rest of life is played out. This is the process of learning, selecting, connecting and changing our neuronal patterns (Edelman, 1992; Zull, 2002). Music plays a core role in this process. Jensen contends that, "music can actually prime the brain's neural pathways" (Jensen, 2000b, p. 246).

The brain has the capacity to structurally change throughout life. As Begley describes, "The actions we take can literally expand or contract different regions of the brain, pour more juice into quiet circuits and damp down activity in buzzing ones" (Begley, 2007, p. 8). During this process of plasticity, the brain is expanding areas for functions used more frequently and shrinking areas devoted to activities that are rarely performed.

Further, in the late 1990's neuroscientific research discovered that the structure of the brain can change as a result of the thoughts we have. As Dobbs' explains, the neurons that are scattered throughout key parts of the brain "fire not only as we perform a certain action, but also when we watch someone else perform that action" (Dobbs, 2006, p. 22). These are mirror neurons, a form of mimicry that bypasses cognition, transferring actions, behaviors and most likely other cultural norms quickly and efficiently. Thus when we *see* something being enacted, our mind creates the same patterns that we would use to enact that "something" ourselves. Because people have stored representations of songs and sounds in their long-term memory, music can be imagined. When a tune is moving through your mind it is activating the same cells as if you were hearing it from the outside world. Further, as we have noted, when you are internally imagining a tune, the visual cortex is also stimulated such that visual patterns are occurring as well (Sousa, 2006).

Not all of these findings were known when music and acoustic pioneer Alfred Tomatis (1983) forwarded the analogy that sound provided an electrical charge to energize the brain. He described cells in the cortex of the brain as cells acting like small batteries, generating the electricity viewed in an EEG printout. What he discovered that was amazing was that these batteries were not charged by the metabolism, but rather through sound from an external source. With the discovery of mirror neurons, this would mean that imagining tunes is also providing a charge. These early Tomatis studies found that sound impacted posture, energy flow, attitude and muscle tone, and that the greatest impact was in the 8000 hertz frequency range (Tomatis, 1983; Jensen, 2000b). Other research took this further, suggesting that low-frequency tones caused a discharge of mental and physical energy, and certain higher tones powered up the brain (Clynes, 1982; Zatorre, 1997).

Researcher Frances Rauscher (1997), contends that music appreciation and abstract reasoning have the same neural firing patterns. However, this was observed in research that occurred several years after her earlier studies introducing the controversial Mozart Effect, and setting in motion a growing interest in the relationship of music and learning.

The Mozart Effect

The Mozart Effect emerged in 1993 with a brief paper published in *Nature* by Frances Rauscher, Gordon Shaw and Katherine Ky. To discover whether a brief exposure to certain music increased cognitive ability, the researchers divided 36 college students into three groups and used standard intelligence subtests to measure spatial/temporal reasoning. Spatial/temporal reasoning is considered "the ability to form mental images from physical objects, or to see patterns in time and space" (Sousa, 2006, p. 224). During the subtests one group worked in silence, one group listened to a tape of relaxation instructions, and the third group listened to a Mozart piano sonata (specifically, Mozart's *Sonata for Two Pianos in D*). There were significantly higher results in the Mozart group, although the effect was brief, lasting only 10-15 minutes (Rauscher *et al*., 1993).

The Mozart Effect quickly became a meme, taking on a life of its own completely out of context of the findings. Perhaps this was because it was the first study relating music and spatial reasoning, suggesting that listening to music actually increased brain performance. There ensued high media coverage with the emphasis placed on the most sensational findings. However, the details of the study—specifically, that these findings were limited to spatial reasoning not general intelligence, and that the effect was short-lived (10-15 minutes)—were not part of the meme.

In 1995, Rauscher, Shaw and Ky performed a follow-on study that was more extensive than the first. This five-day study involved 79 college students who were pretested for their level of spatial/temporal reasoning prior to three listening experiences and then post-tested. While it was found that all students benefited (again, for a short period of time), the greatest benefits accrued to those students who had tested the lowest on spatial/temporal reasoning at the beginning of the experiment (Rauscher *et al*, 1993).

By now, other groups were exploring the Mozart Effect. The results were similar to the earlier results, again for a short period of time (Rideout and Laubach, 1996; Rideout and Taylor, 1997; Rideout *et al*., 1998; Wilson and Brown, 1997). However, a series of similar studies with slightly different approaches demonstrated no relevant differences between the group listening to Mozart and the control group (Steele *et al*., 1999a, 1999b; Chabris, 1999). Still another study began with the premise that the complex melodic variations in Mozart's sonata provided greater stimulation to the frontal cortex than simpler music. When this theory was tested it was discovered that the Mozart sonata activated the auditory as well as the frontal cortex in all of the subjects, thus suggesting a neurological basis for the Mozart Effect (Muftuler *et al*., 1999). Other specific case results were emerging. For example, Johnson *et al*., (1998) reported improvement in spatial-temporal reasoning in an Alzheimer's patient; and Hughes *et al*. (1999) reported that a Mozart sonata reduced brain seizures.

As the exaggerated sensation of the initial finding began to sink into disillusionment, other researchers were building more understanding of the effect. For example, it was determined that while listening to Mozart *before* testing might improve spatial/temporal reasoning, listening to Mozart *during* testing could cause neural competition through interference with the brain's neural firing patterns (Felix, 1993). Studies expanded to include other musical pieces. The University of Texas Imaging Center in San Antonio discovered that "other subsets of music actually helped the experimental subjects do far better than did listening to Mozart" (Jensen, 2000b, p. 247). Thus it was determined that the effect was not caused by the specific music of Mozart as much as the rhythms, tones or patterns of Mozart's music that enhanced learning (Jensen, 2000b). This is consistent with earlier work by researcher King (1991) who suggested that there is no statistically significant different between New Age music or Baroque music in the effectiveness of inducing alpha states for learning (approximately 8-13 Hz), that is, they both enhance learning. However, Georgi Lozanov, a pioneer of accelerated learning, had said that classical and romantic music (circa 1750-1825 and 1820-1900, respectively) provided a better background for introducing new information (Lozanov, 1991), and Clynes (1982) had recognized a greater consistency in body pulse response to classical music than rock music, which means that the response to classical music was more predictable.

Considering the exaggerated early claims publicized without context and based on highly situation-dependent and context-sensitive studies, and the differences in findings among various research groups, it is easy to understand why the Mozart Effect has proved so controversial. Note that the Mozart Effect emerged from studies involving adults (not children) and that it involved short periods of listening to specific music and doing specific subtasks to measure spatial/temporal reasoning. In these studies, effects from long-term listening were not studied or assessed, nor the richer long-term involvement of learning and playing music. This brings us to a discussion of transfer effects.

Transfer Effects

The question of if and how music improves the mind is often couched as a question of transfer effects. This refers to the transfer of learning that occurs when improvement of one cognitive ability or motor skill is facilitated by prior learning or practice in another area (Weinberger, 1999). For example, riding a bike, often used to represent embodied tacit knowledge (Bennet and Bennet, 2008), is a motor skill (in descriptive terms, learning to maintain balance while moving forward) that can facilitate learning to skate or ski.

In cognitive and brain sciences the transfer of learning is a fundamental issue. While it has been argued that simply using a brain region for one activity does not necessarily increase competence in other skills or activities based in the same region (Coch *et al*., 2007), with our recent understanding of the power of thought patterns, one discipline is not completely independent of another (Hetland, 2000). For example, a melody can act as a vehicle for a powerful communication transfer at both the conscious and non-conscious level (Jensen, 2000b). Thus, “Music acts as a premium signal carrier, whose rhythms, patterns, contrasts, and varying tonalities encode any new information” (Webb and Webb, 1990). By “encode” is meant to facilitate remembering. An example is the *Alphabet Song* sung to the tune of *Twinkle, Twinkle Little Star.*

There are different spectral types of real sounds coming from a myriad of sources. Periodic sounds that give a strong sense of pitch are harmonic (sung vowels, trumpets, flutes); those which have a weak or ambiguous sense of pitch are inharmonic (bells, gongs, some drums); and sound that has a sense of high or low but no clear sense of pitch is noise (consonants, some percussion instruments, and initial attacks of both harmonic and inharmonic sounds) (Soundlab, 2008). Specific sounds we hear may include different spectral types; music often includes all three. For example, when hearing a church soloist the noise of a strong consonant is followed by a sung vowel (harmonic). It is also noteworthy that the same part of the brain that *hears pitch* (the temporal lobe) is also involved in *understanding speech* (Amen, 2005). Thus specific combinations of sound may carry specific meaning by triggering memories or feelings whether or not they have words connected to them.

Research findings indicate that music actually increases certain brain functions that improve other cognitive tasks. Perhaps one of the most stunning results in the literature was achieved by a professional musician in North Carolina who was music director of the Winston-Salem Triad Symphony Orchestra. The music director arranged for a woodwind quintet to play two or three half-hour programs per week at a local elementary school for three years: the first year playing for all first graders; the second year playing for all first and second graders; and the third year playing for all first, second and third graders. Note that 70 percent of the students at the elementary school received free or reduced-price lunches. Prior to the study, first through fifth graders had an average composite IQ score of 92 and more than 60 percent of third graders tested below their grade level. Three years into the program, testing of the third graders exposed to the quintet music for three years showed remarkable differences, with 85 percent of this group testing *above grade level for reading* and 89 percent testing *above grade level for math* (Campbell, 2000).

The limbic system and subcortical region of the brain—the part of the brain involved in long-term memory—are engaged in musical and emotional responses. Therefore, when information is tied to music, it has a better chance of being encoded in long-term memory (Jensen, 2000b). Context-dependent-memory connected to music is not a new idea. In a study at Texas A&M University examining the role of background instrumental music, music turned out to be an important contextual element. Subjects had the best recall when music was played during learning and that same music was played during recall (Godden and Baddeley, 1975). This was confirmed in a 1993 study monitoring cortical and verbal responses to harmonic and melodic intervals in adults knowledgeable in music. The results showed consistent brain responses to intervals, whether isolated harmonic intervals, pairs of melodic intervals, or pairs of harmonic intervals. These results indicated that intervals may be viewed as meaningful words (Cohen *et al*., 1993).

It has also been found that background music enhances the efficiency of individuals who work with their hands. For example, in a study of surgeons it was found that background music increased their alertness and concentration (Restack, 2003). The music that surgeons said worked best was not "easy-listening"; rather, that music was (in order of preference): Vivaldi's *Four Seasons*, Beethoven's *Violin Concerto Op. 61*, Bach's *Brandenburg Concertos*, and Wagner's *Ride of the Valkyries.* The use of background music during surgery did not cause interference and competition since music and skilled manual activities activate different parts of the brain (Restak, 2003). This, of course, is similar to the use of background music in the classroom or in places of work.

Dowling, a music researcher, believes that music learning affects other learning for different reasons. Building on the concepts of declarative memory and procedural memory, he says that music combines mind and body processes into one experience. For example, by integrating mental activities and sensory-motor experiences (like moving, singing or participating rhythmically in the acquisition of new information, and for our doctors in the example above their hand movements) learning occurs "on a much more sophisticated and profound level" (Campbell, 2000, p. 173). Conversely, it has also been found that stimulating music can serve as a distraction and interfere with cognitive performance (Hallam, 2002). Thus, much as determined in the early Mozart studies, *different types of music produce different effects in different people* in regard to learning.

The Right and Left Hemispheres of the Brain

The human brain is divided into two hemispheres, simply referred to as the right and left hemispheres. It was previously believed that the right hemisphere was the seat of music, but today we know that both sides of the brain are used to listen to music (Amen, 2005). Music engages the whole brain (Jensen, 2000b). For example, as sound enters the ears it goes to the auditory cortex in the temporal lobes. The temporal lobe in the non-dominant hemisphere (generally the right hemisphere) hears pitch, melody, harmony and beat, and (recognizing long-term patterns) puts this together as a whole piece. The temporal lobe in the dominant hemisphere (generally the left hemisphere) is better at analyzing the incoming sound and hearing the short-term signatures of music, that is, lyrics and *changes* in rhythm (pacing), frequency, intensity, and harmonies (Amen, 2005; Jensen, 2000b; Weinberger, 1995). The frontal lobe associates the sound with thought and stimulates emotions (in the limbic system) and past experiences (from memory scattered all over the brain) (Sousa, 2006), and the cerebellum becomes involved in measuring the beats (spatial aspects) (Jensen, 2000b). For example, while a non-musician would process music primarily in the right hemisphere (with potential strong contributions from the limbic system stimulated by the frontal lobe), a musician who was analyzing the content of a musical form would tend to hear music with his left hemisphere (Amen, 2005) with a heavy dose of the cerebellum thrown in (Jensen, 2000b).

Using PET scans, Eric Jensen, an educator known for his translation of neuroscience, has identified the various brain regions activated by different aspects of music. For example, rhythm activates the Broca's area as well as the cerebellum; melody activates both hemispheres (with a specific recognized melody activating the right hemisphere); harmony activates the left hemisphere more than the right as well as the inferior temporal cortex; pitch activates the left back of the brain and may also activate the right auditory cortex; and timbre activates the right hemisphere (Jensen, 2000b).

Further, activation of various parts of the brain are highly dependent on which senses are involved: aural (hearing music), sight (reading music), touch (playing music). Further, other events such as hearing a story about the Mozart Effect, recalling a Rolling Stones concert, or having an emotional response to certain music are processed differently in the brain (Jensen, 2002). In other words, the experience and thought related to music is spatially diffused throughout the brain. While there are many studies on the connections between music and emotions and between emotion and learning, these are outside the focus of this paper.

As Robert Zatorre, a neuropsychologist at the Montreal Neurological Institute forwards, there is little doubt that music engages the entire brain (Zatorre, 1997). Further, as music has shifted over the last hundred years from baroque or classical (stimulating our non-dominant hemisphere) to more avant-garde styles (stimulating our dominant hemisphere), it has engaged the brain even more fully (Zatorre, 1997).

Impact of Musical Instruction

Substantiating the long-held "knowing" that music is beneficial to human beings, Hodges outlines five basic premises that establish a link between the human brain and the ability to learn.

The first two confirm our earlier discussion of the brain as being hardwired for—or at least having a proclivity for—music. The latter three are pertinent to our forthcoming discussion of the impact of musical instruction on the learning mind/brain. As Hodges forwards (with some paraphrasing): (1) the human brain has the ability to respond to and participate in music; (2) the musical brain operates at birth and persists throughout life; (3) early and ongoing musical training affects the organization of the musical brain; (4) the musical brain consists of extensive neural systems involving widely distributed, but locally specialized regions of the brain; and (5) the musical brain is highly resilient (Hodges, 2000, p. 18).

There are hundreds of studies that confirm that creating music and playing music, especially when started at an early age, provide many more cerebral advantages than listening to music. In a study involving 90 boys between the ages of 6 and 15, it was discovered that musically-trained students had better verbal memory but showed no differences in visual memory. Thus musical training appeared to improve the ability of the Broca's and Wernicke's areas to handle verbal learning. Further, the memory benefits appeared long-lasting. When students who dropped out of music training were tested a year later, it was found that they had retained the verbal memory advantage gained while in music training (Ho *et al*., 2003).

Music and mathematics are closely related in brain activity (Abeles and Sanders, 2005; Catterall *et al*., 1999; Graziano *et al*., 1999; Kay, 2000; Schmithhorst and Holland, 2004; Vaughn, 2000). Mathematical concepts basic to music include patterns, counting, geometry, rations and proportions, equivalent fractions, and sequences (Sousa, 2006). For example, musicians learn to recognize patterns of chords, notes and key changes to create and vary melodies, and by inverting those patterns they create counterpoint, forming different kinds of harmonies. As further examples, musical beats and rests are counted, instrument finger positions form geometrical shapes, reading music requires an understanding of ratios and proportions (duration and relativity of notes), and a musical interval (sequence) is the difference between two frequencies (known as the beat frequency) (Sousa, 2006).

In the brain music is stored in a pitch-invariant form, that is, the important relationships (patterns) in the song are stored, not the actual notes. This can be demonstrated by an individual's ability to recognize a melody regardless of the key in which it is played (with different notes being played than those stored in memory). As Hawkins and Blakeslee detail,

> This means that each rendition of the 'same' melody in a new key is actually an entirely different sequence of notes! Each rendition stimulates an entirely different set of locations on your cochlea, causing an entirely different set of spatial-temporal patterns to stream up into your auditory cortex ... and yet you perceive the same melody in each case (Hawkins and Blakeslee, 2004, pp. 80-81).

Unless you have perfect pitch, it is difficult to differentiate the two different keys. This means that—similar to other thought patterns—the natural approach to music storage, recall and recognition occurs at the level of invariant forms. Invariant form refers to the brain's internal representation of an external form. This representation does not change even though the stimuli informing you it's there is in a constant state of flux (Hawkins and Blakeslee, 2004).

A 1993 study at the University of Vienna revealed the extent that different regions of the human brain cooperate when composing music (this also occurred in some listeners). Professor Hellmuth Petsche and his associates determined that brain wave coherence occurred at many sites throughout the cerebral cortex (Petsche, 1993). For some forms of music, the correlation between the left and right frontal lobes increases, that is, brain waves become more similar between the frontal lobes of the two hemispheres (Tatsuya *et al*., 1997). For example, in a study involving exposure of four-year-old children to one hour of music per day over a six month period, brain bioelectric activity data indicated an enhancement of the coherence function (Flohr *et al*., 2000).

In a study of the relationship of coherence and degree of musical training, subjects with music training exhibited significantly more EEG coherence within and between hemispheres than those without such training in a control group (Johnson *et al*., 1996)[2]. In other words, it appeared musical training increased the number of functional interconnections in the brain. Specifically, the researchers suggested that greater coherence in musicians, "... may reflect a specialized organization of brain activity in subjects with music training for enabling the experiences of ordered acoustic patterns" (Johnson *et al*., 1996, p. 582).

Further, in a study between 30 professional classical musicians and 30 non-musician controls matched for age, sex and handedness, MRI scans revealed that there was a positive relationship between corpus callosum size and the number of fibers crossing through it, indicating a difference in inter-hemispheric communication between musicians and controls (Schlaug *et al*., 1995; Springer and Deutsch, 1997). In other words, the two hemispheres of the brain of the musicians had a larger number of connections than those of the control group. Thus, as Jenson confirms, "Music ... may be a valuable tool for the integration of thinking across both brain hemispheres" (Jensen, 2000, p. 246). And as summed up by Thompson, brain function is enhanced through increased cross-callosal communication between the two hemispheres of the brain (Thompson, 2008).

Musicians have structural changes that are "profound and seemingly permanent" (Sousa, 2006, p. 224). As Sousa describes, "the auditory cortex, the motor cortex, the cerebellum, and the corpus callosum are larger in musicians than in non-musicians" (Sousa, 2006, p. 224). This, of course, moves beyond being able to discern different tonal and visual patterns to acquiring new motor skills. Since the brains of musicians and non-musicians are structurally different yet studies of 5-7 year olds beginning music lessons show no pre-existing differences (Restak, 2003; Sousa, 2006; Norton *et al*., 2005), it appears that most musicians are made, not born. An example is perfect pitch, the ability to name individual tones. Perfect pitch is not an inherited phenomenon. Restak (2003) discovered that perfect pitch can be acquired by average children between three and five years of age when given appropriate training. Structural brain changes occur along with the development of perfect pitch, and continue as musical talent matures (Restak, 2003).

We have now answered two of our introductory questions: listening to music regularly (along with replaying tunes in our brains) helps keep our neurons and synapses active and alive.

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[2] It was also found that females had higher coherence than males, which is in accord with anatomical studies showing that females have a larger number of interhemispheric connections than males.

Listening to the *right* music does appear to facilitate learning. Further, participating more fully in music-making appears to provide additional cerebral advantages. But, as we will discover, some music offers an even greater opportunity to heighten our conscious awareness in terms of sensory inputs, expand our awareness of, and access to, that which we have gathered and stored in our unconscious, and grow and expand our mental capacity and capabilities.

Since music has its own frequencies, it can either resonate or be in conflict with the body's rhythms. The pulse (heart beat) of the listener tends to synchronize with the beat of the music being heard (the faster the music, the faster the heartbeat). When this resonance occurs the individual learns better. As Jensen confirms, "When both are resonating on the same frequency, we fall 'in sync,' we learn better, and we're more aware and alert" (Jensen, 2000b). This is a starting point for further exploring brain coherence.

Hemispheric Synchronization

Hemispheric synchronization is the use of sound coupled with a binaural beat to bring both hemispheres of the brain into unison (Bennet and Bennet, 2007). Binaural beats were identified in 1839 by H.W. Dove, a German experimenter. In the human mind, binaural beats are detected with carrier tones (audio tones of slightly different frequencies, one to each ear) below approximately 1500 Hz (Oster, 1973). The mind perceives the frequency differences of the sound coming into each ear, mixing the two sounds to produce a fluctuating rhythm and thereby creating a beat or difference frequency. Because each side of the body sends signals to the opposite hemisphere of the brain, both hemispheres must work together to "hear" the difference frequency.

This perceived rhythm originates in the brainstem (Oster, 1973) and is neurologically routed to the reticular formation (Swann *et al*., 1982), then moving to the cortex where it can be measured as a frequency-following response (Hink *et al*., 1980; Marsh *et al*., 1975; Smith *et al*., 1978). This inter-hemispheric communication is the setting for brain-wave coherence, which facilitates whole-brain cognition (Ritchey, 2003), that is, an integration of left- and right-brain functioning (Carroll, 1986).

What can occur during hemispheric synchronization is a physiologically reduced state of arousal while maintaining conscious awareness (Atwater, 2004; Fischer, 1971; Delmonte, 1984; Goleman, 1988; Jevning *et al*., 1992; Mavromatis, 1991; West, 1980), and the capacity to reach the unconscious creative state described above through the window of consciousness. In an exploration of tacit knowledge published in *VINE* at the beginning of this year, the authors introduced the use of sound as an approach to accessing tacit knowledge. For example, listening to a special song in your life can draw out deep feelings and memories buried in your unconscious. Further, inter-hemispheric communication was introduced as a setting for achieving brainwave coherence (a doorway into the unconscious), providing greater access to knowledge (informing) and knowledge (proceeding), thereby facilitating learning (Bennet and Bennet, 2008). By reference the ideas forwarded in this work are included here.

In 1971 Robert Monroe—an engineer, founder of The Monroe Institute, and arguably the leading pioneer of achieving learning through expanded forms of consciousness—developed audiotapes with specific beat frequencies which create synchronized rhythmic patterns of concentration called Hemi-Sync. Repeated experiments occurred with individual brain activity observed. The following correlations between brain waves and consciousness were used: Beta waves (approximately 13-26 Hz) and focused alertness and increased analytical capabilities; Alpha waves (approximately 8-13 Hz) and unfocused alertness; Theta waves (approximately 4-8 Hz) and a deep relaxation; and Delta waves (approximately 0.5-4 Hz) and deep sleep. While it was discovered that theta waves provided the best learning state and beta waves the best problem-solving state, this posed a problem. Theta is the state of short duration right before and right after sleep (Monroe Institute, 1985). This problem was solved by superimposing a beta signal on the theta, which produced a relaxed alertness (Bullard, 2003).

This is consistent with the findings from neurobiological research that efficient learning is related to a decrease in brain activation often accompanied by a shift of activation from the prefrontal regions to those regions relevant to the processing of particular tasks (the phenomenon known as the anterior-posterior shift).

The first meta-music developed combining theta and beta waves (*Remembrance* by J.S. Epperson) was released in 1994 (Bullard, 2003). A second meta-music piece combining theta and beta waves, released that same year (*Einstein's Dream*, also by Epperson), was based on a modification of Mozart's *Sonata for Two Pianos in D Major*, **the same piece used in the initial study which produced the controversial Mozart Effect**. This version, however, had embedded combinations of sounds to encourage whole brain coherence.

Thus the Monroe Institute was developing and releasing audiotapes (and then CDs) specifically designed to help the left and right hemispheres of the brain work together, resulting in increased concentration, learning and memory (Jensen, 2000b). While the range and number of similar music products has expanded over the past years, the many years of both scientific and anecdotal evidence available about the use of Hemi-Sync provides a plethora of material from which to explore the benefits of brain coherence as it relates to learning. Thus we will briefly explore the context around this technology.

The Hemi-Sync[3] Experience

There are dozens of recorded studies dated during the 1980's that looked at the relationship of Hemi-Sync and learning, some specifically focused on educational applications. For example, at a government training school the use of Hemi-Sync to focus and hold attention was found to increase mental-motor skills by 75 percent (Waldkoetter, 1982). In a general psychology class, Edrington (1983) discovered that students who listened to verbal information (definitions and terms peculiar to the field of psychology) with a Hemi-Sync background signal ($4 \pm .2$ Hz) scored significantly higher than the control group on five of six tests.

In 1986, Dr. Gregory Carroll presented the results of a study on the effectiveness of hemispheric synchronization of the brain as a learning tool in the identification of musical

[3] While used as a short term for hemispheric synchronization, Hemi-Sync is also the term patented by Robert Monroe to describe the Hemi-Sync auditory-guidance system, a binaural-beat sound technology that demonstrated changes in focused states of consciousness in over 30 years of study.

intervals. While the results of the experimental group were 5.54 percent higher than the control group, this was not considered significant. However, a surprise finding was that individuals in the experimental group had a tendency to achieve higher scores on their post-tests than on their pre-tests. The effect was in both the number of individuals and the amount of individual change. Only 28 percent of the individual responses in the control group post-tests were higher than their pre-tests, while 54 percent of the experimental group did much better (Carroll, 1986). This suggests that Hemi-Sync signals **sustained their levels of concentration during the course of the 40-minute tape sessions**, considerably longer than what occurred (when it occurred) in the Mozart Effect studies.

Hemi-Sync has consistently proven effective in improving enriched learning environments through sensory integration (Morris, 1990), enhanced memory (Kennerly, 1994), and improved creativity (Hiew, 1995) as well as increasing concentration and focus (Atwater, 2004; Bullard, 2003). There is also a large body of observational research. For example, after 14 years of using music as part of his practice, medical doctor Brian Dailey found that the use of sound (specifically, Hemi-Sync) not only had a therapeutic effect for his patients with a variety of illnesses, but could be extremely effective in assisting healthy individuals with concentration, insight, intuition, creativity and meditation (Mason, 2004). This short review has not included the many studies specifically addressing the impact of music, and in particular Hemi-Sync, on patients with brain damage or learning disorders, which is outside the focus of this paper.

In a recent study on the benefits of long-term participation in The Monroe Institute programs[4] involving more than 700 self-selected participants,[5] it was shown that greater experience with Hemi-Sync increased self-efficacy and life satisfaction (Danielson, 2008) at a state of development similar to that of self-transforming (Kegan, 1982). As described in the research results,

> Individuals at this stage of development recognize the limitations in any perspective and more willingly engage others for the challenge it poses to their worldview as the means for growing more expansive in their experiences—to consciously grow beyond where they are rather than merely having it happen to them as a function of circumstances (Danielson, 2008, p. 25).

The 700 study participants (all adults) were evenly divided between single program participation (SPP) and multiple program participation (MPP) (indicating increased usage over a longer period of time). SPP means one week of continuous emersion using Hemi-Sync technology; MPP means multiple weeks of continuous emersion, separated by time periods ranging from weeks to years. Following their Hemi-Sync experiences, participants reported remarkable results. For example, the following percentages of participants *strongly agreed* (on a five-point Likert scale) to the following statements:

> "I have a more expansive vision of how the parts of my life relate to a whole" (25.29% SPP, 61.3% MPP)

[4] Released in early 2008 at the Monroe Institute.
[5] More than 20,000 people worldwide have participated in formal Hemi-Sync programs at the Institute. An equivalent number of people have participated in outreach programs, which are conducted in English, Spanish, French, German and Japanese.

> "I am actively involved in my own personal development" (30.65% SPP, 62.45% MPP)
> "I take actions that are more true to my sense of self" (18.77% SPP, 45.21% MPP)
> "I have been able to resolve an important issue or challenge in my life" (11.88% SPP, 32.57% MPP)
> "I am more productive at work" (4.6% SPP, 14.18% MPP)
> "I have a clear sense of further development I need to accomplish" (29.5% SPP, 40.23% MPP)
> "I am more successful in my career" (6.56% SPP, 17.97% MPP)

Clearly, Hemi-Sync supports a long-term development program for "those interested in playing on the boundaries of human growth and development ... who want to see positive change in their lives" (Danielson, 2008, p. 25).

Final Thoughts

At a dozen places on the Internet, neurologist Jerre Levy of the University of Chicago[6] is credited with saying (paraphrased) that great men and women of history do not merely have superior intellectual capacities within each hemisphere of the brain. They also have phenomenal levels of emotional commitment, motivation, and attentional capacity, all of which reflect the *highly integrated brain in action*.

As we have seen, for the past 30 years, and perhaps longer, there have been studies in the mainstream touting the connections between music and mind/brain activity (from the viewpoints of psychology, music, education, etc.), and another expanding set of studies not as mainstream (from the viewpoint of consciousness). As our thought and understanding as a species is expanding, these areas of focus are openly acknowledging each other and learning together. It is no longer necessary or desirable to limit our thoughts to one frame of reference, nor to place boundaries on our mental capacity and ability to expand or contract that capacity.

We have seen evidence that changes in brain organization and function occur with the acquisition of musical skills. From the external viewpoint, whether as a listener or participant music clearly offers the potential to strengthen and increase the inter-connections across the hemispheres of our brain. As an example, the sound technology of Hemi-Sync offers the potential to achieve brain coherence, thus facilitating whole-brain cognition.

This is not to say that sound, music, Mozart or Hemi-Sync offer a panacea for learning. Let's not produce the disappointment of creating a meme without context. When asked what to expect from the Hemi-Sync experience, engineer and developer Robert Monroe responded,

> As much or as little as you put into it. Some discover themselves and thus live more completely, more constructively. Others reach levels of awareness so profound that one such experience is enough for a lifetime. Still others become seekers-after-truth and add an on-going adventure to their daily activity (Monroe, 2007).

We've come full circle. Learning is occurring in the mind/brain as long as there is life; this is part of the inheritance of Darwinian survival of the fittest. But the amount, quality and direction of that learning, and the environments in which we live, are choices. Yes, Charles

[6] Levy is a strong debunker of the left brain/right brain myth (Levy, 1985).

Darwin, regularly listening to music—and, even better, participating in music-making—would have undoubtedly kept more neurons alive and active, and synapses intact.

Now our opportunity is to fully exploit this understanding in our organizations, in our communities, and in our everyday lives.

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