How Music Helps to Heal the Injured Brain: Therapeutic Use Crescendos Thanks to Advances in Brain Science

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Image courtesy of Dr. Michael Thaut and Taylor & Francis

Editor's note: The use of music in therapy for the brain has evolved rapidly as brain-imaging techniques have revealed the brain's plasticity—its ability to change—and have identified networks that music activates. Armed with this growing knowledge, doctors and researchers are employing music to retrain the injured brain. Studies by the authors and other researchers have revealed that because music and motor control share circuits, music can improve movement in patients who have suffered a stroke or who have Parkinson's disease. Research has shown that neurologic music therapy can also help patients with language or cognitive difficulties, and the authors suggest that these techniques should become part of rehabilitative care. Future findings may well indicate that music should be included on the list of therapies for a host of other disorders as well.

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The role of music in therapy has gone through some dramatic shifts in the past 15 years, driven by new insights from research into music and brain function. These shifts have not been reflected in public awareness, though, or even among some professionals.

Biomedical researchers have found that music is a highly structured auditory language involving complex perception, cognition, and motor control in the brain, and thus it can effectively be used to retrain and reeducate the injured brain. While the first data showing these results were met with great skepticism and even resistance, over time the consistent accumulation of scientific and clinical research evidence has diminished the doubts. Therapists and physicians use music now in rehabilitation in ways that are not only backed up by clinical research findings but also supported by an understanding of some of the mechanisms of music and brain function.

Rapid developments in music research have been introduced quickly into neurologic therapy (see sidebar) over the past 10 years. Maybe due to the fast introduction, the traditional public perception of music as a 'soft' addition, a beautiful luxury that cannot really help heal the brain, has not caught up with these scientific developments.

But music can. Evidence-based models of music in therapy have moved from soft science—or no science—to hard science. Neurologic music therapy does meet the standards of evidence-based medicine, and it should be included in standard rehabilitation care.

Where We Started

While the notion that music has healing powers over mind and body has ancient origins, its formal use as therapy emerged in the middle of the 20th century. At that time, music therapists thought of their work as rooted in social science: The art had value as therapy because it performed a variety of social and emotional roles in a society's culture. In this early therapy, music was used, as it had been through the ages, to foster emotional expression and support; help build personal relationships; create and facilitate positive group behaviors; represent symbolically beliefs and ideas; and support other forms of learning. In the clinic, patients listened to music or played it together with the therapists or other patients to build relationships, promote well-being, express feelings, and interact socially.

Because early music therapy was built upon these laudable and important but therapeutically narrow concepts, many in health care, including insurers, viewed it as merely an accessory to good therapy. For decades it was difficult to collect scientific evidence that music therapy was working because no one knew what the direct effects of music on the brain were. Now, however, the approaches that are central to brain rehabilitation focus on disease-specific therapeutic effects, demonstrated by rigorous research.

Neuroscience Steps Up

During the past two decades, new brain imaging and electrical recording techniques have combined to reshape our view of music in therapy and education. These techniques (functional magnetic resonance imaging, positron-emission tomography, electroencephalography, and magnetoencephalography) allowed us for the first time to watch the living human brain while people were performing complex cognitive and motor tasks. Now it was possible to conduct brain studies of perception and cognition in the arts.[1]

From the beginning of imaging research, music was part of the investigation. Scientists used it as a model to study how the brain processes verbal versus nonverbal communication, how it processes complex time information, and how a musician's brain enables the advanced and complicated motor skills necessary to perform a musical work.

After years of such research, two findings stand out as particularly important for using music in rehabilitation. First, the brain areas activated by music are not unique to music; the networks that process music also process other functions. Second, music learning changes the brain.

The brain areas involved in music are also active in processing language, auditory perception, attention, memory, executive control, and motor control.[2] Music efficiently accesses and activates these systems and can drive complex patterns of interaction among them**.** For example, the same area near the front of the brain is activated whether a person is processing a problem in the syntax of a sentence or in a musical piece, such as a wrong note in a melody. This region, called Broca's area after the French neurologist from the 19th century who described it, is also important in processing the sequencing of physical movement and in tracking musical rhythms, and it is critical for converting thought into spoken words. Scientists speculate, therefore, that Broca's area supports the appropriate timing, sequencing, and knowledge of rules that are common and essential to music, speech, and movement.[3]

A key example of the second finding, that music learning changes the brain, is research clearly showing that through such learning, auditory and motor areas in the brain grow larger and interact more efficiently. After novice pianists have just a few weeks of training, for example, the areas in their brain serving hand control become larger and more connected. It quickly became clear that music can drive plasticity in the human brain, shaping it through training and learning.[4]

Researchers in the field of neurologic rehabilitation have described parallel results. They found that the brain changes in structure and function as a result of learning, training, and environmental influences. Exposure and experience will create new and more efficient connections between neurons in the brain in a sort of "rewiring" process.

This discovery fundamentally changed how therapists developed new interventions. Passive stimulation and facilitation were no longer considered effective; active learning and training promised to be the best strategy to help rewire the injured brain and recover as much ability as possible. Further clinical research has strongly confirmed this approach.[5]

By combining these developments—brain imaging, insight into plasticity, and finding that musical and non-musical functions share systems—therapists finally could build a powerful, testable hypothesis for using music in rehabilitation: Music can drive general reeducation of cognitive, motor, and speech and language functions via shared brain systems and plasticity. Once used only as a supplementary stimulation to facilitate treatment, music could now be investigated as a potential element of active learning and training.

First Steps with Movement

To explore this hypothesis, in the early 1990s we began to extract and study shared mechanisms between musical and non-musical functions in motor control. One of the most important shared mechanisms is rhythm and timing.

Timing is key to proficient motor learning and skilled motor activities; without it, a person cannot execute movement appropriately and skillfully. Rhythm and timing are also important elements in music. Rhythm timing adds an anticipation component to movement timing. The necessary harness for all elements of musical sound architecture, rhythm is also important in learning the appropriate motor control in order to play music.

We hypothesized that by using musical rhythms as timing signals we might improve a person's motor control during non-musical movement. To test this idea, we used rhythmic auditory cues to give people an external "sensory timer" with which they could try to synchronize their walking.

When we tried it with patients with stroke or Parkinson's disease, their improvements in certain areas were instantaneous and stunning. By following the rhythmic cues, patients recovering from stroke were able to walk faster and with better control over the affected side of their bodies. Some of the more complex measures of movement control, such as neuromuscular activation, limb coordination, angle extensions, and trajectories of the joints and centers of body mass, also became significantly more consistent, smoother, and flexible.[6] For those with Parkinson's disease, it was interesting to see that music and rhythm could quicken their movements and also serve as an auditory trigger to keep the movements going and prevent "freezing" (the sudden halt of all movement), which occurs frequently in Parkinson's patients.[7]

These improvements held up over long-term training and also proved to be superior in comparison with other standard physical therapy interventions.[8] We then applied the same concepts to arm therapy, with similar success. Since then, other studies have confirmed and extended our research. The therapy created from it, rhythmic auditory stimulation, now is considered part of the state-of-the-art repertoire in motor therapies.

Our results added weight to the idea that music could shape movements in therapy by accessing shared elements of musical and non-musical motor control (rhythm, timing) and thus powerfully enhance relearning and retraining in a clinical environment. In a recent study that utilized brain imaging in patients with stroke, arm training with auditory rhythm triggered brain plasticity, as predicted. Additional areas in the sensorimotor cortex and the cerebellum were activated by the training. In comparison, standard physical therapy did not result in any evidence of new changes in brain activations.[9]

Reaching for Speech and Cognition

Clinical research studies in the past 10 years have extended the use of music from motor therapy to the rehabilitation of speech, language, and cognitive functions. Scientists wondered if they could design therapeutic music exercises that would affect general cognition and speech and language functions via plasticity in shared brain systems the way they had for motor therapies.

It wasn't as clear from the outset, though, exactly what advantage music would show over other methods of retraining impaired cognition or language functions. It was easier to see that music has advantages over other types of therapies for motor control because of its rhythmic patterns that drive priming and timing of the motor system, and the rich connectivity between the neurons in the auditory system and those in the motor system. One can picture the auditory neurons responding to rhythmic stimuli and firing in patterns that spread via connecting nerve fibers into motor neurons, activating them in synchronicity. How music could facilitate cognition and language training was initially less obvious.

Two insights from research help to bridge this gap. The first extends the idea that the brain systems underlying music are shared with other functions. Evidence suggests that music may activate these systems differently than speech or other stimuli do and might enhance the way the systems work together.[10] For example, music tends to activate brain structures either bilaterally—in both hemispheres simultaneously—or in the right hemisphere more than the left. For injuries on one side of the brain, music may create more flexible neural resources to train or relearn functions. Aphasia rehabilitation is a good example. Singing—which relies mainly on right-hemisphere brain systems—can bypass injured left-hemisphere speech centers to help people produce speech.[11] We have shown in a memory study that learning word lists in a song activates temporal and frontal brain areas on both sides of the brain, while spoken-word learning activates only areas in the left hemisphere.[12] Music also can activate the attention network on both sides of the brain, which can help overcome attention problems caused by stroke or traumatic brain injury.[13]

The second helpful insight was the development of the auditory scaffolding hypothesis.[14] This model proposes that the brain assigns nearly everything that deals with temporal processing, timing, and sequencing to the auditory system. This process works because sound is inherently a temporal signal, and the auditory system is specialized and highly sensitive for perceiving time information. For example, short-term auditory verbal memory (in spoken words) is better than short-term visual memory (in written words). Similarly, people can track and remember auditory tone sequences better than visual or tactile ones. And people who are deaf also often have trouble developing non-auditory temporal skills. Cognitive abilities such as language, learning and remembering, attention, reasoning, and problem-solving require complex temporal organization. Experiences with sound may help bootstrap—or provide a kind of scaffolding for—developing or retraining such abilities. As music may be the most complex temporal auditory language, it may offer superior auditory scaffolding for cognitive learning.

Using these two insights, researchers could make a case for trying music as therapy in speech, language, and cognitive rehabilitation. Evidence from the research that ensued supports the clinical effectiveness of music and has identified the brain processes that underlie these effects.

For example, various studies have shown that therapeutic music exercises can help improve verbal output for people with aphasia, strengthen respiratory and vocal systems, stimulate language development in children, and increase fluency and articulation. Music therapy can retrain auditory perception, attention, memory, and executive control (including reasoning, problem-solving, and decision-making).[15]

Next Frontier: Mood?

The extended shared brain system theory and the auditory scaffolding theory provided a new theoretical foundation for the therapeutic use of music in motor, speech and language, and cognitive rehabilitation. In the future, new theories may help us understand the other effects of music, and point the way to new types of rehabilitation.

For example, how can we harness the ability of music to evoke and induce mood and emotion to help retrain the injured or depressive brain? We know that the capacity for memory improves when people are in a positive mood. We also know that rational reasoning in executive control requires integrating and evaluating both logic and emotion. In this context, one question is whether emotions evoked by music can contribute to executive control training in rehabilitation, and if so, how. The problem is that we still do not know the exact nature of these emotional responses and whether they relate to those that we experience in everyday life. If we find answers to questions like these, we might someday use music to retrain emotional and psychosocial competence—not in the traditional music therapy sense of improving well-being, but rather as a functional goal in cognitive ability.

Biomedical research in music has come a long way to open new and effective doors for music to help reeducate the injured brain. Of course, much still needs to be done: More professionals need specialized training, and other possibilities for rehabilitation require further research and clinical development. Scientists need to better understand what dosages work best, to pay more attention to research that will benefit children, and to focus on disorders in which neurologic music therapy lacks rigorous study so far, such as autism, spinal cord injury, cerebral palsy, and multiple sclerosis. In addition, the effects of brain injury can be complex, and researchers must take individual factors into account and adapt to individual needs. Neurologic music therapists share those aims with practitioners in other rehabilitation disciplines.

What no longer requires confirmation is the premise that music in therapy works, in principle and in practice. It is a fact: Music shows promise for helping to heal the brain. Research has identified specific areas in which music is an effective therapeutic approach. Neurologic music therapy now meets the standards of evidence-based medicine, is recognized by the World Federation of Neurorehabilitation, and should be a tool for standard rehabilitation care.[16] Insurance companies must become familiar with the research evidence and reimburse patients who have conditions for which the evidence supports its effectiveness.

Neurologic music therapy is a specialized practice, but it is based on elements and principles of music and brain function that can be integrated by all rehabilitation professions. In this way, it offers a strong foundation for interdisciplinary teamwork that will benefit patients.

Sidebar

A New Scientific Model: Neurologic Music Therapy

Biomedical research in music has led to the development of "clusters" of scientific evidence that show the effectiveness of specific music interventions. Researchers and clinicians in music therapy, neurology, and the brain sciences have classified these evidence clusters into a system of therapeutic techniques that now is known as neurologic music therapy (NMT).[17] This system has resulted in the unprecedented development of standard clinical techniques supported by scientific evidence. Because NMT is research-based, it will continue to develop, informed by new knowledge.

Five basic definitions articulate the most important principles of neurologic music therapy:

- It is defined as the therapeutic application of music to cognitive, sensory, and motor dysfunctions due to disease of the human nervous system.
- It is based on neuroscience models of music perception and the influence of music on changes in non-musical brain functions and behavior.
- Treatment techniques are based on data from scientific and clinical research and are directed toward non-musical therapeutic goals.
- Treatment techniques are standardized in terminology and application and are applied as therapeutic music interventions (TMIs), which are adaptable to a patient's needs.
- In addition to training in music and NMT, practitioners are educated in the areas of neuroanatomy and physiology, brain pathologies, medical terminology, and rehabilitation of cognitive, motor, speech, and language functions.

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