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Song & stroke

SONG & STROKE

USING MUSIC TO HELP PATIENTS RECOVER

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Five years ago, then eleven-year-old Laurel Fontaine suffered from an ischemic stroke that caused her devastating damage, leaving about 80 percent of the left side of her brain—her language-dominant hemisphere—completely destroyed. Following the stroke, doctors told Laurel and her family it was unlikely that she would recover motor function. She would also likely never walk, talk, or do any other typical motor activities of children her age.

Conventional speech therapy, a typical part of a patient's recovery process following stroke, showed only marginal benefits in Laurel's ability to talk. After a year, she still struggled with speech production, speaking only several words at a time.[1] However, she was soon left in the hands of researchers studying the effects of singing therapy on speech production in stroke patients. After only four months of treatment, Laurel could perform with nearly 100 percent accuracy on one test.[2] Talking to Laurel now, one would hardly recognize that just over five years ago she was completely unable to speak.

The puzzle of how music therapy may improve speech motor function in stroke patients is still being researched. Just how is it that something such as music could cause such noticeable behavioral improvements and what neurological changes are the bases of their recovery?

Understanding the linguistic and motor side effects of stroke

A stroke occurs as the result of rapid changes in blood supply to the brain. If lack of blood supply persists, it can cause irreversible damage, leaving the affected brain tissue dead. While the extent and type of damage incurred varies widely between patients, one common abnormality arising from stroke damage is aphasia. Aphasia is a disorder affecting the comprehension and production of language, making it hard for those affected by it to speak, write, or understand what others are saying. The disorder is caused by damage to areas in the language-dominant hemisphere of the brain that are commonly associated with language, especially in the left hemisphere. Structures in this region include Wernicke's area in the superior temporal gyrus and Broca's area in the inferior frontal gyrus.[3] Some studies estimate that aphasia can occur in as many as one quarter of patients following a stroke.[4] Even with extensive rehabilitative intervention from speech therapists, the prognosis for recovery is not always optimistic.

Like any other function we carry out, the use of language does not just rely upon a few localized areas, but rather entire networks of the brain that interact with and feed back to one another. Production of speech not only requires Broca's area, but also requires involvement of motor control areas. Some studies estimate that as many as 50 percent of stroke survivors experience impaired muscle function even 6 months after their stroke.[5] While this does not necessarily mean full paralysis of the body or of a single limb, it does mean that some stroke patients will suffer from motor impairments. These impairments may interfere with their ability to carry out simple tasks in their daily lives, including speaking.

An estimated 750,000 – 800,000 stroke cases occur in the U.S. every year.[6] Because there is no standardized or completely efficient way of treating stroke-induced impairments such as motor deficits and aphasia, it is important that we search for new and innovative means to help patients recover from such disorders.

Song as a Solution

Stroke patients who are unable to speak are still able to sing their words, suggesting the possibility of multiple networks for vocal production.[7] If there is more than one network that contributes to vocal production, then the possibility of rewiring undamaged networks for language use could allow non-fluent aphasic patients to speak once again.

Gottfried Schlaug and fellow researchers at the Music and Neuroimaging Laboratory at Beth Israel Deaconess Medical Center have directed their focus toward answering this question in recent years. Much of their time has been spent studying the effects of melodic intonation therapy (MIT) on stroke patients with aphasia. Developed as an alternative to traditional speech therapy, MIT requires that patients sing a phrase that they would typically speak while simultaneously producing rhythmic tapping with their left hand. Previous studies have shown that processing of musical components, such as melodic contour, tends to occur in regions in the right hemisphere. Contralateral connections would mean that tapping of the left hand creates more activation in the right hemisphere as well. The researchers believed that MIT could help patients by recruiting right-hemisphere structures analogous to the language structures in the left-hemisphere that had been damaged.[8] Evidence suggests that the therapy is successful. In one study conducted by Schlaug et. al., some patients saw an improvement of over 200% on measures of spontaneous speech.[9]

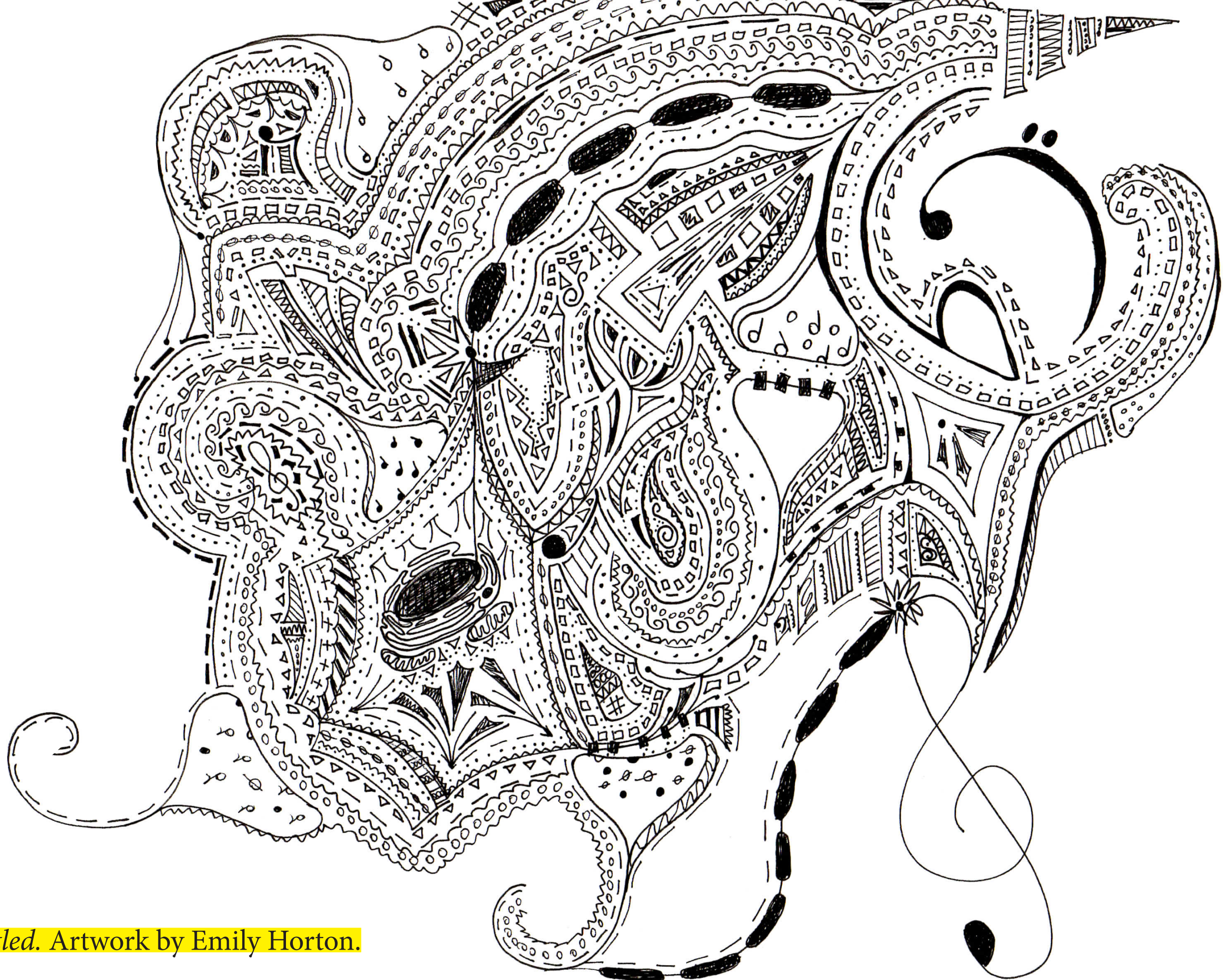
Similar music therapies now exist for treating only the motor side effects of stroke. Music-supported therapy (MST) was created in order to help chronic stroke patients regain movement of paralyzed upper limbs. Patients received daily treatment in which they were required to mimic tones, simple melodies, or scales produced by an instructor. They used either an electronic piano to improve fine motor skill or an electronic drum set that emits piano tones to improve gross motor skill. The therapy made use of massive repetition and immediate auditory feedback of movements, allowing patients to hear whether they were making the correct movement at the correct time.[10]

Studies testing the efficacy of MST have shown that partially paralyzed patients receiving MST made statistically significant improvements in fine and gross motor skill when compared to similar patients receiving standard rehabilitation for the impaired limb. Patients receiving MST showed higher scores in both frequency and speed of finger and hand tapping. They displayed both a wider variety of possible movements as well as an increased quality of movement.[11]

Neural Pathways to Recovery

Why might music therapies work? Language and music share many of the same pathways in the brain. This could, in theory, allow some pathways to become more adapted for language use if pathways normally used for language are damaged. Furthermore, because music performance requires the integration of visual, auditory, and sensorimotor information, it has been suggested that the simultaneous use of the functional brain networks with the impaired motor networks could produce rapid changes in motor regions.[12]

When Schlaug and his colleagues began studying Laurel Fontaine, they had the added bonus of being able to study her twin sister, Heather, as a control subject. Because Laurel and Heather share 100 percent of their genetic material, it would be more likely that any neurological changes Laurel experienced between the beginning and end of the treatment were due to the effects of MIT. Following treatment, researchers noticed increased activation in Laurel's right frontal areas as compared to her own pre-treatment functional magnetic res-



untitled. Artwork by Emily Horton.

onance imaging (fMRI) results and to her sister's fMRI results. Using diffusion tensor imaging, the researchers also found that Laurel's arcuate fasciculus (AF) grew to nearly three times its original size, while her sister's AF did not increase in size.[13]

In another study, one patient receiving MIT also experienced increased AF volume post-treatment.[14] In yet another, lesions to the left AF were shown to cause speech impairment.[15] In healthy individuals, the left AF has been shown to connect language areas to areas that are responsible for motor speech and linking certain sounds to movements.[16] Schlaug and colleagues hypothesized that Laurel's increase in right-hemisphere activation during language tasks, and her increased AF volume, might reflect the recruitment of right-hemisphere regions for language use and increased connectivity between sensory language and motor areas.[17] These changes could be responsible for Laurel's improvements in speech production following melodic intonation therapy.

Patients undergoing therapy for stroke-induced motor impairments seem to experience similar neurological changes. After undergoing MST, patients in one study showed increased auditory-motor circuit connectivity. This appeared most prominently between premotor areas and the inferior frontal gyrus (IFG), an area believed to be involved in processing structural elements of music.[18, 19] Interestingly, the left IFG also houses Broca's area, and also shows activation to semantic processing in language.

The audio-motor coupling hypothesis attempts to provide a theoretical framework for the efficacy of music therapy. This hypothesis claims that the constant feedback between auditory and motor regions during music performance allows for faster and more efficient correction of movements that are paired to specific sounds.[20] Since MIT and MST both pair specific movements to specific sounds, this theory could explain why patients have undergone such a strong degree of improvement. These therapies require constant practice, in some cases totaling up to several hundred hours of therapy over the course of a year. As Laurel Fontaine admits, recovery is "hard at first," but her speech gets "better all the time."[21]

Music has already proven itself instrumental in helping patients to recover from aphasia and motor impairments following stroke. And its benefits do not stop there; certain music therapy has also been theorized to help non-verbal autistic children produce spontaneous speech.[22] Considering the hope that music-based treatments have already given to many patients, it will be interesting to see where future research goes in terms of discovering the neurological benefits that music may have to offer.

Allison Macika *is a senior neuroscience major from New Orleans. She spent this past summer conducting research at Tulane University's Behavioral and Neurodevelopmental Genetics Lab. While she does not plan to continue neuroscience academically or professionally, she has loved every minute of her time spent with the neuroscience department here at BU.*

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