The Effects of Music Therapy on Neurological Disorders

Rishika Kulkarni[1]

[1]Francis Parker School, 6501 Linda Vista Rd, San Diego, CA 92111, USA

Abstract— **Society is quite familiar with the concept of therapy, as it has been utilized for several years now. However, as neuroscience continues to develop, a new form of therapy known as music therapy has emerged. While music therapy is generally new, neurologists believe that music can enhance or form neural networks in the motor cortex, auditory cortex, and sensory cortex. Elements found in music such as rhythm, tone, dynamics, and pitch were found to activate specific brain regions that are needed to perform certain functions that patients with neurological degenerative conditions lack. Both neurologists and music therapists have used evidence-based practice to come to the conclusion that to study the effects of music on the brain, randomized control trials should be performed. They have recently discovered that neural networks in specific brain regions tend to respond automatically to certain elements of music, rather than following verbal instructions. This is due to the innate ability of musical skills that humans carry, versus several cognitive tasks. This review paper will explore the effects of neurologic music therapy on key functions of the brain such as movement, cognition, and mood. It will dissect several parts of the brain and how music can positively enhance their several physiological functions. Additionally, the impact of music on each fundamental function will be supported by case studies performed on patients with various degenerative disorders ranging from Alzheimer's to Autism. By understanding the neuroscience behind the positive effects of music therapy, neurologists and music therapists alike will be able to help patients combat deadly degenerative disorders that have threatened society for years.**

I. INTRODUCTION

Michael Schneider experienced not one, but two traumatic brain injuries during his lifetime. In 2005, he injured his brain in a helicopter accident. Following that, he experienced decompression when training at a high-altitude, which resulted in a stroke. Michael had lost all feeling on the right side of his body. While he did recover, nine years later, he continuously experienced seizures. Additionally, he was diagnosed with PTSD and depression. At this point, Michael had lost all hope; he was certain that he would not make it through the next few years. However, he was then sent to a music therapist who encouraged him to play a few notes on the piano. This was just the beginning of Michael's journey through musical exploration. He started opening up about his struggles, and said that "It was able to open up all these new pathways through my brain."[5]

Music therapy is defined as utilizing different components of music as a clinical treatment method. However, it has not always been a popular concept. In the 1940s, Everett Thayer Gaston, now known as the father of music therapy, researched the benefits of music therapy on mental health. In 1968, he concluded that "music therapy follows the path of a behavioral science." Additionally, he claimed that a music therapist's main goal is to develop an interpersonal relationship with a patient in order to observe the patterns in behavior change.

Music therapy is found to affect three main sections of the brain: the cerebellum, frontal regions, and the hippocampus. The cerebellum is a small section of the brain that controls movement and several motor functions. Because it is connected to the limbic system, which controls emotions, the cerebellum perceives music with a strong production of rhythm and evokes emotional reactions. The neurodegenerative disease, Parkinson's Disease, is analyzed in this paper to understand the role of rhythm production on the cerebellum in patients who have Parkinson's.[2]

The frontal region or the frontal lobe is the largest lobe in the brain and is the most impacted during injury. It controls cognitive functions which are arguably the most important responsibility of the brain. Cognitive functions can range from memory recollection to performing daily tasks. Typically, during traumatic brain injuries, the frontal lobe is the first to be impacted and faces the most damage; this review paper will examine patients with traumatic brain injury and those who experience frequent strokes.

Lastly, the hippocampus is a component of the limbic system, indicating that it controls social functions and the processing of emotions. Because of this, listening to music has been shown to trigger positive emotions and reactions in the limbic system. Mood is a relatively newer topic in its correlation with music therapy due to the constantly changing nature of the limbic system and hippocampus. However, this review paper will discuss a case study performed on patients with Autism and the positive impact of musical components.

Through the several case studies that were performed, researchers have come to the conclusion that music therapy has a multitude of positive effects on the brain and neurodegenerative disorders, especially on movement, cognition, and mood. This review paper will explain the components of music therapy that impact the brain and will use case studies to support this claim.[6]

II. CEREBELLUM

A. Anatomy & Physiology of the Cerebellum

The first aspect of neurology that music therapy affects is movement. The cerebellum, frequently known as the "little brain" because of its small size compared to the cerebrum. It serves as the central processor for motor functions, hence, affecting movement. To ensure coordination and the accuracy of movements, the cerebellum receives information from the spinal cord and other sensory regions. Next, the sensory information is processed which then translates to controlling motor functions. Additionally, the auditory system is closely connected to the cerebellum, therefore, it helps control movement, particularly with automatic responses. However, if the cerebellum were to be damaged, then the loss of functions including balance and posture, would occur.[4]

B. *Effects of Music on the Cerebellum*

Neuroscientists have found that music can morph the brain, especially within the motor and auditory regions by either forming new pathways within the brain, or reinforcing preexisting pathways, all to heal the brain. Listening or even creating music activates motor regions, such as the cerebellum, and results in functional movement. Furthermore, music can be tailored to a particular individual, resulting in the activation of specific neural pathways. Particularly, the cerebellum controls timing of motor functions, specifically processing rhythm. This indicates that music can be altered based on the rhythmic nature to encourage movement in patients. These neural networks are then trained to control fine motor functions, and increase movement within patients who experience a loss of control over motor function.[8]

C. *Case Study on Patients with Parkinson's Disease*

To test this hypothesis, a case study was conducted on patients with Parkinson's disease. Neuroscientists wanted to test if a patient's control over motor functions would increase if rhythm and timing were altered in music.

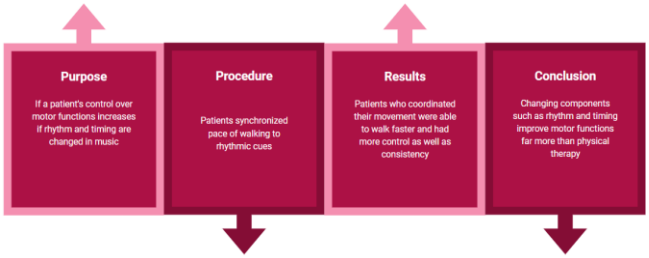

Figure 1- The experimental procedure of altering rhythm in music samples to determine its effect on patients with Parkinson's Disease.

Parkinson patients were asked to synchronize their speed of walking to rhythmic cues. As soon as patients coordinated their movement with rhythmic cues, they were able to not only walk faster, but exhibit more control over their bodies. Their neuromuscular activation, limb coordination, angle extensions were more consistent as well. Not only did altering rhythm increase coordination in Parkinson patients, but also maintained consistency in their movement. Furthermore, this improvement was far more drastic than anything that physical therapy could have done. This led to the conclusion that changing components such as rhythm and timing in music can improve motor functions in not only patients with Parkinson's disease, but also patients who struggle with control over movement.[9]

III. FRONTAL REGION

A. *Anatomy & Physiology of the Frontal Region*

The second aspect of neurology that is affected by music therapy is cognitive functions. The frontal region, as the name indicates, is located at the front of the brain. It serves to control higher-level functions such as attention, planning, memory formation, and more importantly, speech. A particular cortex, known as the prefrontal cortex, is located in the frontal region. The prefrontal cortex plays a major role in decision-making and any executive functions. To do this, it initiates appropriate behavioral responses in order to interact with the environment surrounding it by evaluating different sources of information. By doing this, the prefrontal cortex is able to control decisions when faced with challenging streams of information. Furthermore, it sends signals to other regions of the brain to assist the prefrontal cortex in making executive decisions. However, the prefrontal cortex also takes longer to develop, which also contributes to more impulsive decisions made at a younger age. Additionally, since it plays a vital role in memory creation, it's one of the first areas to be affected by degenerative diseases such as dementia and Alzheimer's.[4]

B. *Effects of Music on the Frontal Region*

More research has been done on the connections between music and the prefrontal cortex, and scientists have determined that patients who have dementia can recognize songs that hold some significance to them. This is because certain regions of the prefrontal cortex that monitor musical endeavors, shut down. However, regions that trigger initiation, increase their activity.

C. *Case Study on Memory*

To further their claim that music therapy strengthens cognitive functions, scientists tried to figure out if specific music exercises would impact cognitive functions such as speech through neuroplasticity. However, this connection was not as obvious as the effect of rhythm on motor functions. Scientists began with two key ideas to explore this concept further: the sharing of functions and the development of the auditory system. The first insight states that the brain's underlying music is used to share with other functions of the brain. This would mean that music stimulates speech and other cognitive function regions differently than other systems. There are two ways music can stimulate the brain: bilaterally or on the right hemisphere more than the left. For example, in injuries that occur solely on one hemisphere of the brain, music is able to form more flexible neural pathways to either strengthen or relearn functions. In a memory study that was conducted by scientists, word lists embedded in song activate the frontal region as well as the temporal lobe, in contrast to only word activities without music, which activates only the left hemisphere. This shows that music therapy involving elements of spoken-word can enhance several regions of the brain, compared to conventional therapy. Moreover, music can stimulate both neural networks on both hemispheres of

the brain which was shown to increase attention span which is often decreased in patients who have experienced traumatic brain injuries.[9]

The other idea was to utilize the auditory scaffolding hypothesis. This states that functions that include timing and processing are sent to the auditory system, which processes time-sensitive information. Cognitive functions require processing time-sensitive information and complex temporal organization. This is why scientists believe that listening to music can provide a scaffolding for either enhancing or relearning certain higher-level functions such as speech. Since music is considered a complex temporal auditory language, it can enhance cognitive learning by using the auditory scaffolding model. After using this reasoning and conducting a study, researchers found that therapeutic music exercises indeed do improve speech in patients who had a traumatic brain injury, strokes, and aphasia.[9]

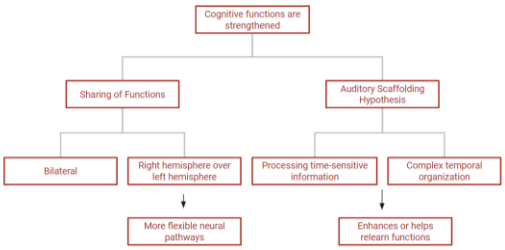

Figure 2- Sharing of functions and the Auditory Scaffolding Hypothesis are two foundational ideas that scientists explored in order to determine the correlation between music and cognitive functions.

IV. LIMBIC SYSTEM

A. *Anatomy & Physiology of the Limbic System*

The final, but developing aspect of neurology that is affected by music therapy is mood. The hippocampus and a structure known as the amygdala are a part of the limbic system which functions as a whole to process memories and manage emotional reactions. Specifically, music triggers emotional responses that are rapidly processed by various neural networks. If an emotion is correlated with a past memory, the neural networks that are activated will be different from a spontaneous response. The hippocampus serves a huge role in memory processing, specifically in sorting short-term memories from long-term memories. Since its main function is to process memories, any damage to the hippocampus will result in loss of memory, leading to degenerative memory disorders. Just as the limbic system associated emotions with past experiences, the hippocampus relies on life experiences to connect with music.[9]

Lastly, the amygdala controls response time to events, for example, the well-known fight-or-flight response. The amygdala sends a signal to the hypothalamus which then activates the sympathetic nervous system—a system of nerves that works in collaboration with the amygdala to carry out the fight-or-flight response. Since the amygdala is responsible for initiating spontaneous responses, it also connects memories with emotional encounters. If the amygdala were to experience any sort of damage, an individual would not be able to recognize emotion in music.[8]

B. *Effects of Music on the Limbic System*

When contrasting the emotion of music—sad or happy—the amygdala has an instantaneous reaction to the mood of music, perceiving it as either pleasant or depressing. This happens through the release of dopamine, a neurotransmitter that triggers feelings of joy. Because of this, an individual's serotonin levels will also increase, thus decreasing negative emotions. By focusing on the melody and mood of the music, the limbic system is activated, stimulating several neural networks in the brain.[3]

C. *Case Study on Patients with Autism*

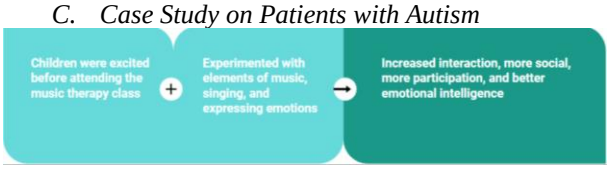

Figure 3- The experimental pathway that was tested to determine the effects of music on kids diagnosed with Autism.

While mood is a rather unexplored field compared to cognition and movement, scientists have conducted several studies in order to prove their hypothesis. One of them was an Occupational Therapist who conducted a study with a group of children attending a specialized school for several disabilities, one of them being Autism. They attended a music therapy class three times a week, and they were clearly excited even before attending the class. In class, they experimented with singing songs, expressing emotions, and playing with several elements of music. After observing the children for a while, the therapist concluded that the students who had Autism, who once struggled with interaction, were now more social with their peers and teachers. Additionally, this motivated them to participate more not only in school, but also at home. This led to therapists believing that music therapy improved social skills and emotional intelligence in children with Autism, especially by altering elements of music such as mood and melodies.[7]

V. CONCLUSION

In conclusion, music therapy has been proven to be effective through its positive impact on degenerative neurological disorders. It has been found to affect three main sections of the brain: the cerebellum, frontal region, and the hippocampus. All three of these regions are drastically affected by neurological disorders ranging from dementia to traumatic brain injuries. In order to heal these particular areas, specific components of music were altered such as rhythm, timing, and mood. In order to determine this, several case studies were conducted and analyzed, all of which examined different neurological conditions. The first study investigated patients with Parkinson's Disease and altered the rhythm production to form the conclusion that timing in a musical sentence would enhance neural networks, specifically in the cerebellum. Following that, a second study was conducted in order to determine the impact of specific music exercises on the frontal lobe. This led to the

development of a complex hypothesis and ultimately proved the connection between music and an increase in cognitive functions. Lastly, the third study focused on kids who were diagnosed with Autism. The purpose of this investigation was to explore the connection between mood, a relatively unexplored area, and the hippocampus. It was later determined that altering melodies in order to change the mood of the musical piece would improve social skills and increase emotional intelligence.

Because of the conclusions drawn from the case studies, scientists have laid the foundation for more creative forms of therapy that can potentially prove more effective than conventional therapy. By utilizing music as a therapeutic mechanism, patients are experiencing a drastic increase in neurological functions that they once lacked. Currently, music therapy has not become a widespread practice, however, by emphasizing its positive impacts of it, scientists have the ability to help more patients and even extend this practice to neurological disorders.

However, while this review paper proved that music therapy is an effective practice for patients diagnosed with degenerative disorders, there were certain factors that were not considered. One of these limitations is neuroplasticity, or the brain's ability to morph its structure in response to external stimuli. Music is considered an external stimulus, and it has even been proven that the brain alters its structure due to music therapy, the field is still developing. Scientists are unsure about the specific role neuroplasticity plays in cognitive functions as well as the involvement of words in music. Additionally, the frontiers of mood are endless and most of it has not been explored yet. Researchers are currently exploring the specific nature of emotional responses. Although they have been attempting to predict these responses, their data has been inconsistent because of its ever-changing nature. Furthermore, while the argument made in the paper regarding emotion heavily relies on music affecting an individual's life experience, scientists still do not exactly know the correlation between the limbic system and how it processes previous occurrences. Lastly, scientists are currently wondering if music therapy can heal an individual's brain, especially through the induction of mood. This area is quite unknown and inducing false emotions presents several constraints. Doing further research could eventually break the barrier surrounding conventional therapy, introducing more alternatives to our society.

Acknowledgments

I would like to thank Adrienne for helping me workshop my paper.

References

[1] Barrett, L. F. (2021, March 3). *That is not how your brain works*. Nautilus. Retrieved October 7, 2022, from https://nautil.us/that-is-not-how-your-brain-works-238138/

[2] Magee, W. L., & Stewart, L. (1AD, January 1). *The challenges and benefits of a genuine partnership between music therapy and Neuroscience: A dialog between scientist and therapist*. Frontiers. Retrieved October 7, 2022, from https://www.frontiersin.org/articles/10.3389/fnhum.2015.00223/full

[3] Trimble, M., & Hesdorffer, D. (2017, May 1). *Music and the brain: The neuroscience of music and musical appreciation*. BJPsych international. Retrieved October 7, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5618809/

[4] *Brain anatomy and how the brain works*. Johns Hopkins Medicine. (2021, July 14). Retrieved October 7, 2022, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

[5] Hamilton, J. (2022, February 19). *Art and music therapy seem to help with brain disorders. scientists want to know why*. News. Retrieved October 7, 2022, from https://www.wgbh.org/news/national-news/2022/02/19/art-and-music-therapy-seem-to-help-with-brain-disorders-scientists-want-to-know-why

[6] Steinhoff, N., Heine, A. M., Vogl, J., Weiss, K., Aschraf, A., Hajek, P., Schnider, P., & Tucek, G. (2015, August 21). *A pilot study into the effects of music therapy on different areas of the brain of individuals with unresponsive wakefulness syndrome*. Frontiers in neuroscience. Retrieved October 7, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4543917/

[7] *Music and understanding emotions in children with autism*. SOUNDSORY. (2021, April 13). Retrieved October 7, 2022, from https://soundsory.com/music-and-understanding-emotions-in-children-with-autism/

[8] Google. (n.d.). *Music therapy handbook*. Google Books. Retrieved October 7, 2022, from https://books.google.com/books?id=mfnhBQAAQBAJ&printsec=frontcover#v=onepage&q&f=false

[9] Sashitzky, I. (2020, May 6). *How music helps to heal the injured brain*. Dana Foundation. Retrieved October 7, 2022, from https://dana.org/article/how-music-helps-to-heal-the-injured-brain/#:~:text=Biomedical%20researchers%20have%20found%20that,and%20reeducate%20the%20injured%20brain.