How the Brain understands Music and how Music Therapy is used to treat various mental Illnesses: Autism Spectrum Disorders, Parkinson Disease, Anxiety

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Abstract:

Music Therapy is bipartite. First is music, which starts as the brain's perception of sound. Frequency, rhythm, pitch, and tone are all critical aspects of music. Once our brain interprets those key parts of the sound, sound transforms into the harmonious melodies we know as music. The second component of Music Therapy treats patients with various mental health issues. By combining both, Music Therapy helps address patients' physical, emotional, cognitive, and social needs. This article provides a framework to visualize how human minds understand sound and music, and the potential that music therapy has shown in treating Autism Spectrum Disorders *(ASD)*, Parkinson Disease *(PD)*, and Generalized Anxiety Disorder *(GAD).*

Auditory Pathway and Processing

This section provides a step-by-step guide on how the brain processes sound, including sound qualities such as rhythm, pitch, and tone. When vocal, instrumental, or mechanical sounds have rhythm, melody, or harmony, the result is music. (*Definition of MUSIC*, 2023) The human body receives sound input via vibrations that create sound waves in the air. The primary mechanism that senses these sound waves is the auditory pathway.

This pathway starts in the ear, which consists of the outer, middle, and inner ear. Sound waves enter the outer ear via the external acoustic meatus, a part of the ear that collects sound waves and funnels them into the ear canal (auditory meatus). The sound is amplified and progresses toward the tympanic membrane (eardrum). The eardrum provides a surface for sound collection, and vibrates with frequencies between approximately 20 and 20,000 Hz (Martini & Nath, n.d.). When the eardrum vibrates, three tiny bones in the ear, the malleus, incus, and stapes, vibrate in unison. These vibrating bones amplify the sound (Martini & Nath, n.d.) to make sound waves understandable to a human brain. The stapes transfers the vibrations to the oval window (a tissue connecting the middle to the inner ear), transferring the pressure waves to the fluid-filled cavity within the inner ear, which is referred to as the cochlea. The fluid-filled cochlea is encased in bone, so the liquid does not leak. Once pressure is applied at the oval window, the fluid has nowhere to bulge except the other exit, the round window. In other words, the round window bulges outward as the stapes moves inward. As the stapes vibrates at the frequency of the sound arriving at the eardrum, pressure waves travel throughout the cochlea. The pressure waves in the cochlea disturb the basilar membrane, which supports the auditory sensory epithelium, the Organ of Corti. The basilar membrane interacts with the previously mentioned oval window to control frequency. The Organ of Corti is the sensory part of the inner ear. High frequency sounds have a short wavelength, vibrating the basilar membrane near the oval window. Lower frequency sounds have longer wavelengths, vibrating the basilar membrane further from the oval window. The ultimate purpose of this membrane is that frequency is interpreted as information about position along the basilar membrane (Martini & Nath, n.d.). This interpretation of frequency translates to understanding different frequencies in music.

Louder sounds move the basilar membrane more. This is because the amount of movement at a given location depends on the magnitude of force applied by the vibrating stapes, which depends on the sound wave's energy. The vibration of the basilar membrane

causes vibration of hair cells in the cochlea. These hair cells rest in rows in a structure of the inner ear called the organ of Corti. A soft sound may stimulate only a few hair cells in a portion of one row. As the sound intensity increases, more hair cells become stimulated and active. In short, the number of hair cells responding in the organ of Corti provides information on the intensity of the sound. Vibration of the basilar membrane moves these hair cells against the tectorial membrane, which depolarizes the hair cells. (Martini & Nath, n.d.). Hair cell depolarization stimulates sensory neurons. The cell bodies of these sensory neurons are located at the center of the cochlea in the spiral ganglion. The spiral ganglion holds sensory neurons and relays information through sound signals from the inner ear to the brainstem. From that point, the data is carried by the cranial nerve VIII cochlear branch to the medulla oblongata cochlear nuclei for distribution to other brain centers. This is where sound starts to be processed as music.

Cranial nerve VIII is the vestibulocochlear nerve and consists of the vestibular and cochlear nerves, which are generally responsible for balance and hearing. This essay's focus is on the cochlear nerve responsible for hearing. More specifically, this nerve is responsible for transmitting auditory signals from the inner ear to the cochlear nuclei within the brainstem and ultimately to the primary auditory cortex within the temporal lobe (Bordoni et al.). To summarize the auditory pathway, auditory sensations are carried by the cranial nerve VIII cochlear branch to the medulla oblongata's cochlear nuclei. From there, the information is relayed to the inferior colliculus, a center that directs various unconscious motor responses to sounds. Ascending acoustic information goes to the medial geniculate nucleus before being forwarded to the auditory cortex of the temporal lobe. The auditory cortex of the temporal lobe is a significant player in pitch. High-frequency sounds activate one portion of the cortex, while low-frequency sounds activate another. The auditory cortex contains a map of the organ of Corti. Thus, information about frequency, translated into information about position on the basilar membrane, is projected in that form onto the auditory cortex, where it is interpreted to produce a person's subjective sensation of pitch (Martini & Nath, n.d.).

Regarding rhythm, a research report used fMRI to identify brain areas involved in auditory rhythm perception." The following regions responded to rhythm sequences: Dorsal premotor cortex (PMD), SMA (Supplementary motor area: Brain area located in the midline cortex, anterior to the primary motor cortex), preSMA, and lateral cerebellum (Bengtsson et al., 2009). While rhythm is a significant part of music, tone is also a major player. The auditory cortex in part recognizes and understands tone. This part of the brain, along with the cerebellum and prefrontal cortex, also works on analyzing a song's melody and harmony (*Your Brain on Music*, n.d.). There is so much involved in processing rhythm, pitch, tone, emotion, and memory. However, this is what makes music and the brain such a fascinating combination. With so many sectors of the brain that music is able to affect, music therapy has the potential to cure so many illnesses.

History of Music Therapy

Music therapy is an art-based health profession that uses music experiences within a therapeutic relationship to sculpt treatments in order to address MT patients' physical, emotional, cognitive, and social needs (Stegemann et al., 2019). Although music therapy is commonly known to be a recent development, the earliest known reference to music therapy appeared in 1789 in an unsigned article in *Columbian Magazine* titled "Music Physically Considered." During the 1800s, the first recorded systematic experiment in music therapy took

place: A neurologist in New York City, James Leonard Corning (1855-1923), used music to alter dream states during psychotherapy. He believed that during pre-sleep and sleep, cognitive processes became dormant, allowing the penetration of "musical vibrations" into the subconscious eliminating morbid thoughts that plagued his patients. (Davis, 2012)

In the 20th century, many more Music Therapy organizations were established. In 1903, Eva Augusta Vescelius founded the National Society of Musical Therapeutics. In 1926, Isa Maud Ilsen founded the National Association for Music in Hospitals. In 1941, Harriet Ayer Seymour created the National Foundation of Music Therapy. However, none of these foundations developed an official clinical profession for Music Therapy that we would see today in something like the clinical profession of Pediatrics. (American Music Therapy Association, 2023). In the 1940s, three innovators stood apart. They were the ones to push forward the development of music therapy as an organized clinical profession. Particularly, the "father of music therapy," E. Thayer Gaston, moved the profession forward from an organizational and educational standpoint. The first music therapy college training programs were also created in the 1940s. Michigan State University established the first academic program in music therapy (1944) (American Music Therapy Association, 2023).

More recently, the American Music Therapy Association (AMTA) was formed in 1998, merging the National Association for Music Therapy (NAMT) and the American Association for Music Therapy (AAMT). AMTA is the largest music therapy association in the United States, representing music therapists in the United States and in over 30 countries around the globe (American Music Therapy Association, 2023). Although regarded as a recent profession, music therapy has come a long way. Everything branched from James Leonard Corning's psychotherapy to the "father of music therapy," prominent E. Thayer Gaston, and finally to various music therapy college training programs and the respected clinical profession that is seen today.

Music Therapy Today

There are four main types of music therapy today. Receptive music therapy is a style in which the client listens to music and responds to the experience silently, verbally, or through another manner (eg. art, dance). Receptive interventions are more appropriate when a client is nonverbal or prefers a passive approach through listening. The goal of receptive music therapy is to improve relaxation, facilitate memory, and develop auditory skills, all whilst enhancing mood and reducing anxiety (Parkinson, 2020).

On the contrary, Re-creation is a music-centered approach where the client is encouraged to play or sing along to a pre-composed song to support identified goals. Re-creation can involve singing familiar or new songs or playing various instruments. Re-creation interventions suit children with developmental delays, clients with acquired brain injury, or seniors with Dementia. Goals pertaining to Re-creation music therapy include strengthening motor skills, social interaction, and promoting the use of one side of the body (Parkinson, 2020).

Improvisation is arguably the most adaptable, in which this style of music therapy involves spontaneous music-making using simple instruments, body percussion, or the voice. This method requires the therapist to hear, interpret, and respond to the client's playing or mood. Improvisation may be helpful with those who are nonverbal or feel uncomfortable expressing themselves directly. Improvisation music therapy aims to manifest an individual's expression and communication through music, all whilst limiting verbal communication to a

comfortable level. This style also focuses on increasing freedom of choice while building a relationship with another individual through music (Parkinson, 2020). Lastly, Composition / Songwriting is a creative process whereby the therapist supports the client in creating their own music or lyrics. These creations may be recorded or performed thereafter. Songwriting centers on externalizing emotions, and fostering different manners of expression and creativity. These four types of music therapy can achieve various goals, ranging from promoting relaxation to stimulating creativity (Parkinson, 2020). These goals are all general benefits of music therapy that can be achieved while staying non-invasive and lacking side effects. Moreover, music therapy is unique in its ability to address multiple symptoms at once, all while staying cost-effective (Bleibel et al., 2023). For example, receptive music therapy can improve stress and memory at the same time. The idea behind Music therapy is to use music and/or elements of music (like sound, rhythm, and harmony) to accomplish goals, like reducing anxiety or caring for other illnesses such as depression. A patient would first contact their healthcare provider. The healthcare provider would then talk to a music therapist, addressing the patient's needs, music preferences, and experiences. The therapist would then tailor each session specifically to the patient's preferences. They also evaluate the patient's progress throughout these sessions, all whilst working with other healthcare providers to coordinate the patient's care (*What Is Music Therapy, and How Can It Help Me?*, n.d.).

Illnesses Music Therapy Cares for:

Music Therapy is very efficient in its process, but what illnesses does it care for? I will discuss three diseases in this section: Autism Spectrum Disorders (ASDs), Parkinson's, and Anxiety. Autism Spectrum Disorders are a group of neurological disorders characterized by social communication impairments as well as the presence of stereotyped and repetitive behaviors and interests (Bhat & Srinivasan, 2013). Music-based therapies form about 12% of all autism interventions (Bhat & Srinivasan, 2013). Other treatments for autism include medication treatment and behavioral management therapy (*What Are the Treatments for Autism?*, 2021).

A study was conducted on the effects of signed and spoken words taught with music on sign and speech imitation by children with Autism. The study examined ten 4–9 year-old children with autism, split into two groups. In the study, two sections within Group 1 had music listening ("Goldilocks Returns") condition training in the 1st week and rhythm condition training in the 2nd week. Group 2 had vice versa. There were 5 trials daily, 4 days in two weeks times. The overall results showed that the children had correct imitations (signs, words) and favored music listening over rhythm condition training (Buday, 1995). In another study, the aim was to determine the effects of developmental speech and language training through music on verbal production. There were fifty 3–5-year-old children with ASD for the subjects of this study. The study included both music and speech training. The children watched music and speech videos for two times a day for three days via TV Monitor. The outcome showed a major improvement in speech production in children with ASD in both music and speech training. There were also greater improvements shown in low functioning children in the music than in the speech training. (Lim, 2010). Children with ASD also proved to have improved understanding of emotion through music therapy. In one study, the objective was to determine effects of background music and song tests on emotional understanding. The test included twelve 9–15 year old children with autism. Background Music was played, the children sang songs, and there were Eight 30 min sessions two times a week Pre and Post Tests. The children also improvised piano pieces based on four emotions; happiness, sadness, anger, fear. The outcomes of the study showed

that all children improved significantly in their understanding of these four previously stated emotions. The background music was the more effective part of the study to the children (Katagiri, 2009). These studies proved successful in using various music therapy approaches to improve sign and speech as well as comprehension of emotion in children with ASD's.

Music therapy has also shown to be effective in Parkinson's patients."Parkinson's disease (PD) is a neurological disorder involving the progressive degeneration of the dopaminergic system, which gives rise to movement-related dysfunctions (such as bradykinesia, tremor, and rigidity) (Raglio, 2015). Music acts as a specific stimulus to obtain motor and emotional responses by combining movement and stimulation of different sensory pathways (Pacchetti et al., 2000). In a 3 month study about active Music Therapy in Parkinson's Disease, thirty-two patients with PD, in two groups of 16 patients each, had weekly sessions of music therapy and physical therapy (PT). The severity of PD was assessed with the Unified Parkinson's Disease Rating Scale, emotional functions with the Happiness Measure, and quality of life using the Parkinson's Disease Quality of Life Questionnaire. Music Therapy sessions consisted of choral singing, voice exercise, rhythmic and free body movements, and active music involving collective invention. PT sessions included a series of passive stretching exercises, specific motor tasks, and strategies to improve balance and gait. Music Therapy had a significant overall effect on bradykinesia as measured by the Unified Parkinson's Disease Rating Scale ($p < .034$) (Pacchetti et al., 2000). Bradykinesia means slowness of movement and speed (or progressive hesitations/halts) as movements are continued. It is one of the cardinal symptoms of Parkinson's disease (*Bradykinesia (Slowness of Movement) | Parkinson's Foundation*, n.d.). Post–MT session findings were consistent with motor improvement. ($p < .0001$). Changes on the Happiness Measure confirmed a beneficial effect of MT on emotional functions ($p < .0001$). Improvements in activities of daily living and in quality of life were also documented in the MT group ($p < .0001$). Lastly, PT improved rigidity ($p < .0001$) (Pacchetti et al., 2000). These studies, showing improvements on symptoms like bradykinesia, prove one step at a time that music therapy is a reliable source of treatment for large-scale illnesses in the present world, such as Parkinson's disease.

Anxiety is a feeling of worry, nervousness, or unease, typically about an imminent event or something with an uncertain outcome. In a review of Music Therapy and Other Music-Based Interventions in Pediatric Health Care, the effect of music listening in reducing anxiety was measured in 11 studies. Effect sizes for anxiety reduction ranged between $d = 0.61$ (moderate effect) and $d = 1.5$ (notable effect) (Stegemann et al., 2019). The findings of another study show the effect of music therapy on the anxiety and depression of patients with cancer. Starting levels of depression and anxiety were assessed using the HADS questionnaire 24-hour intervention. Then, patients listened to music for at least 20 min per day for 3 consecutive days, completing the hospital anxiety and depression scale (HADS) questionnaire at the end of each day. The type of music was based on five experts' opinions. The tape was recorded in the form of relaxing light music like the sea, rain, and water sound. The results demonstrated a significant reduction in the mean scores of anxiety and depression in the intervention group. The Control group's mean scores of anxiety and depression went from 14.72 ± 2.06 to 14.34 ± 2.48 by their 3rd day of music therapy. However, the Music Therapy Group (Intervention group)'s mean scores of anxiety and depression plummeted from 14.46 ± 2.13 to 8.63 ± 2.57 by their 3rd day of music therapy (Jasemi et al., 2016). This change in scores corresponds to a reduction in the patients' anxiety and depression. These studies' scores especially highlight music therapy's impact on caring for wide-scale illnesses today.

Conclusion:

Music is sound in its most basic form. It may start as vibrations in the air, but through auditory processing in the inner ear, and the auditory pathway to the brain, music can turn from sound into a source of enjoyment or healing. This simple premise is the basis of Music Therapy. Through the studies shown thus far, MT has proved to help patients with ASD's, PD, and Anxiety. As music therapy is non-invasive and effective, there are still aspects of these illnesses it cannot address on its own. Thus, it should be used most effectively to supplement more intensive treatments. Moreover, MT is used to treat many other illnesses, such as Alzheimer's or Depression, while being used in an experimental state to treat memory loss. This points out that Music Therapy is an effective and rapidly growing healthcare sector today. Further research into memory and emotion will enhance the settings and illnesses to which music therapy can bring its benefits.

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