The Neuroscience and Healing Powers of Music

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ABSTRACT

Neurological Music therapy refers to the use of the components of music such as rhythm and tone in a medical setting for patients suffering problems in their brain after a trauma or other source. Neurologic Music Therapy (NMT) is a neuroscientifically motivated model of music practice and consists of 20 research-based music therapy techniques (Heyse et al., 2022). For the sake of this review, only 3 will be covered and 1 primary example of what each helps with. Overall, the findings have all demonstrated to have positive impacts on patients which proves the significance of the use of music in medical settings.

Introduction

Music has long been considered a universal language, present in every culture and time period—even predating formal spoken language. Beyond its cultural and emotional impact, music has recently gained attention in the medical and scientific communities for its measurable effects on the brain. NMT therapy leverages music's ability to stimulate various brain regions involved in movement, speech, memory, and emotion. Studies have shown that music can trigger the release of neurotransmitters like dopamine and serotonin, enhance cognitive function, and even promote neural plasticity following brain injury. In this review, I explore how NMT supports patients with conditions such as aphasia, Parkinson's disease, and unilateral spatial neglect through techniques like Melodic Intonation Therapy, Rhythmic Auditory Stimulation, and Musical Neglect Training. By examining current research and clinical applications, this paper highlights the powerful and healing potential of music in neurological rehabilitation.

Neurophysiology

The journey of enjoying music begins with hearing or auditory processing. In short, hearing refers to the awareness of sounds followed by placing meaning to those sounds. It involves a complex series of steps in which several parts of your ear and auditory nervous system work together harmoniously to grant you the innate ability of hearing, unlocking our perception as well as appreciation of the world around us (Cleveland Clinic, 2020)

Like any sound, waves from music are first channeled down into the ear canal and cause the eardrum to vibrate along with the ossicles which consist of three tiny bones: the malleus, incus, and stapes in the mammalian middle ear. These then transmit and amplify the vibrations which were converted from sound waves into the cochlea, the fluid-filled hearing organ. The cochlea contains the nerve endings and hair cells that bend to generate electrical signals that are sent to the brain via the auditory nerve (Stanford Children's Health, 2019).

From there the brainstem handles the basic processing of sound but the most intricate and sophisticated sound processing occurs in the auditory cortex, a region of the brain located in the temporal lobe of the brain on the side of the head. The auditory cortex is responsible for extracting meaning from sounds, recognizing complex auditory patterns, and allowing us to perceive speech, music, and various other auditory stimuli (Fulman, 2023). Similarly, the limbic system (an intricate assembly of neural circuits and pathways located deep within the brain underneath the cerebral cortex) involved in our behavioural and emotional responses (The University of Queensland, 2019), are responsible for the reactions we have when listening to music. Key components of this system, such as the amygdala—responsible for emotional processing—and the hippocampus—integral to memory consolidation—become activated during musical exposure (Toader et al., 2023).

Neurotransmitters, chemical messengers stored in and released from the presynaptic neuron (Neurotransmitter Release - an Overview | ScienceDirect Topics, n.d.), play a significant role in the emotions felt during the music listening experience—most notably dopamine and serotonin. Dopamine, often called the "feel-good" neurotransmitter, is released when you listen to music you enjoy, contributing to feelings of pleasure and happiness. Serotonin, which regulates mood, sleep, and anxiety, can also be influenced by music, particularly calming music (Intermountain Health, 2019).

Music Therapy

Music Therapy is a form of therapy used to help people of all ages with improving quality of life through the usage of music and/or elements of music (like sound, rhythm and harmony) (Cleveland Clinic, 2023). There are multiple approaches for patients to undergo music therapy. The main approaches are receptive, re-creational, compositional, and improvisational. First, the receptive approach involves listening to music and reflecting on its impact. Re-creational focuses on active participation through singing or playing familiar songs. Compositional involves creating original music, such as songwriting or composing pieces. Finally, the improvisational approach encourages spontaneous musical expression through improvisation (logue, 2024).

Engaging in musical activities not only shapes the organization of the developing brain but also produces long-lasting changes even after brain maturation is complete. The fact that the adult brain can undergo continual modifications highlights the potential of rehabilitation treatments that are designed to induce plastic changes to overcome impairments due to brain injury. For this purpose, music may be a suitable medium because it transmits visual, auditory, and motor information to a specialized brain network (Europe PMC, 2016).

Dementia

According to the American Psychiatric Association’s Diagnostic and Statistical Manual, Fifth Edition (DSM-5), dementia is a major neurocognitive disorder that is diagnosed when one or more cognitive domains, such as complex attention, executive ability, learning and memory, language, praxis, and social cognition, are impaired. Several studies have proposed therapy with music as a possible strategy to slow down the cognitive decline and behavioral changes associated with aging in combination with pharmacological therapy.

A systematic review and meta-analysis done by Moreno-Morales et, al to check whether the application of music therapy in people living with dementia has an effect on cognitive function, quality of life, and/or depressive state found that, after 8 studies with 816 subjects, the intervention with music improves cognitive function in people living with dementia. The perception of sounds, rhythms, and lyrics as well as the response to the sound requires attention to an environment, requiring the brain to have many areas activated (Moreno-Morales et al., 2020).

Neurologic Music Therapy

Melodic Intonation Therapy (MIT)

Melodic intonation therapy (MIT) is an intonation-based treatment method for nonfluent or dysfluent aphasic patients that was developed in response to the observation that severely aphasic patients can often produce well-articulated, linguistically accurate words while singing, but not during speech (Zhang et al., 2022).

Steps for Practice

1. Therapist takes the patient's left hand and taps to a beat during the entirety of the practice
2. Therapist hums a phrase with different pitches
3. Therapist sings phrase
4. Therapist and patient sing together
5. Therapist fades out
6. Immediate repetition
7. Response to question where the patient replies with the learned phrase

(Melodic Intonation Therapy, n.d.)

Aphasia

Aphasia, which is a language disorder commonly caused by a stroke or other brain injury which impacts a person's ability to communicate, is essentially bypassed when the patient sings(Tactus Therapy, 2020)— being able to sing but not speak. The approach takes advantage of the undamaged right hemisphere by engaging areas that are capable of language and rerouting speech pathways from the damaged left side of the brain. The key for accomplishing this is rhythm such as intonation and left hand-tapping because it activates the right hemispheric language area. It is thought that the melodic & rhythmic prosody, slower rate of articulation, and continuous voicing that result from MIT may reduce the dependence on the left hemisphere, thus aiding in the production of speech.

Additionally, MIT has positive effects on neural plasticity of cerebral networks in patients with non-fluent aphasia after a stroke (Zhang et al., 2023). Fractional Anisotropy (FA), an index of the degree of anisotropy of water molecules in white matter used as a quantitative biomarker of white matter integrity, is used to visualize the amount of FA before and after MIT treatment for patients with aphasia. The degree of anisotropy can be measured, and allows to infer alterations in the axonal diameter, fiber density or myelin structure (Vandermosten et al., 2012)— after music-based MIT intervention after one month, the experimental group of patients with non-fluent aphasia after stroke showed higher neural plasticity of cerebral networks than those that were not subject to the treatment.

Musical Neglect Training (MNT)

Mainly, MNT capitalizes on the brain's intrinsic ability to anticipate and complete musical patterns (Kasuya-Ueba & Maeda, 2025). The active musical exercises are structured in pitch, time and tempo, and using musical equipment (tone bars, keyboards, drums, etc.) whose physical setup is configured to focus active attention to the neglect field of the brain after a stroke. Participants are asked to complete musical (melodic or rhythmic) patterns on musical instruments that are increasingly extended into the visual neglect field (Kang & Thaut, 2019). The melodic and rhythmic pattern initially begins from the right unaffected side of the patient then goes to the left. Their attention is driven to the left in order to complete the melody by playing on the instrument (handbells for example). Then, the direction of the melody can be reversed so that the patient begins on the left side (Music Therapy Tales, 2016).

Unilateral spatial neglect (USN)

Unilateral spatial neglect (USN) is a neuropsychological syndrome characterized by an attention deficit in the contralesional side of space (Posner et al., 1984). USN cannot be linked to a sensory or a motor deficit. USN patients fail to orient themselves toward contralesional targets. Many spatial deficits can appear with USN patients colliding with left side objects while walking, dressing only one side of their body or failing to eat the food on the neglected side of their plate (Guilbert et al., 2014). Although USN isn’t consistently classified into types in existing literature, there are two main categories:

1. Sensory neglect: causes disordered awareness of sensory inputs originating from their contralesional side of space.
2. Personal and spatial neglect: Personal neglect is specifically the lack of exploration of half of the body contralateral to the damaged hemisphere (Beschin & Robertson, 1997). An example of this would be only shaving half of their face or only putting on one shoe. It is characterised by an unawareness of the body part itself, whereas sensory neglect refers to an unawareness of external stimuli, e.g., vision or touch. Spatial neglect is defined as neglect where the abnormal behaviour is not located in personal space; this thus refers to failure to acknowledge stimuli on the contralesional side of space.

One way to test for USN is Albert’s test. Patients must cross out lines that are placed in random orientations on a piece of paper. USN is indicated when lines are left uncrossed on the same side of the page as the patient's motor deficit or brain lesion is located (Perception/Unilateral Spatial Neglect – Strokengine, n.d.).

Case Study

In a case study done by Kyurim Kang and Michael H Thaut with two patients, they both improved their test results after MNT training over the course of 6 sessions. The most significantly improved participant, a 69 years old male who had sustained stroke 10 years before entering. His ischemic stroke resulted in left hemiparesis and sensory impairment in the left side.

The two cases of chronic persistent hemispatial neglect presented here provide statistically significant evidence for MNT driving within session effects for the Albert Line Crossing test (Kang & Thaut, 2019).

Rhythmic Auditory Stimulation (RAS)

Rhythmic Auditory Stimulation is designed to facilitate rehabilitation of movements that are intrinsically rhythmical. It is based on entrainment models in which the auditory cues synchronize motor responses into stable time relationships (Koshimori & Thaut, 2023). Its design is specific for treating gait, a person's manner of walking, which consists of a rhythm.

This is done by having auditory cues synchronize motor responses into stable time relationships. RAS is applied in the form of regular isochronous auditory pulses such as metronome clicks, or metrical acoustical beats embedded in instrumental music (usually in 2/4 or 4/4 m). It is first matched to an individual's preferred cadence and gradually increased or decreased by 5-10% to optimize their gait parameters such as cadence, velocity, and stride length.

Parkinson’s Disease (PD)

As a gait disorder, Parkinson’s Disease is one of the most prominent applications for RAS. A walking pattern before RAS training consists of a short stride, high cadence, and asymmetry of the steps, which are not synchronized with the music beats. After the training, synchronization of the biological rhythm of gait to the rhythmic beats causes longer stride length, lower cadence, and more symmetrical steps. Music provides a strong, extrinsic rhythmic cue that may be used as a replacement for the lack of “internal clock” in PD patients which facilitate movement (Nombela et al., 2013).

Conclusion

Traditional medicine sometimes just isn’t enough for certain disorders and diseases. Music is often overlooked as just entertainment but it is actually an extremely powerful form of therapy for those who aren’t getting the help they deserve traditionally. Neurological music therapy improves quality of life for the ill, giving them a new chance at living normally. For now, clinical applications of music are mainly unheard of and misunderstood but hopefully this study brought some light to the amazing healing powers music holds.

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