

A Comprehensive Review of the Mechanisms of NMT for Reversing Neurodegenerative Disorders

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ABSTRACT

This paper reviews the literature concerning the mechanisms of music therapy that improve the quality of life for patients with neurodegenerative diseases. Music therapy is a remedial practice involving music to help improve health. Certain professional therapists practice Neurologic Music Therapy (NMT) as an allied health profession that provides evidence-based care to hospitalized patients, not just as a source of comfort, but also as a source of healing. This is especially the case for patients with neurodegenerative disorders such as Alzheimer's disease, Parkinson's disease, and expressive aphasia. The current growing body of researchers is investigating the effects of music therapy on memory, speech, motor control, and behavior. However, various questions remain unanswered. In this review paper, we gathered primary literature to evaluate the use of music therapy and the mechanisms that lead to successful outcomes. Music therapy is important because it provides a way to enhance comfort for diseased patients, whether in a hospitalized state or an average daily scenario. In patients with neurodegenerative diseases, music increases plasticity in areas of the brain that may improve speech, memory, behavior, and more. As we better understand the mechanisms and optimize music therapy, it may provide more ease to patients and even treat and cure certain disorders in the future.

Introduction

Music is a therapeutic intervention used to improve mental health and motor control, reduce stress, enhance the immune system, and stimulate the brain (Rebecchini, 2021; Clements-Cortes & Bartel, 2018). Music therapists use several forms of musical exposure, including listening to music, singing, discussing lyrics, composing music, or playing an instrument. Neuroscientists find music therapy interesting because of its unique involvement and mechanisms that can especially benefit mental health. While every model of music therapy provides relief to a patient's physical and mental health, there is a specific model of music therapy in neuroscience called Neurologic Music Therapy (NMT). NMT is a research-based treatment system in which professional therapists consistently provide rehabilitative exercises to heal mental dysfunctions caused by neurodegenerative ailments and increase neuroplasticity in the brain (Stacks & Harris). The four levels of NMT are Learned cognitive response/Isomorphic and primal response, cognitive activation of neural circuits, stimulated neural coherence, and cellular-genetic response (Fig. 1). Benefits derived from levels 2-3 include the use of compensatory circuits to improve neuroplasticity. (Clements-Cortes & Bartel, 2018).

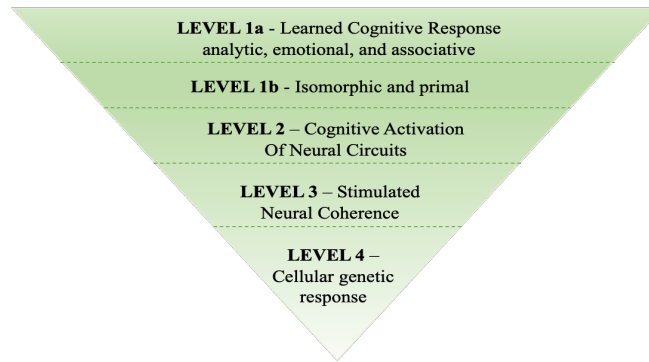


Figure 1. Diagram outlining the levels of Neurologic Music Therapy (NMT). *Adapted from Clements-Cortes & Bartel, 2018*

The awareness of music therapy is flourishing, and there has been a documented rise in research publications about music therapy across the Internet over the past couple of decades (Li et al., 2021). Current research provides increasing evidence that the benefits of music therapy are even more promising than previously believed, and many are studying the permanence of the effects of music therapy. Certain mechanisms of NMT could generate lasting changes in regions of the brain and even provide therapeutic options for patients with various neurological diseases and disorders. More awareness is needed to inform the public about the research and advancements in NMT, as well as the therapeutic potential of NMT for various neurodegenerative disorders. Neurodegenerative diseases that result in neurodegeneration or the deterioration of the nervous system are simultaneously growing in prevalence across the world (Gitler et al., 2017). Thus, it is increasingly necessary to understand the mechanisms that contribute to the widespread benefits of music therapy on neurological disorders such as Alzheimer’s disease (AD), expressive aphasia, and Parkinson’s disease (PD).

This review paper is compiled from primary sources and studies testing and observing the effects and mechanisms of NMT on patients affected by a variety of neurodegenerative disorders and neurodevelopmental conditions. First, this paper will review how NMT contributes to positive patient outcomes in behavior affected by AD. Next, this dissertation will investigate the mechanisms of NMT on memory in AD patients. Then, the paper will analyze the benefits of NMT for motor control deficits in PD patients. Finally, it will discuss the improvement of speech through NMT in expressive aphasia patients. In its entirety, this review is mainly focused on NMT and its influence on behavior and cognition.

Results and Discussion

Behavior

AD is a neurodegenerative disorder that progressively results in dementia, cognitive decline, and death. The progressive nature of AD occurs through memory impairment and behavioral changes such as anxiety and depression (Gómez Gallego & Gómez García, 2017). Current therapy for behavioral deficits in AD and autistic patients relies on pharmacologic interventions. However, the medicine has been considered unreliable for controlling neuropsychiatric symptoms and has been known to worsen motor control and increase the risk of early death. NMT is known to be advantageous in improving behavioral deficits in AD and autistic patients through singing and solely listening to music. Current research efforts continue to pursue non-pharmacological interventions, including NMT to further improve amelioration of neuropsychiatric symptoms of AD and dementia (Gómez Gallego & Gómez Garcia, 2017).

Singing is one aspect of NMT, and research verifies it as a musically therapeutic intervention for many neurodegenerative diseases, let alone AD (Clements-Cortes & Bartel, 2018). The fundamental use of singing is proven to decrease cortisol and immunoglobulin A levels (Clements-Cortes & Bartel, 2018). This results in a decrease in stress, lower blood glucose levels, and decreased pain perception, while also increasing levels of relaxation and boosting the immune system (Clements-Cortes & Bartel, 2018; Kreutz et al., 2003). These results show that singing, like other interventions such as listening to music and motor facilitation through rhythm, plays a large factor in NMT (Clements-Cortes & Bartel, 2018).

Another intervention of music therapy involves fundamental listening to music. In a research effort held at the University of Murcia (Gómez Gallego & Gómez García, 2017), the results depicted an overall decrease in anxiety and depression among the population of patients. Irritability, delusions, disinhibitions, and other behavioral symptoms of dementia improved significantly, especially in the group with moderate dementia. The results suggested that music therapy increases stress tolerance and thus decreases symptoms of agitation and irritation in AD. This is because music is a pleasant stimulant for the brain as it decreases the activation of stress in the parasympathetic nervous system and the adrenomedullary system. It also brings forth dopamine, relieving stress and leading to more positive emotions. The data also suggests that the small sample size of the patients during the therapy sessions promoted sociability and participation levels, which helped to improve their moods as they bonded together through music. In addition, the reduction of agitation and irritation caused by music therapy resulted in a decrease in prescribed drug use for many of the patients (Gómez Gallego & Gómez García, 2017). Thus, through mechanisms of singing and listening to music, music therapy can support positive outcomes in AD patient behavior and physiology.

Memory

Memory impairments are a major characteristic of certain neurodegenerative diseases like AD. AD patients experience progressive memory and cognitive decline and have dementia (Gómez Gallego & Gómez García, 2017). However, NMT can improve memory in patients influenced by AD with the usage of familiar music and its relationship with emotion.

Research shows that NMT improves the encoding in brain regions of patients involved in memory. Familiarity with certain types of music is used as an intervention of NMT to improve memory in patients with Alzheimer's. In the same research initiative held at the University of Murcia, researchers observed patients felt gushes of previous emotions, memories, and phrases connected to well-known music and benefited more from the familiarity of the tunes rather than through unfamiliar pieces, and experienced better orientation, cognition, and language. The researchers hypothesized that this could result from how the mechanisms of music change auditory networks in the brain to increase neuroplasticity, or perhaps from how music activates the brain to increase attention. Music therapy also engages regions of the brain's right hemisphere that are involved in speech and language processing, improving linguistic awareness. The permanence of these effects on memory, however, still requires investigation, but evidence of progressive improvements during sessions of music therapy may point to long-lasting effects. (Gómez Gallego & Gómez García, 2017).

The connection between music and the evocation of emotions is shown to provide universal emotional and social benefits for a variety of people suffering from different diseases, especially older adults. For instance, researcher Amy Clements-Cortes verified the aid of chamber music concerts attended by a handful of elders with a variety of mental ailments, where the elderly sang and listened to familiar classical music. Reports pointed to improving mood and energy and decreasing pain due to these gushes of memories and familiar activations of regions of the brain and auditory networks (Clements-Cortes & Bartel, 2018). Through familiar music and its connection to emotion, NMT can assist memory in AD.

Motor Control

Music therapy is known to have beneficial effects on motor control in Parkinson's disease (PD) (Clements-Cortes & Bartel, 2018). Parkinson's disease is a chronic neurodegenerative disorder that is especially notorious for its effects on motor control, along with speech and behavior (García-Cesares et al., 2018). It is the result of the degradation of a system of neurons called the dopaminergic pathways, which is a set of neural pathways where dopamine is released as a neurotransmitter to control movement, cognition, and the reward system (García-Cesares et al., 2018). In healthy humans, the supplementary motor cortex, cerebellum, and basal nuclei are connected by the dopaminergic system and receive an internal prompt to commence and handle the motor activity (Clements-Cortes & Bartel, 2018). However, this prompt is absent in people with PD because of the damaged circuits lacking dopamine. Testing shows that music boosts motor skills in patients because of emotional reactions, which is utilized in a special form of music therapy known as sensorimotor training to assist people with symptoms of PD (Clements-Cortes & Bartel, 2018). Also, as previously described, sensorimotor training can be synthesized with already existing forms of music therapy for other ailments, such as hand tapping used to activate the sensorimotor networks of the brain during modified intonation therapy for aphasia (Clements-Cortes & Bartel, 2018).

One instance of sensorimotor training to elicit an emotional response is the use of rhythm as an intervention. Researchers at Oxford University tested rhythmic auditory stimulation (RAS) as a form of sensorimotor training that utilized rhythm to improve gait, which was successful. As discussed earlier, patients with PD lack an internal prompt to initiate motor activity because of the degraded dopaminergic pathways. However, with the help of rhythmic auditory stimulation, an external prompt through rhythm has been shown to provide dopamine. This activates the disrupted dopaminergic circuits and replaces the absent internal prompts (Clements-Cortes & Bartel, 2018).

Although RAS is the most popular type of intervention in sensorimotor training for PD, other beneficial operations such as Pattern Sensory Enhancement (PSE) and Therapeutic Instrumental Music Performance (TIMP) have similar mechanisms. PSE uses complex music elements that simulate movements of daily life and doesn't necessarily involve rhythms such as pitch and dynamics to enhance temporal and spatial movement patterns and stabilize balance, motor coordination, postural control, and more. Meanwhile, TIMP utilizes musical instruments, especially percussive instruments, to produce the same effect on motor control and benefit dexterity, postural control, etc. A study at the University of Physical Education in Krakow, Poland tested the combined effects of PSE and TIMP on the motor system compared to RAS with the hypothesis that the synthesis of all three sensorimotor techniques would improve both gait and postural stability in their PD patients. Moreover, the results showed that these interventions successfully benefitted motor coordination, gait, and proprioception. This is because even though the chosen music did not completely suit the subjects' tastes, the ability of the human brain to entrain with the rhythm of movement allowed the subjects to react to the beat. The ideal rhythmic stimulation varies from 60 to 150 beats per minute, depending on the patient's preferred velocity. Also, NMT was shown to improve the rhythmical motions of patients mostly by transferring the center of mass forward or backward (walking, daily activities). The second portion of this study, which examined how research protocol affected stability, cannot be positively confirmed. Many commonplace actions, including walking, coordinate the transfer of body weight in the sagittal plane as well. Proprioception and body perception can be improved if stability is improved without a significant visual component. Although it was discovered in this study that physical therapy is also needed in addition to auditory stimulation for stability and balance training, researchers still emphasized the important role that rhythm and music play in improving patients' mobility, gait, stability, balance, and overall quality of life. Further research is necessary to ascertain whether long-term NMT effects on motor control might be provided by a more longitudinal design, as current evidence only indicates short-term impacts. (Bukowska et al., 2016). Consequently, the operations of RAS, PDE, and TIMP can be used as a treatment for motor control affected by PD.

Speech

Speech impairments are hallmarks of conditions like expressive aphasia. Aphasia, on the other hand, is mainly characterized by the inability to speak and comprehend linguistics because of neurotrauma (Conklyn et al., 2018). A specific form of aphasia is known as expressive aphasia, non-fluent aphasia, or Broca's aphasia, can be caused by brain damage resulting from AD, dementia, stroke, etc., and affects Broca's area in the frontal lobe of the brain. Separate neural networks in Broca's area handle propositional (complex and cognitive speech) and non-propositional language (formulaic and memorized speech), where the neural networks controlling propositional language are affected due to expressive aphasia, leaving the non-propositional networks intact (Clements-Cortes & Bartel, 2018). Speech in expressive aphasia can be improved through music therapy in the forms of MUSTIM (musical speech stimulation training), MIT (melodic intonation therapy), familiar music, and NMT.

Certain interventions of music therapy involving speech/language training have been indicated to guide the advancement of speech debilitated by conditions, such as aphasia and AD. One tested example of speech/language training is Musical Speech Stimulation (MUSTIM), in which therapists utilize different levels (depending on the severity of the patient's ailment) of reading and comprehension activities to elicit specific non-propositional language from the patient. As an example of this method, at the easiest level, therapists sing the lyric of a song and leave the last word out for the patient to respond through either singing or speaking; or at more progressive levels of MUSTIM, therapists could ask the client a question, leaving the patient to complete either already learned sentences or comprehend and create new ones. Regardless of the level, though, MUSTIM is successful because it targets and tests the previously mentioned intact non-propositional neural pathways of Broca's area consistently. As a result, during MUSTIM, the expressive aphasic patient learns to practice certain simple, non-propositional phrases and terms of speech through these procedures until those phrases and terms are retained and can be spoken effortlessly (Clements-Cortes & Bartel, 2018).

Another example of intervention of neurological music therapy for speech/language training is for expressive aphasia which frequently results from stroke. The form of neurological music therapy is known as melodic intonation therapy (MIT), which, like MUSTIM, involves regular sessions where the therapist assists the patient in intoning words and phrases rhythmically and melodically to elicit speech and activity in the right hemisphere of the brain. Studies on MIT have shown its effectiveness in improving neuroplasticity, especially in little sample sizes of therapy clients. It works because even though the neural networks that allow normal speech to access Broca's area are destroyed, sung language, being a form of music rather than actual language, uses a different set of neural networks to reach Broca's area. The slow and constant intonation of phrases is especially beneficial in building neural connections with words since it is believed that the right hemisphere of the brain handles slower signals while the left hemisphere of the brain handles faster signals; as a result, the left hemisphere is also potentially less involved in the therapy. Moreover, this intervention could also be used to treat motor control and activate the sensorimotor network if the patient chooses to move along with the rhythm or melody of the therapy through hand tapping, for example (Clements-Cortes & Bartel, 2018).

NMT has been shown to also be more effective in aphasic patients compared to other forms of therapy. Speech-language therapy (SLT), like neurologic music therapy, can also be used to treat post-stroke aphasic patients. However, unlike NMT, speech-language training uses pictures and spoken language rather than music therapy to stimulate speech comprehension and expression. One study by doctors at Inje University and Kwandong University in South Korea compared the effectiveness of the two forms of therapy for aphasia. They found that while both were equally effective in treating chronic stroke, NMT was better in treating post-stroke aphasia than speech-language therapy, especially in patients with subacute non-fluent aphasia because there are more opportunities to discern phonemes that are made up of words and phrases when singing. Moreover, significant gains were seen in spontaneous speech, understanding, and identification in the group of patients who received NMT treatment, while only repetition increased significantly in the chronic group that had SLT. Nevertheless,

results point towards the success of both treatments for chronic non-fluent aphasia, with the two NMT and SLT groups showing notable therapeutic outcomes. (Lim, K.-B. et al., 2013). As a result of interventions through familiar music, MUSTIM, and NMT over other forms of therapy, music therapy can be used to assist speech in expressive aphasia patients.

Conclusion

This paper examines how music therapy, especially NMT, improves the quality of life for patients with neurodegenerative disorders and conditions and its effects on behavior, memory, speech, and motor control. These results provide evidence for NMT on neurodegenerative diseases, including AD, aphasia, and PD, and offer music as potential therapeutics. Although music therapy is not widely known or understood by the public (Golden et al., 2022), it continues to create striking improvements in the mental well-being of the people who receive it. As the global awareness of the profession grows, the hope for many professional music therapists is for more research into the topic and its implementation within the field of medicine.

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References

- Rebecchini, L. Music, mental health, and immunity. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8566759/#:~:text=Other%20studies%20have%20demonstrated%20the,stimulation%2C%20and%20immune%20system%20enhancement.> (accessed Dec 19, 2022).
- Clements-Cortes, A.; Bartel, L. Are we doing more than we know? possible mechanisms of response to music therapy. <https://www.frontiersin.org/articles/10.3389/fmed.2018.00255/full> (accessed Sep 22, 2022).
- Stacks, C.; Harris, B. Neurologic music therapy in neurorehabilitation. <https://www.biausa.org/public-affairs/media/neurologic-music-therapy-in-neurorehabilitation> (accessed Dec 20, 2022).
- Li, K.; Weng, L.; Wang, X. The State of Music Therapy Studies in the past 20 years: A Bibliometric analysis. <https://www.frontiersin.org/articles/10.3389/fpsyg.2021.697726/full> (accessed Dec 18, 2022).
- Gitler, A. D.; Dhillon, P.; Shorter, J. Neurodegenerative Disease: Models, mechanisms, and new hope. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5451177/> (accessed Dec 18, 2022).
- Gómez Gallego, M.; Gómez García, J. Music therapy, and Alzheimer's disease: Cognitive, psychological, and behavioural effects. <https://www.elsevier.es/en-revista-neurologia-english-edition--495-articulo-music-therapy-alzheimer39s-disease-cognitive-S217358081730072X> (accessed Oct 10, 2022).

- Kreutz, G.; Bongard, S.; Rohrmann, S.; Hodapp, V.; Grebe, D. Effects of choir singing or listening on secretory Immunoglobulin A, Cortisol, and Emotional State. <https://www.kdov.nl/documents/SINGING%20Kreutz2004JBM.pdf> (accessed Dec 17, 2022).
- García-Casares, N.; Martín-Colom, J. E.; García-Arnés, J. A. Music therapy in Parkinson's disease. [https://www.jamda.com/article/S1525-8610\(18\)30540-1/fulltext](https://www.jamda.com/article/S1525-8610(18)30540-1/fulltext) (accessed Oct 10, 2022).
- Bukowska, A. A.; Krężałek, P.; Mirek, E.; Bujas, P.; Marchewka, A. Neurologic music therapy training for mobility and stability rehabilitation with Parkinson's disease - a pilot study. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4726780/> (accessed Dec 14, 2022).
- Conklyn, D.; Conklyn, C. to D.; Novak, E.; The Cleveland Clinic Foundation Google Scholar More articles by this author; Boissy, A.; Bethoux, F.; Chemali, K. The effects of modified melodic intonation therapy on nonfluent aphasia: A pilot study. <https://pubs.asha.org/doi/full/10.1044/1092-4388%282012/11-0105%29> (accessed Sep 22, 2022).
- Lim, K.-B.; Kim, Y.-K.; Lee, H.-J.; Yoo, J.; Hwang, J. Y.; Kim, J.-A.; Kim, S.-K. The therapeutic effect of neurologic music therapy and speech-language therapy in post-stroke aphasic patients. <https://synapse.koreamed.org/articles/1149696> (accessed Oct 10, 2022).
- Golden, T. L.; Tetreault, L.; Ray, C. E.; Kuge, M. N.; Tiedemann, A.; Magsamen, S. The state of music-based interventions for mental illness: Thought leaders on barriers, opportunities, and the value of Interdisciplinarity. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8186512/> (accessed Dec 19, 2022).