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Definition and Application of Music Therapy: Its Role in Neurodegenerative Disease Treatment and Mental Health Promotion

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Abstract. As a safe and non-pharmacological intervention, music therapy has developed rapid global contribution in treating neurodegenerative diseases in recent years. Now, its application scope has been continuously expanding, and the integration of related technologies has been deepening. It has gradually assisted as an important therapy in fields such as mental health, rehabilitation medicine, special education, and elderly care. However, there's a lack of personalized music treatment for patients. This study gives the definition of music therapy (characteristics, categories, and application fields) and introduces the main physiological mechanism behind the effects, finally analyzing the application of music therapy to three common diseases (AD, ADHD, and depression). Based on these analyses, music therapy is a worthwhile treatment for the disease. In addition, this study provides a conceptual and summative reference for the treatment of NDD disease for future research. And the future research can also start from how to provide more personalized treatment to patients and how to make this treatment more universal and standardized.

Keywords: Music therapy, neurodegenerative disease, mental health.

1. Introduction

Mental health is a widespread issue today. And the mental health problems may cause a lot of people to endure long-term suffering. According to the report of the National Institutes of Health. It has been calculated that more than one in five U.S. adults have a mental illness, with 59.3 million in 2022 and 23.1% of the adult population）[1]. For almost all mental illnesses, the most common way to treat this disease is drug therapy. Such as antidepressant drugs, antipsychotic drugs, and anxiolytics. However, these drugs may inevitably cause some side effects. The symptoms of increased weight, impotence, insomnia, chronic sedation, and inattention are present. And taking drugs in excessive amounts may lead to some prevalent neurological complications of psychiatric drugs, specially, antipsychotics and antidepressants. Such as extrapyramidal syndromes, neuroleptic malignant syndrome (NMS), and serotonin syndrome. But, as a treatment method with fewer side effects, musical intervention or musical therapy can also work effectively on treating mental health problems.

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The specific attributes of music are used collaborating with a music therapist as a therapeutic relationship to make up music therapy (MT) [2]. While music listening intervention is the study that examined the impact of listening to prerecorded music daily. Since listening to music can significantly reduce the levels of cortisol, lower heart rate, and decrease mean arterial pressure. Meanwhile, music can also play a role in increasing positive emotions and feelings, such as subjective worry, state anxiety, restlessness, or nervousness. All of them can contribute to the recovery of both physical health and mental disorders. Therefore, musical therapy or musical intervention already serves as the treatment for Alzheimer's disease (AD), Parkinson's disease, insomnia, and stress reduction.

This study will introduce the influence of MT and intervention on mental health problems nowadays. At the same time, analyze whether it is effective, as well as its advantages and disadvantages in applications.

2. Music Therapy (MT)

Using music in treating mental problems could be divided into receptive MT and active MT. Both therapies need a credentialed music therapist. Who is responsible for achieving individualized goals within a therapeutic relationship in order to fulfill physical, emotional, mental, social, and cognitive needs. Furthermore, the definition or characterization of music includes melody, harmony, and rhythm. Countless combinations emerge from the three core elements -- each possessing variations in sequence, tempo, and dynamic parameters.

The two types of therapy have their own characteristics. Receptive MT lays special emphasis on the internal mental experience. That is, receptive therapy often includes using techniques like music-assisted relaxation, guided imagery, and lyric analysis while listening to live or recorded music. Facilitating by a trained therapist, can help alleviate stress, anxiety, and pain while also enhancing relaxation [3]. To help some patients with limited mobility or patients with difficulty in expression, like autism sufferers. So receptive therapy is more focused on emotion adjustment and trauma treatment. While active therapy places emphasis on the behavior and interaction. The main role for the therapists is as collaborators, which encourages the patients to express themselves through instrument playing, singing, creative music activities (e.g., improvisation, lyric composition), facilitate emotional expression and physical movement. Active therapy is often used to treat the patients with inattention or executive impairment [3]. For example, the attention-deficit/hyperactivity disorder (ADHD) children, stroke rehabilitation patients, and individuals with social anxiety.

3. Main physiological mechanism

The essence of MT is based on the plasticity of the brain and the balance of the autonomic nervous system to achieve neurochemical regulation. Music listening may stimulus neural networks that structurally preserved in individuals with some neuron disease, such as AD [4].

While listening to music could effectively help the brain to release some neurotransmitters. Dopamine, for example, is a well-known factor that participates in reducing the negative feelings, such as depression. When the patients listen to the music, the mesolimbic pathway can be effectively formed [2]. That is, the ventral tegmental area could project dopamine neurons to the nucleus accumbens in order to release dopamine by the NAcc and overall help patients reduce negative feelings. On the other hand, the secretion of serotonin is closely linked to the regulation of emotions. Since the release of serotonin could suppress the overreaction of the amygdala in the prefrontal

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cortex, it could finally lower the stress response. While the amygdala and mesolimbic reward brain system are the brain structures that receive modulation of activity, the patient with depression could play a regulatory role in emotional enhancement [2]. Listening to music can significantly decrease stress levels because cortisol levels, which are tightly associated with stress expression, can be reduced by activating the parasympathetic nervous system and inhibiting the excessive response of the HPA axis. Furthermore, there is evidence indicating that a group's music activities can produce synchronization among its members, resulting in positive feelings of a sense of belonging. The release of neurotransmitters endorphin and oxytocin may be responsible for this, which plays a crucial role in the defensive response to stress.

In addition to the neurotransmitter, the brain structure and neural plasticity also be a key factor in MT. To be specific. The auditory and prefrontal cortex may become structurally and operationally plastic due to piano training, which can improve the executive abilities, such as attention and decision-making skills. The long-term music training can also thicken the corpus callosum, enhancing the ability of information integration and promoting language rehabilitation after stroke [5]. Despite their age, there are cognitive and perceptual-motor advantages in the hippocampus and other areas of the brain, as well as in distant and local white matter pathway and effective connectivity. Some of these mental health benefits may already be promoted by concentrated music listening and learning [5].

4. Applications in Neurodegenerative Diseases (NDDs)

AD, ADHD, and depression are the three main NDDs. While MT has accumulated a substantial body of confirmatory research on the application of these diseases, leading to the development of relatively mature intervention models. Analyzing the methods and fields of music training used in those diseases could effectively give more specific guidance to the clinical practice.

NDD is one of the main target groups for MT, especially AD. The special value of music for the patients of AD is to activate their existing memory network and serve as a meaningful connection with themselves and their loved ones or events, even though the hippocampus has already experienced serious damage. There are three potential brain mechanisms for music intervention methods in AD: Neurogenesis and neuroplasticity are stimulated by activating the anterior hippocampal formation and neurogenesis, dopamine release and the process of inflammation (the peripheral autonomic excitation with concomitant immune modulation) can also be evoked [6,7].

AD patients are still able to reminisce about personal memories and elicit intense emotions through listening to music. According to the investigation of El Haj et al., MEAMs have been observed in both healthy adults and patients who are likely to develop AD, they compared a self-directed music exposure relative to a muted condition [8]. The music condition resulted in AD patients recovering their memory more quickly, being more specific, affectively intense, and having a greater impact on mood, as found. An increase in the frequency of emotional words during recall has been observed with self-selected music [9]. And for another study by Anna Maria Matziorinis et al., they make a comparison of the AD patients with MT and physical activity. Singing lessons with music therapists, along with a negative control group that does not receive any intervention. This study is designed to focus on patients within mild to moderate ranges of AD patients and excludes those with other forms of dementia. And after 12 months' experiment duration, the use of MT has been highly recommended to enhance emotional well-being, reduce affective disorders, facilitate episodic memory retrieval and reduce BPSD of AD patients. However, there's still a lack of clear evidence of the alleviation of BPSD, but because of its safety, MT can still be further studied and applied to improve the BPSD symptom of AD patients.

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ADHD is a common neurodevelopmental disorder; the core symptoms include difficulties in impulse control, inattention, and hyperactivity. While ADHD is more prevalent among children, meta-analyses confirm a 65% persistence rate into adulthood [10]. Incorporating three independent pathways into ADHD deficits has been revealed by recent studies: the dorsal cognitive control circuit, the ventral mesolimbic reward network, and the cerebellar-frontal timing pathway [10]. Perceptual timing tasks in ADHD patients are often difficult to distinguish between seconds and milliseconds, resulting in lower performance in motor timing and prefrontal temporal anticipation [10].

According to the optimal stimulation theory and the Moderate Brain Arousal (MBA) model [11], which indicates that individuals with ADHD often experience a baseline level of under-arousal, urging them to look for external sources of stimulation to attain the optimal arousal levels necessary for effective functioning [11]. Music stimuli, characterized by temporally organized acoustic patterns, can activate multiple brain regions, such as the regions of perceptual integration, motor execution, and the brain's reward system. Another important effect of music is that the motivation and reward processing depend on dopaminergic pathways, including the nucleus accumbens, which are stimulated by it. In ADHD patients, this stimulation may help prevent the development of dopamine receptor function or specific disruptions in the ventral frontostriatal pathway [12].

There is a study by Ghetti et al. that used music listening for patients with ADHD [13]. Eight individuals were examined in their study, who differed in terms of gender, language of origin, music history, phase of treatment, and length of experience with MT. It has been found in their study that participants experience music and MT as a tool for regulation, motivation, competence attainment, social belonging, and personal growth. So, music has effectively helped ADHD patients to be more focused on adaptive and wellness-enhancing field. In addition, they also find that participants could alleviate the symptoms of ADHD through music listening instead of drug therapy. Which can significantly reduce the side effects of using drugs in the treatment of ADHD [13]. On the other hand, the study is inconclusive because it cannot completely distinguish the experience of MT from that of music in everyday life in all aspects of the findings. So, the potential for further research may cover diverse settings, including normal life settings, like schools, which provide a feasible approach to treatment access, and such a concentrated place and time duration could provide less disruption for the treatment [14].

More than 300 million people worldwide are affected by depression, which has been reported to be a common mental disorder. Long-term depression with moderate or severe intensity has the potential to cause serious health problems [15,16]. While most of the methods used to treat depression are usually medication. As a symptomatic management strategy, it demonstrates only transient efficacy in symptom suppression and carries substantial limitations, particularly regarding the non-negligible risks of drug treatment. So compared to medication, MT provides more sustainable and safe effects.

Since the atrophy of neurons and hippocampal structures, mediated by depression-induced alterations in brain-derived neurotrophic factor (BDNF) expression, represents a key neuropathological mechanism. The relationship between music-evoked joy and hippocampal formation is well-documented, and music-evoked joy is associated with increased levels of BDNF. Based on a previous study, it was found that the serum BDNF levels of patients receiving MT were higher than that of patients who did not receive MT, indicating that MT may stimulate BDNF secretion and contribute to neural function restoration [17]. In addition, MT demonstrate the capacity of α waves activity in cortical regions, thereby inducing physiological relaxation in elderly

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populations. This effect may subsequently enhance their independence and reinforce self-efficacy perceptions [18].

According to the study of Bing Xue et al., the study of receptive MT, that is, the musical intervention was conducted by the experimental group that consisted of music listening, discussion, and progressive relaxation training of musical muscles four times a week for 8 weeks. Their suggestion was for the participants to talk about and share their stories to improve emotion and foster social interaction among older adults [17]. After every treatment, they measured the MoCA and GDS of the participants. They found that MT can effectively reduce depression levels in older adults. The result is well confirming the theory that music therapy can effectively associated with the improvement of cognitive function in older adults for those have cognitive impairment. Besides confirming the benefits of MT, they also indicate that it is important to use MT in a more concentrated area, like the places of schools, community centers, nursing homes, and participants' homes, is more worth doing for.

5. Conclusion

To sum up, music therapy serves as a promising and safe treatment method, which is worth using in the treatment of psychological disorders. Especially for group therapy methods, which can both help the patients improve their cognitive function, and with such a concentrated area, patients may gain a sense of belonging, then provide them a tight environment for social interaction. However, both active and receptive therapy are beneficial for the recovery; it depends on whether the patient is suitable. In addition, personalized music therapy is the core principle of modern music therapy practice, which is based on the recognition that there are significant differences in individuals' responses to music. Because of age, cultural background, personal experiences, and emotional states, individuals have different preferences for music, even for the type of therapy. So before applying for the standardized treatment, it is essential to know the patients' opinions and may change some ways for a more personalized experience.

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