Music Therapy in Traumatic Brain Injury Rehabilitation

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Greek philosopher, Plato, once said, “music gives wings to mind” (Tikka & Nizamie, 2014). Different genres of music elicit various emotions based on each individual’s experience with music and this concept is similar to the idea of music therapy. Music therapy was used decades ago in the post-World War II period during which musicians were hired to improve the effects of the physical and emotional trauma war veterans encountered (Tikka & Nizamie, 2014). Clinics observed significant benefits of music on the health of those who suffered from traumatic brain injuries (Tikka & Nizamie, 2014). Music therapy is, “the clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional” (Magee, 2020). Therapeutic interventions are designed to ultimately accomplish clinical goals that aim to meet the patient’s individual health goals as well as to develop a holistic understanding of the patient.

Each year 1 to 1.8 million patients are admitted to the hospital with traumatic brain injuries and between 70,000 and 90,000 of these patients suffer with permanent physical, cognitive, or behavioral disabilities (Berger et al., 1999). A traumatic brain injury (TBI) is defined as, “an injury to the brain from an external agent or force,” and it can cause short-term or long-term impacts on neurological and neurophysical functioning (Hedge, 2014). The location and severity of the injury determines the sequelae of impairment in physical, psychological, and social functioning. The social and psychological impacts that follow TBIs, “are far more disabling and burdensome to the individual, the caregivers as well as the society at large” (Hedge, 2014). After suffering a TBI, the road to recovery is challenging because patients must relearn motor and cognitive functions that were compromised as a result of the injury. Rehabilitation can take many forms including physical, occupational, speech, psychiatric, and

social support. It is important to form individualized care plans for TBI patients because no two patients will have the same exact needs and preferences, therefore it is important for the individuals working in healthcare to constantly research the effectiveness of different interventions for their patients. Music therapy can be implemented for TBI patients because it can, "improve functioning across all the behavioral domains, including motor, cognition, communication and psychosocial" (Magee, 2020). Music is an easily accessible and inexpensive resource compared to other treatments, but it does require, "planned and careful application with vulnerable populations," because overuse creates, "the possibility of triggering strong emotional reactions" (Magee, 2020). An advantage of music therapy is that is can be implemented by itself or it can be used as part of a more complex treatment plan (Kleinstäuber & Gurr, 2006). While looking at the studies and information in regard to music therapy and traumatic brain injuries, it is evident that the principles of music therapy facilitate the recovery process of motor and cognitive function through rhythmic auditory stimulation and live music-making for patients with traumatic brain injury.

INTERACTION BETWEEN MUSIC AND THE BRAIN

Several areas of the brain are stimulated when exposed to music in some capacity. Music is processed through the brain in such a manner that it produces a therapeutic effect. Music stimulates the higher cortical and subcortical areas of the brain, which are also the same areas of the brain that maintain and modulate emotions (Hedge, 2014). All known cognitive functions and emotional processes are engaged when music is being processed within the brain.

Additionally, music activates and regulates the release of neurochemicals such as dopamine and endorphins and inhibits the release of cortisol (Tikka & Nizamie, 2014). Dopamine plays a role in the brain's reward system and when these neurotransmitters are

released the individual has increased motivation to repeat the action to feel the sense of satisfaction again (*Dopamine*, 2021). When endorphins are released, it produces, "physical effects such as vasodilation, local warming of the skin, and a reduction in blood pressure," all of which will decrease the level of pain the patient feels while recovering from the injury (Tikka & Nizamie, 2014). Cortisol is known as the stress hormone and high levels of cortisol indicates that the individual is under some type of physical or physiological stress. High levels of this hormone for long periods of time puts an individual at risk for weight gain, high blood pressure, and muscle weakness (Schaefer, 2017). Exposure to music inhibits the release of cortisol in the brain, which means lower levels of cortisol are present, creating a positive effect on the patient's health.

Furthermore, "listening to music facilitates neurogenesis or the regeneration and repair of cerebral nerves by adjusting the secretion of steroid hormones, finally leading to neural plasticity" (Hedge, 2014). Neural plasticity is the neural networks' ability, "to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections" (Puderbaugh & Emmady, 2022). This process is essential in forming neural connections between damaged areas of the brain and healthy brain tissue which will lead to improvements in functioning controlled by the brain.

A biological effect of listening to music involves the activation of the cerebellum, basal ganglia, and motor areas of the brain, which are areas that, "are reported to coordinate motor movement in response to music" (Tikka & Nizamie, 2014). This process can facilitate improvements in motor function for patients in neurorehabilitation. Moreover, to improve motor processing the, "medial geniculate nucleus processes complementary movements that occur when listening to music, such as a body sway, foot tap, or simple head nod" (Tikka & Nizamie,

2014). This motor processing is important when music is used in a healthcare-related care plan to help individuals improve their motor movements after an injury.

REWARD SYSTEM AND MOTIVATION INDUCED BY MUSIC

Patients that have been impacted by a traumatic brain injury often experience disturbances in mood and affect typically presented as anger, restlessness, irritability, loss of motivation, and frustration (Baker & Wigram, 2004). These mood disturbances have a negative impact rehabilitation, "because patients become overwhelmed by the intensity of their feelings and emotions and are unable to divert their attention to the tasks required of them in the therapy session" (Baker & Wigram, 2004). If patients are not able to concentrate on their treatment plan and if they are not motivated to follow through with their rehabilitation process, they will ultimately not be able to participate in the interventions, thus failing to progress through the stages of their recovery.

Music plays a role in motivation in that it, "has the ability to engage the brain's reward system, which is of high importance in individuals with a traumatic brain injury, considering that problems of initiation and motivation are often linked to the injury" (Siponkoski et al., 2021). The mesolimbic dopaminergic system, also referred to as the reward system, is activated by music and it, "regulates memory, attention, executive functions, mood, and motivation" (Sihvonen et al., 2017). TBI patients may have difficulty maintaining arousal and attention which can interrupt their level of focus in rehabilitation, but "data of neuroimaging studies point out that both attention and musical processing are partially localized in the right temporal-parietal lobe areas, which suggests that music engages complex neural systems for human attention" (Kleinstäuber & Gurr, 2006).

PRINCIPLES OF MUSIC THERAPY

There are four theoretical principles of music therapy that support the use of music in rehabilitation for patients with neurological deficits. Music therapy facilitates communication because singing and speech share underlying neural mechanisms including, "respiratory muscles, articulators and phonators, and rhythmic cueing stimulates and organizes speech musculature" (Magee & Baker, 2009). Music enables better expression by means of improved vocal quality and volume, naturalness of speech and verbal output, therefore this is beneficial for patients with neurological damage that affected their speech. Another principle of music therapy is that it facilitates social interaction (Magee & Baker, 2009). For patients who have endured a life-altering injury, it is likely that they will be isolated and possible experience depression. Music is a powerful social medium in almost all cultures, thus through dancing, singing, and playing music, music therapy can become a social activity that increases social interaction (Magee & Baker, 2009). Music therapy is also known to facilitate the expression of emotion (Magee & Baker, 2009). During the recovery process, medical professionals encourage patients to implement emotional exercises because the expression of emotions is an important part of human interactions and conversations. Music provides a positive coping mechanism that enables individuals to explore and express their feelings of loss, grief, adjustment, and anxiety (Magee & Baker, 2009). Furthermore, music creates a more relaxed environment for individuals to reflect on their emotional responses. Lastly, music therapy stimulates neuronal connections in the brain because it promotes neuroplasticity (Magee & Baker, 2009). Neuroplasticity is the, "brain's ability to modify, change, and adapt both structure and function throughout life and in response to experience" (Voss et al., 2017). This process enables connectivity between healthy and

damaged centers of the brain, ultimately leading to formation of new pathways that will help patients re-establish functions that were disturbed as a result of their brain injury.

Neurologic music therapy can be implemented in the rehabilitation treatment plan for TBI patients because it targets specific areas of functioning that are essential for humans to live a more purposeful and engaging life after sustaining traumatic brain injuries. Music therapy is important in facilitating sensorimotor functioning in that it advances motor functions such as gait, fine motor movement, and gross motor functions (Hedge, 2014). Attention, memory, executive functions, language, and emotional processing are considered cognitive functioning skills that music therapy can also promote improvements in (Hedge, 2014).

Everyone's relationship with music is different based on their culture, upbringing, experiences, and influences. Music is a multifaceted form of art that has several benefits. The benefits of music in a therapeutic environment include, "making positive alteration in mood and emotional states, improving concentration and attention span, developing coping and relaxation skills, exploring self-esteem and personal insight, enhancing awareness of the self and the environment and improving social interactions" (Tikka & Nizamie, 2014).

COGNITIVE IMPAIRMENTS AND REHABILITATION WITH MUSIC THERAPY

Following a traumatic brain injury, patients suffer from cognitive impairments which have a tremendous impact on their quality of life. A patient's quality of life is, "a multidimensional construct comprising of physical/medical, psychological and social factors," (Berger et al., 1999) and when looking at a TBI patient, it is necessary to include a cognitive component as a fourth domain since changes in personality and cognition are common among this population (Berger et al., 1999). Cognitive impairments include, "deficits in attention, information processing, planning, decision-making, language, and emotional processing,"

(Hedge, 2014) and these impairments tend to have an impact on an individual's personal and socio-occupational functioning, eventually leading to other concerns such as depression and isolation (Hedge, 2014).

Cognitive rehabilitation has become a more available treatment to facilitate the restoration of cognitive functions and develop strategies to overcome cognitive deficits post-TBI or other brain injuries. The goal of cognitive rehabilitation is to help patients adapt to their disability to improve functioning and this retraining is achieved through cognitive drills and exercises targeting specific cognitive functions (Hedge, 2014). When patients participate in this treatment, they encounter a repetition of drills that facilitate, "the recovery of the damaged neural circuits and restoration of function such as attention, memory, and executive functions" (Hedge, 2014). The goal of these repeated drills and exercises is to reestablish, "a near normal or normal level of functioning as comparable to the functioning due to an intact brain without any injury" (Hedge, 2014).

Music-based interventions is one method of cognitive rehabilitation. For one, music shows, "positive results in reducing levels of anxiety, depression, agitation and in inducing stable mood state," (Hedge, 2014), which is an important aspect of promoting successful treatment. Music helps to initiate the process of stimulating cognitive processes in the brain such as information processing, learning memory decision making, and emotion, which in turn, "can be generalized and transferred to non-musical therapeutic applications" (Hedge, 2014). Studies indicate that the addition of music interventions to treatment plans leads to early responsiveness in TBI patients which ultimately facilitates cognitive rehabilitation in early phase of recovery (Hedge, 2014). Another link between music and cognitive functioning is shown through neuroimaging which indicates that both attention and music processing are localized in the right

temporal-parietal lobe areas suggesting that, “music seems to engage important and complex neural systems for human attention” (Kleinstäuber & Gurr, 2006).

The use of live music making interventions is helpful in recording the progress that the patient makes throughout their recovery because it, “enables the therapist to match a patient’s baseline response, thereby subtly altering parameters to increase the difficulty and extend a patient’s functioning” (Magee & Baker, 2009). The therapist guides the patient through increasingly complex stages in order to achieve the ultimate goal of near-normal or normal functioning. This form of music therapy is unique because the pace of therapy can be adjusted based on individual patient needs (Magee & Baker, 2009) which is important because altering the therapy rather than taking away an intervention all together is essential to keep the patient motivated in their recovery.

Live music making is another method of music therapy that can be utilized to improve cognitive functioning in TBI patients. Although listening to music has a therapeutic effect, “to reduce stress and enhance emotional health,” (Hedge, 2014) it is important to consider the benefits of live music making. Cognitive skills are required to integrate acoustic events as well as memory and attention to address language production (Magee, 2020). Communication goals are addressed through singing and vocalizing because the actions of speech and singing share musculature for respiration, phonation, articulation, and resonance which are all impacted after a traumatic brain injury (Magee, 2020). The ability to hold conversation is an essential aspect of human interaction, and so any interruption in this process will have consequences in an individual’s quality of life. The implementation of music therapy, specifically with singing, has shown improvements in, “speech naturalness for individuals following traumatic brain injury, (Magee & Baker, 2009). Playing an instrument involves an array of skills, and in regard to

cognitive functioning, it allows patients to improve their problem-solving, decision-making, sequencing, listening, and attention skills (Magee & Baker, 2009). Furthermore, the skills that patients learn in their own rehabilitation sessions can be meshed into a group therapy setting, "which additionally demands social behaviors encompassing reasoning and turn-taking" (Magee & Baker, 2009).

Traumatic brain injuries can cause impaired intonation or speech production which affects an individual's quality of life. Intonation is defined as, "rises and falls in pitch over time with a spoken phrase" (Baker et al., 2005) and its purpose is to allow expression of mood, emotion, thought, and experiences. Patients with speech difficulties are, "at risk of being misunderstood and of being unable to engage and maintain conversations with people and are, therefore, predisposed to social isolation" (Baker et al., 2005). Impairments in intonation interferes with the patients', "psychological equilibrium, as feelings of self-consciousness and inadequacy, paranoid ideation, diminished interpersonal communication, social withdrawal, alcoholism, depression and even suicidal tendencies," (Baker et al., 2005) which are apparent in some degree in TBI patients. Music therapy is beneficial in intonation disorder because it, "facilitates a relaxation response which directly facilitates vocal fold flexibility, enabling the speaker to express more emotional dynamics in his voice" (Baker et al., 2005). Moreover, singing, "often bypasses the thought mechanisms required to complete other activities…clinicians can expect a *flow* and enhanced performance in their clients' use of voice, not achieved in other contexts" (Baker et al., 2005). When music therapy programs incorporate singing songs, it stimulates cortical activity, "that resulted in re-engaging dormant or disconnected pathways that were also involved in intonation production" (Baker et al., 2005). This process is important because, depending on the extent of the traumatic brain injury, certain

neural pathways are disrupted, which will interfere with cognitive functioning. Music therapy enables neuroplastic changes to reconnect those damaged neural pathways.

Patients that experience traumatic brain injuries experience life-changing effects and their recovery process is slow and challenging which leads to an accumulation of negative emotions. Singing gives patients an opportunity to release their unexpressed emotions and built-up tension. Emotional processing is improved through singing which is evidenced by, "increased feelings of happiness and decreased feelings of tension, fear, sadness and confusion" (Baker et al., 2005). The inability to express emotions leads to mood disturbances which, "negatively impact client treatment, as clients become overwhelmed by the intensity of their emotions and are unable to divert their attention toward the required therapy tasks," (Baker et al., 2005), therefore this stimulation of positive emotional expression is important for the treatment team and for long-term recovery outcomes. Music therapy, if utilized early in the recovery process, allows the patient and the treatment team to move steadily through the tasks because of its ability to motivate patients to fully participate without an overwhelming number of limitations (Baker et al., 2005).

Cognitive functioning is an essential aspect of maintaining a fulfilling quality of life, and so when TBI patients experience interruptions in their cognitive functioning, there could be negative long-term consequences that can prolong recovery even more. Music therapy has shown to provide a unique rehabilitation experience for patients with extensive brain damage because music has the ability to trigger emotional responses and increase motivation to participate in therapy. Live music making is an important part of cognitive rehabilitation because the skills used in making music can be translated to non-musical activities and skills. The treatment team reports increased participation and engagement in therapy because they are able to manipulate

the limitations of therapy based on the complexity of the music and music-making skills that are exercised.

MOTOR IMPAIRMENTS AND REHABILTATION WITH MUSIC THERAPY

Depending on the severity and location of the traumatic brain injury, impairments to motor functioning can be endured, which requires rehabilitation to achieve near normal or normal functioning post-TBI. The motor impairments that could result, "include abnormal posture, altered muscle tone, paresis, reappearance of primitive reflexes, ataxia, decreased balance, and lack of coordinated movement" (Subramanian et al., 2021). Motor impairments specifically related to gait in TBI patients include, "reduced walking speed, stride length, and cadence, as well as increased step- to-step variability and abnormal muscle activation patterns of lower extremity muscles" (Braun Janzen et al., 2022). Motor functioning is a vital part of daily living and when there is an interruption in motor processing, there is a negative impact on functional independence in activities of daily living. Music therapy plays a role in rehabilitation of motor functioning because, "motor regions within the cortex are sensitive to and driven by auditory stimuli as the auditory system processes temporal information rapidly and precisely, creating entrainment between rhythmic signal and movement" (Magee, 2020). The use of music therapy provides structure to rehabilitation through repetitive music making tasks that improves the timing, range, strength, coordination, and duration of movement (Magee & Baker, 2009).

One unique aspect of music therapy that is beneficial for patients who are attempting to improve their impaired motor functions is rhythmic auditory stimulation (RAS). RAS is a neurological music therapy technique that consists of a, "series of auditory stimuli presented at a fixed rhythm, and movements are synchronized (entrained) to the rhythm" (Sihvonen et al., 2017). Music creates a strong driving force for movement and the use of an external rhythmic

auditory stimuli, such as a metronome or music with a distinct beat, is, "readily and precisely detected by the auditory system, inducing entrainment of neuronal activity in auditory and motor regions of the brain involved in rhythm perception and movement production" (Braun Janzen et al., 2022). Rhythmic entrainment is defined as an, "inherent tendency to time movements to regular beat of music" (Sihvonen et al., 2017). This is the foundation of RAS, and it acts as an external timer to aid patients in executing movements, thus bypassing the dysfunction. With proper arrangements made by the treatment team, "rhythmic cues are matched to the individual's preferred cadence and, once the movement is entrained to external cues, the rhythm is gradually increased or decreased by 5-10% over baseline" (Braun Janzen et al., 2022).

Live music making is a method that can also be used in improving motor functioning. Playing an instrument elicits the utilization of range of motion in upper extremity gross motor movements, fine motor skills, muscle strength, endurance, and trunk control and balance (Magee & Baker, 2009). Learning the dexterity to play an instrument as part of rehabilitation, "provides feedback about a movement which is literally 'sounded out' in the music created," (Magee & Baker, 2009) and this is a part of the motivational and reward system concepts discussed earlier that will ensure participation in the recovery process.

Motor functioning determines the extent to which an individual can perform activities of daily living. For patients who have sustained extensive brain damage, there could be negative consequences to their motor functioning leading to loss of functional independence. The loss of independence can lead to long-term undesirable outcomes such as isolation, depression, or substance abuse. By implementing music-based interventions into patients' rehabilitation treatment, the treatment team would be able to exercise the affected gross motor and fine motor skills. The underlying idea that music triggers motivation and the reward system is an advantage

of music therapy because the obstacles of rehabilitation can cause frustration if the patient does not have the right mindset and motivation to participate in rehabilitation. RAS is another advantage of music therapy that allows patients in rehabilitation to follow a continuous beat to move along in their tasks.

CONCLUSION

Music plays a role in many cultures in some capacity, and it allows people to express emotions, to communicate with others, and to engage in social activities. Music therapy is starting to gain prevalence in rehabilitation centers to promote early responsiveness in patients who suffered a traumatic brain injury. Music therapy has unique characteristics that stimulate the reward system and motivation in the brain, which is useful in TBI patients who struggle with initiating or progressing through therapeutic interventions as a result of their injury. This therapeutic method can be used to exercise both cognitive functioning and motor functioning through live music making, singing, and rhythmic auditory stimulation. Depending on the extent of brain damage an individual endures, the treatment plan must be individualized to meet the needs and preferences of the patient. Music therapy allows the therapist and the patient to create a unique treatment plan that allows for repetitive exercise of the impaired functions in addition to creating a motivating and relaxed environment that facilitates success in therapy. Patients that suffer a traumatic injury lose control over many aspects of their life, but music therapy allows these patients to make choices and to gradually regain control through a more flexible therapy method. Therefore, it is evident that music therapy can be implemented in the rehabilitation process of a patient who has suffered from a traumatic brain injury to allow them to make progress in their recovery.

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