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A Holistic Approach to Neuro-informed Music Therapy for Acute TBI Rehabilitation

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A Holistic Approach to Neuro-informed Music Therapy for Acute TBI Rehabilitation:

Development of a Method

Capstone Thesis

Lesley University

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Music Therapy

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Abstract

This capstone project is the development of a holistic neuro-informed method of music therapy for acute rehabilitation from traumatic brain injury. This method is grounded in research in the fields of neuroscience and neurochemistry and has been developed and implemented through the lens of a holistic patient centered theory of music therapy. The review of literature focuses on previous research in neuroscience, neurochemistry, neurologic music therapy, medical music therapy and the overall relationship between music and the brain. The method was explored using one 17-year-old female participant at a Boston area children's hospital recovering from traumatic brain injury. The patient's entire catalog of presenting problems upon admission as well as any physical and psychological history were taken into consideration in developing a holistic neuro-informed music therapy treatment plan. The plan was implemented over a six-week period of time, and all documentation was recorded via MediTech, the hospital's medical recordkeeping database. The results were recorded based on patient self-report and showed improvements in gait, balance, respiratory strength, and oral motor control as well as increased emotional expression and regulation. Further research and explorations of neuro-informed music therapy in various populations will help to progress the method and clarify its efficacy.

A Holistic Approach to Neuro-informed Music Therapy for Acute TBI Rehabilitation

Introduction

In considering options for this capstone thesis project, my main goal was to settle on a topic that would drive and push both me and my career, as well the field of music therapy as a whole. It is easy to become overwhelmed by grandiose ideas, extremely involved research projects, and other motivating factors that life as a grad student simply does not allow time for. I have slowly but surely let go of these unrealistic aspirations, for the time being that is, and instead have focused my attention on the start of something new; the introduction of the next big thing, and the development of a method that will bridge gaps instead of creating new ones. The purpose of this capstone thesis is to introduce neuro-informed music therapy as a comprehensive and holistic approach to rehabilitative music therapy. In doing this I will establish and expand upon the definition of holistic as it relates to this method of music therapy. Additionally, a large focus of this project will be examining the difference between neurologic music therapy and neuro-informed music therapy, including why there is an importance for such a distinction. Due to the nature of my current work, most of my focus on neuro-informed music therapy as it is applied in a pediatric setting addressing post-traumatic brain injury rehabilitation. This adds another layer of complexity and innovation to the project, given that there is currently minimal research on neurologic music therapy with children. Focusing specifically on pediatric neuro-informed music therapy is a unique and exciting opportunity because of the extreme plasticity and resilience of a child's brain, combined with additional social, emotional, and motivational challenges presented in working with children and adolescents. This will be highlighted and expanded upon in the case study detailing my work with one patient at my internship. I will explore the existing research in the field of neurologic and neuro-informed music therapy

specifically with children and adolescents, and make suggestions for further research and exploration. As I mentioned previously, by developing a method of pediatric neuro-informed music therapy I hope to bridge the gap between neurologic music therapy and a neuro-informed approach to patient centered holistic music therapy. I hope to start a conversation about the validity and need for both methods without one establishing itself as superior or exclusive.

Neurologic Music Therapy vs. Neuro-informed Music Therapy

As previously stated, it is important to establish the current distinction between neurologic music therapy and neuro-informed music therapy as well as their respective definitions. According to Dr. Michael Thaut, “Neurologic Music Therapy (NMT) is a research-based system of 20 standardized clinical techniques for sensorimotor training, speech and language training, and cognitive training. ... Therapeutic goals and interventions address rehabilitation, development, and maintenance of functional behaviors” (Thaut,2014). The key aspect to focus on in this definition is the fact that NMT is standardized in its approach meaning that the 20 exercises absolutely cannot be altered. If a music therapy intervention deviates from the standardized NMT approach, it can no longer be considered NMT. This is where neuro-informed music therapy comes in. My current working definition of neuro-informed music therapy is a method of music therapy that uses knowledge and research in the field of neuroscience to design interventions that meet the unique and complex needs of each patient. This includes three separate domains or areas of focus when designing interventions: rehabilitative, compensatory, and psycho-social-emotional. These will be presented and explored in-depth in the patient case study, which will explore one patient in a Boston area children’s hospital recovering from traumatic brain injury.

Defining Holistic

In the field of music therapy, holistic is a term many clinicians use regularly to describe their theoretical orientation and practice. However, when it comes to neurologic music therapy specifically, it seems as though this word has always carried with it a negative connotation and is glaringly absent from all discussions, research, and other literature. In the interest of bridging the gap between NMT and the rest of the music therapy field, I would like to clarify the definition of holistic specifically as it relates to the developing method of neuro-informed music therapy. In a medical setting, holistic refers to addressing the whole person, including their physical, mental, and emotional health, while taking social factors into consideration. This could be specific to diagnosis, in which case a holistic approach might consider all possible symptoms; or holistic treatment, which may be very creative and empowers the patient to take charge of their own care. Holistic medicine includes conventional and alternative treatments (Jasemi, 2017). This is important to consider in introducing the method of holistic neuro-informed music therapy because it provides a basic understanding of the word holistic as it relates to the medical field, and sets this method up to be established as a standard of practice. Hopefully, this will help to eliminate or reduce the negative connotation that often comes with the word holistic in the medical field.

Literature Review

Music and the Brain

The human brain is divided up into four lobes: frontal, temporal, parietal, and occipital plus the cerebellum. The frontal lobe is associated with planning, self-control, critical thinking and making sense out of the countless signals that the brain receives. The temporal lobe is associated with hearing and memory. The parietal lobe is associated with motor movements and

spatial skill, and the occipital lobe with vision. The cerebellum is involved in emotions and the planning of movements, and is the evolutionarily oldest part of our brain (Levitin, 2007).

According to (Levitin, 2007), musical activity involves nearly every region of the brain that we know about, and nearly every neural subsystem. Different aspects of music are handled by different neural regions, and the brain uses functional segregation for music processing. “The brain employs a system of feature detectors whose job it is to analyze specific aspects of the musical signal such as pitch, tempo, timbre, and so on” (Levitin 2007). This is vitally important to consider when establishing neuro-informed music therapy as a holistic approach because it suggests that the musical interventions we as clinicians choose to implement could potentially address more than one neural network at a time. Specifically, performing or playing music involves the frontal lobes, motor cortex, and sensory cortex for the planning of your behavior and the subsequent feedback you receive. Reading music involves the visual cortex, in the back of your head in the occipital lobe. Listening to music, including recalling lyrics and familiar songs involves language centers, including Broca’s and Wernicke’s area, which are areas often affected by receptive and expressive aphasia in traumatic brain injury (TBI) patients (Levitin, 2007).

Music as Medicine

The notion that music is medicine has roots that extend deep into human history through healing rituals practiced in pre-industrial, tribal-based societies (Levitin, 2013). In contemporary society, music continues to be used to promote health and well-being in clinical settings, such as for rehabilitation, pain management, relaxation, psychotherapy, and personal growth. Although much of this clinical use of music is based on unproven methods, an emerging body of literature addresses evidence-based music interventions through peer-reviewed scientific experiments.

Daniel J. Levitin (2013) examines the scientific evidence supporting claims that music influences health through neurochemical changes in the following four domains: reward, motivation and pleasure; stress and arousal; immunity; and social affiliation (Levitin, 2013). This is extremely important to consider in treating a patient holistically through a neuro-informed lens. Although neurologic music therapy (NMT) is grounded in neuroscience and neuroanatomy, there is little focus on the neurochemistry of music as it relates to holistic rehabilitation from brain injuries. Levitin says that the four previously mentioned domains directly affected by music parallel the neurochemical systems of dopamine, cortisol, serotonin, and oxytocin which are the pleasure and reward systems in the brain (Levitin, 2013). He confirms that a great deal has been discovered about the neuroanatomical basis for music as we know from the 20 standardized NMT exercises, whereas not much is known about its neurochemical basis. Therefore, research and studies of the neurochemistry of music may be the next great frontier, particularly as researchers try to investigate claims about the effects of music on health outcomes.

Music in Neurorehabilitation

Regarding music therapy for neurorehabilitation, there are many ways to approach a neuro-informed treatment plan depending on the patient's specific presentation. Gilbertson (2008) highlights how music can be used in a variety of ways to address rehabilitative goals in TBI patients. In order to develop a holistic neuro-informed method of music therapy, it is important to consider the existing research on music therapy interventions for TBI rehabilitation, including limitations, biases, and ideas for further research and exploration. This will allow me to design clinically informed music interventions backed by research and implement them with my patient in the upcoming case study.

Awareness, orientation and memory.

Knox and Jutai (1996) suggest music activities are extremely effective in post-traumatic brain injury attention rehabilitation because of the specific neural pathways that are activated. “The partial localization of attention and musical processing in the right temporo-parietal lobe areas suggest that music seems to engage the most important and complex neural system for human attention and memory” (Knox and Jutai, 1996). Regarding awareness, research shows that people experiencing post-traumatic amnesia recall events that occur in the music therapy intervention better than events occurring in other situations (Baker, 2001). This shows strong support for the field of music therapy in addressing amnesia in the early stages of rehabilitation of people with traumatic brain injury. I have seen this in my own clinical experience working with both children and adults. When assessing memory, music can be used creatively according to a patient’s previous musical preferences. For example, if a patient was a piano player at baseline, we can assess memory and awareness by playing live or recorded versions of familiar songs, or by engaging the patient in playing the instrument itself. Baker (2001) also highlights that music therapy techniques lead to statistically significant positive changes in the orientation of patients who have suffered post-traumatic amnesia and shows that playing live or recorded music leads to an increase in orientation and memory.

Speech and language.

Many authors refer to the benefits of music therapy strategies in the rehabilitation of speech and language disorders resulting from traumatic brain injury. This is one of the most prominent areas of rehabilitative focus for neurologic music therapists. There are two main exercises used to address speech and language deficits due to traumatic brain injury. The first

exercise is called melodic intonation therapy (MIT). “MIT is a therapy technique that uses melodic and rhythmic elements of singing phrases and words to assist in speech recovery for patients with aphasia. Functional phrases or brief statements/utterances are sung by the patients, whereby the musical prosody should be modeled closely to the normal speech inflection patterns of the verbal utterance” (Thaut, 2014). The basic rationale for MIT is the use of rhythmic musical elements to engage language-capable regions of the undamaged right hemisphere (Thaut, 2014). The second most commonly used NMT technique used to address speech and language deficits is called musical speech stimulation (MUSTIM). MUSTIM is a neurologic music therapy technique for non-fluent aphasia, that utilizes musical materials such as songs, rhymes, chants, and musical phrases to simulate prosodic speech gestures and trigger automatic speech (Thaut, 2014). In many patients with aphasia, overlearned musical phrases or songs can be used to stimulate spontaneous speech output. Thaut (2014) says that MUSTIM is an appropriate technique to select for patients who do not meet the criteria to be good candidates for melodic intonation therapy (MIT), due to decreased cognition, and can also be an appropriate follow-up technique for patients who are beginning to show increased functional language after MIT and are ready to increase their spontaneous output of speech. As you can see the definitions and applications of these NMT techniques are very standardized and leave little room for creativity and/or a patient centered approach. Using Thaut’s research and findings thus far, we have the potential to exponentially increase a patient’s progress post-traumatic brain injury by creating a holistic neuro-informed treatment plan. Kennelly et al. (2001) says that alongside vocal exercises, pre-composed song and song creation, improvised singing has been used in joint music and speech therapy interventions with children who have experienced TBI. Both song creation and improvisation are extremely taboo concepts in the field of neurologic music therapy.

However, combinations of music therapy techniques can be used especially with children recovering from traumatic brain injury, and joining music therapy approaches with elements of speech therapy can help to create interventions that meet the specific needs of children with speech/language dysfunction following TBI (Gilbertson, 2008).

Emotional expression/mood.

Music therapy has been suggested as a relevant therapeutic strategy in providing patients with traumatic brain injury with an adequate form of emotional expression (Gilbertson, 2008). This is especially important to consider in working with children and adolescents, as fluctuation of emotions and mood can often be much more pronounced than in an adult patient with the same diagnosis. Children and adolescents also often lack the emotion and mood regulation skills needed especially after suffering a traumatic brain injury. In many patients recovering from brain injury, a common side effect of the condition is agitation and anxiety. Based on my observations in a pediatric neuro-rehab setting this can be attributed to many things including realization of a new cognitive baseline, diminished use or complete loss of physical functions, and loss of independence. A study by (Tremblay, Lee & Rudy, 2016) showed the reduction in agitation of TBI patients occurred when their preferred music was being played. They proposed that preferred music elicits pleasing memories and positive emotions because preferred music is integrated into a person's life and chosen according to personal preferences. These positive memories and emotions might influence a reduction in agitation and improve a patient's ability to regulate mood and emotions. This can be explained by the neural mechanism underlying pleasant emotional responses to music. The use of preferred music in designing neuro-informed interventions can activate pleasant emotional responses such as increased activity of the ventral striatum, which is associated with reward and pleasure, and decreased activity in the amygdala,

which is known to be involved in fear and other negative emotions (Tremblay et al. 2016). As stated previously, addressing emotional expression and regulation in children and teens recovering from traumatic brain injury is a main focus in neuro-informed music therapy. The development of this method could benefit from more in-depth studies related to the effects of preferred music on mood and emotional expression in children and teens recovering from traumatic brain injury.

Involvement in rehabilitation.

Often, motivating children and teens to participate in therapies is one of the biggest hurdles to overcome. Although resistance is arguably a natural part of the therapeutic process, motivating a patient to participate in therapies is extremely important in a neuro-rehab setting. However, in a way recovery means performing, and being severely injured often means that getting engaged in activities is extremely challenging and confronting. Resistance to therapies especially in children and teens often comes from a feeling of performance anxiety and a fear of failure. One study described how a patient with previous musical experience but decreased ability as a result of traumatic brain injury, regained the ability to play music in a structured and rhythmically organized manner through music improvisation techniques (Jochims 1994). This author describes the patient as being more active and involved in music therapy than in all other therapies in the rehabilitation hospital. This implies that music therapy can offer patients the opportunity to behave differently in music therapy sessions compared to other situations and settings. This is of utmost importance in moving forward in the treatment plan and therapeutic process. Once a client-therapist relationship has been established and a level of trust built, music can be used in combination with other therapies to increase participation and engagement in the treatment process. In the neuro-informed method of music therapy, this means modifying

neurologic music therapy interventions, using preferred music or musical instruments, and collaborating with other therapies to achieve the rehabilitative goals of each patient.

Interpersonal aspects and independence.

Quite often when working in a hospital setting on a daily basis, the intra and interpersonal aspects of human experience are neglected, particularly in neurorehabilitation where physical and cognitive functioning may be severely impaired. By attending to the emotional and psychological state of these patients, music therapy can provide a balance for the dominating aspect of functional retraining of physical ability (Gilbertson, 2008). In this sense music therapy provides a balance to the overall rehabilitative treatment strategy. Additionally, Magee (1999) highlights that the social and emotional needs of the client are often seen as being less important than the more physical rehabilitative needs and certainly are more difficult to objectively measure. Magee, (1999) states that it is often immensely difficult to prove the value of this type of contact in a neurorehabilitation setting, except by attempting to incorporate more physical and functional goals within a music therapy treatment plan. In doing this, we can show the enormous additional potential for emotional neurorehabilitation that music therapy offers. Finally, identity and independence are also huge factors in rehabilitation from a traumatic brain injury. Following traumatic brain injury, many patients experience changes in their functional independence, for instance in terms of getting dressed, eating, drinking and other activities of daily living (ADLs). During neurorehabilitation, regaining independence and establishing a new normal can also contribute to establishing a new sense of identity. Gilbertson, (2008) points out that many music therapy approaches have been used successfully to assist the redevelopment of self-identity, encourage a sense of individuality, or create a new identity following physical and emotional trauma.

Neuroplasticity in Children and Adolescents

Focusing specifically on children and adolescents in neuro-informed music therapy is a unique and exciting opportunity because of the extreme plasticity and resilience of a child's brain. Research in the field of neuroscience and genetics has given us great insight into the understanding of learning and behavior and changes in the brain in response to experience. It is seen that the brain is dynamically changing throughout life and is capable of learning at any time, however, plasticity of the brain is maximal in the early years of life (Mundkur, 2005.) Specifically related to neurorehabilitation, the brain has the ability to reorganize itself after neurological trauma to re-enable function. This basic idea is referred to as the neuro-plasticity theory, and means that new connections in the brain can be used to complete tasks that are initially unable to be completed by the patient post-injury or that undamaged parts of the brain may take over functions from damaged areas (Kolb & Whishaw, 2004). The human brain is not fully mature until at least twenty years old. Additionally, during this long period of development, the human brain is highly dependent on and is modified and shaped by experience. This extreme plasticity of the brain is also maximal during critical periods. A critical period is a period during which some crucial experience such as a brain injury has an effect on normal development or learning resulting in a required change in neuro-connectivity (Mundkur, 2005). As it relates to traumatic brain injury, this critical period generally lasts about six months and has become the standard window of time for maximum rehabilitation potential. In children and adolescents as the brain continues to actively develop, learn, and create new neuropathways, its neuroplasticity capabilities are heightened allowing for faster set-shifting, reorganization, and rehabilitation during this critical period. This explains the fact that children and adolescents are able to recover

from head injury much better than adults, and that the recovery of functions is much more complete.

Tri-pronged Neuro-informed Approach

Daveson (2008) states that changes to therapy services in healthcare are constantly shaped and driven by government and professional requirements and recently, the need for adaptable models of music therapy within neuro-disability and neurorehabilitation have been extremely prevalent. Additionally, the Department of Health has emphasized the need for patient-led and patient-centered care, which is a core aspect of neuro-informed music therapy as a developing method. Neuro-informed music therapy uses a tri-pronged approach in order to achieve this model of patient-centered care consisting of three treatment domains: rehabilitative, compensatory, and psycho-social-emotional approaches. Each approach uses research in the field of neuroscience to inform treatment plans and goals in each area. The rationale for the need for such a multi-pronged approach is that patients with brain injury and neuro-degenerative disease can present with various types of needs at one point in time and that such complexity of need cannot always be met through the use of one music therapy model (Jochims, 2004). This is also the case with traumatic brain injury or neuro-degenerative diseases. As a result of a patient's injury or disease, changes may occur in many areas including cognitive, behavioral, psychological, emotional, communication and physical realms.

Rehabilitative approach.

The rehabilitative approach to neuro-informed music therapy aims to restore function toward a level that is similar or close to the level of functioning prior to injury (Daveson, 2008.) Generally, the rehabilitative approach is driven by the belief that music is able to assist with restoring function through the use of the neurological, information-processing, and sensory

components involved when music is used (Daveson, 2008.) Neurologic music therapy (NMT) focuses mainly on this approach and many of the standardized exercises are restorative in nature. However, as is also the case with many NMT exercises, the rehabilitative approach is most useful with patients who have active rehabilitation goals, are responding to and engaging with their treatment team and therapists, and are assessed as most probable to make functional gains (Daveson, 2008). This approach is characterized by frequent sessions that require the patient to actively participate in the achievement of goals, and is usually also characterized by co-treatments with other therapies such as occupational therapy (OT), physical therapy (PT), and speech-language pathology (SLP). If a patient does not meet the ideal profile for a rehabilitative approach to music therapy, NMT techniques are mostly out of the question. However, with a tri-pronged neuro-informed approach to music therapy there are other aspects of a patient's rehabilitation process that can be addressed.

Compensatory approach.

The compensatory approach involves the music therapist working with the patient to develop strategies that compensate for losses that have occurred due to change in neurologic baseline. The compensatory approach is useful in assisting those with neuro-degenerative disease to compensate for losses due to disease progression, such as deterioration that occurs throughout Huntington's disease (Daveson, 2008.) However, this model could also be used with a patient after a significant traumatic brain injury where the patient is experiencing a change in functionality and/or ability from their previous baseline. Although complete or even partial rehabilitation of ADLs may not be possible for these patients, using music to access the undamaged parts of a patient's brain can help them to achieve goals in areas such as communication, identity, expression, and emotion regulation. This compensatory approach is

informed by research and clinical work that has reported benefits in the field of neuro-disability in achieving various outcomes, including the maintenance of skills in some areas despite overall decline in function, communication and social relationship maintenance, the use of music to lift mood despite physical decline or loss of ability

Psycho-social-emotional approach.

The psycho-social-emotional approach to neuro-informed music therapy stems from an understanding of the use of music to convey emotions, alter emotions, enable socialization and social skill development, and shape psychological functioning. The psycho-social-emotional approach is most useful with patients who are less willing to participate in restorative and compensatory opportunities or cannot engage in rehabilitation due to psychological, social or emotional complications. It is also very useful to those who have psycho-social-emotional needs that are related to their neuro-disability and can be addressed during the length of their stay at the hospital, or transferred to outpatient for a continuum of care (Magee & Davidson, 2002). The ability music has to impact many areas of the brain simultaneously is particularly useful in a psycho-social-emotional approach to neuro-informed music therapy. Levitin (2007) says the emotions we experience in response to music involve structures deep in the primitive, reptilian regions of the cerebellar vermis, and the amygdala—the heart of emotional processing in the brain. Music can evoke a wide variety of strong emotions, including joy, sadness, fear, and peacefulness or tranquility. Furthermore, if a patient's preferred music is taken into consideration, there is a potential for additional psychological benefits. A study done by Levitin (2013) shows that listening to preferred music initiates brainstem responses that, in turn, regulate heart rate, pulse, blood pressure, body temperature, and muscle tension via noradrenergic neurons that regulate cholinergic and dopaminergic neurotransmission. More simply put, when

preferred music is heard and processed in the pleasure and reward centers of the brain, it causes increased production of neurotransmitters we know as endorphins such as dopamine, serotonin and cortisol. This is vitally important to consider in creating a holistic and patient-centered approach to neuro-informed music therapy because it may allow the therapist to improve and increase rehabilitation results by using a patient's preferred music.

Methods

Participant

Gretta (Pseudonym) is a previously healthy 17-year-old young woman who was an unrestrained passenger in a roll-over motor vehicle accident in August, 2019. She presents with a diffuse axonal traumatic brain injury (TBI), multiple intracranial hemorrhages, rotational malalignment of C1 and C2, bilateral subluxation of the atlantooccipital joints, and fractures of the pelvis, ribs, right upper extremities, clavicle and spine. She has a long-term history of depression including non-suicidal self-injury and multiple suicide attempts. Social history is significant for neglect in early childhood as well as exposure to domestic violence. She is currently under Maine Department of Health and Human Services (DHHS) custody and has been in the foster care system since sixth grade. Gretta reported that she has been depressed for as long as she can remember and also has a history of non-suicidal self-injury starting at age 13 or 14. This transitioned to body piercings, including piercing her gums down to the roots of her teeth. She has a history of suicide attempts at around age 12 or 14. She also has a history of drug use, including an overdose approximately a year and a half ago. According to medical records, she has a previous diagnosis of anxiety and a prescription for an anti-anxiety medication. Gretta was born with Marcus Gunn Jaw-Winking syndrome, which includes ptosis of the right eye. Her left peripheral vision has always been poor, but she has been able to compensate for this through

tilting her head. Due to her visual difficulties, she has always had trouble walking down stairs and would sometimes fall when walking down a new stairway. She also had difficulty playing sports.

Clinically speaking, Gretta has made significant progress with her recovery from her brain injury and will likely continue to make gains over the next number of months, at which point she will continue to improve but her rate of progress will begin to slow down. This is due to the previously mentioned critical period for rehabilitation post-TBI. Although we do not know at what point her recovery will begin to slow down, nor the extent of any other deficits, many young adults with injuries as extensive as hers do have some residual, long-standing difficulties, particularly in the area of new learning and memory. While they can learn new information, they often require more time, repetition, and practice than their uninjured peers (Kolb & Whishaw, 2004). Gretta's brain is still maturing, and while this is optimal for neuroplasticity and neurorehabilitation, problems may arise at later points when yet-to-be-developed skills would be expected to emerge. Gretta's neurocognitive deficits are predicted to be an ongoing clinical theme in her life. As more is expected in adult life, those with injuries such as Gretta's sometimes discover that aspects of the injury not apparent at her current stage may affect skills needed later (Kolb & Whishaw, 2004). This being said, it is important to continue to monitor her progress over the coming years to ensure that she is receiving the kinds of support and intervention that will allow her to develop to her potential. It is also important to take advantage of this current phase of rapid progress to work on regaining lost knowledge and skills correctly and to learn strategies for compensating for deficits and for learning new information.

Neuro-informed Music Therapy Treatment Plan

Based on the information provided above, it is clear that the patient was in need of a holistic treatment plan that took into consideration all of her pre-and-post-accident obstacles. The idea for developing this patient's treatment was to look at what existing research in the field of neuroscience says about the brain's connection to music, as well as previously established neurologic music therapy techniques in order to create holistic patient-specific rehabilitation goals. Considering the patient's history and current presenting problems, a series of specific neuro-informed music therapy goals were set and addressed in a six-week treatment plan prior to the patient's planned discharge. The six sessions outlined in this plan took place in a Boston area children's hospital both in the patient's room on the inpatient medical units as well as in the physical therapy gym in the outpatient therapies portion of the hospital. All gait sessions were co-treatments with physical therapy and therefore took place in the PT gym or outside in an attempt to simulate more realistic obstacles. Length of sessions varied slightly. Most sessions were one hour with the exception of the initial gait sessions that were only 30-45 minutes before being increased to an hour to meet gait improvement goals. All sessions were one-on-one sessions with the exception of gait sessions which were co-treatments with a physical therapist.

The sessions in this treatment plan were set to be the final six sessions before discharge for this patient. Upon discharge, the patient was slated to move on to a post-acute TBI rehab facility. However, due to complications and restrictions surrounding the Coronavirus (COVID-19), the hospital was unable to discharge her to this care facility. Therefore, Gretta remains at the Boston area children's hospital until these restrictions are lifted. The sessions were documented in detail via MediTech notes by the music therapy intern as well as any additional notes from co-treating therapists, and all sessions were under the additional supervision of a licensed music

therapist. The goals addressed by neuro-informed music therapy for this patient were increased emotional expression, improved emotional regulation, improved gait and balance, increased respiratory strength, and improved intelligibility of speech. These goals were addressed holistically throughout the six-week treatment plan.

Session #1 directive/goal addressed: gait and balance.

Rationale.

based on Gretta's rehabilitation progress up to this point, improving strength and endurance of gait was one of the most important goals for her successful transition back into the community. At the time of this session Gretta presented with an uneven gait pattern due to impaired activation of her left lower extremity (LLE). Using music with a consistent rhythmic pattern helped to establish a positive feedback loop in Gretta's brain as she entrained to the music. Implementing this intervention first and continuing it over the course of the six-weeks worked to build strength and endurance as well as improve balance and cadence of Gretta's gait. Materials used in this session were guitar, metronome/headphones, gait belt and walker.

Outline of the session.

This session took place in the physical therapy gym and was a co-treatment with Gretta's physical therapist. Gretta transitioned from her room on the inpatient medical unit down to the gym which took about 10 minutes as was anticipated based on previous duration of similar transitions. Gretta was transported via wheelchair for this session in the interest of time and preventing fatigue. Once in the PT gym, Gretta was asked to walk the length of the gym (100ft) with her walker, PT with contact guard/minimum assistance, and no rhythmic musical cuing. The music therapist assessed the approximate baseline speed of Gretta's gait using a metronome and headphones. Once she has reached the end of the gym, Gretta was asked to walk back and the

music therapist provided gait assistive musical cuing using a guitar and walking (backwards) in front of Gretta. This continued for approximately 10 minutes. At this point the music therapist stopped the musical cuing and assessed any progress/improvements in gait. Gretta transitioned back to her wheelchair and was transported back to her room.

Session #2 directive/goal addressed: increasing emotional expression, improve intelligibility of speech, increase respiratory strength.

Rationale.

Based on results of neuropsychological testing, Gretta showed clinically significant symptoms related to her emotional/behavioral functioning including intrusive thoughts related to past negative events, feelings of sadness, anger, and worry, fear of the dark, and sensation seeking behaviors. Additionally, there were concerns related to interpersonal relationships, self-esteem, and self-reliance. Identifying and expressing these emotions verbally can be very intimidating, and the goal was to increase the brain's capacity to identify, process and express emotions by using preferred prerecorded music. Additionally, the idea to conduct this session as a "karaoke" session allowed the therapist to address speech and respiratory goals as well. Materials used in this session were ipad, speaker/microphone, appropriate cables.

Outline of the session.

Often, motivating children and adolescents to participate in therapies is one of the biggest hurdles to overcome. That being said, I attempted to make this session fun and motivating for Gretta while also addressing many of her rehab and therapeutic goals. This session was set up as a "Karaoke" session in Gretta's room, and she was able to invite whoever she wanted from her treatment team as well as other kids on the unit. This helped Gretta address goals related to interpersonal relationships and self-esteem. Gretta was asked to choose up to three songs to sing

in karaoke. She was not prompted to choose music based on her current mood, but instead at the end of the session she was asked to briefly analyze why she chose those songs and why/how she related to them. Because this is a holistic approach and treatment plan, often more than one goal is addressed in each session. An additional goal addressed in this session is that of building respiratory strength. Post-decannulation, most children and adults struggle to rebuild respiratory strength. By singing and “belting” preferred songs in karaoke, Gretta was able to work on respiratory strength and vocal projection. Finally, with each song Gretta chose and sang she improved her oral motor control allowing her to work towards improved intelligibility of speech.

Session #3 directive/goal addressed: gait and balance w/o assistive device.

Rationale.

As Gretta’s gait strength, speed, and endurance increased, we transitioned from walking with an assistive device (walker) to walking independently with only contact guard from PT. The positive feedback loop created in the last session when Gretta entrained to the preferred music played by the music therapist will allow her to make more rapid and substantial progress each session. Additionally, it is important to note the significance of the therapist providing live music on guitar as opposed to pre-recorded versions of the songs. This allows the therapist to control the tempo and cadence of the song, increasing these elements as appropriate to match Gretta’s progress even over the course of a single session. Materials used in this session were guitar, metronome/headphones, gait belt.

Outline of the session.

This session was increased in duration to one hour and took place in the PT gym. Gretta was once again transported to the gym via wheelchair. During this session, Gretta was asked to walk the length of the gym without a walker and without musical cuing before the music therapist

began the intervention, so speed and cadence baseline could be re-assessed. The gait assistive musical cuing was implemented in the same manner as last session but continued for 20 minutes, increasing in duration by 10 minutes from previous session. Gretta transitioned back to her wheelchair and returned to her room.

Session #4 directive/goal addressed: songwriting for emotional expression.

Rationale.

Songwriting is a great tool for promoting emotional expression because it allows the client to let the music reflect their mood and feelings. This intervention can be implemented in various ways ranging from very structured to quite open with minimal directive. Songwriting can provide the client with a sense of accomplishment and provides them with a tool and emotional coping strategy for the future. Additionally, from a neuro-informed lens, the frontal lobe is most prominently involved in critical thinking, decision making, and planning. This area of the brain is extremely engaged in the songwriting process, promoting growth and rehabilitation in these neurologic functions. Materials used in this session were piano, iPad or other recording device, paper or tablet to write lyrics, other rhythm instruments to accompany when desired.

Outline of the session.

This session took place in Gretta's room on the inpatient medical rehabilitation unit. Based on Gretta's age and cognitive functioning, using a very structured approach could potentially have been too limiting. Therefore, the following process was used:

1. Identify a theme (love, moving on/forward, self-confidence etc).
2. Identify the elements of a song (Melody, harmony, rhythm, words).
3. Choose a key (major or minor) this directly reflects the client's mood.
4. Write lyrics in poem form.

5. Therapist provided chordal structure on piano while client explored putting the poem into song form.

This structure required the therapist to be constantly reading cues from the client and adjust music accordingly. At the end of the 45-minute session, Gretta was given the option to record the song she wrote, and chose to do so on the iPad provided.

Session #5 directive/goal addressed: gait and balance (community based).

Rationale.

This session was a community based gait session in preparation for Gretta's transition back into society. This means that Gretta was asked to go outside the hospital and navigate situations she may experience on a daily basis. Although Gretta has been making great progress in gait sessions in the hospital setting, the purpose of this was to help her apply these skills to real life situations. This included uneven surfaces, environmental distractions, and other uncontrollable external factors. Materials used in this session were guitar, metronome/headphones, walker/gait belt.

Outline of the session.

This session took place outside of the hospital in an enclosed adaptive playground. The session duration was increased to one hour and 15 minutes from previous one hour session. Gretta transitioned from her room on the medical unit out to the playground which took about 10 minutes. Gretta was transported by wheelchair to the playground. As per usual, the playground was occupied by several other children and/or families, meaning there was no need to simulate environmental distractions as they were already in place. Gretta was asked to complete a series of tasks without her walker and with the assistance of musical cuing from the music therapist:

1. Walk up and down a handicap ramp three times.

2. Walk across an uneven surface three times.
3. Navigate a path that includes one step (two times down and two times back).
4. Complete each of these tasks one time each without musical cuing.

The total time spent outside completing the tasks was about 45 minutes. Gretta then returned to her wheelchair and was transported back to her room. The walker was available to Gretta only if she showed great difficulty in completing one or more task without assistive device. The walker was not needed and she was able to complete all tasks without an assistive device. Contact guard from PT was in place at all times. Due to the strengthening of newly formed neuropathways established in previous gait sessions, Gretta was able to add and successfully process other external factors and distractions, which will be crucial for her success outside the hospital.

Session #6 directive/Goal addressed: Improved emotional regulation (anti-anxiety playlist).

Rationale.

This was a vital step in Gretta's treatment plan, as it gave her the tools she needed to regulate her anxiety and emotions as she transitioned out of the hospital setting and back into the community. Gretta was still experiencing significant symptoms of anxiety and a fair amount of distress that made her susceptible to depression. Creating an anti-anxiety playlist provided her with a coping strategy for when these symptoms arise. Additionally, given that Gretta was in a motor vehicle accident, it is likely that there will continue to be a lot of anxiety surrounding transportation. If Gretta could come up with a playlist effective in reducing her anxiety, it would help regulate her in these situations among others. Materials used in this session were an ipad or personal music listening device.

Outline of the session.

This session took place in Gretta's room on the inpatient medical unit. This was a one-on-one session with only Gretta and the music therapist. This was as much a talk therapy and termination session as it was a session used to create a playlist. This is important to consider in a holistic neuro-informed approach given that the goal is to treat the whole patient from a neuro-informed lens. This is an element of treatment that does not exist in traditional neurologic music therapy, but is extremely beneficial and crucial in neurorehabilitation. During the session, the therapist helped to brainstorm anxiety provoking situations and songs that could relate to those situations, talked through them, and added them to the playlist. Situations covered in this conversation included:

1. Transportation via motor vehicle.
2. Social anxiety.
3. Anxiety related to self-image, self-worth, and self-confidence.
4. Anxiety regarding family, occupation and professional life.

The therapist suggested that this was a tool that could constantly change and develop to fit Gretta's needs as she transitioned back into the community. Again, considering the functions of the frontal lobe and amygdala, responsible for processing emotion, it is extremely important that Gretta have these tools especially as her brain continues to recover post-discharge.

Results**Rehabilitative**

Results for neuro-informed rehabilitative goals were determined by comparing the patient's baseline at the beginning and end of each session. It is important to note that due to Gretta's social anxiety, participation in therapies was often a challenge. However, given that

Gretta was able to incorporate her preferred music into gait and balance sessions, she was both motivated and excited to participate each week. Gretta reported that being included in the process of choosing a song and structuring each session made her feel an increased sense of independence and autonomy leading to a higher level of motivation to participate. Gretta's gait speed increased from 62 beats-per-minute (bpm) at the beginning of the first gait and balance session, to 87 bpm at the end of the final gait and balance session. This remained consistent with the incorporation of environmental distractions and the removal of assistive devices, showing an overall increase in balance from Gretta's initial presentation. Gretta also showed gains in respiratory strength and speech intelligibility. By the end of treatment, Gretta was able to sustain a pitch for up to five seconds, increased from just over one second at the beginning of the first session. Gretta's speech intelligibility improved significantly as she worked on oral motor control singing preferred songs during karaoke.

Compensatory

Many of Gretta's rehabilitative goals were accompanied by compensatory components as new baselines for her ADLs were established. This compensatory approach can also be used when Gretta has achieved many of her rehabilitative goals or her potential for further rehabilitation is significantly diminished. During assessment, the music therapist identified that Gretta's speech intelligibility was severely compromised and that withdrawal from social contact was a risk, as was isolation and low mood. In music therapy sessions, Gretta was able to express herself via improvisation and playing preferred songs, choose moods and themes to improvise upon, and experience a lift and consolidation of mood as a result of music-making (as verified through the use of self-report measures). Gretta's compensatory work enabled her to increase expression of feelings and mood through the use of music, despite deterioration of verbal and physical abilities.

Psycho-social-emotional

Psycho-social-emotional goals comprised a large part of Gretta's treatment plan. As previously highlighted in the participant introduction, Gretta has had a challenging life. In early childhood she experienced neglect, witnessed domestic violence, and subsequently multiple moves and changes of caretaker with her family. Since sixth grade, she has been in foster care. She reports having been depressed ever since she can remember and has a history of multiple suicide attempts as well as non-suicidal self-injury. She also has a history of engaging in risky behaviors, including drug use that resulted in an overdose. Despite all these challenges prior to her accident, she was an accomplished, high-achieving student who was taking advanced classes while holding a job. Gretta's psycho-social-emotional results were measured based on self-report and clinician observation. By creating an anti-anxiety playlist, Gretta reported that she felt a sense of comfort and security having this tool, while also maintaining a sense of autonomy by being in control of the songs on the playlist. Gretta also reported that using music to gather people and start a conversation in a social setting made it easier to develop interpersonal relationships, and help to ease the social anxiety that had increased as a result of her new cognitive baseline. Gretta reported that she especially enjoyed the songwriting activity and learning to play simple melodies on the piano, and was hoping to explore this further upon discharge.

Discussion

Gretta has made significant progress with her recovery from her traumatic brain injury and as previously mentioned she will likely continue to make gains over the next number of months, at which point she will continue to improve but her rate of progress will begin to slow down. Further cognitive recovery will continue over the following 12 to 18 months or longer, but at an extremely reduced rate. Gretta has responded particularly well to music therapy and it would be extremely

beneficial for her to continue receiving services once she is discharged from the hospital. In addition to achieving physiological rehabilitative milestones, Gretta has acquired new tools for emotional expression and regulation that can continue to help her move in a positive direction. Particularly important to consider is Gretta's history with unhealthy drug use. Both the physiological and psychological pain associated with recovering from a traumatic brain injury and re-integrating into society can put a patient at risk for self-medicating after discharge. In Gretta's case it would be very easy to revert to the drug use that has previously provided her with emotional and physical relief. However, given the tools she acquired in music therapy sessions, Gretta may be less likely to engage in this risky behavior. Although music therapy interventions are not always quantitatively measurable, the promise of music-based treatments is that they are noninvasive, have minimal or no side effects, are inexpensive, convenient, and completely natural (Levitin, 2006). This eliminates the possibility for developing dependence on a drug or falling back into an unhealthy addictive lifestyle.

In a neuro-informed music therapy treatment plan it is important to always think holistically and keep the patient at the center of every decision regarding their care. Take for example Gretta's self-reported interest in furthering her newly acquired piano skills. This statement was made while calculating Gretta's psycho-social-emotional results, however, continuing to incorporate piano into music therapy sessions could also significantly improve Gretta's finger dexterity, motor planning and executive functioning. Similarly, it is important to highlight the consistent element of choice throughout Gretta's treatment plan. Given what we know about her volatile past in and out of the foster care system, it is likely that Gretta had little control over significant life changes and events. During rehabilitation in an extremely structured medical environment, providing Gretta with some autonomy in her treatment plan allows her to

develop trust and interpersonal relationships while working towards specific neuro-rehabilitative goals.

Conclusion

Claims about the healing power of music are found in many pre-industrial societies and in ancient Greece (Levitin, 2013). However, if the notion of music as medicine is to be taken literally, it is crucial that we collaborate within the field of music therapy to establish this concept. This is not to discredit the scientifically proven techniques specific to neurologic music therapy (NMT), but instead to suggest an additional method grounded in neuroscience and neurochemistry that uses research in these areas to provide holistic neuro-informed patient centered care. The healing power of music knows no borders, holds no biases and does not discriminate. We as music therapists, the helpers and healers ourselves, should attempt to mirror these qualities in our work. As a child, beginning my lifelong love affair with music, my grandfather R.D. Mooney impressed upon me that we as musicians hold a gift, a universal language and an art form that transcends the often-unspoken shortcomings of human nature. In an attempt to come full circle, I want to revisit and acknowledge the use of 'holistic' in a method that seems so scientifically based. This method may be grounded in neuroscience and based on scientific research but the unifying factor, the 'active ingredient' if you will, is music. Music is science, music is math, music is history and physical education. Music develops insight and demand research. Music is all of these things but most of all, music is art. In the words of my grandfather, that is why we use music; not because we expect you to major in music, or because we expect you to play and sing all your life...But so you will be human, so you will recognize beauty, so you will be closer to an infinite beyond this world. So you will have something to cling to, so you will have more love, more compassion, more gentleness, more good, and in short, more life (Mooney, 1969).

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THESIS APPROVAL FORM

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In the judgment of the following signatory this thesis meets the academic standards that have been established for the above degree.

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