

**Evaluating Therapeutic Instrumental Music Performance (TIMP) as a form of Upper
Limb Mobility Rehabilitation for Various Disorders and Neurological Diseases:
A Proof of Concept Feasibility Study**

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Acknowledgements

I would like to thank my mentor, Dr. Concetta Tomaino, for her support throughout this research project, as well as guiding me through the process after. I would also like to thank the music therapist, Sheri Aronowitz, for her support during the study's interventions. Additionally, I would like to share my gratitude to staff and volunteers at Wartburg Nursing Care. Lastly, I would like to thank my parents and Mrs. Evangelista for their continued backing of my research journey.

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Abstract

Gross motor impairments are common after strokes, neurological diseases, and severe injuries. With varying therapies possible for patients, music therapy stands out with an effect of increasing motivation in patients during the therapy intervention. Therapeutic Instrumental Music Performance (TIMP) has provided patients with a form of rehabilitation that supplies both physical rehabilitation as well as psychological support. TIMP facilitates upper limb movement in patients using basic technique of percussion instruments. 4 patients received Therapeutic Instrumental Music Performance from a therapist individually 3 times per week for 30 minutes each. The sessions were scheduled, continued for 6 weeks, with each patient receiving a total of 18 interventions. Response to the intervention resulted in all 4 patients improving in measurements compared to the baseline of the Nine Hole Peg Test, Range of Motion Evaluation, and the *Garageband* Velocity Measure. Patients with the lowest ability to complete the tests developed the greatest improvement in measurements from the interventions. Findings from this study suggest that patients who have dealt with a neurological disease for longer than 2 years may find improved motor skills from participating in Therapeutic Instrumental Music Performance following some form of active rehabilitation.

Introduction

Gross motor impairments are common after strokes, neurological diseases, and severe injuries. Stroke is the sudden death of brain cells due to the lack of oxygen, caused by blockage of blood flow or rupture of an artery to the brain. Loss of speech, weakness, or paralysis of one side of the body can be early symptoms of an apparent stroke. More than 750,000 people suffer from a stroke each year in the United States and greater than 75% of this population are aged 65 years or older (National Stroke Association, 2017). Prominent forms of stroke include ischemia, which is caused by inadequate blood supply to an organ or part of the body, especially the heart muscles, and hemiplegia, which causes paralysis to one side of the body. 80% of stroke victims experience Hemiplegia. When a stroke is present, there is a loss of control over movement/muscle. This prevents the correct use of everyday objects and movements (American Stroke Association, 2017). As this can hinder everyday activities, patients that suffer from a stroke become reliant on another relative or caretaker to complete daily tasks. Limb immobility can also be caused by other forms of neurological diseases, including Parkinson's Disease, Multiple Sclerosis, post-stroke Dementia, Spinal Cord injuries, Hypoxic brain damage, Cerebral Palsy, and Spina Bifida (Tolea et al., 2017) (Thaut et al., 2014). This prohibits patients from completing activities of daily living and may have a need for a form of rehabilitation.

Recovery plans from neurological diseases include rehabilitation therapies including Rehabilitation Nursing, Physical Therapy, Occupational Therapy, and Recreational Therapy (American Stroke Association, 2017). These therapeutic options offer reliable, well-funded, and sustainable programs for patients to enroll in. Many therapy types lack an incentive or fail to provide motivation, thus proven to be less successful psychologically on patients (Raghavan et al., 2016). Music Therapy fills this void by offering an engaging alternative for neurological rehabilitation (Street et al., 2018). To help with lower motivational levels of patients under a physical therapy program, patients receive psychotherapy on separate days. This setup of separate therapies has resulted in patients exhibit traits of depression, anxiety,

social isolation, and increased mood changes (Yoo, 2018). Music Therapy combines the disciplinary ideas of the two subsequent forms of therapy by focusing on physical and psychological improvement at the same time (Raghavan et al., 2016).

As for upper limb rehabilitation, Music Therapy supplements the combination of practical muscle movement, seen in physical therapy, as well as psychological connection development. Therapeutic Instrumental Music Performance (TIMP), a form of music therapy, is a motor and muscle-based rehabilitation that utilizes instruments in facilitating limb movement (Yoo, 2009). The design of this rehabilitation program was for practical use of motor movement to supply the daily movements used by patients. The intended purpose of this technique is to engage participants in playing music, thus initiating spontaneous motor movement to improve overall daily activity and quality of life (Yoo, 2018). Therapeutic Instrumental Music Performance utilizes percussive instruments, as these have shown to have the most practical and beneficial use for improving gross motor and fine motor skills. The combination of auditory music cues while patients create rhythmic patterns along to it builds the muscle plasticity needed to strengthen functional movements (Lim et al., 2011). As this process develops, the auditory response by patients also stimulates the more spontaneous movements during the intervention and outside therapy sessions (Street et al., 2015).

Statement of Purpose

This study sought to find the efficiency of utilizing Therapeutic Instrumental Music Performance as a form of rehabilitation for various neurological diseases that created a need for upper limb recovery. Despite recent studies demonstrating the effectiveness of music therapy, it is not a reimbursable treatment for neurological rehabilitation. TIMP has not been tested as a recovery format for neurological diseases other than stroke. It was hypothesized that the patients undergoing progressive rehabilitation of TIMP would improve overall upper limb movement, sensory motion, and well-being in patients recovering from impairment of upper limb mobility.

Methodology

Patient Selection and Study Overview

Patients were selected in this study by the supervising mentor, and the student researcher. Patients were selected for this therapy program from the Wartburg Nursing Facility's Adult Day Care Program. The supervising mentor, in coordination with the director of the ADC, created a list of patients that suffered from a neurological disease that affected upper limb mobility; this list included contact information for the student researcher to contact as well as each patient's schedule at the ADC. The student researcher selected 15 possible patients based on their schedule as well as the current therapy they were undergoing. Each patient was contacted and provided an overview of the study program and what they would experience during the therapy intervention. Patients voluntarily accepted this invitation of participation, totaling to 4 patients that fit the inclusion criteria as well as having an interest in participating. Each participant was sent an informed consent form to completely confirm their participation in this program. Refer to table 1 to view the patient demographic of the 4 participants in the study.

Table 1. Patient Demographic

| | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|-------------------------------|----------------------------|--------------------------------|--------------------------------|-------------------------------|
| Age | ~55 | ~70 | ~60 | ~80 |
| Neurological Disorder(s) | Cerebral Palsy Dementia | Multiple Sclerosis Dementia | Developmental Delay MMRD | Hemiplegic Stroke Dementia |
| Time following rehabilitation | 2 Years | 6 Years | 3 Years | 2.5 Years |
| Gender | Female | Male | Male | Female |

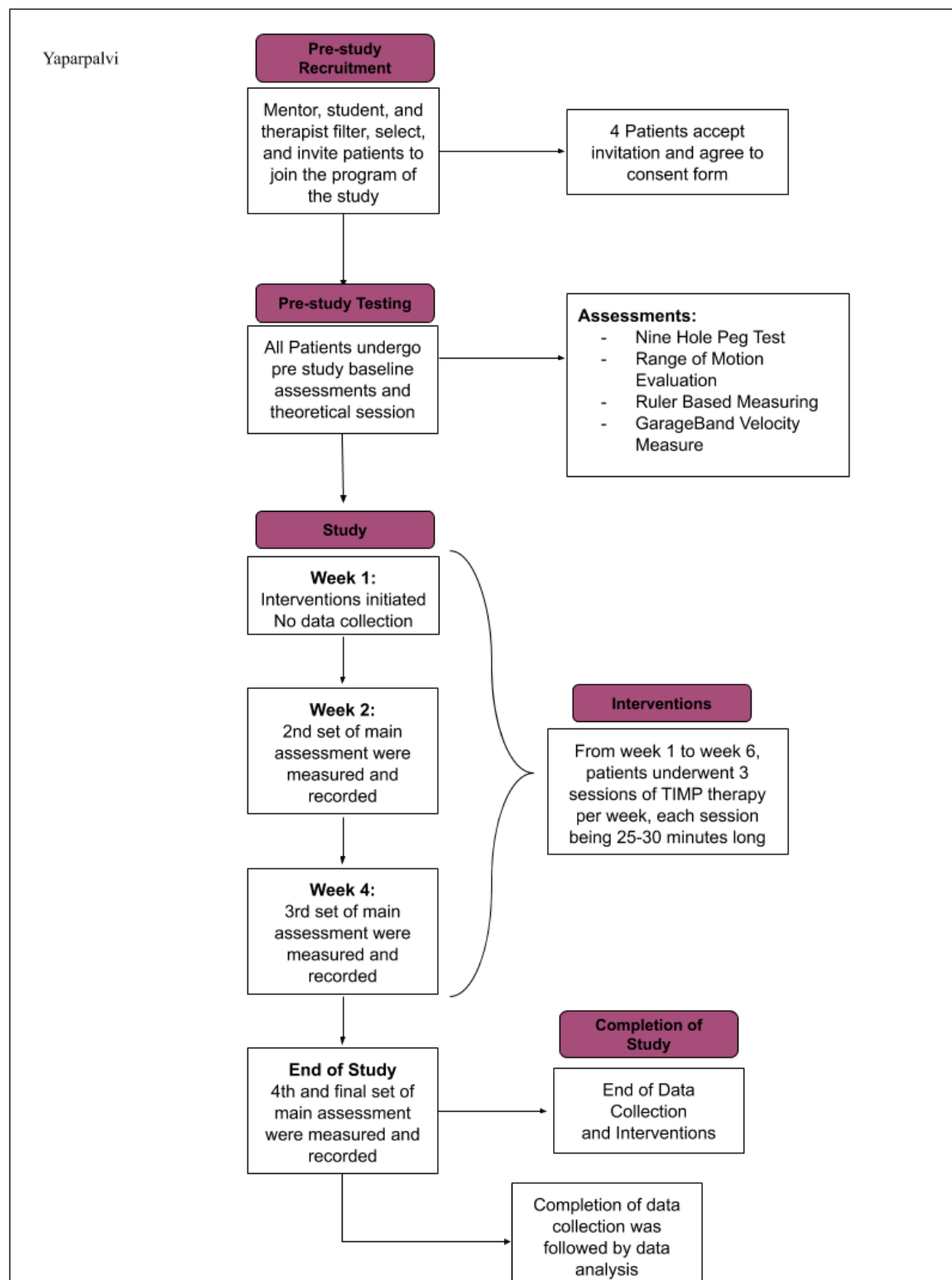


Figure 1. Flow chart outlining the step-by-step process of the study, including data collection points and start and finish of interventions

Intervention Overview

The 4 patients underwent 18 TIMP interventions over 6 weeks. Based on their schedule, each patient received 3 sessions per week that lasted approximately 25-30 minutes long. Assessments were taken prior, throughout, and after the time of these interventions (Figure 1). The certified music therapist and the patient met in a professional therapy studio in the rehabilitation center, setup with the equipment and technology used for each session.

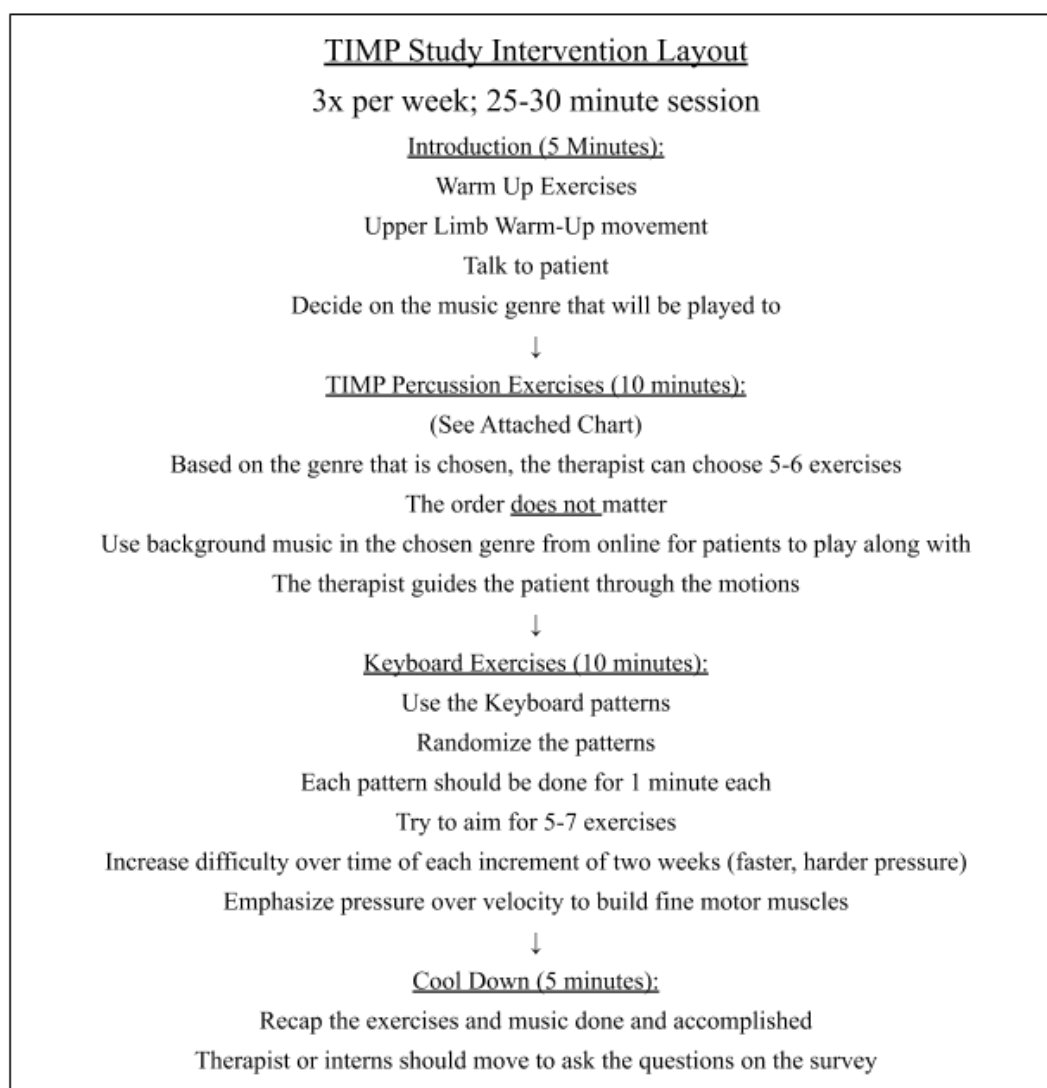


Figure 2. An intervention layout of the used process for the sessions for each patient

Warmup/Beginning

The therapy interventions were carried out by a current Music Therapy student. At the beginning of the intervention, the therapist warmed up the movement of the patient by involving the patient in simple music exercises. These exercises included simple drumming, repeated note beating, clapping, or listening to music. Then the therapist introduced the music and exercises the therapist and patient would be playing during the certain intervention.

Percussion Exercises

The patients were introduced to each exercise by the therapist. Listed below (Figure 2.) are certain exercises that were used in the intervention, based on the physical ability of the patient. Some exercises are listed for 2 patients but can be substituted by having the therapist play the role of the 2nd patient. Also, some exercises require an instrument that may need to be adjusted or substituted based on the physical ability of the patient. These exercises were performed for 1-2 minutes each for 10 minutes in total. The order of exercises did not matter as all of the exercises were around the same level of difficulty. The therapist either accompanied the patient with background music or put on accompanying background music. Background music for this section was chosen by the student researcher and therapist in collaboration by compiling a list of pieces based on the average speed of the song, in beats per minute (bpm). Based on the difficulty of the exercise for each specific patient, the therapist chose a song that was challenging yet suitable for the intended arm motion and ideal arm fluidity during the motion of the exercise. While the exercise was performed, the therapist watched over and guided the patient as they went through the motion of the exercise for the allotted time.

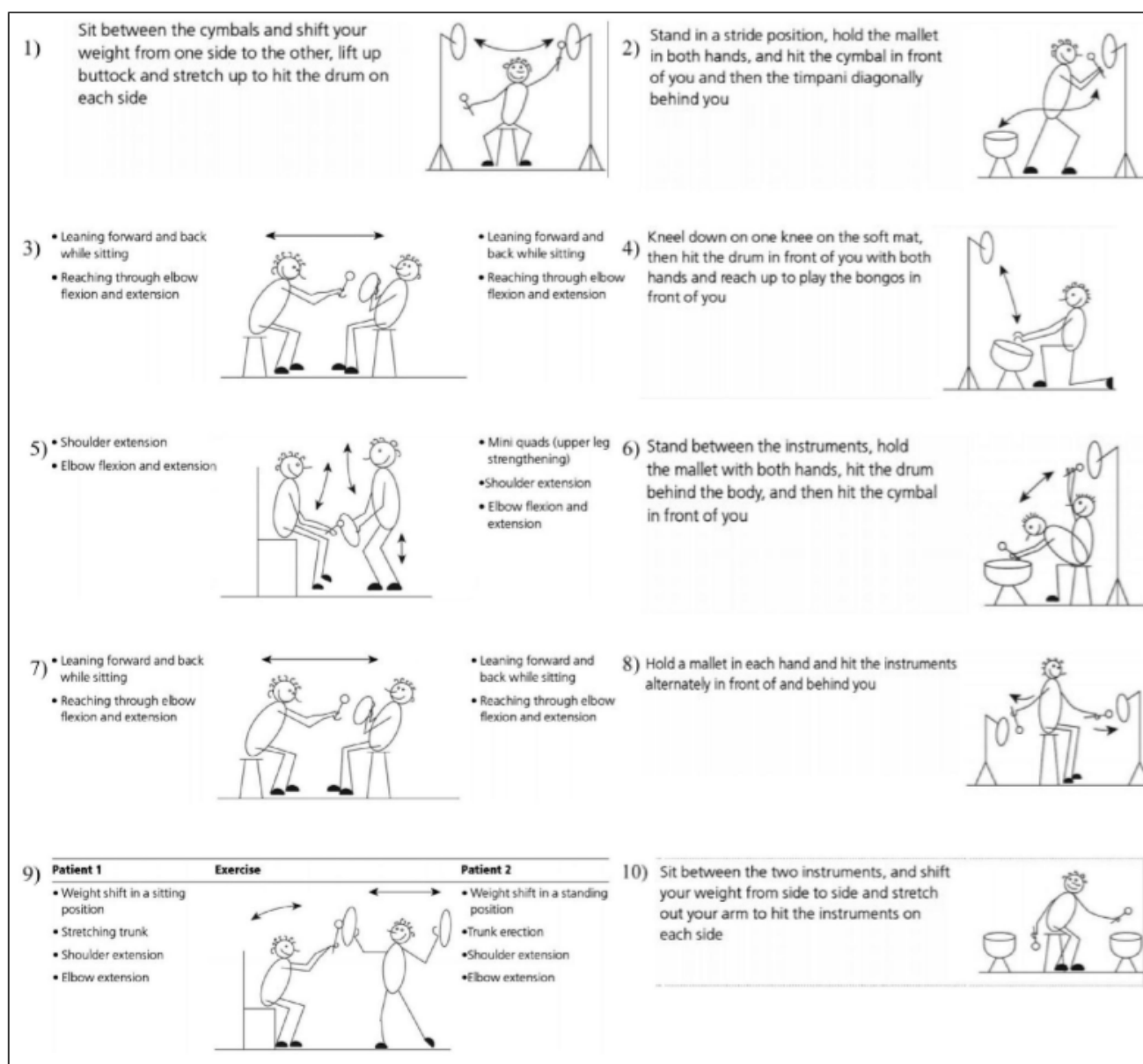


Figure 3. Compilation of Gross Motor Exercise Diagrams (Thaut et al., 2014)

Keyboard Exercises

Next, the therapist guided the patient to switch from percussive instruments to the keyboard. Here, patients participated in fine motor exercises. These exercises utilized an electronic piano. Patients performed a variety of beginner exercises, fundamentals, and patterns with the help of the therapist. As the study progressed, the patients built the basics of piano playing and music reading to be able to do

more intricate compositions. As compositions increased in difficulty, fine motor skills and finger/wrist muscles were inevitably exercised more. The utilized keyboard was connected to a laptop, for the use of the program *Garageband*; This device was installed in order to track the finger velocity of patients—another area of assessment. These exercises were also performed for a total of 10 minutes.

Cool Down/End of Intervention

Following the fine motor set of exercises, the patient and therapist completed cool down, where they rested the exercised muscles and went through a recap of what went on during the session. At this point in the intervention, the therapist or other interns asked the patient to answer questions from the survey. Succeeding the conclusion of the survey, the therapist and the patient had reached the end of the session. This session procedure was followed through for each intervention a patient would go through during this study.

Baseline Assessments

This study consisted of 6 testing methods for assessing change in various variables. Assessments and data collection were completed by the student researcher and music therapist, with the supervision of the mentor. Assessment periods occurred a week prior to the start of interventions, after 2 weeks of interventions (~6 interventions), after 4 weeks of interventions (~12 interventions), and after the 6 week period of interventions (18 interventions). For this study, 6 assessments were utilized to measure the change in physical and psychological ability. These groups of assessments include the Nine Hole Peg Test, the Range of Motion Evaluation, the Ruler Based Measuring, and the *Garageband* Velocity Measure Test.

Nine Hole Peg Test

One of the primary assessments used for this study was the Nine Hole Peg Test (NHPGT). The Nine Hole Peg Test measures finger dexterity, or fine manual dexterity, through the testing of the patient's ability to pick up the nine pegs one at a time as quickly as possible, puts them in the nine holes,

and, once they are in the holes, removes them again as quickly as possible one at a time, replacing them into the shallow container. It can be used with a wide range of populations, including clients following a stroke, experiencing a neurological disorder, or undergoing injury. Additionally, the 9 hole peg test is a relatively inexpensive test and can be administered quickly.

Range of Motion Evaluation

The Range of Motion Evaluation is a set of exercises that are measured to see improvement in various joint movements throughout the body. From this set of tests, the upper limb, hand, and upper body movements will be utilized to see improvement in patients. This assessment helped create a baseline and final measure, with progression data, to track improvement throughout all the muscles and joints that were affected by the interventions. Additionally, the Ruler Based Measuring- which is a photo or live recording of range of motion, vertically or horizontally, using a meter stick- was used in this study.

Garageband Program

The last key component to tracking change in patients was the use of the *Garageband* Program. The *Garageband* Velocity Measure Test used the program, connecting a computer to an electric piano and measured finger velocity of the patient while they were playing a 5 note scale ascending and descending 4 times. This pattern was designated as the unitary method for testing with this program. These tests were administered before the start of the study, again after 2 weeks, 4 weeks and at the end of the 6-week study.

Post- Intervention Assessment

The following assessments were performed with patients at the end of each session. The Wong-Baker Scale was employed to rate the psychological and physical state the patient felt they were in following the intervention. The scale showed a series of faces ranging from a happy face at 0, or "no pain", to a crying face at 10, which represents "hurts like the worst pain imaginable". Based on the faces and written descriptions, the patient chose the face that best describes their level of pain. This scale was

implemented in the next assessment. The patient survey was created by the student researcher, specifically for patients to respond immediately following the intervention. The survey was administered electronically that patients answered with simple responses. Survey asked questions regarding enjoyment, pain, enthusiasm, comfort, and comments on therapy sessions.

Results

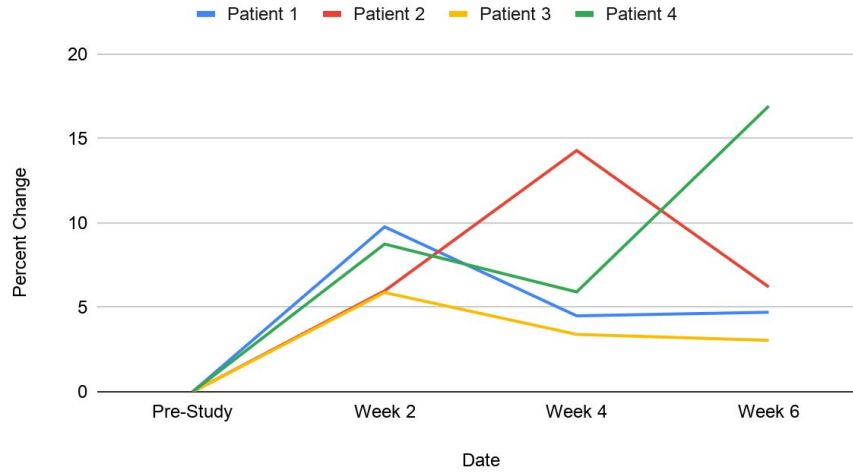
The process of data collection, from August 2019, to end of the process, October 2019, included 4 patients of various neurological diseases (table 1.) being assessed to see changes in upper limb functionality based on Therapeutic Instrumental Music Performance therapy. For Statistical Analysis of this study, the following procedures were employed. Data from the assessments during the study for each individual were viewed and compared to quasi-baseline data from before the study to find changes in patients' abilities in upper limb arm movement. This included comparing the data of the Nine Hole Peg Test, Range of Motion Evaluation, the velocity measurements, as well as the Wong-Baker Scale scores.

As seen in table 2, the NHPGT scores/times of each individual decreased over the span after each two week period. Individuals that showed the most improvement in this assessment were the ones who suffered from the most functional limitations in their upper limbs, according to figure 3. Patients were tested on both arms, however the data shown in this table focuses on the arm that was most negatively affected by the neurological disease/injury.

Table 2. NHPGT Scores

| Time Period | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|-------------|-----------|-----------|-----------|-----------|
| Pre Study | 33.15 s | 63.83 s | 39.62 s | 240.31 s |
| Week 2 | 30.2 s | 60.23 s | 37.42 s | 220.98 s |
| Week 4 | 28.9 s | 52.7 s | 36.19 s | 208.64 s |
| Week 6 | 27.6 s | 49.62 s | 35.12 s | 178.45 s |

Figure 4. NHPGT Percent Change



The Range of Motion Evaluation data, according to table 3, also replicates similar improvement in the patients functionality in specific joint movement. After collecting raw data, the same conclusion is prominent; Patients with a higher degree of limitation in completing the movements of each exercise from the evaluation found a greater level of improvement in the completion of this assessment over the course of the study. In table 3, the results of the Range of Motion Evaluation are separated for each joint movement and split, for each patient, and for each period of physical assessment in the study. Joint movements were all taken into consideration when choosing the percussive instruments.

| Joint area of Measurement | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|-----------------------------------|-----------------------------|------------------------------|-----------------------------|-----------------------------|
| Shoulder Abduction/Extension | 80/84/93/105 18/22/23/25 | 91/95/102/107 21/22/23/25 | 92/94/99/103 19/22/24/26 | 78/85/89/100 16/19/21/24 |
| Elbow Flexion Pronate/Supinate | 68/73/79/89 33/35/36/39 | 74/76/85/92 28/30/31/34 | 70/76/83/88 25/28/32/33 | 60/67/73/83 22/24/28/31 |
| Wrist Horizontal (radial/ulnar) | 7/9/13/16 12/13/17/22 | 10/13/15/15 11/13/15/16 | 9/11/12/16 11/12/15/20 | 7/11/14/18 10/14/16/21 |
| Wrist Vertical Flex./Ext. | 40/44/49/54 37/39/43/48 | 44/47/52/55 40/44/50/52 | 40/41/47/56 34/38/44/48 | 35/39/46/50 31/37/39/45 |
| Thumb (MCP Joint) | 23/27/31/35 | 22/26/29/34 | 20/25/26/35 | 17/21/28/30 |
| Thumb (IP Joint) | 41/47/51/54 | 45/48/51/55 | 37/40/44/49 | 33/37/44/48 |

Table 3. Range of Motion Evaluation Progression. (-/-/-/-) are used to show data collection from pre study, week 2, week 4, and week 6. Each measurement is a representation of the degree of motion.

For the Garageband Velocity Measurements, patients played a simple, 5 note $\frac{1}{2}$ scale of C Major, pattern up and down on the keyboard for 8 measures. It was completed in a fashion where one measure was played with the pattern, followed by a measure of rest. This same pattern was used for the measurement-- which was assessed 4 times throughout this study. Below is a figure visualizing how each pattern was recorded for the measurement, including patterns used for exercises during the intervention to understand the weaknesses of each patients' fine motor skills. The green indicates the pattern being recorded and the spacing between the segments in the track represents how it lines up, thus being able to keep track of velocity in the recording.

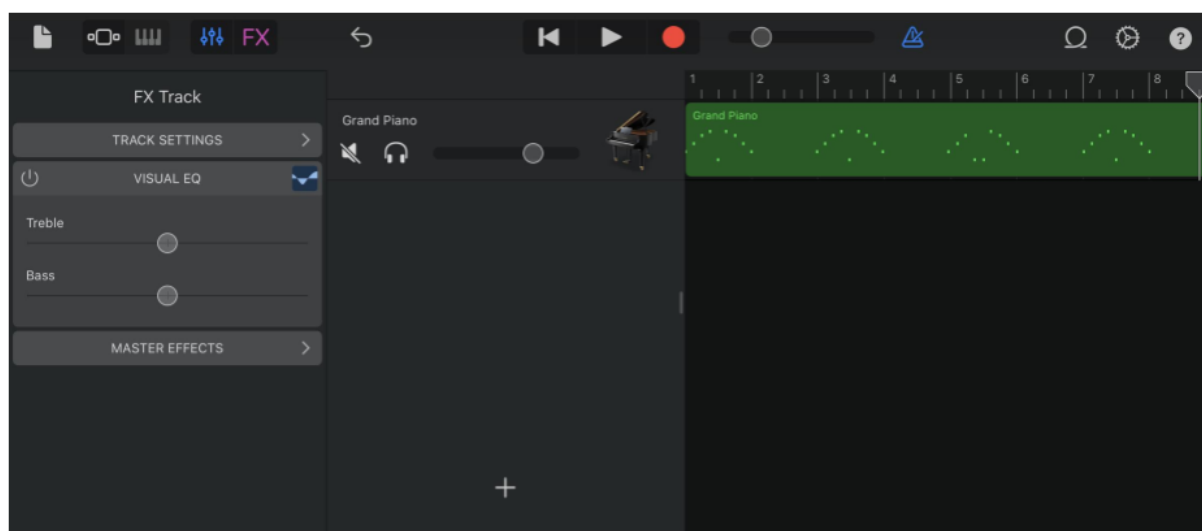
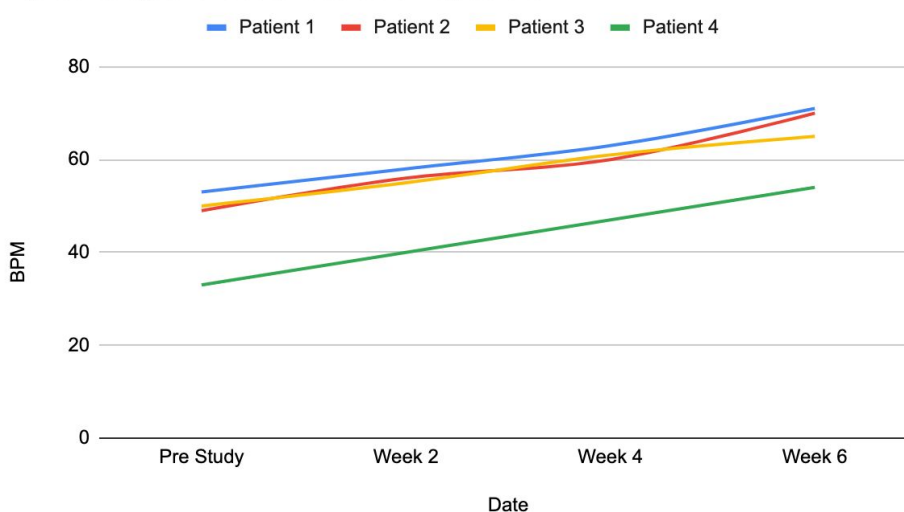


Figure 5. Screen capture of the MIDI recording from *Garageband*, measuring velocity of finger speed.

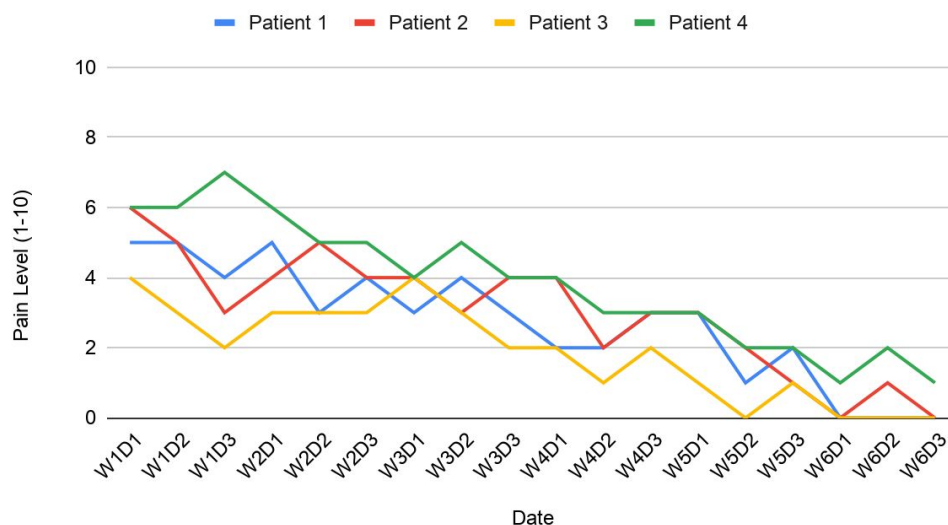
As seen in table 4, the changes in finger velocity of this particular pattern indicated significant improvement in finger speed and overall fine motor skills in all 4 patients. Compared to the other two assessments, however, this measurement signified equally distributed levels of improvement in the population rather than others indicating a greater improvement to those who were more limited in the beginning of the study.

Table 4. Garageband Velocity Measurements and Progression

| Time | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|-----------|-----------|-----------|-----------|-----------|
| Pre Study | 53 bpm | 49 bpm | 50 bpm | 33 bpm |
| Week 2 | 58 bpm | 56 bpm | 55 bpm | 40 bpm |
| Week 4 | 63 bpm | 60 bpm | 61 bpm | 47 bpm |
| Week 6 | 71 bpm | 70 bpm | 65 bpm | 54 bpm |

Figure 6. Garageband Velocity Measure and Progressions

Additionally, patients completed a post-intervention survey with the help of the music therapist. The main component of the survey was the results of the Wong- Baker Scale in the survey, which correlated to the sense of pain each patient felt during their session. In Figure 7, the trends of pain are detailed based on the progression of sessions over time. Trends generally showed lower levels of pain as patients completed more interventions during this program. These results can be correlated with the adaptation and possible improvement in patients overall upper limb motor skills.

Figure 7. Wong Baker Scale Changes

Overall, the results of this study conclude that the patients with a higher degree of limitation in completing the movements of each exercise from the evaluation found a greater level of improvement in the completion of this assessment over the course of interventions. This promising outcome can also establish that Therapeutic Instrumental Music Performance is a viable, main method of rehabilitation for patients who suffer from severe limitations in their upper limbs due to post-neurological disease strokes or injuries.

Discussion

Assessing TIMP

This study sought to find the feasibility of utilizing Therapeutic Instrumental Music Performance as a form of upper limb rehabilitation following post-neurological disease strokes, injuries, and limitations. As hypothesized, it was found that the 4 patients who underwent this treatment had significant improvements in upper limb movement, sensory motion, and day-to-day well-being. It was also

concluded that patients who underwent prior rehabilitation also found equally benefiting results from undergoing the 6 week intervention process.

Previous research has pointed to an increase in the use of music therapy for wide recovery benefits. It's benefits have been spread from not only general speech rehabilitation but to physical rehabilitation as well. The form's ability has been reached to high levels of research, reproducing many similar results in large population sizes (Altenmüller et al., 2009). However, music therapy and TIMP have not been tested for its service as a method of upper limb recovery in a wider variety of neurological diseases and disorders. Even though TIMP is not a cure for the disease or illness itself, this study defined it's potential to be implemented as a mechanism to build motor independence in daily actions for more patients. Another general limitation that was non-existent this study was to create more functional advancements in all the tests with patients who suffered from more limitations prior to the start of the sessions. According to a preceding study (Coupar et al., 2012) research concluded that patients with the most severity in limitations improved the least out of all patients in the sample size. Although it is not presently concluded what caused the opposite in this current study, some factors that may have improved that include intervention setup, frequency of sessions, and sample size comparisons.

Feasibility

The aim of this study was to not only understand the benefits and limitations of TIMP as the predominant form of upper limb recovery-- but to also assess its ability to be applied as a feasible source of rehabilitation. Although one of the limitations of this study was that the patients could only go through the interventions in the rehabilitation facility, the equipment for the sessions as well as the setup of the room was condensed to make it portable. The musical instruments-- keyboard, drums, cymbals, mallets and other devices-- were able to be transported, as well as other equipment to assess changes. This characteristic of music therapy-- and especially this model of TIMP-- makes it a feasible option for patients to undergo in a home-like environment. In a prior case study, Street et al. found that the

feasibility of creating a comfortable environment for the patient was manageable for researchers as well as therapists. The patients in the current study stayed at the rehabilitation center and the assisted living, making them comfortable with the facility the interventions were conducted in. TIMP's ability to be condensed into a model that is suitable for multiple locations of intervention gives it an advantage of feasibility over other forms of rehabilitation that require less-portable equipment and utilize high conditioned facilities.

Specialization of Methods towards Patients

As described previously in figure 2, patients went through many similar exercises to those that are detailed in the diagrams (Thaut et al., 2014). However, another use for the pre-intervention assessments were to identify each patient's functional strengths and weaknesses. Based on that, there was more of a heavy emphasis on that certain muscle group and area of the upper limb. To elaborate more on this topic, patient 4 from this study is an ideal example in which upper limb function was varied between muscle groups. Patient 4 suffered from a hemiplegic stroke. However previous rehabilitation as well as general recovery helped them gross motor skills rapidly following their stroke. However, pre-study assessments highlighted their severely limited fine motor skills. Thus, the student researcher and music therapist proportioned the time ratio more towards keyboard and fine motor exercises to help advance that rather than focusing on gross motor skills. Even with this approach, the patient made significant improvements in fine motor skills as well as furthering gross motor mobility.

Conclusion

This pilot study aimed to understand the applicability of Therapeutic Instrumental Music Performance on various neurological diseases that caused injuries and limitations on the upper limbs. It was hypothesized that the patients undergoing progressive rehabilitation of TIMP would improve overall upper limb movement, sensory motion, and well-being in patients recovering from impairment of upper

limb mobility. This hypothesis is concluded to be accurate, promising more applicability of this method in other forms of physical rehabilitation. Other than the physical benefits for patients, it was also found that the feasibility of this program was very low cost and could be portable to many locations, a unique and crucial benefit of this rehabilitation process.

Limitations

With this study being low cost, as well as a pilot study, multiple limitations come with the resulting conclusions. Sample size of this study was very limited- only with 4 patients- due to the availability and number of patients who volunteered to be part of this program from the rehabilitation center. Another limitation to this study was that no control group was used to compare scores of assessments. Data conclusions have been made on baseline data from patients before the intervention process was initiated. Lastly, the program itself does not serve all patients. Many patients may opt to go with a form of rehabilitation that is more supported behind research, including physical and occupational rehabilitation. However, this study was able to test a modern method TIMP in application with various neurological diseases and injuries and conclude that improvement in upper limb movement, sensory motion, and well-being in patients recovering from impairment of upper limb mobility is possible and can serve to create a feasible, viable, and alternative option in the rehabilitation process.

Future Research

Due to the previously mentioned limitations, future research regarding this methodology and application would differ in approach. To establish this process' validity, it would be necessary to increase sample size as well as increase variety in diseases patients deal with. Additionally, the increase in population size would also present the opportunity for researchers and therapists to further assess the feasibility of this program in a home-based environment. Another limitation that further research would target would be the absence of a control group. This would aid the comparison to other forms of rehabilitation with data that would be concurrent with that of the data collected from patients undergoing

TIMP rehabilitation. Furthermore, the condensing of materials can further be enhanced by using more modern forms of technology, such as tablets, that are able to combine the exercises of fine motor skills through touch sensitivity, as well as recording the velocity measures. The technology would also expand the researchers to a vast selection of current assessments through portable electronics.

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