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The Effects of Therapeutic Instrumental Music Performance on Endurance Level, Self-Perceived Fatigue Level, and Self-Perceived Exertion of Inpatients in Physical Rehabilitation

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The present study investigated the effects of a Neurologic Music Therapy (NMT) sensory-motor rehabilitation technique, Therapeutic Instrumental Music Performance (TIMP) as compared to Traditional Occupational Therapy (TOT), on endurance, self-perceived fatigue, and self-perceived exertion of 35 hospitalized patients in physical rehabilitation. The present study attempted to examine whether an active musical experience such as TIMP with musical cueing (i.e., rhythmic auditory cueing) during physical exercises influences one's perception of pain, fatigue, and exertion. All participants were diagnosed with a neurologic disorder or had recently undergone orthopedic surgery. Investigators measured the effects of TOT and TIMP during upper extremity exercise of the less affected or stronger upper extremity. Results showed no significant difference on endurance measures between the 2 treatment conditions (TIMP and TOT). Statistically significant differences were found between TIMP and TOT when measuring their effects on perceived exertion and perceived fatigue. TIMP resulted in significantly less perception of fatigue and exertion levels than TOT. TIMP can be used for an effective sensory-motor rehabilitation technique to decrease perceived exertion and fatigue level of inpatients in physical rehabilitation.

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The therapeutic effects of music, in particular the effects of rhythmic stimuli, are being recognized and reported within the medical community, including the field of physical rehabilitation (Baker & Tamplin, 2006; Paul & Ramsey, 2000). Quantitative research studies have reported the effective use of musical and rhythmic stimulation in physical rehabilitation, particularly in gait training and upper extremity movement training (Cevasco & Grant, 2003; de l'Etoile, 2008; Freeman, Cody, & Shady, 1993; Hurt, Rice, McIntosh, & Thaut, 1998; Malcolm, Massie, & Thaut, 2009; Miller, Thaut, McIntosh, & Rice, 1996; Thaut, Schleiffers, & Davis, 1991; Thaut, Brown, Benjamin, & Cooke, 1996; Thaut, McIntosh, & Rice,1997; Thaut, et al., 1996). The impact of music and rhythm on motor processes has become a focus of clinical practice in neurologic rehabilitation and has been foundational in the development of Neurologic Music Therapy (Thaut, 2005). The benefits and therapeutic outcomes have been explained by basic mechanisms underlying auditory-motor interaction in the brain: entrainment, audio-spinal motor facilitation, rhythmic cueing, and stepwise limit cycle.

Rhythmic entrainment involves the auditory phenomenon of perceiving and detecting periodic-temporal patterns (i.e., rhythmic patterns) and synchronizing movement patterns to them. The effect of entrainment can be observed even at levels below conscious perception, indicating that auditory-motor entrainment can take place without intensive cognitive learning effort or high levels of mental exertion (Thaut, 2005). Many studies have examined the effects of entrainment on gait during rhythmic auditory stimulation (RAS) (de l'Etoile, 2008; Hurt et al., 1998; Miller et al., 1996; Stephan, et al., 2002; Thaut et al., 1996; Thaut, et al., 1996; Thaut et al., 1997). Participants who have been able to entrain to RAS have included healthy individuals as well as patients with stroke, Parkinson's disease, traumatic brain injury and spinal cord injury. Results indicated that gait was affected by entrainment to the auditory stimulation, and that patients with neurologic disorders showed a greater reliance on external auditory cues for rhythm production in their movement. The mechanism of rhythmic entrainment demonstrates a strong auditory-motor interaction important to sensorimotor rehabilitation (Thaut, 2005).

Audio-spinal motor facilitation has been investigated in many quantitative studies, in particular, studies regarding the effects of rhythmic auditory stimulation (RAS) on gait training in physical rehabilitation (Freeman et al., 1993; Hurt et al., 1998; Miller et al., 1996; Thaut et al., 1996; Thaut et al., 1997). RAS primes the auditory-motor pathway in the central nervous system by physiological entrainment. For effective audio-spinal motor facilitation and entrainment to occur, auditory rhythmic cuing of the movement period is essential. The rhythmic cue provides a continuous time reference during the planning and execution of the movement by producing temporal patterns including both phase information (i.e., frequency entrainment to target beats) and period information (i.e., duration entrainment of the movement sequence to the entire rhythmic interval) (Thaut, 2005).

Freeman and colleagues (1993) found that withdrawal of external rhythmic cuing resulted in marked impairment of rhythm generation in patients with Parkinson's disease. Safranek, Koshland, and Raymond (1982) examined changes in the electromyogram patterns of two antagonist muscles when healthy adult participants performed a motor task with and without auditory rhythmic cuing. The results indicated that rhythmic cueing might alter muscle activation. The authors suggested that rhythmic cueing can be used to modify the onset, duration, and consistency of muscular activity as an effective rehabilitative technique (Safranek et al., 1982). Thaut et al. (1996) examined the effects of rhythmic auditory cueing on the spatiotemporal organization of four sequential movements in a forward arm-reaching task targeting five different locations oriented vertically. The researchers found that participants were unable to produce evenly timed sequential movements without auditory cueing. In contrast, rhythmic auditory cueing led to a significant increase in timing consistency. Furthermore, rhythmic auditory stimuli should be adapted to the patient's current limit cycle in order to stabilize and maximize movement parameters at that personalized limit cycle (frequency at which any moving system performs optimally) (Thaut, 2005). Once stability has been achieved at that level, new limit cycles can be gradually achieved through a stepwise entrainment process, thus enabling optimal functioning at more desirable frequencies.

Thaut, Brown, et al. (1996) examined the sequential flexion-extension elbow movements of one arm with temporal beat patterns presented in the visual, auditory, and tactile sensory modalities. Auditory cueing resulted in a significantly greater number of accurate reproductions of beats as compared to tactile or visual cueing. The study did not investigate the effect of the combination of visual, auditory, and tactile stimulation in facilitating spatiotemporal organization of complex, sequential movements; however, it is possible to postulate that a task such as musical instrument playing, when it involves visual, auditory, and tactile sensory modalities, might enhance motor learning and efficiency of sequential functional movements.

Among various musical experiences with rhythmic stimuli, musical instrument playing has been widely used for retraining and enhancing functional movements in physical rehabilitation. Thaut (2005) indicates that playing musical instruments involves a large number of complex kinesiologic processes. Therefore, well-structured and facilitated instrumental performance can require a high level of sensorimotor integration in order to produce efficient movement patterns. A neurologic music therapy technique called therapeutic instrumental music performance (TIMP) utilizes instrument playing to structure, coordinate and facilitate specific functional movement patterns in rehabilitative exercise. For example, playing percussion instruments can train eye-hand coordination, increase motor planning and coordination of upper extremities on both sides, improve range of motion of the elbow, shoulder or wrist, or increase muscular strength and endurance (Thaut, Thaut, & Lagasse, 2008). Thaut (2005) states the following:

> The therapeutic design of the TIMP exercise is based on three elements: (1) the musical structure facilitating the organization of movement in time, space, and force dynamics, (2) the choice of instruments and the mechanics for playing the instruments to enhance therapeutically meaningful movements, and (3) the spatial arrangement and location of the instruments to facilitate desired motion paths of the limbs and positions of the body. (p. 154)

The act of instrument playing stimulates auditory-motor integration. In addition, instruments often provide visual target points for designated movements while providing auditory feedback to the performer.

Pacchetti and colleagues (2000) found that musical activities, in particular instrument playing (i.e., percussion instruments), demonstrated a significant improvement in bradykinesia factors in movements of 32 patients with Parkinson's disease (PD); the researchers concluded that active music making can improve motor abilities and emotional status of patients with PD. In a study by Schneider, Shonle, Altenmuller, and Munte (2007), stroke patients showed significant improvement in speed, precision and smoothness of movement, as measured by 3D movement analysis and clinical motor tests, after music treatment consisting of drum and piano playing. Patients who received music training showed clear improvement regarding the range of target movements, the speed of movement, and the quality of movement, while those receiving only conventional therapies did not. The researchers explained that the mechanisms involved in the dramatic benefits to patients who received music training included auditory feedback, audio-motor integration and patient enjoyment/motivation.

Cevasco and Grant (2003) compared four music conditions and their effects on upper and lower extremity exercises of clients with Alzheimer's disease. Conditions were as follows: exercise to vocal music, exercise to instrumental music, exercise with instruments to vocal music, and exercise with instruments to instrumental music. The researchers indicated that instrumental music resulted in more participation (i.e., movement production) than vocal music. Also, exercise with instruments to instrumental music resulted in more participation than exercise with instruments to vocal music. Hagen, Armstron-Esther, and Sandilands (2003) compared the effects of an occupational therapy group (OT) and a music exercise group (MT) on improvement of the physical, cognitive, and behavioral status and life satisfaction of 60 older residents in a long-term care facility. The results of the study show that both OT and MT improved participants' overall physical and cognitive functions; however, MT showed significantly greater improvement in more areas such as balance, joint flexibility, cognitive abilities, behavioral ratings, and life satisfaction than OT. The researchers suggested that both MT and OT resulted in increases in cognitive abilities and behavior ratings as both programs involved social interaction, mental stimulation and meaningful activities; however, participants described the music exercise group as the more "fun" of the two programs. The study did not indicate what underlying mechanisms might be responsible for the superior therapeutic outcome of the music exercise group (Hagen et al., 2003).

Numerous researchers have suggested that music has the potential to make physical exercise enjoyable (Dyrlund & Wininger, 2008; Kendzierski & DeCarlo, 1991; Tenenbaum, et al., 2004; Wininger & Pargman, 2003). Boldt (1996) found that music significantly increased exercise endurance for long-term bone marrow transplant participants, and indicated that music sessions were more effective in increasing patients' self-reported relaxation, motivation and comfort levels. He concluded that the music therapy protocol was beneficial in the areas of psychological well-being and physical comfort for patients in physical rehabilitation. Specifically, when music acts as a strong sensory stimulus that distracts one's attention away from the physical sensations of the exercise, the exerciser might perceive less mental exertion and fatigue. Dyrlund and Wininger (2008) examined the effects of music preference and exercise intensity on exercise enjoyment, perceived exertion and attentional focus. The authors found that the most preferred music condition resulted in the highest levels of enjoyment. The results of the study, however, indicate that there were no differences in the level of perceived exertion among those exercising while listening to preferred music, non-preferred music, or while not listening to any music. This finding suggests that the style and/or preference of music might elevate the exerciser's mood; however it is not strongly related to the exerciser's perceived exertion and physical sensation.

Edworthy and Waring (2006) reported that more positive affect was observed among exercisers during the music condition in comparison to the no-music condition and that fast, loud music might be played to enhance optimal exercising. However, no significant differences for ratings of perceived exertion (RPE) were found in music (i.e., fast/loud, fast/quiet, slow/loud, slow/quiet) and no-music conditions. Tenenbaum and colleagues (2004) examined the effect of music type on running perseverance and coping with effort sensation. RPE and heart rate were measured while subjects ran on a motorized treadmill, and discomfort symptoms were examined. The results indicated that music did not make a significant difference in perceived exertion, heart rate, or sensations of exertion. Music, however, was perceived as beneficial by the majority of healthy normal adults. Potteiger, Schroeder, and Goff (2000) investigated the influence of music listening on RPE during 20 minutes of moderate intensity exercise. Participants were randomly assigned to the conditions of fast upbeat music, classical music, self-selected music, and no music. Potteiger, Schroeder, and Goff (2000) indicated that no significant difference was found in heart rate among the four conditions. Each type of music resulted in a reduced level of perceived exertion when compared with the no-music condition. The results suggested that different types of music can act as effective passive distracters during physical exercise and are associated with RPE.

Researchers thus far have primarily studied the effects of music listening, or passive musical activities, on perceived exertion (Boldt, 1996; Dyrlund & Wininger, 2008; Edworthy & Waring, 2006; Potteiger et al., 2000). Unfortunately, the findings in the previous research studies examining the effect of music on perception of exertion and fatigue level during physical exercise are not consistent. The relationship between perceived fatigue level and outcome of physical exercises (e.g., endurance) has not been thoroughly investigated. In order to investigate the level of perceived exertion or physical sensation (i.e., fatigue or discomfort), research should examine the structural components of music, including tempo and dynamics, as auditory stimuli, and these stimuli need to be matched to participants' internal clocks or limit cycles and their motoric capacity. More specific neurologic mechanisms for the effect of musical stimuli on level of perceived exertion and physical sensation of fatigue or pain need to be studied. In addition, the effect of active musical experiences such as TIMP on perceived fatigue and exertion levels needs to be explored. The actual mechanisms underlying auditory-motor interaction should be considered in examining the relationship between music stimuli and perception of physical sensation, including fatigue and pain. The researchers presenting this paper recognize the need for studies that take into account the mechanisms of entrainment, audio-spinal motor facilitation, rhythmic cueing, and stepwise limit cycle while exploring the effects of NMT techniques on level of endurance and perceived exertion/fatigue.

The purpose of the present study is to investigate the NMT sensory-motor rehabilitation technique, Therapeutic Instrumental Music Performance (TIMP), as a visual, auditory, and tactile sensory modality which provides a visual and tactile target (i.e., musical instrument) to produce functional movements and a source of rhythmic auditory feedback (i.e., kinesthetic sensory feedback) to enhance the physical exercises of inpatients in physical rehabilitation. The study also examines whether the musical stimuli (i.e., auditory rhythmic cueing) during the physical exercises influences one's perception of pain, fatigue, and exertion. This study compares effects of non-musically facilitated exercise alone, hereafter referred to as Traditional Occupational Therapy (TOT), to TIMP on endurance, self-perceived fatigue, and self-perceived exertion of hospitalized patients in physical rehabilitation. Investigators measured the effects of TOT and TIMP during upper extremity exercise of the less affected or stronger upper extremity. All patients were diagnosed with a neurologic disorder or had recently undergone orthopedic surgery.

Investigators, including two board-certified music therapists (MT-BC) and one registered occupational therapist, sought to answer the following research questions:

1. Does endurance level for upper extremity movement exercise differ between the two treatment conditions?
2. Does patient-perceived fatigue level (PFL) following treatment differ between the two conditions?
3. Do ratings of perceived exertion (RPE) following treatment differ between the two conditions?
4. Does endurance level, PFL, or RPE differ by order of treatment conditions?
5. Does any relationship exist between treatment condition, order of treatment, patient's musical background, and endurance level?
6. Does any relationship exist between treatment condition, order of treatment, patient's musical background, and PFL?
7. Does any relationship exist between treatment condition, order of treatment, patient's musical background, and RPE?

8. Does any relationship exist between entrainment level, endurance level, PFL, and RPE with the music condition (TIMP)?

Method

Participants

Research participants included 35 individuals who had physical impairments due to neurologic disorders or orthopedic surgeries. Eight participants were diagnosed with strokes, one participant was diagnosed with Parkinson's disease, and 16 participants had orthopedic surgeries including total hip arthroplasty, total knee arthroplasty and knee amputation. Three participants were each diagnosed with ankle fracture, back pain and shoulder injury, and four participants were diagnosed with physical de-conditioning due to medical surgeries. All participants were admitted to inpatient rehabilitation at Huntsville Memorial Hospital, Huntsville, TX, and all signed informed consent forms. Those unable to comprehend informed consent forms or unable to sign for themselves were excluded from the study.

Materials and Measurement Tools

Functional target movements. Each joint in the human body has the potential to move in certain directions and to certain limits of motion due to its structure and the integrity of surrounding tissues (Trombly & Radomski, 2004). The term "functional human movement" relates to a range of purposeful movements associated with common task-related activities (Dureward, Baer, & Rowe, 1999; Trombly & Radomski, 2004).

Music stimuli. Since research in music therapy generally indicates that familiar, preferred music is most effective in treatment, investigators chose songs they presumed to be familiar to the general population served on this particular hospital's inpatient rehabilitation unit (i.e., adults over the age of 65). MT-BC investigators arranged a 7-min instrumental version of the traditional "I've Been Working on the Railroad" for Part 1 and instrumental versions of Foster's "Swanee River," and Irving Berlin's "Alexander's Ragtime Band" for Part 2. The arrangements were recorded and played through a Yamaha YPG-225 keyboard at approximately 85 decibels, with tempos individualized as described below for maximum entrainment potential.

Music was arranged with strong emphasis on the down beats and consideration of patterning principles, especially specific metric and rhythmic features, to facilitate the desired movements. Therapists also chose patient instruments based on their relevance and "fit" within the recorded arrangements in order to maximize the patient's perception of active contribution to the music versus focus solely on exercise.

Measurement of rhythmic auditory entrainment. During the TIMP session, each participant's rhythmic auditory entrainment level was determined with 100% agreement by two board-certified music therapists. For the rhythmic auditory entrainment level, the participant received a score ranging from 0 to 3. Entrainment level 0 indicates "no noticeable entrainment to the rhythmic auditory cueing." Entrainment level 1 indicates "minimal entrainment to the rhythmic auditory cueing," level 2 indicates "moderate entrainment to the rhythmic auditory cueing," and level 3 indicates "maximum entrainment to the rhythmic auditory cueing."

Measurement of endurance. Endurance is the ability to reach or maintain the energy output necessary to perform an activity (Smith, 1993). The present research protocol provided the patient with interest-sustaining activities that were gradable along the dimensions of time or repetitions. Informal clinical assessment of endurance can be administered by timing the duration of an activity or counting the number of repetitions the patient can perform (Smith, 1993; Trombly & Radomski, 2004). Exercise to increase endurance utilizes moderately fatiguing activity for progressively longer periods of time with intervals of rest to allow for metabolic recovery (Smith, 1993; Trombly & Radomski, 2004). During Part 1 of each condition, exercise duration was recorded, as were number of exercise sequences completed, therefore yielding both duration and frequency data.

Measurement of fatigue. Fatigue develops in a muscle fiber if insufficient recovery time is allowed for re-absorption of lactic acid, which begins to build up during more fatiguing activity (Smith, 1993). Following Part 2 of each condition, subjects completed the Patient Perceived Fatigue Scale, which is an original tool to measure Patient-Perceived Fatigue Level (PFL) created by the principal investigator. The tool measures perceived fatigue on a 0–3

TABLE 1
Patient Perceived Fatigue Scale

Please indicate your current level of fatigue. (Check only one item below.)
0 —— I am not tired at all. ( )
1 —— I am not tired, but I feel I need a break. ( )
2—— I am tired, and I definitely need a break. ( )
3—— I am very tired and I feel pain/soreness and fatigue in my body. ( )

scale with descriptions ranging from "not tired at all" to "very tired and I feel pain/soreness and fatigue" (see Table 1).

Measurement of exertion. Following Part 2 of each condition, subjects completed the Ratings of Perceived Exertion (RPE). RPE measures perceived exertion on a one-item scale ranging from 6 (no exertion at all) to 20 (maximal exertion) with corresponding descriptors of exercise intensity (see Table 2). RPE is highly correlated (.80–.90) with heart rate and a number of other physiological measures of exertion (Borg, 1982).

Design and Procedure

Each patient was randomly assigned to participate individually in a single session of Traditional Occupational Therapy (TOT) or Therapeutic Instrumental Music Performance (TIMP) on Day 1 of the study. Those participating in TOT on Day 1 were assigned to TIMP on Day 2. Those participating in TIMP on Day 1 were assigned to TOT on Day 2. Due to the wide variety of etiologies and functioning levels, and in order to focus the study specifically and narrowly on endurance, perceived fatigue, and perceived exertion, each patient was asked to perform the exercises with his or her strongest arm. The protocol utilized for each condition is described below:

TIMP: Part 1

Target Movement: from seated position, full elbow flexion/extension with shoulder flexed to 90 degrees.

Recorded music: "I've Been Working on the Railroad" in 4/4 with emphasis on beats 1 and 3.

Instrument: Light mallet with 1 lb. weight added to the patient's wrist, targeting a paddle drum.

TABLE 2
Ratings of Perceived Exertion

Please rate the level of effort you put forth in order to complete this exercise. (Circle a number in the rating scale below.)	
6	
7	**Very, very light**
8	
9	**Very light**
10	
11	**Fairly light**
12	
13	**Somewhat hard**
14	
15	**Hard**
16	
17	**Very hard**
18	
19	**Very, very hard**
20	

Step 1: With an assistant holding a paddle drum just above eye level so that the player's shoulder was flexed to 90 degrees, the investigator demonstrated the target movement by flexing to tap her shoulder, extending to strike the drum, then repeating the sequence. The patient was instructed to touch his or her shoulder, hit the drum, and then repeat the sequence at a comfortable pace. For data purposes, from shoulder tap to shoulder tap was considered one full sequence.

Step 2: The patient practiced the target movement while the investigator calculated optimal tempo for entrainment purposes. This was done by calculating the number of sequences performed during a 10 second interval without rhythmic auditory cueing and determining approximate sequences per minute. Metronomic tempo was then selected to facilitate synchronization to rhythmic auditory stimuli at that limit cycle.

Step 3: The investigator set music to the tempo derived from the patient's approximate number of sequences per minute and started the music. The patient performed sequences during a 10 second practice interval with musical cueing, and optimal tempo was adjusted as needed to maximize entrainment potential.

Step 4: The patient was instructed to tap the shoulder and strike the drum along with the music until he or she could no longer continue due to pain or fatigue. Music was re-started and the investigator or assistant performed the movement along with the patient, providing visual cues.

Step 5: Music and exercise were stopped when the patient stated that he or she was too fatigued or in too much pain to continue.

Step 6: The investigator measured and recorded the number of movement sequence repetitions as well as duration of exercise.

TIMP: Part 2

Target Movements (all from a seated position):
A. Bicep curls with arm in neutral, flexing to shoulder and back
Instrument: 1 lb. jingle stick

B. Shoulder flexion with elbow extended across mid-line, back to neutral, to opposite side, then back to neutral
Instrument: light-weight mallet with 1 lb. weight added to wrist, targeting 2 free-standing conga drums

C. Elbow flexion/extension with shoulder fully flexed
Instrument: light-weight mallet with 1 lb. weight added to wrist, targeting a tambourine secured to an IV pole and positioned in front of the patient and overhead

Step 1: The investigator demonstrated Target Movement A and defined parameters in terms of targets and range of motion desired.

Step 2: The patient practiced the target movement while the investigator calculated optimal tempo for entrainment purposes. This was done by calculating the number of sequences performed during a 10 second interval without rhythmic auditory cueing and determining approximate sequences/minute. Metronomic tempo was then selected to facilitate synchronization to rhythmic auditory stimuli at that limit cycle.

Step 3: The investigator set music to the tempo derived from the patient's approximate number of sequences/minute and started the music. The patient performed sequences during a 10 second practice interval with musical cueing, and optimum tempo was adjusted as needed to maximize entrainment potential.

Step 4: The patient was instructed to play the instrument along with the music, as modeled, for the duration of the song. The investigator or assistant performed the movement along with the patient, providing visual cues.

Step 5: Song 1, "I've Been Working on the Railroad," was structured to facilitate 32 repetitions of the exercise and was played for its duration regardless of number of times the patient started and stopped the exercise. When the song 1 ended, the patient and investigator proceeded to Target Movements B and C, which were introduced and individualized in the same manner. (Steps 1–4 repeated.) Song 2, "Swanee River," was structured to facilitate 16 repetitions and was played for its duration regardless of number of times the patient started and stopped the exercise. Song 3, "Alexander's Ragtime Band," was structured to facilitate 32 repetitions and was played for its duration regardless of number of times the patient started and stopped the exercise.

Step 6: Following the completion of all exercises, the patient completed the Patient Perceived Fatigue Scale (PFL) and the Ratings of Perceived Exertion (RPE).

TOT: Part 1

Target Movement: from seated position, full elbow flexion/extension with shoulder flexed to 90 degrees.
Instrument: 1 lb. hand-held weight

Step 1: The investigator demonstrated the target movement by flexing to tap his shoulder, extending fully with the shoulder flexed to 90 degrees, then repeating the sequence. The patient was instructed to touch his or her shoulder, extend, and then repeat the sequence at a comfortable pace. For data purposes, from shoulder tap to shoulder tap was considered one full sequence.

Step 2: The patient practiced the target movement for 20 sec.

Step 3: The investigator instructed the patient to perform the exercise until he or she could no longer continue due to pain or fatigue. The investigator or assistant performed the movement along with the patient, providing visual cues.

Step 4: Exercise was stopped when the patient stated that he or she was too fatigued or in too much pain to continue.

Step 5: Investigator measured the number of movement sequence repetitions as well as duration of exercise.

TOT: Part 2

Target Movements (all from a seated position):
A. Bicep curls with arm in neutral, flexing to shoulder and back
Instrument: 1 lb. hand-held weight

B. Shoulder flexion with elbow extended across mid-line, back to neutral, to opposite side, then back to neutral
Instrument: 1 lb. hand-held weight

C. *Elbow flexion/extension with shoulder fully flexed*
Instrument: 1 lb. hand-held weight

Step 1: The investigator demonstrated Target Movement A and defined parameters in terms of targets and range of motion desired.

Step 2: The patient practiced the target movement for 20 sec.

Step 3: The investigator instructed the patient to perform the exercise as modeled for 32 repetitions. The investigator or assistant counted repetitions aloud as they were performed and performed the movement along with the patient, providing visual cues.

Step 4: After 32 repetitions, the patient and investigator proceeded to Target Movements B and C, which were introduced and individualized in the same manner, with Target Movement B performed for 16 repetitions and Target Movement C for 32 repetitions.

Step 5: Following the completion of all exercises, the patient completed the Patient Perceived Fatigue Scale (PFL) and the Ratings of Perceived Exertion (RPE).

Results

Results were obtained from 35 participants who had physical impairments due to neurologic disorders or orthopedic surgeries. Nine participants were male and 26 were female. The average age of the participants was 79. Responses to musical background questions indicated that 11 participants had played at least one musical instrument and/or sung in a choir and 24 did not have

TABLE 3
Mean and Standard Deviation for Difference between TIMP and TOT

	Min	Max	*M*	*SD*
TIMP				
Frequency	19	210	64.74	44.87
Duration (sec)	28	324	87.88	60.01
PFL (0–3)	0	3	1.2	0.72
RPE (6–20)	6	19	11	2.87
TOT				
Frequency	16	208	58.17	42.43
Duration (sec)	24	287	91.66	60.75
PFL	1	3	1.8	0.63
RPE	9	18	13	2.22

Note. PFL = Perceived Fatigue Level; RPE = Ratings of Perceived Exertion.

musical background. Demographic information indicated that 16 participants completed the research procedure with treatment order A, participating in TIMP on Day 1 of the study and TOT on Day 2, while 19 completed the research procedure with treatment order B, participating in TOT on Day 1 and TIMP on Day 2.

The descriptive results show that the mean frequency of the target movement during TIMP was 65 repetitions and the mean duration of the exercise was 89 sec. The mean frequency of the target movement during TOT was 58 repetitions and the mean duration of the exercise was 92 sec. The results indicate that participants produced a greater number of target movements within shorter duration in TIMP, and fewer target movements within longer duration in TOT (see Table 3). Data indicate that, on average, more participants responded "*I am not tired, but I feel I need a break* "after completing exercises with TIMP, and that more responded "*I am tired and I definitely need a break*" after completing the same exercises in TOT. The results also indicate that, on average, participants rated their exertion level "*Fairly light*" after TIMP; however, they rated their exertion level "*Somewhat hard*" after TOT.

One simple *t* test ($\alpha = 0.05$) was used to examine the first research question, "Does endurance level for upper extremity movement exercise differ between the two treatment conditions?" The results indicate that the difference in mean duration between

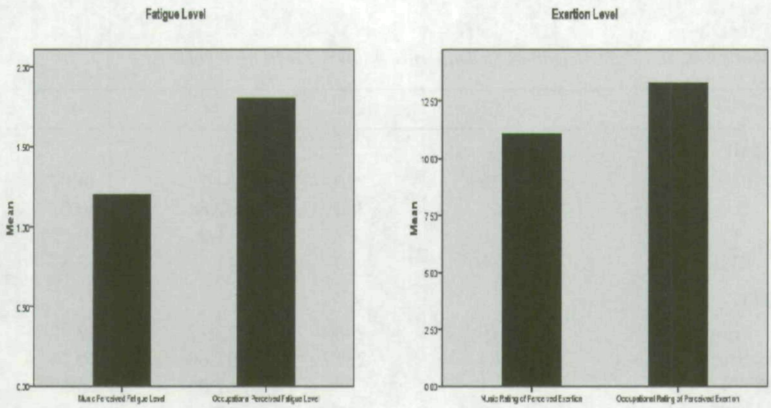

FIGURE 1.
Patient perceived fatigue and exertion level after TIMP and TOT.

TIMP and TOT was not significant (p = 0.679), and that the difference in mean frequency between TIMP and TOT was not significant (p = 0.134). Another paired t test was used to examine the second and third research questions, "Does PFL following treatment differ between the two conditions?" and, "Does RPE following treatment differ between the two conditions?" The results show that the difference between PFL following TIMP and PFL following TOT was significant (p = 0.00). The difference between RPE following TIMP and RPE following TOT was also significant (p = 0.00). TIMP resulted in significantly lower levels of perceived fatigue and exertion than TOT (also see Figure 1). A two-way MANOVA was conducted to answer research Question 4, "Does endurance level, PFL, or RPE differ by order of treatment condition?" The results indicated no significant main effect of order of treatment conditions on any dependent variable.

Correlation coefficient analysis was conducted to examine the reliability of endurance level (frequency and duration), PFL and RPE, and to define the directions and relationships between variables (i.e., research Questions 5, 6, & 7) (see Table 4). The results of the analysis indicate a high correlation between frequency and duration (r = 0.92); the correlation was significant at the 0.01 level (2-tailed), and the reliability for duration and frequency was high (Cronbach's alpha = 0.94). The results indicated that frequency and duration in TIMP have a significantly positive correlation (r = 0.84), and that frequency and

TABLE 4

Significant Correlation Coefficient between Variables

Pearson *r* Sig.	TIMP Frequency	TOT Frequency	TIMP Duration	TOT Duration	TIMP PFL	TOT PFL	TIMP RPE	TOT RPE
TIMP	1	.833**	.841**	.726**	−.440**	−.339*	−.360*	−.523**
Frequency		.000	.000	.000	.008	.047	.033	.001
TOT	.833**	1	.640**	.940**	−.463**	−.177	−.373*	−.517**
Frequency	.000		.000	.000	.005	.308	.027	.001
TIMP	.841**	.640**	1	.607**	−.281	−.257	−.297	−.450**
Duration	.000	.000		.000	.102	.136	.084	.000
TOT	.726**	.940**	.607**	1	−.398*	−.221	−.361*	−.474**
Duration	.000	.000	.000		.018	.202	.033	.004
TIMP	−.440**	−.463**	−.281	−.398*	1	.478**	.406**	.535**
PFL	.008	.005	.102	.018		.004	.016	.001
TOT	−.339*	−.177	−.257	−.221	.478**	1	.394*	.294
PFL	.047	.308	.136	.202	.004		.019	.087
TIMP	−.360*	−.373*	−.297	−.361*	.406**	.394*	1	.297
RPE	.033	.027	.084	.033	.016	.019		.083
TOT	−.523**	−.517**	−.450**	−.474**	.535**	.294	.297	1
RPE	.001	.001	.007	.004	.001	.087	.085	

$N = 35$.

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

duration in TOT also have a significantly positive correlation ($r = 0.94$). The results indicated that PFL and RPE were moderately correlated ($r = 0.59$), and the Chronbach's Alpha for the two variables was 0.471. The results show that PFL and RPE in TIMP have a significantly positive correlation ($r = .406$; $p = .016 < 0.01$). PFL and RPE in TOT also have a positive correlation; however, the correlation is not significant ($r = .294$; $p = 0.87 > 0.05$). Collectively, the results indicated that duration and frequency have a meaningful relationship, and perceived fatigue level and exertion have a positive relationship. The results of correlation coefficient analysis found no significant relationship between patient's musical background with other variables such as endurance level (frequency and duration), PFL, and RPE. Likewise, no significant relationship was found between the order of treatment and other variables.

Results of the correlation analysis indicate that frequency scores from TIMP and TOT have a higher correlation ($r = 0.833$) than duration scores from the two different therapy conditions ($r = 0.$

TABLE 5
Rhythmic Auditory Entrainment, Endurance, and PFL and RPE in TIMP

	Frequency		Duration		PFL		RPE	
Entrainment level	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1 (n = 9)	47.89	19.68	64.67	19.63	1.33	1.00	11.00	3.60
2 (n = 10)	47.70	18.26	74.40	35.74	1.40	0.52	11.80	2.97
3 (n = 16)	84.88	57.98	109.38	79.08	1.00	0.63	10.63	2.45
Total (N = 35)	64.74	44.87	87.89	60.01	1.20	0.72	11.06	2.88

607). Both frequency and duration scores from TIMP and TOT show a positive correlation, which indicates that each participant performed the endurance exercise in a relatively similar manner in TIMP and TOT; in particular, the participant produced the similar number of repetitions in TIMP and TOT. The results also indicate that the participants' exercise frequency in TIMP was negatively correlated to their perceived fatigue level (PFL) and exertion level (RPE) after the exercise. This finding suggests that if a participant exercised a higher number of target movements with music in TIMP, there might be less perception of fatigue and mental exertion. The results indicate exercise duration in TIMP was also negatively correlated with TIMP PFL (r = −.281) and RPE (r = −.297); however, the correlations were not significant. Duration of exercise with music might cause participants to perceive fatigue and exertion more than frequency does in TIMP. The exercise frequency and duration in TOT was negatively correlated to only RPE after the TOT exercise. This finding suggests that if a participant exercised a higher number of target movements with a longer duration in TOT, he might perceive less mental exertion after the exercise. Overall results of the correlation analysis suggest that actual endurance (i.e., exercise frequency and duration) or physical work load are not positively related to the perception of fatigue or exertion.

The rhythmic auditory entrainment level of each participant was measured in TIMP (See Table 5). Results show that 9 participants were given an entrainment score of 1, indicating "minimal entrainment to rhythmic auditory cueing." Ten participants were given a score of 2, indicating "moderate entrainment to rhythmic auditory cueing," and 16 participants were given a score of 3, indicating "maximum entrainment to the rhythmic auditory cueing." Descriptive analysis indicate that the participants with a high rhythmic auditory entrainment level executed a higher frequency of target movements and longer exercise duration in TIMP than the participants with a low rhythmic auditory entrainment level. After completing the TIMP session, the participants with a high entrainment level (level 3) on average indicated their ratings of perceived fatigue level (PFL) at 1.0 — "*I am not tired, but I feel I need a break*" and perceived exertion level (RPE) at 10.6 — between "*Very light*" and "*Fairly light.*" The participants with a low entrainment level (level 1) indicated their ratings of PFL at 1.3 and RPE at 11 —"Fairly *light*." A two-way MANOVA was conducted to examine whether any significant difference existed between entrainment level, endurance level, PFL, and RPE within the music condition (TIMP). The results of the analysis did not show any significant relationship between entrainment level and other dependent variables in TIMP.

Discussion

The primary purpose of the present study was to investigate the effects of Therapeutic Instrumental Music Performance (TIMP), as compared to Traditional Occupational Therapy (TOT), on endurance, self-perceived fatigue, and self-perceived exertion of inpatients in physical rehabilitation, given a single application of each treatment condition. The results of the present study indicate that TIMP and TOT did not yield meaningful differences in endurance measures, as defined by frequency and duration of a specific target movement. The results of the analysis indicate that outcomes were not significantly affected by order of condition, patients' musical background, or patients' level of entrainment to rhythmic auditory stimuli.

Statistically significant differences were found between TIMP and TOT when measuring their effects on patient perception in the present study. The finding suggests that engaging in an active musical experience facilitated by specific neurologic mechanisms for sensory-motor enhancement can decrease perception of exertion and fatigue. Previous studies have indicated that under the influence of periodic rhythmic stimulation, not only did temporal variability of physical response decrease, but spatial variability of the trajectories of the entire exercise also decreased

(Thaut et al., 1996). Although the present research findings do not indicate greater endurance with TIMP vs. TOT in a single session, the effects of TIMP on perceived fatigue and exertion level lend support to the idea that an exerciser might move more efficiently by producing less spatial and temporal variability in movements with rhythmic auditory stimulation. Thus, due to actual preserved energy, one might perceive less physical sensation (e.g., pain or fatigue) and less mental exertion with the presence of such stimulation.

Furthermore, the results of the present study indicate the negative correlation between movement frequency and perception of fatigue and exertion after exercise with TIMP. The finding suggests that playing instruments with musical cueing provides a sensory stimulus that focuses one's attention away from the physical sensations of the exercise, resulting in perception of less exertion and fatigue. These effects on perception might, in turn, be connected to attentional focus, energy level, and motivation. The utilization of TIMP as a regular treatment technique could result in less perceived exertion and fatigue and improved energy levels throughout the recovery process. This decreased perception of exertion and fatigue could have long-term effects on recovery since increased energy levels should lead to greater motivation to take on more demanding or more frequent tasks in therapy. General sense of well-being should also improve with decreases in perceived fatigue and exertion, potentially impacting psychosocial factors which, in turn, affect recovery.

One of the most important unanswered questions arising from the present study concerns factors related to time and practice. Investigators measured the effects of TIMP and TOT in a single session. While perception of fatigue and exertion were significantly different between the two conditions in a single session, one might find even greater differences when techniques are utilized over time. Furthermore, it will be important to compare the two techniques and their effects on endurance given multiple sessions versus one. Future studies should focus on the effects of TIMP and TOT with multiple presentations over time.

While recorded music with adjustable tempo was utilized for this study in order to narrow variables, investigators were limited in their ability to simplify accompaniment and adapt to patient performance in the moment. Recorded music may have also resulted in patients' decreased feelings of contribution to the musical product, which in turn could have affected perception and motivation. Future studies should examine the effects of TIMP utilizing live accompaniment versus recorded. Likewise, the effects of preferred, patient-chosen music versus familiar, investigator-chosen music could be explored. One possible limitation of the study was the use of different investigators for TIMP and TOT sessions. Utilizing the same investigator for both techniques would eliminate variables associated with relationship between investigator and patient.

Since therapists working in sensorimotor rehabilitation are very often concerned with strengthening and maximizing function of the most affected regions of the body while also restoring strength and overall function to the entire body, investigators carefully considered the decision to focus exercises on the stronger arm. Due to the wide variety of patient diagnoses and needs, and due to the emphasis on perception of fatigue and exertion for patients in physical rehabilitation who would typically be involved in an endurance exercise group, investigators chose to narrow variables by studying the stronger arm; future studies should focus on perceptual effects of TIMP on the weaker side, particularly for patients with stroke and traumatic brain injury. Diagnosis might also be considered as a variable in future analysis.

Research studies with larger sample sizes might investigate the effects of rhythmic entrainment level on endurance and perception of fatigue and exertion. In order to more carefully explore rhythmic entrainment level, a more specific evaluation tool should be developed. While the present study investigated endurance and perceptual factors, future studies should measure the effects of TIMP and TOT on changes in actual movement quality (e.g., timing, range of motion, velocity, or dexterity), then analyze relationships between changes in movement and perception of fatigue and exertion. In comparing TIMP procedures to TOT procedures, it became evident that both involved repetitive cueing; in TIMP, cueing was musical while in TOT, cueing was verbal (i.e., counting repetitions). Investigators question whether replacing counting with musical cueing might have directly resulted in decreased perception of fatigue and exertion. Future directions might include exploration of different cueing techniques (e.g., verbal vs. musical or loud vs. silent) and their specific effects.

Both researchers and clinicians in sensorimotor rehabilitation are concerned with the effects of various techniques on actual physical function as well as the effects of techniques on patient perception. Since the medical community is well aware of the connection between mind and body, it must also recognize that affecting either may affect both, and impacting either in a specific, positive manner can bring significant therapeutic change. The present study found a strong relationship between TIMP and perception of fatigue and exertion. As future studies further explore this relationship, clinicians may find TIMP a highly useful technique in physical rehabilitation, due to both perceptual factors that in turn affect physical outcomes and neurophysiological factors that in turn affect perception.

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