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The Effect of Sound Stimuli on Neurologic Rehabilitation of Upper and Lower Limbs: A Meta Analysis

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I would like to dedicate this to my parents whose unconditional love and support at all times has enabled me to grow in many ways.

This thesis is also dedicated in loving memory to Pastor Janet Goldsmith, whose life has been my inspiration.

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ABSTRACT

The purpose of this study was to analyze the existing quantitative research evaluating the effect of sound stimuli on neurologic rehabilitation of upper and lower limbs. Seventeen studies were used in two separate analyses. The first one evaluated the effects of sound stimuli on within-subjects groups. Data were recorded before and during music intervention. The second analysis evaluated the effects of sound stimuli on between-subjects groups using an experimental /control design. Overall results indicated that music has proven to be significantly effective in rehabilitation of the limbs (d = .81 for the pre-post studies and d = 1.04 for the experimental/control studies

INTRODUCTION

Music comes from nature, and indeed, music itself possesses a natural essence. That is one reason why it can integrate and synchronize with the human body and mind. Perhaps the most powerful characteristic of music is the fact that music is energy. It is kinetic energy in motion. This energy is able to connect tones in sequence, and with the variety of durations embodied in them, the kinetic energy increases and becomes a significant force that provide rhythm with the spark of life (McClellan, 1988).

In both psychological and physiological perspectives of humans' health, music plays a tremendously great role. People attend to what is pleasurable for them, and music has the ability to distract from the perception of pain (Lowe, 2003). With this in mind, music therapy can be neatly structured for clinical applications to meet the needs of individuals. Now that music therapy is recognized in medical settings, Standley (2000) describes the use and methods of music therapy as beginning to emulate the medical model.

In order to understand how to use music for treatment, there is a need for a deeper understanding about music. As previously mentioned, music comes from nature and music itself is natural. Rhythm contained in music is an essential and significant basic element found in natural processes of life.

While discussing about commonalities in the central nervous system's involvement with complementary medical therapies, Stefano et al. (2004) stated that

> Although rhythm and music are not entirely synonymous terms, rhythm constitutes one of the most essential structural and organizational elements of music: Time structure of music is the essential element relating music specifically to motor behavior. Thus, the motor system appears to be strongly sensitive to auditory priming (p. 11).

Indeed, everything in life is in rhythm. In an older manuscript, Wernli (1961) writes:

> First, there is calculation of time, which we determine by the rotation of the earth around the sun. This rotation is a cosmic rhythm, influential in the biological processes of the universe. Spring, summer, fall, and winter succeed each other. The sun governs our calendar and sets our time-pieces, thereby regulating all our

> activities. This rhythm has become so much a part of our lives that we hardly notice it. (p. 21).

Because we are living in a rhythmic universe, "the concept of merging with the pulse of the music is important" (Beaulieu, 1987, p. 80).

The interconnectedness between rhythm and the human body is an important key to achieving good health. The Academic Music Therapy Forum (AMT) (2001) points out that in the area of the three-structured system of the autonomic rhythms, respiratory, and circulatory rhythms, organization of life processes must be balanced.

Modern day researchers discovered that there is a direct correlation between musical frequencies and brain wave patterns (Cardinal, 2004). With neuroimaging technologies and biofeedback, it has been revealed that sound and imagery play an integral role in assisting clients to achieve their physiological objectives. Using biofeedback, we can see through an audio signal the ascending and descending of pitches which correspond with tightening and loosening of muscles. Audio signal ascends in pitch when the muscle tightens and descends in pitch as the muscle relaxes (Miller, 2004).

Music possesses acoustical components. In regards to Vibroacoustics (therapy technique that uses vibrations), Gazette (2004) stated that the therapy "has been found to reduce stress, nausea, headache, anxiety, fatigue and depression. Also, calm and soothe restless behavior, improve range of motion, promote muscle tone, and develop sensory awareness"(p. 1).

Found to be strongly connected with emotions, music may also have effects on the body's immune system. In a research that examined the effects of music on the immune system of ten healthy individuals (McCraty, 1999), results showed that listening to music designed to facilitate stress reduction increased DHEA, reduced cortisol, improved autonomic balance and increased coherence in the ANS, as well as facilitated the entrainment of physiological systems" (p. 2).

Aldridge (2001) explains that in order to function in the world, people need co-ordination of time and space, because we exist in the here and now. He stated:

> While we consider chronological time as important for what we do in terms of co-ordination, it is the idea of time as *kairos* that is significant. If *chronos* is time as measured, *kairos* is time considered as the right or opportune moment. It

> contains elements of appropriateness and purpose; that is, intention. Inherent within the term is the concept of decisiveness; there is tension within the moment that calls for a decision and there is also the expectation that a purpose will be accomplished. Rhythm demands intention (p. 2).

Aldridge theorizes that what happens with neuro-degenerative illness is that when physical health is beginning to fail, people fall out of time. In this case, an internal timekeeper fails to function. Initiation of activities to promote coherence cannot take place. They suffer not a chronic illness, but a kairotic illness. Therefore, an external source is needed to resynchronize movements. Aldridge (2001) also claims that one of the benefits of music therapy for neuro-degenerative diseases is to offer a temporal structure for processing inputs where timing can be practiced. This process of what we regard as constructing the time is actually the basis of cognition.

REVIEW OF LITERATURE

The neurological pathway of motor activity consists of input and output signals to and from a structure like motor cortex, which are classified as command input, command output in spinal interneuron, and sensory feedback in the muscle-based proprioceptive coordinates (Loeb, 1999). Morasso and Tagliasco (1986) mention that impairments in pathological gait patterns with conditions related to the corticospinal and motor neurons are usually caused by lesions of the central nervous system, which is where input signals are located. In these cases, development of movement patterns depends not only on the internal parts of muscles, but also on external forces including environmental constrains.

Staum (1981) explains that since gait is controlled and modified by sensations that occur externally with impulses and by the muscle tone, the use of augmented auditory cues in rehabilitating pathological gait should be applicable in facilitating this control.

In a 1983 study, Staum investigated the application of rhythmic auditory stimuli as a superimposed structure in facilitating rhythmic gait control using reversal design. Twenty-five subjects of varying ages and gait disorders were asked to listen to their preferred music and additional rhythmic percussive sounds while attempting to match their footsteps to the stimuli. At the last part of this experiment, the music and rhythmic stimuli faded away. Results of the study showed significant gains in patients' rhythmic control not merely when the stimuli were present, but even throughout fading procedures.

Music and Muscle Activity

General outcomes of phase-dependent modulation during arm-cycling/arm movement are changes in the level of EMG activity (Carroll et al., 2005). In an experimental study, Safranek et al. (1982) analyzes the effect of auditory rhythm on muscle activity. The study showed contraction of medial triceps and biceps muscles when rhythm was imposed.

In a study that observed thirty-two Parkinson's patients divided into two groups—one group went through weekly physical therapy while the other group received music therapy sessions (consisted of listening to music, instrumental playing, and moving to rhythms), researchers found that unlike physical therapy, music therapy helped patients improve their ability to do daily tasks. Participants of the study also reported that they were less likely to fall or experience the sudden freezing up of muscles (Morelli, 2000).

Music and Movement

Auditory cues can be utilized to facilitate activities to restore and temporarily recover from the loss of time perception. Ghez et al. (2000) mentions that motion and sound processing might have some parallels. The connection between sound and movement encourages self-awareness and repetition to facilitate learning (National Institute on Developmental Delays, 2002).

As to facilitate temporal muscular control of movement patterns, auditory stimuli functions by: influencing timing of motor skills, decreasing fatigue feelings, facilitating movement performance, improving reaction time and response quality, and providing auditory feedback (Thaut, 1988).

A common music technique used for movement exercises is known as Rhythmic Auditory Stimulation (RAS). The Center for Biomedical Research and Music (2002) defines RAS as a technique using rhythmic, melodic, harmonic, and dynamic-acoustical elements of music to structure and cue movement. With RAS, the texture of music varies.

Texture of music matters. In an experiment with five musicians as subjects, Miller et al. (1996) measured the timing of EMG and keyboard-playing responses to rhythmic auditory stimuli. They found that with the additional auditory information, the response became more synchronous with the cueing.

Rhythmic training can also entrain biological rhythms including areas such as respiration, heart-rates, motor movements, body movements of people during conversation, and brain waves (Strong, 1997). An example of an entrainment exercise would be the TA KE TI NA rhythm process. TA KE TI NA are "four sounds from a rhythm language used by various indigenous cultures as a tool for healing mind and body through rhythm"(Flatischler, 1996, p. 344). The exercise usually uses drumming activity to express this rhythm. (Flatischler, 1996). Flatischler also noted that after some TA KE TI NA sessions, 80% of people who suffered from asthma, arrhythmia, and high blood pressure reported a decrease of their symptoms and improvement of well-being.

In order to reach and synchronize with the body, sound processing starts from the ears and gets more complicated thereafter. Martin (2004) who researched Dalcroze Eurhythmics writes that "Dalcroze believed the ears were the agents to appreciate and understand sound, but rhythm required the education of the entire nervous system" (para

14).

Ehrsson et al. (2000) did a PET study on simultaneous movements of upper and lower limbs and found significant results. Their data suggested that those movements were coordinated by macro-anatomical regions of the brain that specifically control isolated movements.

According to Hurt-Thaut, and Johnson (2003), there are three concepts of motor control in conjunction with the role of music: sensorimotor control, motor programming, and goal-directed movement. All these are steps of motor planning, which is defined by Kranowitz (1998) as "the ability to conceptualize, organize, and realize a complex sequence of unfamiliar movements" (p. 119), is important in a music-assisted rehabilitation program. In many cases, motor planning is more individualized because people function according to the structure of their body parts.

Overall, it can be summarized that the application of music or auditory stimuli in clinical settings aims to stimulate, elicit, or to facilitate movement through paired stimuli, and also to elicit neuromuscular feedback (Staum, 2000). Concerning strengthening exercises in particular, Wong (2004) wrote that "music should serve a purpose, such as to cue motion, the speed of the gait, or provide a more enjoyable environment"(p. 77).

The effect of having auditory stimulation sometimes can be greater than what we expect. In a study of error-correction in sensorimotor-synchronization, Praamstra (2003) et al. found that the auditory stimulation not only activated phase-correction mechanisms, but also invoked period-correction mechanisms. This means that the presence of an auditory stimulus has the capacity to extend duration of exercises.

Kendelhardt (2003) did a study examining the effects of live contingent music on exercise duration of thirty subjects enrolled in physical rehabilitation. The subjects were divided into experimental and control groups with an equal number of individuals in each. For the experimental subjects, the researcher sang and played the subject's preferred music while the subject was pedaling on a restorator machine. Subjects were also encouraged to sing and participate with the researcher. The control subjects received regular physical therapy. Results showed that the music group had significantly longer exercise duration times than the control group.

In a research study that used BATRAC (bilateral arm training with rhythmic auditory cueing) program for patients in stroke recovery, researchers found no significant difference between the experimental and the control groups. However, for the patients that showed fMRI brain changes during training, their arm function improved significantly compared to the others (Hitti, 2004), meaning that rhythmic auditory training has to first activate the brain prior to activating limb movements.

In an experiment conducted to determine movement patterns in the index fingers of professional banjo players, Kenyon and Thaut (1998) observed the index fingertip paths during instrumental playing and measured the time duration. They found that each player developed a very individualized motor program or sequence of muscle contractions to control their finger function. Kenyon and Thaut discussed that this finding of finger movement analysis is a way to proceed toward planning strategies to improve motor functions.

Gervin (1991) utilized the music therapy technique of song lyrics to help the dressing process of a patient with brain injury. The patient completed dressing in a shorter amount of time with the music therapy intervention. Gervin concluded that, indeed, developing creative and valid treatment alternatives is necessary to assist individuals with traumatic brain injury who have residual deficits.

Evans et al. (1998) conducted an experiment on a patient with frontal lobe damage, investigating the use of mneumonic cueing systems such as checklists in the rehabilitation of executive impairments. They found that external aids, particularly those associated with rehabilitation of memory functioning are indeed useful in rehabilitation of external functioning impairments. This study opened up ways for music to perform its function as an external stimulus.

In a study that investigated the effectiveness of RAS in a home based gait training program for Parkinson’s disease patients (Thaut et al., 1995), the result was found to be significant for all parameters measured. Thaut et al. concluded that RAS is a program that is simple and cost effective which patients can use at home to maintain and improve their functional independence.

Malcolm et al. (2004) examined the abilities of constrained induced therapy (CIT) and Rhythmic facilitation (RF) to promote motor re-learning in the paretic upper-limb of stroke patients. They concluded that CIT alone does not significantly improve movement and motor control. In contrast, RF therapy does improve the spatiotemporal organization of movement.

The purpose of this meta-analysis is to analyze the use of music in upper and lower limb rehabilitation in order to understand how music therapy works and how it affects individuals who suffer from neurological disorders that cause dysfunction or weakening of the limbs of the body.

METHOD

Study Inclusion

Criteria for inclusion in this meta-analysis were: 1) Studies using group or individual subject designs; 2) Studies on upper and lower limbs rehabilitation with subjects who had neurological disorders; 3) Studies with different sound stimuli (anything that has tones, rhythm, or both) utilized as an independent variable contrasted with a no-sound control condition; 4) Studies with quantitative results reported with sufficient information to extract an effect size; and 5) Studies reported in the English language of design, procedures, and results amenable to replicated data analysis.

Studies which involved only healthy subjects or subjects with no indicated neurological disorder were excluded.

The procedures followed the four basic steps of a meta-analysis as defined by Standley (2003) : "(1) a complete literature search was conducted to find all possible members of the defined population of studies whether from published or unpublished sources; (2) the characteristics and qualities of the collected studies were identified, described, and coded; (3) these assigned codes were independently reviewed for reliability with discussion and re-review until full agreement was obtained, then (4) each study's results were statistically analyzed and converted to computed effect sizes using meta analysis software"(p. 2).

The identification process involved exhaustive searches of the *Journal of Music Therapy*, MEDLINE, PsycINFO, and Google. There were no restrictions on sources or years of publication. Keyword for searches of electronic indexes included sound, music, neurologic, rehabilitation, and limbs. The reference lists of all identified articles and texts were also searched (REI Institute, 1997; The Infography about Music Therapy in Neurologic Rehabilitation, 2005; Rathbun, 2005; The Center for Biomedical Research and Music, 2002). After articles were obtained, the researcher then examined the articles and filled out a research analysis form (see appendix) on each article. Data on the forms were then entered into the meta-analysis program. Reliability of categorization of studies was attained through the assistance of another music therapy student who independently filled out the same research analysis forms. Reliability was computed on the two sets of forms by dividing total number of agreements by total number of agreements plus disagreements (Madsen & Madsen, 1998). The reliability score was .96.

Study Descriptions

Eighteen studies met criteria for inclusion in the meta-analysis. These studies are marked with an asterisk in the references and are summarized below.

Two meta-analyses were done on studies using experimental/control groups versus those using subjects as their own control.

In studies with subjects serving as their own control (pre-post tests), five studies investigated effects of gait training or motor rehabilitation on stroke patients (Thaut, McIntosh, & Rice, 1997; Prassas, Thaut, McIntosh, & Rice, 1997; Bütefisch, Hummelsheim, Denzler, & Mauritz, 1995; Thaut, McIntosh, Prassas, & Rice, 1993; McIntosh, Thaut, & Rice, 1996). There were seven studies examining gait training and rehabilitation programs on patients with Parkinson's disease (Pacchetti et al., 2000; Thaut et al., 1996; McIntosh, Brown, Rice, & Thaut, 1997; Freedland et al., 2002; Freeman, Cody, & Schady, 1993; del Olmo & Cudeiro, 2005; Miller, Thaut, McIntosh, & Rice, 1996). The study by McIntosh, Brown, Rice & Thaut (1997) measured the effect of rhythmic auditory-motor facilitation in Parkinson's disease patients on-and-off medication. Both results are listed in this meta-analysis. Two studies looked at the effect of RAS on movements of patients with traumatic brain injury (Hurt, Rice, McIntosh, & Thaut, 1998; Kenyon & Thaut, 2000). One study examined gait training in patients with Huntington's disease (Thaut, Miltner, Lange, Hurt, & Hoemberg, 1999). One study examined rehabilitation of gait on patients with various neurological disorders (Staum, 1981), and there was another study that investigated rhythmic instrument playing in persons with severe dementia (Clair, 1995).

There were five studies with experimental and control groups. Three of these investigated training with stroke patients (Thaut, Kenyon, Hurt, McIntosh, & Hoemberg, 2002; Thaut, McIntosh, & Rice, 1997; McIntosh, Thaut, & Rice, 1996) and two studies analyzed the effect of sound stimuli versus no sound control condition on patients with Parkinson's disease (Pacchetti et al., 2000; Thaut et al., 1996).

Twenty-one additional neurologic music therapy articles were obtained, evaluated, and determined to not meet criteria for inclusion in the study. These included: 1) Studies with healthy subjects or subjects with no indicated neurological disease (Kendelhardt, 2003; Thaut, Schleiffers, & Davis, 1992; Caroll, Zehr, & Collins, 2005; Safranek, Koshland, & Raymond, 1982; Praamstra, Turgeon, Hesse, Wing, & Perryer, 2003; Ehrsson, Naito, Geyer, Amunts, Zilles, Forssberg, & Roland, 2000; Kenyon & Thaut, 1998); 2) Studies with insufficient quantitative data to extract an effect size (Gervin, 1991; Ghez, Rikakis, DuBois, & Cook, 2000; Whitall, Waller, Silver, & Macko, 2000); 3) A study with insufficient information on group n (Schauer & Mauritz, 2003); 4) Studies that were unavailable in full-text formats including abstracts in proceedings (Brown, Thaut, Benjamin, & Cooke, 1993; Thaut, Hurt, & McIntosh, 1997; Rice, Thaut, McIntosh, & Miller, 1995; Thaut, Lange, Miltner, Hurt, & Hoemberg, 1996; Thaut, Hurt, Dragon, & McIntosh, 1998; Tecchio, Salustri, Thaut, & Weckel, 1998); 5) Articles with duplicated studies already selected for this analysis (Thaut, McIntosh, McIntosh, & Hoemberg, 2001; McIntosh & Thaut, 1997; Staum, 1983); and 6)Study with graphed data with insufficient labeling to obtain necessary data for analysis (Thaut, McIntosh, Prassas, & Rice, 1992).

Quality Analysis

Studies were coded for the following variables:

1. Age of participants: (a) 18-50 years old versus (b) >50 years old versus (c) combination;
2. Sound stimuli: (a) music alone versus (b) rhythm alone versus (c) both music and rhythm versus (d) non-music sound (metronome, clock ticks, electronic device) versus (e) unspecified;
3. Type of sound stimuli: (a) live versus (b) recorded;
4. Motor area: (a) all four limbs versus (b) upper limbs only versus (c) lower limbs only;
5. Statistics: (a) mean of groups versus (b) F score (ANOVA/MANOVA) versus (c) t test score versus (d) % improvement for the groups;
6. Duration of experiment: (a) weeks (<4) versus (b) months versus (c) unspecified;
7. Dependent variable: (a) deviation/accuracy/symmetry versus (b) in time with beat versus (c) degree of movement/rigidity versus (d) velocity (acceleration or speed) versus (e) stride length versus (f) cadence (strides per minute) versus (g) frequency versus (h) EMG amplitude variability of muscles; and

8. Type of disease: (a) Parkinson's versus (b) Stroke versus (c) TBI versus (d) Huntington versus (e) Other.

Data Extraction

One or two dependent variable(s) were selected from each study that contrasted music with a no-music control condition. Each was considered the primary measurement of effect in the study. The values were then converted to an estimated effect size, Cohen's *d* (Cohen, 1988). Table 1 shows the selected dependent variables and other qualities of each study that were coded for analysis of pre-post or within subjects design. The earliest article was from 1981 and 61% of the studies were conducted by Dr. Michael Thaut of the Biomedical Research Center at Colorado State University.

Table 1—*Studies by Coded Qualities, Part A*

Study Authors & Year	Age of Participants	Sound Stimuli	Type of Sound Stimuli	Motor Area
Bütefisch et al. (1995)	Combination	Non-music sound	Recorded	Upper limbs
Thaut et al. (1999)	Combination	Both music & rhythm	Recorded	Lower limbs
Freedland et al. (2002)	>50 yr old	Non-music sound	Recorded	Lower limbs
Freeman et al. (2003)	>50 yr old	Rhythm alone	Recorded	Upper limbs
Kenyon & Thaut (2000)	18-50 yr old	Non-music sound	Recorded	Lower limbs
Clair (1995)	>50 yr old	Rhythm alone	Live	Upper limbs
Del Olmo & Cudeiro (2005)	>50 yr old	Unspecified	Recorded	All four limbs
Thaut et al. (1997) (Elsevier)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1998) Exp 1	18-50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1998) Exp 2	18-50 yr old	Both music & rhythm	Recorded	Lower limbs
Prassas et al. (1997)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1996) (Elsevier)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1997) (JNNP)[1]	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1997) (JNNP)[2]	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1996) (MM)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Pacchetti et al. (2000)	>50 yr old	Music alone	Live	All four limbs
Thaut et al. (1993)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1996) (MD)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Staum (1881)	Combination	Both music & rhythm	Recorded	Lower limbs

Table 1, Part B

Study Authors & Year	Statistics	Duration of Experiment	Dependent Variable	Type of Disease
Bütefisch et al.	T test score	Weeks	Velocity	Stroke
Thaut et al.	F score	Unspecified	Velocity Stride Length	Huntington
Freedland et al.	F score	Unspecified	Stride Length Cadence	Parkinson's
Freeman et al.	F score	Unspecified	Frequency	Parkinson's
Kenyon & Thaut	T test score	Unspecified	Deviation/accuracy	TBI
Clair	Mean of groups	Months	In time w/ beat/ error rate	Other
Del Olmo & Cudeiro	Mean of groups	Weeks	Velocity Stride Length	Parkinson's
Thaut et al. 97 (Elsevier)	Mean of groups	Months	Velocity Stride Length	Stroke
Thaut et al. 98 (Exp 1)	Mean of groups	Months	Velocity Stride Length	TBI
Thaut et al. 98 (Exp 2)	F score	Months	Velocity Stride Length	TBI
Prassas et al.	F score	Months	Degree of movement Stride Length	Stroke
Thaut et al. 96 (Elsevier)	T test score	Weeks	Velocity Stride Length	Parkinson's
Thaut et al. 97 (JNNP)[1]	T test score	Unspecified	Velocity Stride Length	Parkinson's
Thaut et al. 97 (JNNP)[2]	T test score	Unspecified	Velocity Stride Length	Parkinson's
Thaut et al. 96 (MM)	Mean of groups	Months	Velocity Stride Length	Stroke
Pacchetti et al.	Mean of groups	Months	Degree of movement	Parkinson's
Thaut et al. 93	% improvement of groups	Months	Deviation/accuracy Amplitude variability	Stroke
Thaut et al. 96 (MD)	T test score	Weeks	Velocity Stride Length	Parkinson's
Staum	Mean of groups	Weeks	Deviation/accuracy Cadence	Other

Table 1, Part C

Study Authors & Year	How Music was Used
Bütefisch et al.	Electronic device--acoustic signal
Thaut et al.	RAS: 10% faster than baseline cadence
Freedland et al.	Metronome set to 10% above the baseline cadence
Freeman et al.	Pulses: produced by tapping movements of healthy subjects
Kenyon & Thaut	RAS: frequency matched to baseline frequency
Clair	Instrumental playing—entrainment
Del Olmo & Cudeiro	Rhythm matched to subjects' preferred gait
Thaut et al. 97 (Elsevier)	RAS: a timekeeper to synchronize step patterns and gradually entrain higher stride frequencies
Thaut et al. 98 (Exp 1)	RAS: set at a tempo 5% faster than the fast walk without music
Thaut et al. 98 (Exp 2)	RAS: set at a tempo 5% faster than the fast walk without music
Prassas et al.	Tempo of music set to each subject's gait cadence (baseline)
Thaut et al. 96 (Elsevier)	RAS with unspecified pulse
Thaut et al. 97 (JNNP)[1]	RAS beat frequency matching the baseline cadence
Thaut et al. 97 (JNNP)[2]	RAS beat frequency matching the baseline cadence
Thaut et al. 96 (MM)	RAS matched to free speed gait cadence
Pacchetti et al.	Active MT improvisations by therapist; patients play an active role improvising using instrument and voice
Thaut et al. 93	RAS: Tempo varies
Thaut et al. 96 (MD)	RAS: started with baseline cadence; tempo gradually increased by 5-10% each week
Staum	Music and accented beats on different tempi

[1]Patients on-medication

[2]Patients off-medication

Table 2 shows the selected dependent variables and other qualities of each study that were coded for analysis of experimental-control design or between subjects design.

Table 2—*Studies by Coded Qualities, Part A*

Study Authors & Year	Age of Participans	Sound Stimuli	Type of Sound Stimuli	Motor Area
Thaut et al. (2002)	>50 yr old	Non-music sound	Recorded	Upper limbs
Thaut et al. (1997)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Thaut et al. (1996) (MM)	>50 yr old	Both music & rhythm	Recorded	Lower limbs
Pacchetti et al. (2000)	>50 yr old	Music alone	Live	All four limbs
Thaut et al. (1996) (MD)	>50 yr old	Both music & rhythm	Recorded	Lower limbs

Table 2, Part B

Study Authors & Year	Statistics	Duration of Experiment	Dependent Variable	Type of Disease
Thaut et al. 02	t test score	Unspecified	Degree of movement	Stroke
Thaut et al. 97	Mean of groups	Months	Velocity Stride Length	Stroke
Thaut et al. 96 (MM)	Mean of groups	Months	Velocity Stride Length	Stroke
Pacchetti et al.	Mean of groups	Months	Degree of movement	Parkinson's
Thaut et al. 96 (MD)	F score	Weeks	Velocity Stride Length	Parkinson's

Table 2, Part C

Study Authors & Year	How Music was Used
Thaut et al. 02	Frequency of rhythmic cue was matched to the patient's baseline frequency
Thaut et al. 97	RAS: time keeper to synchronize step; gradually entrain higher frequencies
Thaut et al. 96 (MM)	RAS matched to free speed gait cadence
Pacchetti et al.	Improvisations by therapist; patients improvise using instrument and voice
Thaut et al. 96 (MD)	RAS: started with baseline cadence; tempo increased by 5-10% each week

RESULTS

Pre-Post Design

For the Pre-Post or within subjects design (Table 3), results showed the overall mean effect size of .81 ($p = .00$). Since the 95% confidence interval did not include 0, this effect size is considered statistically significant. All studies resulted in positive effect size which indicate that there is a promising future for the functions of music therapy in neurological rehabilitation, particularly on rehabilitation of the limbs of the body. The homogeneity Q value was significant ($p = .00$), which means that the effect sizes of studies were inconsistent.

Qualities of studies were analyzed to find reasons for inconsistency in the results. Table 4 lists data by categories and subcategories.

The first category was age of participants. All age categories were significant as the confidence interval did not include zero. Consistent results ($p = .50$) indicated that effects of age did not differ. Analysis shows that results of therapy were not dependent upon age of patients.

For sound stimuli, there were significantly different effects by different sound stimuli ($p = .01$) with non-music sounds showing the best results.

On the type of sound stimuli category, recorded music was significantly better than live ($p = .05$)

With regard to motor area, results were significantly different ($p = .04$) with procedures measuring all four limbs showing poorer results.

For statistics category, there were significant differences in effects among the type of statistics used ($p = .01$). Studies analyzed with t-tests showed greatest effects.

Results for duration of experiment were not significant. Duration of experiment (weeks versus months) made no difference in results.

With regard to type of dependent variable, there was no significant difference in results ($p = .06$).

Data indicate that results did not vary among types of disease ($p = .08$).

Table 3—*Results of Meta-Analysis—Within Subjects Design*

Study		*N*	*D*	95%CI	*R*	*P*
Bütefisch et al.	V	15	1.44	+0.63/+2.24	.60	.00
Thaut et al.	V	27	1.62	+0.08/+1.17	.31	.02
	SL	27	.20	-0.33/+0.74	.11	.44
Freedland et al.	SL	16	1.36	+0.59/+2.13	.58	.00
	Cad	16	.77	+0.05/+1.49	.38	.03
Freeman et al.	Freq	9	1.38	+0.35/+2.41	.61	.00
Kenyon & Thaut	Dev	5	1.98	+0.47/+3.49	.78	.00
Clair	In time	40	.37	-0.07/+0.81	.19	.09
Del Olmo & Cudeiro	V	15	.23	-0.49/+0.94	.12	.52
	SL	15	.12	-0.60/+0.83	.06	.74
Thaut et al. 97 (Elsevier)	V	10	1.73	+0.71/+2.76	.68	.00
	SL	10	1.08	+0.14/+2.02	.51	.02
Thaut et al. 98 (Exp 1)	V	8	.77	-0.24/+1.79	.40	.11
	SL	8	.78	-0.50/+2.07	.44	.17
Thaut et al. 98 (Exp 2)	V	5	1.15	-0.19/+2.48	.58	.06
	SL	5	1.20	-0.15/+2.55	.60	.05
Prassas et al.	Deg	8	.08	-0.90/+1.06	.04	.87
	SL	8	.59	-0.41/+1.59	.32	.22
Thaut et al. 96 (Elsevier)	V	8	2.18	+0.94/+3.42	.77	.00
	SL	8	1.25	+0.18/+2.33	.58	.01
Thaut et al. 97 (JNNP)[1]	V	21	.92	+0.29/+1.56	.43	.00
	SL	21	.79	+0.17/+1.42	.38	.01
Thaut et al. 97 (JNNP)[2]	V	10	1.25	+0.29/+2.21	.56	.01
	SL	10	1.10	+0.16/+2.04	.52	.02
Thaut et al. 96 (MM)	V	4	1.46	-0.09/+3.03	.71	.03
	SL	4	1.32	-0.20/+2.86	.67	.05
Pacchetti et al.	Deg	16	.70	-0.01/+1.42	.35	.05
Thaut et al. 93	Dev	10	.75	-0.15/+1.66	.38	.09
	Amp	10	.68	-0.22/+1.58	.35	.12
Thaut et al. 96 (MD)	V	15	1.32	+0.54/+2.12	.57	.00
	SL	15	1.25	+0.47/+2.04	.55	.00
Staum	Dev	25	1.42	+0.80/+2.04	.59	.00
	Cad	25	.46	-0.10/+1.02	.23	.10
Overall:			.81	+0.66/+0.96	.37	.00

Total N = 449

Table 4

Results of Quality Analysis—Within Subjects Design

Quality Category	Homogeneity *P*	*N* Studies	*d*	95%CI	*R*	*P*
Age of Participants						
18-50 yr old		5	1.09	+0.52/+1.65	.48	.85
>50 yr old	.49	23	.83	+0.66/+1.00	.38	.16
Varies		5	.72	+0.45/0.98	.34	.03
Sound Stimuli						
Music alone		1	.70	-0.01/+1.42	.33	1.00
Rhythm alone		2	.53	+0.12/+0.94	.26	.21
Both music & rhythm	.01*	24	.88	+0.71/+1.05	.40	.31
Non-music sound		4	1.23	+0.80/+1.65	.52	.58
Unspecified		2	.17	-0.33/+0.68	.08	.98
Type of Sound Stimuli						
Live	.05*	2	.46	+0.09/+0.84	.23	.74
Recorded		31	.87	+0.72/+1.02	.40	.22
Motor Area						
All four limbs		3	.35	-0.06/+0.76	.17	.69
Upper limbs	.04*	3	.71	+0.35/+1.07	.34	.07
Lower limbs		27	.91	+0.75/+1.07	.41	.60
Statistics						
Mean of groups		12	.68	+0.46/+0.89	.32	.11
F score	.01*	9	.68	+0.42/+0.94	.32	.32
t test score		10	1.19	+0.93/+1.46	.51	.79
% improvement		2	. 72	+0.08/+1.36	.34	.99
Duration of Experiment						
Weeks (<4)		9	.92	+0.67/+1.17	.42	.01
Months	.50	14	.71	+0.47/+0.96	.34	.70
Unspecified		10	.82	+0.59/+1.05	.38	.28
Dependent Variables						
Deviation/accuracy		3	1.29	+0.80/+1.77	.54	.51
In time with beat		1	.37	-0.07/+0.81	.18	1.00
Degree of movement		2	.48	-0.09/+1.06	.23	.60
Velocity	.06	11	1.00	+0.75/+1.26	.45	.21
Stride Length		12	.77	+0.53/+1.02	.36	.31
Cadence		2	.58	+0.14/+1.02	.45	.80
Frequency		1	1.38	+0.35/+2.41	.57	1.00
Amplitude var of muscle		1	.68	-0.22/+1.58	.32	1.00
Type of Disease						
Parkinson's		14	.92	+0.71/+1.14	.42	.22
Stroke		9	.97	+0.64/+1.30	.44	.49
TBI	.08	5	1.09	+0.52/+1.65	.48	.85
Huntington		2	.41	+0.03/+0.79	.20	.56
Other		3	.65	+0.34/+0.95	.31	.05

N = 33 variables

**p* < .05. Subcategories are not homogeneous and have significantly different results from each other.

Experimental-Control Design

For the experimental-control or between-subjects design (Table 5), effect sizes ranged from .72 to 1.33 with an overall mean effect size of 1.04. The 95% confidence interval did not include 0; therefore, the effect size is considered statistically significant and indicates that music therapy generally has a positive and significant impact in neurological rehabilitation of the limbs. The largest outlier was Pacchetti (2000), a study which used live music that resulted in negative effect on degree of movement/rigidity ($d = -4.56$). In this case, the reason could be that the technique used for intervention was not one that best suited the group. All other results were in a positive direction for the effects of music. The homogeneity Q value was significant ($p = .00$), which shows that the effect sizes of the studies were inconsistent and could not be represented by the single, mean effect size. Therefore, a quality analysis was conducted with the removal of the largest outlier (Pacchetti, 2000). Table 6 shows data by categories and sub-categories.

For the sound stimuli category, effects were not significantly different ($p = .99$), indicating that effects were not contingent upon the sound stimuli.

With regard to motor area, results were not significantly different ($p = .99$), indicating that studies on upper limbs and lower limbs did not have different results.

In the category of statistics, there was no significant difference in effects among the type of statistics used ($p = .86$).

Results for duration of experiment were not significant ($p = .86$). Duration of experiment made no difference in results.

With regard to dependent variables, effects were not significantly different among the different variables ($p = .82$). Procedures measuring velocity showed the best results.

Type of disease did not have different results ($p = .64$).

None of the variables analyzed in this meta-analysis accounted for the variability in effect sizes. Futher investigation is warranted as research in this area develops.

Table 5—*Results of Meta-Analysis—Between Subjects Design*

Study		Total N	D	95%CI	R	P
Thaut et al. 02	Deg	42	1.04	+0..40/+1.69	.47	.00
Thaut et al. 97	V	20	1.05	+0.12/+1.99	.48	.03
	SL	20	1.18	+0.23/+2.13	.52	.01
Thaut et al. 96	V	8	1.26	-0.26/+2.78	.59	.10
	SL	8	1.33	-0.20/+2.87	.61	.08
Thaut 96 MD	V	37	1.21	+0.50/+1.93	.53	.00
	SL	37	.72	+0.05/+1.40	.35	.03
Overall			1.04	+0.72/+1.37	.46	.00

Total N = 172

Table 6—*Results of Quality Analysis—Between Subjects Design*

Quality Category	Homogeneity *p*	*N* Studies	*d*	95%CI	*R*	*P*
Sound Stimuli						
Both music & rhythm	.99	6	1.05	+0.67/+1.42	.46	.97
Non-music sound		1	1.04	+0.40/+1.69	.46	1.00
Motor Area						
Upper limbs	.99	1	1.04	+0.40/+1.69	.46	1.00
Lower limbs		6	1.05	+0.67/+1.42	.46	.97
Statistics						
Mean of groups		4	1.17	+0.60/+1.73	.50	1.00
F score	.86	2	.96	+0.46/+1.45	.43	.61
t test score		1	1.04	+0.40/+1.69	.46	1.00
Duration of Experiment						
Weeks (<4)		2	.96	+0.46/+1.45	.43	.61
Months	.86	4	1.17	+0.60/+1.73	.50	1.00
Unspecified		1	1.04	+0.40/+1.69	.46	1.00
Dependent Variables						
Degree of movement		1	1.04	+0.40/+1.69	.46	1.00
Velocity	.82	3	1.17	+0.64/+1.70	.50	. 99
Stride Length		3	.93	+0.41/+1.45	.42	.82
Type of Disease						
Parkinson's	.64	2	.96	-0.46/+1.45	.43	.61
Stroke		5	1.11	+0.69/+1.54	.48	1.00

N = 7 variables

**p* < .05. Subcategories are not homogeneous and have significantly different results from each other.

DISCUSSION

The results of both analyses revealed positive outcomes. In most of the studies, the music group was found to have improvements on gait-training measurements. Overall results (d = .81 for the pre-post studies and d = 1.04 for the experimental-control studies) are significant and considered high.

In the first meta-analysis which included age of participants as its first quality, it was shown that age did not result in different effects. Perhaps this is due to the fact that almost all the studies found were on older patients.

Utilizing non-music sound and both music and rhythm together were shown to be more effective. Data showed poorer results on live music in comparison with recorded music. An argument against this case might state that careful selection of music is required, and that the patients' comfort levels need to be fully considered while planning sessions. Perhaps the rhythmic emphasis in live selections was less pronounced than in recorded ones. Due to the fact that almost all studies used recorded music and only two studies used live music, further research is needed in this area.

Studies on upper limbs and lower limbs done separately were shown to be much more effective than studies on both upper and lower limbs together. This might indicate that rehabilitation needs to focus on one motor area at a time in order to achieve maximum results.

Overall, both analyses provide sufficient evidence on sound stimuli techniques and applications utilized in neurologic music therapy. However, additional quantitative research is believed to have the ability to provide even more evidence on the benefits of music for neurologic rehabilitation to demonstrate what music therapy can contribute in clinical settings.

Recommendations for further research include complete quantitative studies on children and adolescents to get a more compact analysis as well as more heterogeneous age groups, studies that evaluate and compare the effects of different kinds of live music with more variety on delivery techniques, and more studies on both upper and lower limbs done at the same time.

Implications for Practice

According to the results of this meta-analysis, sound stimuli have significant overall effect on neurologic rehabilitation of the limbs. The use of sound stimuli to cue and to structure movement activities helps patients improve their gait. Moreover, music can take the mind away from difficult and sometimes exhausting physical exercises and make them more enjoyable for the patient. When music therapy is used in movement activities or in gait training, the pace of sound stimulus is an important thing to consider in addition to its type and texture.

Working on upper and lower limbs separately is recommended. Procedures need to be conducted on all age ranges and all neurologic diseases. RAS is an effective technique. Non-music sounds and rhythmic emphasis in music are more effective than music alone. Perhaps such stimuli should be paired with music. Further research is needed in this area. Little research was found on contingent music. Previous research would indicate this is a fertile area for more research. Durations of as little as four weeks were effective. Clinical practice in music therapy with limb rehabilitation should measure deviation/accuracy, velocity, stride length, cadence, and degree of movement for outcome assessments.

APPENDIX A
Research Analysis Form

Title:

Author(s):

Source:

Year:

N:

Design: ___Within (same subjects) ____Between (different subjects)

APPENDIX B

Age of Participants

1. 18-50 yr old 2. >50 yr old 3. Combination

Sound Stimuli

1. Music alone 2. Rhythm alone 3. Both music& rhythm
4. Non-music Sound 5. Unspecified

Type of Sound Stimuli

1. Live
2. Recorded

Motor Area

1. All four limbs 2. Upper Limbs 3. Lower Limbs

Statistics

1. Mean of groups
2. F Score (ANOVA)
3. t test score
4. % improvement for the groups

Duration of Experiment

1. Weeks (<4)
2. Months
3. Unspecified

Dependent Variable

1. Deviation/accuracy of movement/tremor
2. In time with beat (error rate not in-time with beat)
3. Degree of movement/rigidity
4. Distance
5. Duration
6. Velocity
7. Stride Length
8. Cadence – Strides/min (beats/min)
9. Frequency
10. EMG Amplitude variability of muscle

Type of Disease:

1. Parkinson's
2. Stroke
3. TBI
4. Huntington's
5. Other

APPENDIX C
Abbreviations

V = Velocity
SL = Stride length
Cad = Cadence
Freq = Frequency
Dev = Deviation
In time = In time with beat
Deg = Degree of movement
Amp = Amplitude variability of muscles

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