This is to certify that the
thesis entitled

THE EFFECTS OF RHYTHMIC AUDITORY STIMULATION
(RAS) ON GAIT TRAINING FOR PERSONS WITH
TRAUMATIC BRAIN INJURY

presented by

Jody L. Wilfong

has been accepted towards fulfillment
of the requirements for the

M.M. degree in Music Therapy

Major Professor's Signature

April 6, 2009

Date

THE EFFECTS OF RHYTHMIC AUDITORY STIMULATION (RAS) ON GAIT TRAINING FOR PERSONS WITH TRAUMATIC BRAIN INJURY

By

Jody L. Wilfong

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER of MUSIC

Music Therapy

2009

THE EFFECTS OF RHYTHMIC AUDITORY STIMULATION (RAS) ON GAIT TRAINING FOR PERSONS WITH TRAUMATIC BRAIN INJURY

By

Jody L. Wilfong

ABSTRACT

Persons suffering from the debilitating effects of Traumatic Brain Injury (TBI) often require gross motor rehabilitation after injury. Previous research has shown positive relationships between motor functioning with rhythmic pulses, brain functioning, and temporal motor management in physical rehabilitation with persons suffering with neurologic diseases. The purpose of this study was to examine the effect of rhythmic auditory stimulation on gait rehabilitation for adults with TBI. Rhythmic Auditory Stimulation (RAS) is a specific neurologic music therapy technique that uses the physiological responses to rhythm, to assist in controlled movement within the body's motor system (Thaut, 2005). Gait exercises were observed and tested during auditory stimulation to collect data in the following components of gait: Cadence, Velocity, and Stride Length. Seven subjects from two long term care day treatment centers in southeastern Michigan were referred to rhythmic auditory stimulation testing by the physical therapy department from each treatment center. Data were collected using a stride analyzer before and after treatment and analyzed accordingly. Testing revealed a significant difference towards normal between baseline and posttest results using a pair t-test (Cadence: $t(6) = -3.017$, $p = .023$; Velocity: $t(6) = -3.518$, $p = .013$; Stride Length: $t(6) = -2.454$, $p = .050$). This study suggests that the use of rhythmic auditory stimulation in gait training assists in overall gait proficiency for persons suffering with debilitating gross motor deficiencies due to TBI.

ACKNOWLEDGEMENTS

This thesis is dedicated to my family Kayla, Tye, and Jeremy Wilfong who remind me everyday how blessed my life is. To my parents Diana and Gerald Priestley and my Aunt Annette who all helped me achieve my dreams of continuing my education. To my good friend Christopher Showerman who continues to remind me that ALL THINGS are really possible. To the memory of my grandmother Adelaide Cook. To Dr.Ted Tims who taught me more about myself as a therapist and engrained a solid sense of confidence in the skills required to be a good music therapist. To Dr. Cynthia Taggart who provided endless guidance and encouragement from the first day of graduate school. To Roger Smeltekop who has remained a constant source of knowledge and support in my professional endeavors, and to the clients of Willowbrook rehabilitation who continue to serve as a source of inspiration in researching the field of neurologic rehabilitation

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Music therapy techniques and methods vary among clinical settings and populations served, including those for persons with traumatic brain injuries (TBI). Head injuries disable more people than any other type of neurological damage and are the second leading cause of death in men under the age of 35 (Merck Manual, 1997). In 2006, The National Center for Injury Prevention and Control reported 1.4 million cases of TBI in America alone, among which were 50,000 reported deaths and over 235,000 people hospitalizations. Over one million received emergency medical treatment directly related to TBI complications (NCIPC website, 2007). The Center for Disease Control (CDC) identified the following causes of traumatic brain injuries in 2006: 28% occurred because of a fall, 20% occurred during motor-vehicle crashes, 19% were caused due to a collision with or against a moving or non-moving object, and 11% were a result of an assault (CDC, 2007).

Characteristics of TBI Patients

Traumatic brain injuries often cause varying degrees of permanent disabilities, depending on the location in the brain where the damage occurs. The National Institute of Neurological Disorders identifies the following disabilities resulting from TBI: "Cognitive impairments (thinking, memory, and reasoning), sensory processing (sight, hearing, touch, taste, and smell), communication limitations (expression and understanding), and behavior or mental health problems (depression, anxiety, aggression, and social inappropriateness)" (National Institute of Neurological Disorders on-line publication, retrieved Nov. 15, 2005 at http://www.ninds.nih.gov/disorders/tbi/tbi.htm). Presently, there is a small amount of research specifically designed to study the physical and neuro-motor impairments associated with traumatic brain injuries. The majority of the research in this field has focused primarily on the behavioral and cognitive areas causing a need for future inquiry within the neuro-motor domain (Walker & Pickett, 2007).They identify the common neuro-motor impairments including: paresis, ataxia and postural instability associated with severe traumatic brain injuries.

More serious injuries to the brain can result in coma, vegetative state, or persistent vegetative state. The Glasgow Coma Scale (GSC) assists medical personnel in assessing the Severity of the neurological condition. The GSC (See Appendix A) is comprised of three tests including eye, verbal and motor responses. Each category, including eye opening, verbal and motor responses are scored from Three being the lowest (no response to stimulus), to 15 as the highest (full response to stimulus).

Table 1.

Types of Traumatic Brain Injury (GCS)

Mild Brain Injury	13-15 points
Moderate Brain Injury	9-12 points
Severe Brain Injury	> 9 points

(Public Safety on-line publication, retrieved August 1, 2008 at http://publicsafety.com/article/photos/1154448509235_71_5.jpg.

Overview of the Brain

Neuroscience has identified various regions in the brain that are responsible for different functioning aspects in humans and notes that injury to different regions can cause debilitating effects in human functioning. The brain contains three main structures, the cerebrum, cerebellum and brainstem. The cerebrum contains the left and right hemisphere; each hemisphere contains the frontal, temporal, occipital and parietal located within the brain. The frontal lobe involves movement, planning, reasoning, speech, problem solving, and emotions. The parietal lobe involves movement, recognition, orientation and perception. The occipital lobe involves visual processing, and the temporal lobe involves recognition of auditory stimuli, speech, memory and perception (Baker and Tamplin, 2007). The cerebellum is located above the brain stem and is responsible for the coordination of balance, muscle activity and movement. It assists in the coordination of incoming sensory stimulus from the inner ear to provide the appropriate movement for body control (Baker and Tamplin, 2007). The brainstem is comprised of the medulla oblongata, pons and spinal cord. It assists in the control of attention, alertness and awareness. It controls the body's vital living functions such as blood pressure, heart rate, respiration and digestion (Baker and Tamplin, 2007).

Impairments Associated with TBI

In TBI patients, varying degrees of brain injury can cause physical manifestations that are dependent upon the location of injury sustained. For example, sustained injury in the cerebrum can cause the following impairments: Adiadochokinesia, Aphasia, Asynergia, Ataxic dysarthria, Gait ataxia. Adiadochokinesia or the inability to alternate physical movements, Aphasia or the ability to express language, Asynergia or slow, uncoordinated movements, Ataxic dysarthria or slurred speech, disrupted gait patterns (gait ataxia).

Many TBI patients suffer from disabilities related to long and short term memory recall (National Institute of Neurological Disorders, 2005). Due to the various injuries sustained after a TBI, deficits can also be found within the body's motor and sensory systems directly affecting balance and posture, causing gait disturbances (Hurt, Rice, McIntosh & Thaut, 1998).

In working with the TBI population, I have found that one must identify the varying functioning levels of long and short-term memory recall processes, as well as sustained physical injuries for each individual. As a result, TBI patients often require longer periods of time to acclimate to their surroundings, which may require several repetitive sessions before therapeutic techniques are successful. This results in the need for longer periods of time during testing before significant improvements can be detected (Falkner, 2007). Individuals suffering with the debilitating effects associated with a TBI often find themselves with newly acquired physical limitations affecting many areas of their lives, including: leisure activities and simple tasks needed for vocational skills (Gallahue, 1982). Gallahue identified a relationship between the degree of physical activity, and the patient's view of self-worth throughout the rehabilitation process.

The synthesis of existing research identifies successful rehabilitation processes, including treatment for gross motor impairments, as well as effective therapy including music-based treatment that specifically addresses the physical, emotional, and behavioral needs of traumatic brain-injured patients. Researchers also have articulated the importance of assisting all TBI patients in adapting to their newly acquired physical limitations, identifying appropriate coping skills, compensating for dysfunctions, and strengthening their overall capabilities in the rehabilitation setting.

Widespread impairments in several physical functions, as well as cognitive impairments can occur after traumatic brain injuries (Falkner, 2007). However, music therapy has effectively assisted patients with cognitive impairments, communication deficits, and socio-emotional barriers due to neurologic disorders (Lucia, 1987). According to Claeys, Miller, Dalloul-Rampersad, and Kollar (1989), music therapy assisted in motivating subjects engaged in physical and occupational therapy. The researchers suggested that applied music selections provide the structured rhythm, duration, and repetition needed to assist in optimizing the subjects overall physical workout, thus maximizing results of the prescribed rehabilitative exercise routines. Similar studies in physical and occupational therapy also yielded significant results when music-based treatment assisted the overall level of motor functioning (Thaut, McIntosh, Prassas & Rice, 1992; Kwak, 2007; Mauritz, 2002; Morris, Suteerawahananon, Etnyre, Jankovic, & Protas, 2004). Music therapy research that is focused on neurological disorders, such as traumatic brain injuries, suggests the music stimulus assists in the overall brain functioning. Music stimulation can help integrate movement in patients with physical disabilities by providing structure and motivation in treatment. Music and rhythm have been used as an accompaniment to movement by acting as a natural pacemaker in muscle movement timing (Thaut, McIntosh, & Rice, 1997; Nelson, & Rothman, 2002; Hummelshein, 1999).

Davis, Gfeller, and Thaut (1999), identify three advantages of using music as therapeutic aid in the following areas: The natural organization of rhythm found in music (such as accented rhythms) provides predictable cues that can assist in organized patterned movement. Music is a natural auditory stimulus, noted as one of the earliest senses developed. The central nervous system is naturally activated when sounds are perceived. "When we hear a sound, neurons in the motor system are excited, and our muscles are set into a state of readiness" (Davis, Gfeller, and Thaut 1999, p.267). This allows muscles to synchronize with rhythm, plan the sequences of motions and coordinate the use of muscles needed to move smoothly without interruption. This process is known as muscular entrainment through rhythmic auditory stimulation (Thaut, 2005).

Neurologic Music Therapy

"Neurologic Music Therapy (NMT) is defined as the therapeutic application of music to cognitive, sensory, and motor dysfunctions due to neurological disease of the human nervous system" (Thaut, 2005, p.126). NMT implements specific, goal-oriented treatment objectives that facilitate functional rehabilitation in persons with neurological disorders. Techniques include standardized Therapeutic Music Interventions (TMI), which are adapted to each individual's specific need. For example: A neurologic music therapist can implement rhythmic auditory stimulation (RAS) as a Therapeutic Music Intervention for a TBI patient with severe gait ataxia. Rhythmic auditory stimulation (RAS), which is a specific neurologic music therapy intervention, is defined as a "neurological technique using the physiological effects of auditory rhythm in the motor system to improve the control of movement in rehabilitation and therapy" (Thaut, 2005, p.139). Primarily used in gait therapy, RAS assists in the recovery of walking patterns in patients with Parkinson's disease, as well as those suffering from the effects of aging, stroke, or other neurological impairments. Neurologic Music Therapists receive specialized training in the areas of neuroanatomy, physiology, brain pathologies, medical terminology, as well as rehabilitation of cognitive and motor functions (Training Manual for Neurologic Music Therapy). The purpose of this study is to determine if the use of rhythmic auditory stimulation (RAS) assists in the overall functioning in gait training for adult TBI patients.

Research Predictions

Following are three research predictions for the study: (1) RAS-enhanced gait training will improve cadence of subjects tested, (2) RAS-enhanced gait training will improve velocity of subjects tested, and (3) RAS-enhanced gait training will improve stride-length of subjects tested.

CHAPTER TWO

REVIEW OF LITERATURE

The majority of RAS studies are with patients suffering from the debilitating effects of Parkinson's disease. There are undoubtedly many similar characteristics that exist between the traumatic brain injured patients and persons with Parkinson's disease, as well as other neurological disorders. Currently, there is one published article from the Center for Biomedical Research in Music, in which research specifically addresses the effects of NMT with TBI patients. Hurt, Rice, McIntosh & Thaut (1998) explore the use of RAS in gait training with those suffering with TBI. Results of this study suggest a relationship between sensory motor functions, gross motor movement, and rhythmic motor entrainment when RAS is used in gait training. The investigators of this study tested the effects of RAS within an entrainment design, and a specific gait training method to help assist in each participant's gait rehabilitation. 8 participants were tested in the entrainment design, where all three gait parameters (Cadence, Velocity, and Stride Length) were tested. Once a baseline Cadence was established for each participant, cadences were then matched to RAS for gait exercises. Participant's were asked to walk at the fastest pace possible, and then requested to walk to the matched rhythmic cadences (5% faster than the initial baseline cadence).

Five participants in the training design experiment were later asked to conduct prescribed daily gait exercises to RAS musical tapes independently. Prescribed tempos were initially set at the participants normal Cadence, then set at a faster tempo after each week of training. The music therapist reassessed each participant at the end of each week for endurance levels and vital statistics for precautionary measures. RAS sessions were then increased by one minute per week. Foot switches recorded strides to ensure accurate calculations of the gait parameters tested during the pretest and posttest, and compared. Results of the first experiment were all found to be statistically nonsignificant, although increases in velocity during the normal and fast walk phases were recorded. Increased cadences in both normal and fast walking condition were also recorded, when RAS was present. Results also suggest an overall increase in stride length throughout normal and fast walking trials, again when RAS was present. Aspects of gait symmetry were also increased during walking phases with RAS. Investigators analyzed scores between pretest and posttest data after the 5 week independent RAS experiment. Results indicate significant changes in all three gait parameters, with an overall 50% increase in Velocity, 16% increase in Cadence, and a 29% increase of Stride Length. Analysis of symmetry did not yield a statistical significant increase, although overall mean percentages increased by 12%.

Participants in the entrainment design model were only allowed enough time to measure each individual's ability to entrain to a given tempo during time of testing. The individualized RAS treatment designs were tested; endurance levels were reassessed and increased by one minute at the end of each week of training. There were no music therapists or physical therapists present on a daily basis to administer stride analysis throughout these independent gait exercises. The results of this study suggest that participants in the independent study improved in all three gait parameters after daily exercises for 5 weeks. A daily systemic analysis of gait during these exercises could have possibly assisted the participants in achieving even more improvements. This study was the first of its kind, and investigates important issues concerning the specific needs of TBI patients suffering with gait deficits, and identifies RAS as an effective therapeutic technique used in gait rehabilitation.

Fernandez del Olmo, Arias, Furio, Pozo, & Cudeiro (2006) evaluated the effects of rhythmic movement by using an auditory stimulation with Parkinson's patients in fine and gross motor movement exercises. Through careful study of timed variability in finger-tapping and gait training, results indicate a decline in the overall variability of movements in subjects tested. Nine participants were tested in fine and gross motor movement exercises, as well as a control group consisting of five patients with no history of neurological pathologies. Subject's attended treatment sessions for one hour per day, five days per week for a four week period. Assessments of fine and gross motor movement abilities were recorded before and after assigned exercises including the special temporal patterns of footsteps, velocity, step length, cadence and variation coefficients found between each footstep. Fine motor testing consisted of finger-tapping exercises, repetitive extension and flexion movements for a 30 second time period. Tapping exercises were performed with the index finger on the side of the body most affected by Parkinson's disease. Tapping frequencies were recorded in Hz and coefficient variation of intervals recorded between consecutive taps. PET scans were performed before and after movement exercises resulting in a statistical significance found within variable movements upon completion of assigned exercises, consistent timing regularity was also detected in both fine and gross motor movement exercises. Results suggest auditory stimulation enhances both fine and gross motor tasks over a 30 day period by improving the regularity of temporal motor movements in participants tested in this study.

Pacchetti, Mancini, Aglieri, Fundaro, Martignoni, and Nappi, (2000) observed that music activities consisting of rhythmic free body movements, choral singing, and voice exercises, combined with physical therapy, produced a positive, significant overall effect on patients with Parkinson's disease. In this study, the combination of rhythmic movement and auditory stimulation through different pathways of the brain resulted in an enhancement of motor skills, affect, and behavioral functioning. Hamburg and Clair (2003) suggest that rehabilitation should include more than the physical workout; it should focus attention on attitudes, motivation, endurance, and emotional components that music has been known to affect directly. In this study, music was used to enhance movements in physical exercises that contribute to an increase of motor control and balance in patients with neurological disorders. Research also suggests that the rhythm in music can improve different types of physical movements, including range of motion and speed, while concurrently reinforcing dynamics, duration, and timing of movements in the elderly (Hamburg and Clair, 2003).

As demonstrated in a 1993 study by Georgiou, Iansek, and Bradshaw, music and rhythm are effective cues for fine motor responses. The subjects in their study had Parkinson's disease, and the researchers tested fine motor functioning by assessing each individual's ability to press spatially sequential keys located on a board. Treatment yielded improvements in fine motor movement as demonstrated by the participant's abilities to press keys with temporal cuing. The rhythmic pulses assisted in a natural temporal pace of finger movement. This reinforces the assumption that rhythm can be used as a support for rhythmic timing in the brain.

Humans regularly perform intrinsic rhythmic movement daily while walking (Roth &Wisser, 2004).The effects of music and rhythm on walking abilities also suggest increases of gait efficiency through the use of rhythmic auditory stimulation. Rhythmic auditory stimulation has been the focus of clinical studies with several populations, and the results of these studies suggest a significant relationship between rhythm and physical movement (Kwak, 2007; Prassas, Thaut, McIntosh, & Rice, 1997; Thaut, McIntosh, Rice, Miller, Rathbun, & Brault, 1996).

Staum (1983) investigated rehabilitative rhythmic control of gait. Twenty-five patients with gait disorders listened to preferred music and rhythmic percussion selections, while attempting to synchronize footsteps to the stimulus. Observations of patients while the loudness of auditory stimuli faded indicated a significant gain in rhythmic control and accuracy throughout gait training exercise.

McIntosh, Brown, Rice, & Thaut (1997) tested gait patterns of Parkinson's patients for which a musical tempo was set. Each patient's heel strike was recorded on strong rhythmic pulses. Treatment yielded a significant increase in velocity, cadence, and stride symmetry found within each participant's gait pattern suggesting a positive relationship between musical tempo and gait.

Molinari, Leggio, Demartin, Cerasa, & Thaut (2003) studied neurobiology of rhythmic motor entrainment with Parkinson's patients. These researchers found a relationship between movement and rhythm by identifying how rhythm is intrinsically perceived and reproduced, while patients synchronized finger tapping to a rhythmic stimulus. Results of motor responses throughout the tapping exercises were tracked through neuroimaging of the brain, suggesting that differing levels of timing in the brain are processed both consciously and unconsciously. Treatment yielded a positive relationship between unconscious temporal movement and rhythmic auditory stimulation.

While working with persons suffering from neurological disorders, the therapist must take into account direct effects of medication, especially the use of dopaminergic drugs, which are known to affect the basal ganglia functioning in the brain. The basal ganglia are associated with timing functions of motor control and postural coordination. For example, when the brain initiates an action, such as finger movement, nerve cells in the basal ganglia process the signals for movements, helping to smooth the movements, and the coordination of posture. These signals are processed in the basal ganglia by neurotransmitters, primarily dopamine (Thaut, 2006). Researchers must also take into account the effects of dopaminirgic medicine on the basal ganglia, when testing patient's suffering from neurologic impairments and motor movement, to ensure accurate data collection.

Elliot, McCoy, Joyce, and Kohl (2002) observed significant changes in gait cycles of subjects with Parkinson's disease. Participants walked to accentuated rhythm with metronome pulses. A significant increase in walking velocity was observed, but was limited to only stride length of the left leg and increases in range of motion in the left shoulder. These were most likely caused by the use of drugs used to suppress the debilitating effects of Parkinson's disease, including tremors, muscle rigidity, and sluggish initiation of movements. A similar study, also with Parkinson's patients, tested subjects without medication for a forty-eight hour period. Results indicate that the deficient basal ganglia functioning did not alter rhythmic entrainment (Rao, Mayer, & Harrington, 2001).

Throughout the related research, the use of RAS has been shown to have a positive effect on gross motor movement in gait rehabilitation for persons with debilitating neurological disorders. These studies are important in identifying rhythm as an asset in physical rehabilitation and potentially define the temporal motor and timing functions of the brain. Therefore, rhythmic auditory stimulation may be an appropriate form of treatment in neurological rehabilitation including gait training with TBI patients.

Kwak, (2007) observed significant changes in gait performances of children with spastic cerebral palsy after a three-week treatment period using RAS. Twenty five participants, in need of gait stabilization and coordination due to the debilitating affects of spastic cerebral palsy were randomly divided into three groups: self guided training, therapist guided training and control group. The control group received gait training with a physical therapist, without RAS. The therapist-guided training group received gait training with physical therapists, music therapist and RAS gait exercises. The self-guided training group received gait training with physical therapists and self guided RAS training. All three groups were tested in stride-length, velocity, cadence and gait symmetry. Data were collected using a stride analyzer and compared pre-test/post-test results. Results between groups suggest RAS enhanced gait therapy assists in the overall gait performances of participants.

Rhythmic Auditory Simulation in Gait Training for Patients with Traumatic Brain Injury (Hurt, Rice, McIntosh & Thaut, 1998) is the only published article that specifically addresses RAS with TBI patients. Research that investigates the use of gait rehabilitation techniques for TBI patients is important in assisting those suffering with gait deficits. Research that systematically records the immediate effects of RAS in gait rehabilitation (through daily gait and observational analysis) will assist in a better understanding of the relationship between rhythm and gross motor movement in gait rehabilitation.

The following study was conducted to assist in determining if there is an effect of tempo on cadence synchronization, by measuring Cadence, Velocity, and Stride Length with RAS as an auditory cue.

CHAPTER THREE

METHOD

Participants

Seven adults with TBI who had previously been diagnosed at an in-patient rehabilitation center, comprised the participants in the study. Two rehabilitation sites were chosen, both located in Michigan. Four participants from one site and three from another site were identified through referrals by each facility's head physical therapist. Participants had lived in a long term care in-patient rehabilitation program for a minimum of six months post-injury to ensure safety while participating in rehabilitative gait therapy.

Demographics for the participants can be seen in Table 2.

Table 2.

Demographics of Participants

ID	Sex	Age	Balance difficulty	Gross Motor function
A1	F	26	YES	Below 50%
B2	F	34	YES	Below 50%
C3	M	28	NO	Below 50%
D4	F	29	YES	Below 50%
F6	M	19	YES	Below 50%
G7	M	53	YES	Below 50%
H8	M	54	YES	Below 50%

*Observational Gross Motor scores were recorded in each participant's chart, based on professional observations by the physical therapist before the treatment.

Referrals by the physical therapist were based on the following criteria:

1. Interest in music.
2. Uneven or labored gait patterns.
3. Lack of motivation in physical gait exercises.

Rhythmic auditory training was administered for a three-week period to allow participants the time to establish a familiar routine during gait training. Participants were tested three times per week in fifteen-minute sessions. One original participant did not meet the selection criteria, and was, therefore, omitted form the data analysis. One participant was unable to meet three times per week due to scheduling conflicts; his data were analyzed and included for the 7 days in which he participated.

Inclusion Criteria

(1) Participants were free of hearing deficits as determined by on-site speech and language pathologists prior to treatment to assure that the participants could hear instructions and auditory stimuli.

(2) Participants adequately understood and spoke English to assure that each participant understood instructions.

(3) Participants had enough physical stamina to complete a fifteen-minute gait exercise session as determined by the on-site physical therapy departments.

(4) Participants presented a baseline motor proficiency score of 50% or lower, as determined by the physical therapist, using Ranchos Los Amigos Gait Assessment test (see Appendix B.).

Apparatus and Materials

- The Ranchos Los Amigos Gait Proficiency test (see Appendix B) was used to identify gross motor abilities, including speed and agility, balance, bilateral coordination, and strength. The observational test was created in 1992 specifically for the Ranchos Los Amigos Neurological Rehabilitation Center in California. The

Ranchos Los Amigos has been used in similar studies of RAS and gait training (Kwak, 2007) and is a prevalent observational test currently used in physical therapy. There were no studies found by the author regarding the reliability and validity of the observational Ranchos Los Amigos Gait Proficiency Scale.

- A timed metronome within a CASIO CTX-501 keyboard provided rhythmic auditory stimulation.
- A Stride Analyzer (Model SA-IV), developed by B & L Engineering, Inc. is a microprocessor designed for recording foot to floor contact. Footswitches have pressure sensitive points for the purpose of recording foot to floor contact. The stride analyzer calculates data from the footswitches and compares results to normal gait parameters according to gender and age (see Appendix C). Foot contact patterns (see Appendix D) display walking patterns of each participant's heel, great toe, fifth and first metatarsals. Walking pattern data was collected through recorded data from the footswitch pressure points. This analyzer was used to accurately calculate cadence, velocity and stride length of participants in this study.
- A Sony Digital Handy Cam Model DCR-SR45 was used for videotaping purposes

Procedure

Seven adult TBI patients were seen in two separate rehabilitation centers in Michigan. Participants were approached and asked if they had an interest in participating in this study using the assent script (see Appendix E). Consent forms and HIPPA forms were sent to guardians and individuals interested, and each participant gave informed consent (see Appendix F &G). The physical therapists administered an observational gait analysis based on the Ranchos Los Amigos Gait Assessment prior to the onset of this

study. This testing allowed the researcher and physical therapist to choose subjects with similar gross motor functioning levels. Disabilities of the participants included mild cognitive impairments, sensory processing delays, communication limitations, behavior or mental health problems, and gait disturbances. Participants were seen in their respective day-treatment rehabilitation centers for RAS treatment. Rhythmic auditory stimulation (RAS) is a specific neurologic music therapy technique that uses rhythm to assist in temporal gross motor movements throughout gait exercises for persons with neurologic disabilities. Out of respect for each participant's physical well-being, gait exercises were no longer than fifteen minutes per RAS session. Participant's stride length, speed, and velocity were evaluated during gait exercises. The researcher observed each participant's ability to synchronize rhythm in gait patterns. This allowed the researcher to evaluate each participant's ability to maintain a steady cadence with an auditory stimulus. Gross motor functioning levels were measured prior to testing by administering an Observational Ranchos Los Amigos Gait Assessment. Each participant's proficiency score was 50% or lower to reduce the variance in levels of motor proficiency. The auditory stimuli were specifically designed to match each participant's current natural gait cadence throughout all gait exercises.
During training all data were recorded and analyzed by a stride analyzer, and compared using a paired *t*-test for statistical analysis.

Every participant was tested on the following stride parameters:

(1) Cadence was measured by counting all heel strikes for sixty seconds.

(2) Velocity was measured by recording meters walked in sixty seconds.

(3) Stride Length was measured by recording the distance form one heel strike to the next heel strike (on the same side).

RAS sessions were scheduled for each participant three times per week in 15 minute sessions, for a total of three weeks. Data were collected on three separate gait variables: Stride Length, Velocity and Cadence. A 14 meter walkway was marked with 10 meters for testing purposes. Two meters were used before and after the walkway for acceleration/deceleration purposes throughout gait exercises. Quantitative data were collected using a stride analyzer. Foot switches were measured using each participant's shoe and fit to match the insole of each individual foot. After measuring footswitches to fit each participant, footswitches were placed over the insoles of each shoe. A waistband was placed around each participant; the stride analyzer was secured using Velcro tape on the back of the waistband. Foot switches were attached to the stride analyzer and each participant walked 10 meters at a comfortable tempo, while data were collected. A pretest assisted in identifying each individual's baseline in cadence, velocity and stride length. Rhythmic tempo was matched and recorded with a metronome. Rhythmic tempo established in the pretest was observed and increased or decreased dependent upon each participant's percentage of normal calculated by the stride analyzer. Increases were set to 5% the second week of testing and increased by 10% the third and final week of testing. If the individual was unable to increase the tempo of the gait, the current level was maintained until the researcher and physical therapist conferred, observed, and agreed when increases were safe for each individual. This was done for each session. If rhythmic tempos were decreased, the participant was asked to identify the rhythm and begin walking at a slower tempo. Participants were instructed to listen to the tempo and count to eight with the metronome before starting each RAS exercise. The participants were instructed to notify the researcher of any discomfort or fatigue throughout testing. If exercises ceased due to fatigue, testing continued when the individual was able to resume exercises. RAS exercises took place in the physical therapy gym of each individual testing site. To determine whether rhythmic auditory stimulation affected gait rehabilitation, baseline data were graphed and compared to RAS data for each individual session (see Appendix I). Paired *t*-tests were performed, using the SPSS program, version 16.0, to identify improvements in each of the gait parameters. Raw measurement data were compared to normal before and after treatment (see Appendix J) in Cadence, Velocity, and Stride Length. This comparison was helpful in identifying if rhythm and music interventions improved rehabilitative motor functioning with adult traumatic brain injured patients.

CHAPTER FOUR

RESULTS

The purpose of this study was to assist in determining if a causal relationship exists between melodic tempo and temporal cadence synchronization during gait training for persons with Traumatic Brain Injuries. Data collected included participant's Cadence, Velocity, and Stride Length in both pretest and post-test. Data were recorded and analyzed by a stride analyzer and paired *t*-tests were run to identify improvements in each of the gait parameter. This chapter includes quantitative results presented by the order of each research question. Descriptive data were also presented to assist in a more complete understanding of each participant's injury and functioning level (see Appendix I). It is of interest to note the differences of recorded data between each participant. In the case of B2, the participant was extremely cognizant of walking to the exact rhythmic beat presented, which may have caused the natural gait parameters to decrease. Participant B2 did increase in the overall Stride length during testing. In one of the cases, Participant A1 increased both Cadence and Velocity, while Stride Length decreased. Examining the footswitch data assisted in identifying that participant A1 often walked on her toes. Balance was an issue with this participant and matching the set rhythmic tempo was a difficult task throughout testing. The Cadence and Velocity of this participant increased, while the heel to heel contact measured in stride-length decreased, possibly due to the physical limitations.

Similar to A1, participant G7 walked with a weak right ankle, although data yielded dramatic improvements in all three gait parameters. G7 was required to wear a flexible AFO (flexible orthotic) throughout gait exercises, which assisted in strengthening the right ankle throughout testing and normal everyday walking. All three gait parameters improved (Velocity and Stride Length improved dramatically).This participant easily identified the increase in tempo and was able to entrain to the RAS immediately. In the case of H8, baseline data was recorded with a walker. By session number 2, the participant requested to walk without the walker and was permitted to do so. Data yielded an overall improvement in all three gait parameters throughout RAS testing without the use of a walker 5 out of 6 sessions (Participant H8 was tested 7 out of 9 sessions due to scheduling). Throughout testing, it was apparent that the Participant's enjoyed gait exercises when RAS was implemented (as demonstrated by a positive affect and participation throughout sessions). Many participants requested melodic accompaniment throughout gait exercises, which was unavailable in RAS treatment.

Quantitative Results

Research Prediction #1: RAS-enhanced gait training will improve Cadence of subjects tested. Cadence was administered and based on the participant's ability during gait exercises and testing. Dependent upon the Participant's observational gait analysis, the goal was set to increase cadence in seven Participants. The recorded outcomes were consistent with projected goals for most of the cases (see Appendix I). Contrary to the initial set goals, Cadence decreased in one of the seven participants (B2). Cadence increased overall by 6.64% (Table 3).

Table 3.

Means, Standard Deviations and Standard Error Mean for Cadence

	Mean	SD	SEM
Group Baseline (N=7)	78.2143	8.19927	3.09903
Group Posttest (N=7)	87.5429	4.06729	1.53729

The paired *t*-test for Cadence indicates a significance difference ($p < .05$) between baseline and post-test data (Table 4).

Table 4.

The paired *t*-test for Cadence

t(two-tailed)	df	p
-3.017	6	.023

Research Prediction #2: RAS-enhanced gait training will improve velocity of subjects tested. Velocity was measured and recorded as the average speed in meters per minute. An overall increase was recorded for each participant with the exception of one participant (B2) who showed a slight decrease in Velocity. The overall increase of the group was consistent with predicted results with an increase of 13.24%. (Table 5 includes the differences between baseline and post-test data.)

Table 5.

Means, Standard Deviations and Standard Error Mean for Velocity

	Mean	SD	SEM
Group Baseline (N=7)	57.0143	19.20672	7.25946
Group Posttest (N=7)	72.2286	10.75712	4.06581

The paired *t*-test for Velocity indicates a highly significance difference between baseline and post-test data (Table 6).

Table 6.

Results of *t*-test for Velocity

t(two-tailed)	df	p
-3.518	6	.013

Research Prediction #3: RAS-enhanced gait training will improve Stride Length of subjects tested. Stride length was measured in meters from one heel to the next on the same side. The measurement comparisons revealed an overall increase of 10.7%. In one subject (A1), the stride length decreased. Table 7 displays the Means, Standard Deviations and Standard Errors for baseline and post-test data.

Table 7.

Means, Standard Deviations for Stride length

	Mean	SD	SEM
Group Baseline (N=7)	72.4286	21.31570	8.05658
Group Posttest (N=7)	84.8286	10.75743	4.06593

The paired *t*-test on Stride Length indicates a significance difference between baseline and post-test data in (Table 8).

Table 8.

The *t*-test for Stride Length

t(two-tailed)	df	p
-2.454	6	.050

Data were collected and analyzed using a paired *t*-test and percentages. A significant improvement was found in all three gait parameters tested. The data for each participant demonstrates the variability in individual participants (see appendix I). After RAS training, there were significant improvements in all three stride parameters: Cadence, Velocity, and Stride Length.

CHAPTER FIVE

DISCUSSION AND CONCLUSIONS

Persons suffering from the effects of Traumatic Brain Injury often require gross motor rehabilitation after injury (Hurt et. al, 1995). While in previous research, RAS has improved results in gait performances of persons with neurologic disorders, this study found significant improvement in all three gait parameters: Cadence, Velocity, and Stride Length of participants after RAS. Set goals were consistent with an overall increase to normal in all three gait parameters of participants after treatment was administered: Cadence yielded an overall improvement of 6.64% towards normal, Velocity yielded an overall improvement of 13.24% towards normal, and Stride Length improved by 10.7% towards normal.

Kwak (2006) found results similar to this study, although her study was with children who had cerebral palsy. She observed casual relationships between tempo and gait in all three gait parameters tested. The present RAS study yielded significant improvements in all three gait parameters tested with TBI adults, while observational results yielded trends towards normal in the 2006 study by Kwak. It should be kept in mind that any differences may have been that the Kwak study was an intervention with children with a different neurological disorder.

Similar to the 1998 study by Hurt et. al, RAS resulted in significant improvement in all three gait parameters tested. Noted differences between these two studies include the experimental testing of motor entrainment, a five week independent gait training method, daily data collection via stride analyzer, and daily assessments of gait performances in the present study. While these two studies had differences, they found similar results, including overall significant improvements towards normal in all three gait parameters tested.

The overall results of this study and previous research suggests that the use of neurologic music therapy and RAS for persons with traumatic brain injuries is a valuable clinical tool.

Implications for practice

Due to time constraints in the sessions, the researcher identified the need for additional time for RAS sessions. Many participant's schedules did not permit the extra time needed to assemble the equipment necessary for testing, thus causing the tests to run over the allotted 15 minutes for RAS treatment. Stride analyzer comparisons with the norms were analyzed and compared. Future analyses should consider the participant's stature (weight, build, bone structure), not only the age and gender of participants to produce thorough individualized comparison of gait parameters. Also, a better measurement tool needs to be found.

Qualitative measures in future studies may enhance a better understanding of the participants experiences. These components might ask such questions as how the participants felt about testing, what they liked or disliked about the process.

Future research with RAS and TBI participants should also consider controlling for the time elapsed after the initial rehabilitation process of the TBI. Through future inquiry, music therapy can assist in better understanding and acceptance of RAS in neurologic rehabilitation.

Conclusion

The present data suggest that rhythm and music assists in muscular time management of gross motor movement exercises when a rhythmic tempo is present, even with Participants who have suffered cerebellar injuries or TBI. This study suggests that the use of neurologic music therapy and RAS for persons with traumatic brain injuries can be a valuable clinical tool when used in gait rehabilitation for TBI patients.

Appendix A

(Glasgow Coma Scale)

Glasgow Coma Scale

A. Motor Response Scores

- 6 – responds to commands fully
- 5 - responds to noxious stimuli
- 4 - withdraws from noxious stimuli
- 3 - abnormal flexion
- 2 - extensor response
- 1 - No response

B. Verbal Response Scores

- 5 – Is alert and oriented
- 4 - Confused, although coherent and is able to speak
- 3 – Inappropriate jumbled words
- 2 - Incomprehensible sounds
- 1 - No sounds

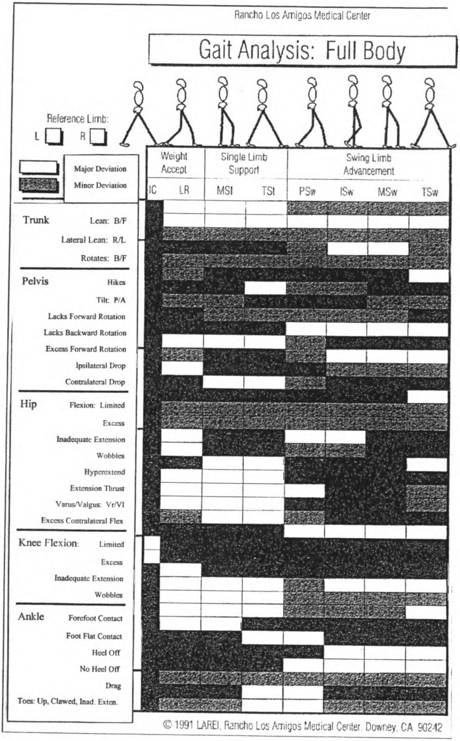
C. Eye Opening Scores

- 4 – opens eyes spontaneously
- 3 – opens eyes to verbal cuing
- 2 - opens eyes to pain
- 1 - No eye opening

Final scores are determined by adding A, B and C. Numbers help determine the severity of injuries sustained. Four levels: Mild (13-15), Moderate (9-12), Severe (3-8), Vegetative State (>3). Persistent Vegetative State, Brain Death (tbi.COM)

Appendix B

(Observational Gait Analysis)


Rancho Los Amigos Medical Center
Gait Analysis: Full Body
Reference Limb:
L
R
Major Deviation
Minor Deviation
Weight Accept
Single Limb Support
Swing Limb Advancement
IC
LR
MSt
TSt
PSw
ISw
MSw
TSw
Trunk
Lean: B/F
Lateral Lean: R/L
Rotates: B/F
Pelvis
Hikes
Tilt: P/A
Lacks Forward Rotation
Lacks Backward Rotation
Excess Forward Rotation
Ipsilateral Drop
Contralateral Drop
Hip
Flexion: Limited
Excess
Inadequate Extension
Wobbles
Hyperextend
Extension Thrust
Varus/Valgus: Vr/Vl
Excess Contralateral Flex
Knee Flexion:
Limited
Excess
Inadequate Extension
Wobbles
Ankle
Forefoot Contact
Foot Flat Contact
Heel Off
No Heel Off
Drag
Toes: Up, Clawed, Inad. Exten.
© 1991 LAREI, Rancho Los Amigos Medical Center, Downey, CA 90242

Appendix C

(Normal Gait Parameters)

From: Gait Analysis, Normal and Pathological Function Book, by Jacqueline Perry, SLACK Incorporated, 1992, pg. 432. & Oberg T., Karszania A, Oberg K, Basic gait parameters: Reference data for normal subjects, 10-79 years of age. Journal of Rehabilitation Research and Development, Vol. 30, No.2, 1993, pg. 210-223.

VELOCITY

Normal gait Male		Normal gait Women	
AGE (years)	Mean (m/min)	AGE (years)	Mean (m/min)
10-14	79.4	10-14	65.2
15-19	81.1	15-19	74.3
20-29	73.6	20-29	74.5
30-39	79.0	30-39	77.1
40-49	79.7	40-49	74.8
50-59	75.1	50-59	66.3
60-69	76.6	60-69	69.4
70-79	70.9	70-79	66.8

CADENCE

Normal gait Male		Normal gait Women	
AGE (years)	Mean (steps/min)	AGE (years)	Mean (steps/min)
10-14	128.4	10-14	118.2
15-19	121.2	15-19	125.4
20-29	118.8	20-29	124.8
30-39	120.0	30-39	127.8

40-49	120.6	40-49	129.6
50-59	117.6	50-59	121.8
60-69	117.0	60-69	123.6
70-79	114.6	70-79	121.8

STRIDE LENGTH

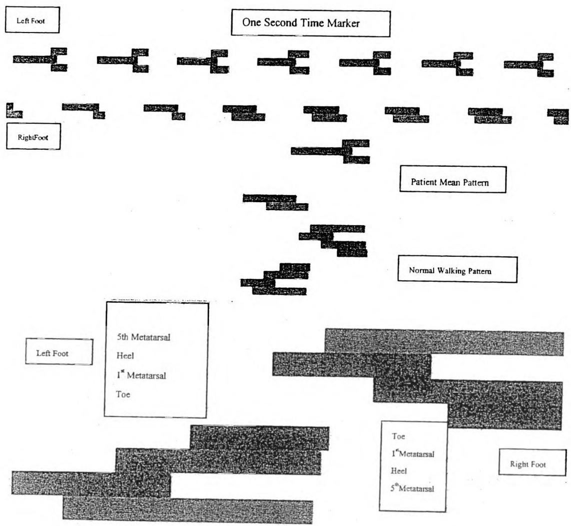
(measurement of length from one heel strike to the next on the same side)

Normal gait Male		Normal gait Women	
AGE (years)	Mean (meters)	AGE (years)	Mean (meters)
10-14	.615	10-14	.542
15-19	.660	15-19	.593
20-29	.616	20-29	.591
30-39	.649	30-39	.597
40-49	.647	40-49	.571
50-59	.635	50-59	.535
60-69	.650	60-69	.553
70-79	.615	70-79	.542

Appendix D

(Foot Switch Patterns)

Foot Switch Patterns



Appendix E

(Assent script)

ASSENT SCRIPT

I am Jody Wilfong and I'm a graduate student at MSU studying Music Therapy. I'm interested in learning more about how people walk when they hear music. I'm hoping you might be willing to help me learn more about that through participating in my research study. If you want to participate, we'll also talk to your physical therapist and s/he will be here when we do our activity. These exercises won't take long approximately 15 minutes per session. I'll come back three times a week for the next three weeks. The family members who work with you will help you decide if you want to do this. Staff from this facility will help us schedule these exercises at a time that is convenient for you. Do you think you would like to participate?

Appendix F

(RAS testing Consent Form)

RHYTHMIC AUDITORY STIMULATION ON GAIT TRAINING.

Dear Parent(s)/Guardian(s):

I am Jody Wilfong, a Graduate student at MSU majoring in music therapy. I am interested in studying the effects of rhythmic auditory stimulation on gait with traumatic brain injured adults. I am interested in developing a specific music neurological program for the TBI patients. This study will focus on rhythmic stimulation and each individual's ability to synchronize steps to rhythmic stimulus throughout rehabilitative gait training. The sessions will be taking place twice a week during a 6-week period at____________ Michigan. Each session will be 15 minutes long. It will be videotaped for analyzing purposes only.

The following information is provided for you to decide whether you and ___________________________wish to participate in the present study. You should be aware that even if you agree to participate, you are free to withdraw at any time without affecting opportunities for participation in future projects offered by the researcher.

An advisor in the School of Music, Division of Music Education and Music Therapy at Michigan State University has approved all procedures. I ask for you and _________________________'s participation in this study, but it is strictly voluntary. Do not hesitate to ask any questions about the study before, during, or after the research are complete. Rest assured that you and _______________________ will not be associated with the research findings in any way. Names will be replaced with pseudonyms in all research data. If you prefer, you can choose your pseudonym, otherwise I will select a random pseudonym. Confidentiality will be upheld to the highest extent of the law.

Enclosed is a consent form requiring a signature, which will allow the use of each Participant's medical records to record the age and diagnosis. You may choose not to participate at all or you may refuse to participate in certain procedures or answer certain questions.

The expected benefits associated with participation in this study are to explore the relationship between music and movement. This study, as a part of long term study, is geared toward exploring the effects of rhythm on movement and the development of neurological music therapy programs for the traumatic brain injured adult. It will enhance the quality of music therapy service offered in rehabilitation. The discomfort and/or risks are minimal. Michigan State University requires all studies involving human subjects to include the following statement in all consent forms: "If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or are in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. You may contact Jody Wilfong (810)266-4045 with any questions or to report an injury."

If you have any questions about this study, please contact: Frederick Tims, PhD, by phone (517- 353-9856), email (tims@msu.edu), or regular mail (201 Music Practice Building, East Lansing, MI 48824); or Jody Wilfong by email (Jjktwilfong@aol.com), or regular mail.

If you have any questions or concerns regarding your rights and your son/daughter/ward's rights as study participants, or are dissatisfied at any time with any aspect of this study, you may contact-anonymously, if you wish Peter Vasilenko, PhD, Chair of the MSU Human Research by phone: (517) 355-2180, fax: (517)432-4503, e-mail: irb@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824-1047.

I appreciate your assistance.

Sincerely,
Jody Wilfong, MT-BC

By signing below, you acknowledge receiving information about the research and that having a chance to ask questions. You also acknowledge receiving a copy of this form.

I voluntarily agree to permit your son/daughter/ward__________________________

to participate in this study.

Signature of Guardian

Date____

I agree to allow videotaping of the (RAS) Gait testing to be used for gait assessment and evaluation throughout each session.

Signature of Guardian_________________________ Date______________________

Appendix G

(HIPPA Consent Form)

PATIENT AUTHORIZATION FOR DISCLOSURE

Patient

Name: ____

Address: ____

D.O.B.____

I AUTHORIZE THE DISCLOSURE OF MY HEALTH INFORMATION

FROM:___________________________________

TO:_____________________________________

Name of hospital or health care system or provider	**Name of researcher or research group**
________________________________	________________________________
Address	**Address**
________________________________	________________________________
________________________________	________________________________
Phone/Fax Number	**Phone/Fax Number**

DESCRIPTION OF INFORMATION TO BE DISCLOSED (select one of the following):

___ALL information contained in my medical record.

OR

___ ONLY disclose the following information:

RESEARCH STUDY FOR THIS DISCLOSURE:

Title of
Study:____

Name of
Research Leader:____

Affiliation of
Researcher:____

IRB#_______________________________________

Name of IRB_________________________________

EXPIRATION (fill in one of the following):

Your Authorization to disclose the above information expires on_____________________; or

Has no expiration date _______; or

Expires at the end of the research study ______; or

Expires six months from the date signed_______.

REVOCATION, REFUSAL, REDISCLOSURE:

You may revoke this Authorization in writing at any time by
contacting____

(e.g., the healthcare system or provider or hospital named above),but it will not affect any information already released to the researcher(s).

You may refuse to sign this authorization and your refusal will not affect your ability to obtain treatment, however, it may affect your ability to participate in this research study.

Your information that is disclosed to the researcher(s) may no longer be protected by Federal privacy regulations if the researcher(s) is not a health care provider covered by the regulations, however the researcher(s) agrees to protect your information as required by law.

____

Signature of Patient or Personal Representative/Date

____

Name of Personal Representative and Relationship to Patient (or description of authority to act on behalf of the patient)

PROVIDE COPY TO PATIENT

Appendix H

(Sample Data from Stride Analyzer)

Sample Data from Stride Analyzer

Date:	06/17/08	Conditions:	
Diagnosis:	tbi	Strides:	6
Age:	29 years 12 months	Trial Type:	Walking Trial
Gender:	Male	Distance:	6.000meters

Stride Characteristics

	Actual	%Normal
Velocity (M/MIN):	37.8	46.1
Cadence (STEPS/MIN):	96.6	88.8
Stride Length (M):	0.782	52.0
Gait Cycle (SEC):	1.24	111.5

	-R-	-L-
Single Limb Support		
(SEC):	0.395	0.520
(%Normal):	58.2	76.7
(%GC):	31.9	41.6
Swing (%GC):	42.0	31.6
Stance (%GC):	58.0	68.4
Double Support		
Initial (%GC):	10.3	15.8
Terminal (%GC):	15.8	10.4
Total (%GC):	26.1	26.2

Left Foot (stance =68.4% GC)

Heel	----Normal Contact at 0.0% GC (0.0% stance) Delayed Cessation at 50.2% GC (73.4% stance)
5th Metatarsal	----Delayed Contact at 41.1% GC (60.1% stance) Delayed Cessation at 63.7% GC (93.1% stance)
1st Metatarsal	----Delayed Contact at 42.6% GC (62.3% stance) Delayed Cessation at 64.3% GC (94.0% stance)
Toe (0 strides)	----

Right Foot (stance = 58.0% GC)

Heel	----Normal Contact at 0.0% GC (0.0% stance) Delayed Cessation at 44.0% GC (75.9% stance)
5th Metatarsal	----Delayed Contact at 18.8% GC (32.5% stance) Premature Cessation at 63.7% GC (93.1% stance)
1st Metatarsal (0 strides)	----
Toe (0 strides)	----

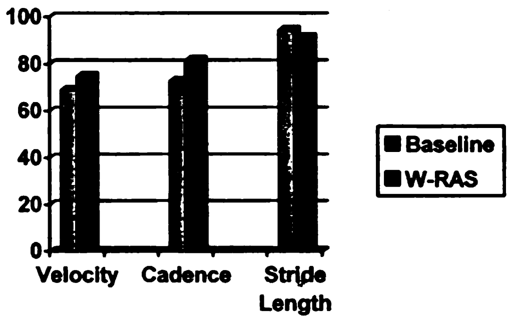
Appendix I

(Individual results)

A1

26 year old female sustained traumatic brain due to a pedestrian/motor vehicle accident at the age of 11. Difficulties due to injury include left cranial lobe damage, ataxic dysarthria, short term memory loss, dysphasia and gait disturbances.

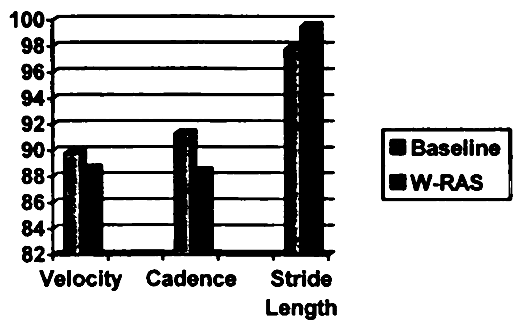
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards normal
Cadence					
86.1	124.8	72.7%	96.7	81.5%	+8.8%
Velocity					
55.7	74.5	68.9%	60.5	74.8%	+5.9%
Stride Length					
1.294	.591	94.3%	1.252	91.2%	-3.1%



B2

34 year old female sustained traumatic brain injury due to motor vehicle accident at 16 years of age. Difficulties due to injury include decerebrate posturing, left temporal lobe and right frontal lobe damage, behavior and gait disturbances

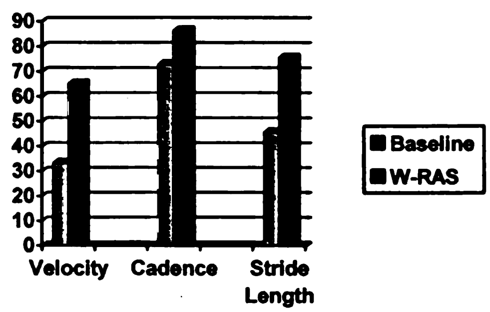
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards normal
Cadence					
108.3	127.8	91.3%	104.8	88.4%	-2.9%
Velocity					
72.6	77.1	89.8%	71.6	88.6%	-1.2%
Stride Length					
1.341	.597	97.8%	1.366	99.5%	+1.7%



C3

28 year old male sustained traumatic brain injury due to a pedestrian/motor vehicle accident at the age of 3. Difficulties due to injury include left hemi paresis, sensory deficits, spasticity, mild hemi paretic gait.

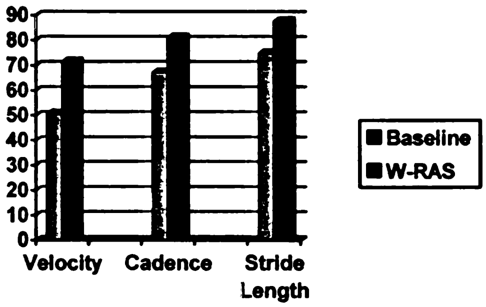
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards Normal
Cadence					
78.5	118.8	72.9%	92.9	86.3%	+13.4%
Velocity					
26.9	73.6	33.3%	52.7	65.1%	+31.8%
Stride Length					
0.687	.616	45.7%	1.134	75.5%	+29.8%



D4

29 year old female who sustained sub arachnid hemorrhage and front parietal hematoma from a collision with a school bus, while riding a bicycle at the age of 12. Difficulties due to injury include poor attention, short and long term memory recall, impulsivity and gait disturbances.

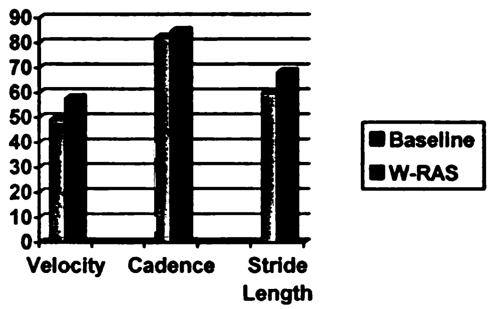
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards Normal
Cadence					
79.7	124.8	67.2%	96.1	88.4%	+21.2%
Velocity					
40.9	74.5	50.6%	57.8	71.4%	+20.8%
Stride Length					
1.027	.591	74.8%	1.202	87.6%	+12.8%



F6

19 year old male who sustained left side hemiplegic and spasticity in left hand due to a motor vehicle accident while a passenger in an infant car seat. Difficulties include left side spasticity, ataxic dysarthria, long and short term memory, cognitive and gait disturbances

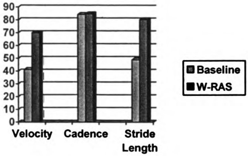
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards Normal
Cadence					
89.3	121.2	82.1%	92.1	84.6%	+2.5%
Velocity					
40.3	81.1	49.2%	47.3	57.7%	+8.5%
Stride Length					
0.901	.660	59.9%	1.027	68.2%	+8.3%



G7

53 year old male sustained traumatic brain injuries due to a motor vehicle accident at the age of 24. Difficulties due to injury include right frontal lobe damage, cognitive, short term memory recall, attentiveness and gait disturbances.

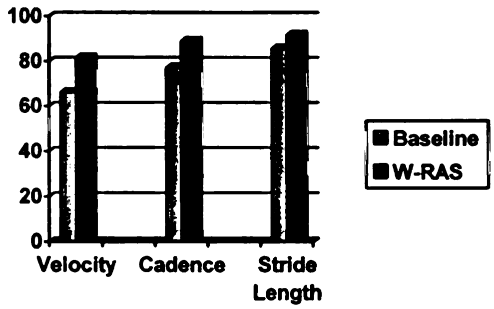
Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards Normal
Cadence					
91.6	117.6	84.2%	96.7	84.7%	+0.5%
Velocity					
33.7	75.1	41.2%	60.5	70.0%	+28.8%
Stride Length					
0.736	.635	48.9%	1.252	80.2%	+31.3%



H8

54 year old male sustained traumatic brain injury including cerebral edema, fractured maxilla, lacerated spleen at the age of 22. Subject was hit by a truck, while riding a toboggan pulled by a snowmobile. Difficulties due to injury include extension rigidity with episodic decorticate posturing, short and long-term memory recall and gait disturbances.

Baseline	Normal	Compared to Normal	After RAS	Compared to Normal	Change towards Normal
Cadence					
88.1	117.6	77.1%	101.6	88.9%	+11.8%
Velocity					
55.4	75.1	66.1%	68.4	81.6%	+15.5%
Stride Length					
1.257	.635	85.6%	1.346	91.6%	+6.0%



Appendix J

(Individual raw percentage data used in statistical analysis)

Individual Raw Percentage Data Used In Statistical Analysis

CADENCE	Baseline	After RAS
A1	72.7	81.5
B2	91.3	88.4
C3	72.9	86.3
D4	67.2	88.4
F6	82.1	94.6
G7	84.2	84.7
H8	77.1	88.9

VELOCITY	Baseline	After RAS
A1	68.9	74.8
B2	89.8	88.6
C3	33.3	61.5
D4	50.6	71.4
F6	49.2	57.7
G7	41.2	70.0
H8	66.1	81.6

STRIDE LENGTH	Baseline	After RAS
A1	94.3	91.2
B2	97.8	99.5
C3	45.7	75.5
D4	74.8	87.6
F6	59.9	68.2
G7	48.9	80.2
H8	85.6	91.6

REFERENCES

References

Aldridge, D. (1991). Creativity and Consciousness. *Arts in Psychotherapy, 18*(4), 359-362.

American Music Therapy Association (2005). *Music therapy in medicine.* Retrieved November 15, 2005, from www.musictherapy.org.

Baker, F., and Tamplin, J. (2006). Neurological damage and models of rehabilitation. *Music therapy methods in neurorehabilitation, a clinicians manual.* London: Jessica Kingsley.

Claeys, M. S., Miller, A. C., Dalloul-Rampersad, R., & Kollar, M. (1989). The role of music and music therapy in the rehabilitation of TBI clients. *Music therapy perspectives, 6*, 71-77.

Davis, W. B., Gfeller, K.E., & Thaut, M. H. (1992). Music therapy in the rehabilitation of stroke and traumatic-brain-injured clients. *An introduction to music therapy theory and practice*. Dubuque: Wm. Brown.

Elliott, S.M., McCoy, R.W., Joyce, A.S., & Kohl, R. (2002). The impact of auditory cues on gait control of individuals with Parkinson's disease. *Journal of human movement studies, 42*, 229-236.

Fernandez del Olmo, M., Arias P., Furio, M.C., Pozo, M.A., and Cudeiro, J. (2006). Evaluation of the effect of training using auditory stimulation on rhythmic movement in Parkinsonian patients- a combined motor and FDG PET study. *Parkinsonism and related disorders, 12,*155-164.

Freedland, R.L., Festa, C., Sealy, M., McBean, A., Elghazaly, P., Capan, A., Brozycki, L., Nelson, A. J., and Rothman, A.(2002). The effects of pulsed auditory stimulation on various gait measurements in persons with Parkinson's disease. *Neurorehabilitation, 17*, 81-87.

Gallahue, D. (1982). Motor development and movement experiences. New York: John Wiley.

Gaston, E. T. (1968). Man and music. In E.T.Gaston (Ed.), *Music in therapy* (pp. 7-29). New York: Macmillan.

Georgiou, N., Iansek, R., Bradshaw, J.L., et al. (1993). An evaluation of the role of Internal cues in the pathogenesis of Parkinsonian hypokinesia. *Brain, 116*, 1575-

1587.

Gfeller, K.E. (1987).Music theory and practice as reflected in research literature. *Journal of music therapy, 24*,176-194.

Greenfield, D. (1982). Development of NAMT standards for music therapy education. *Voice of the lakes* (Newsletter of the Great Lakes Regional Chapter, National Association for Music Therapy), *26*(4), 172-177.

Hamburg, J., and Clair, A. A. (2003).The effects of a movement with music program on measures of balance and gait speed in healthy older adults. *Journal of music therapy*, Fall 2003.

Harrington, D. L., and Haaland, K. Y. (1999). Neural underpinnings of temporal processing: A review of focal lesion, pharmacological, and functional imaging research. *Reviews in neuroscience, 10*, 91-116.

Hummelshein, H. (1999).Rationales for improving motor function. *Current opinion in neurology, 12*, 697-701.

Hurt, C. P., Rice, R. R., McIntosh, C., Thaut, M. H. (1998).Rhythmic auditory stimulation for patients with traumatic brain injury. *Journal of music therapy 35*(4), 228-241.

Kenyon. G. P., and Thaut, M. H. (2000). A measure of kinematic limb instability modulation by rhythmic auditory stimulation. *Journal of biomechanics, 33*(10), 1319-1323.

Kwak, E. (2007). Effect of rhythmic auditory stimulation on gait performance in children with spastic cerebral palsy. *Journal of music therapy 44*(3), 198-216.

Lucia, C. M. (1987). Toward developing a model of music therapy intervention in the rehabilitation of head and trauma patients. *Music therapy perspectives, 4, 34*-39.

Mauritz, K. H. (2002).Gait training in hemiplegics. *European journal of neurology 9*, 23-29.

McIntosh, G. C., Brown, S. H., Rice, R. R., & Thaut, M. H. (1997). Rhythmic auditory motor facilitation of gait patterns in patients with Parkinson's disease. *Journal of neurology, neurosurgery, and psychiatry, 62*, 22-26.

Merck Manual of Medical information. (1997). *Brain injuries*. (pp. 357-358).Whitehouse Station: Merck Research Laboratories.

Michel, D. E. (1976). Music Therapy: *An introduction to therapy and special education through music*. Springfield: Charles C. Thomas.

Miller, R. A., Thaut, M. H., McIntosh, G. C., & Rice, R. R. (1996). Components of EMG symmetry and variability in Parkinsonian and healthy elderly gait. *Electroencephalography and clinical neurophysiology, 101*, 1-7.

Molinari, M., Leggio, M., Demartin, M., Cerasa, A., & Thaut, M. H. (2003). Rhythmic facilitation of gait training in hemi paretic stroke rehabilitation, *Ann. N. Y. academy of science, 999*, 313-321.

Morris, G. S., Suteerawatananon, M., Etnyre, B. R., Jankovic, J., and Protas, E. J. (2004). Effects of visual and auditory cues on gait in individuals with Parkinson's disease. *Journal of neurological sciences, 219*, 63-69.

National Institute of Neurological Disorders, *Traumatic brain injuries*. Retrieved Nov.15, 2005 from http://www.ninds.nih.gov/disorders/tbi/tbi.htm.

Pacchetti, C., Mancini, F., Aglieri R., Fundaro, C., Martignoni, E., & Nappi, G. (2000). Active music therapy in Parkinson's disease: An integrative method for motor and emotional rehabilitation. *Psychosomatic medicine, 62*, 386-393.

Prassas, S., Thaut, M. H., McIntosh, G. Rice, R. (1997). Effect of auditory rhythmic cuing on gait kinematic parameters of stroke patients. *Gait and posture, 6*, 218 223.

Public Safety On-line Journal, *Traumatic brain injuries.* Retrieved Aug. 1, 2008 from http://publicsafety.com/article/photos/1154448509235_71_5.jpg.

Rathbun, J. A. (2001). Not the same old song: Using music therapeutically in the rehabilitation hospital setting. *The interdisciplinary journal of rehabilitation on-line journal*. Retrieved November 15, 2005 from http://www.rehabpub.com/features/112002/2.asp.

Rao, S. M., Mayer, A. R., & Harrington, D. L. (2001). The evolution of brain activation during temporal processing. *Nature of neuroscience, 4*, 317-323.

Roth, E. A., Wisser, S. (2004). Music and rhythm of recovery. *The case manager, 15*(3), 52-56.

Staum, M. J. (1983). Music and rhythmic stimuli in the rehabilitation of gait disorders. *Journal of music therapy, xx* (2), 69-87.

Thaut, M. H. (1983). The use of auditory rhythm and rhythmic speech to aid temporal and quantitative muscular control in children with gross motor dysfunction. Unpublished doctoral dissertation, Michigan State University.

Thaut, M.H., (2005). The neural dynamics of rhythm. *Rhythm, music and the brain: Scientific foundation and clinical application.* New York and London: Routledge.

Thaut, M. H., McIntosh, G. C., Prassas, S. G., and Rice, R. (1993). Effect of rhythmic auditory cuing on temporal stride parameters and EMG patterns in hemiparetic gait of stroke patients. *Journal of neurologic rehabilitation, 7* (1).

Thaut, M. H., McIntosh, G. C., Rice, R. R., Miller, R. A., Rathbun, J., Brault, J.M. (1996). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. *Movement disorders, March 11*(2), 193-200.

Thaut, M. H., Rice, R. R., McIntosh, G. C. (1997). Rhythmic facilitation of gait training in hemi paretic stroke rehabilitation. *Journal of neurological science, 151*, 207 215.

Walker, W. C., Pickett, T. C. (2007). Motor impairment after severe traumatic brain injury: a longitudinal multicenter study. *Journal of rehabilitation, research and development, 44*(7), 975-982.