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A Content Analysis of Literature on Rhythmic Auditory Stimulation (RAS) to Improve Gait in Individuals with Neurologic Disorders

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A CONTENT ANALYSIS OF LITERATURE ON RHYTHMIC AUDITORY STIMULATION (RAS) TO IMPROVE GAIT IN INDIVIDUALS WITH NEUROLOGIC DISORDERS

By

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ABSTRACT

Music therapy is the evidence-based and clinical use of music interventions to accomplish the specific goals of an individual within a therapeutic relationship with a certified music therapist that has completed an approved music therapy program. Neurologic Music Therapy (NMT), and evidence-based music therapy treatment model, centers specifically around music and rhythm's physical effect on the brain and neuropathways. This is accomplished through specific NMT interventions which are applied in a consistent manner based on the goal of individuals (Hoemberg & Thaut, 2014). Of particular interest to the current study are gait training goals of individuals with neurologic conditions and the use of Rhythmic Auditory Stimulation (RAS) within a rehabilitative setting. The purpose of this analysis was to identify and discuss the use of RAS for individuals with neurologic conditions focusing on velocity, stride length, and cadence in gait training interventions. The intention of this content analysis is to reach a more comprehensive understanding of effective auditory production methods in interventions and populations that may benefit from RAS. Five of the six studies (83.33%) in this content analysis show in increase in the measured gait training functions. Live feedback as the primary auditory production method was used in two of the six (33.33%) studies found. Research using live feedback as the primary auditory production method within rehabilitation was limited, however, delivered positive results. Results may provide a starting point for further, more in-depth research on the therapeutic benefits of RAS gait training with neurologic disorders and the use of live feedback as the primary auditory production method within rehabilitative populations.

CHAPTER 1

INTRODUCTION

Music Therapy in Rehabilitation

Music therapy is an evidence-based and clinical use of musical interventions to accomplish the specific goals of an individual within a therapeutic relationship with a certified music therapist that has completed an approved music therapy program. It is required to complete a six-month internship before being certified in music therapy (MT-BC) (Hanser, 2018). Dependent on individual needs, music therapists use the qualities of music such as melody, rhythm, words, harmony, timbre, tempo, dynamics, and form to accomplish the goals of patients. A music therapy session may consist of active participation in making music, memory exercises, expression of emotion through music, or listening to music.

Among the individuals that benefit from music therapy are people with neurologic disorders, such as Parkinson's disease (PD), cerebrovascular accident or stroke (CVA), traumatic brain injury (TBI), and spinal cord injury (SCI) (Hanser, 2018). Common side-effects of neurologic disorders may be aphasia, ataxia, seizures, slow and/or shortened motor movements, and tremors (Horton & Dean, 2012).

With new technological developments, there is scientific evidence to support the physical benefits of music therapy. Within music therapy practice, one approach to the Neurorehabilitation population is Neurologic Music Therapy. Neurologic Music Therapy (NMT) is defined as a system of standardized clinical techniques for sensorimotor training, speech and language training, and cognitive training (Hoemberg & Thaut, 2014). Of particular interest to the current study are those relating to gait training, which is categorized under the umbrella of sensorimotor training. Neurologic Music Therapy's primary method for gait enhancement is Auditory Stimulation (RAS) (Hoemberg & Thaut, 2014). Primarily, this content analysis will examine the success of sensorimotor techniques within neurorehabilitation populations.

Operational Definitions

For the purpose of this review, the author used the following operations definitions for the interest of outcome measures.

Rhythmic Auditory Stimulation (RAS): Neurologic technique that uses the physiological effects of auditory rhythm to enhance motor movement and assist with gait training (Thaut & Abiru, 2010). This is done by a board-certified neurologic music therapist.

Entrainment: the ability of the motor system to synchronize with auditory rhythm and drive movement patterns (Rice & Johnson, 2013).

Neurologic conditions: diseases or disorders of the brain, spine, and nerves that connect them. Such conditions include, but are not limited to, multiple sclerosis (MS), Parkinson's disease, stroke, traumatic brain injury (TBI), brain tumors, and spinal cord injury (SCI) (Horton, Dean, & Noggle, 2012).

Music therapy: a research-based practice implemented by a board-certified music therapist from an accredited university.

Cadence: the number of steps that a person takes within 30-60 seconds (Hoemberg & Thaut, 2014).

Velocity: the speed at which someone walks measured in meters/minute (Hoemberg & Thaut, 2014).

Stride length: refers to the length of a stride from heel strike of one foot until the next time the same heel touches the ground (Hoemberg & Thaut, 2014).

Purpose

The purpose of this content analysis is to identify and discuss the use of music therapy for individuals with neurologic conditions focusing on gait goals. The intention of this content analysis is to reach a more comprehensive understanding of populations that may benefit from RAS.

Research Questions

1. What types of neurologic disabilities were successful in gait-related goal achievement through RAS?
2. Does live feedback, metronome, and/or recorded music effect gait cadence, velocity, and/or stride?

CHAPTER 2

REVIEW OF LITERATURE

Music and The Brain

During the past three decades, new brain and electrical recording techniques (functional magnetic resonance imaging, positron-emission tomography, electroencephalography, and magnetoencephalography) have changed our view of music therapy, and rehabilitation (Thaut, 2010). Since the beginning of imaging research, music has been used as a model to study how the brain processes information. Such studies looked at how the brain processes complex time information, verbal versus nonverbal communication, and how musician's brains enable the advanced and complicated motor skills necessary to perform musical work (Altenmuller & Furuya, 2016). Two findings have been of particular importance to the use of music in rehabilitation. First, the areas of the brain activated by music are not unique to music. The networks that process music also process other functions such as language, auditory perception, alertness/attention, memory, executive control, and motor control (Thaut, 2010). Second, learning tasks through the use of music changes the brain (Bengtsson et al., 2009). Music activates and efficiently accesses the various systems of the brain and assists with interactions among them. For example, Broca's area of the brain is activated whether a person is processing a problem in the arrangement's phrasing of prose or a musical piece, such as a wrong note in a melody (Fadiga, Craighero, & D'Ausilio, 2009). This area of the brain is also critical for converting thought into spoken word and is essential in tracking musical rhythms and processing the sequencing of physical movement (Schlaug, 2015).

In regard to the second finding, research clearly shows that music learning, auditory, and motors areas in the brain grow larger and interact more efficiently (Thaut, 2010). For example, when pianists with little to no prior experience have just a few weeks of training, the areas in their brain serving and control become larger and more connected, showing that music can drive plasticity in the human brain, shaping in through learning and training (Pascual Leone, 2001).

Entrainment

In the early 1990s researchers explored shared mechanisms between musical and non-musical function in motor control (Thaut, 2010). One of the most essential shared aspects of physical movement and music is rhythm and timing (Molinari et al., 2003). A consistent rhythm provides an anticipation component to movement (Grahn & Watson, 2013).

Entrainment occurs when the body synchronizes with the structured auditory stimulus. The given rhythm provides time between each beat, offering structured cues for central pattern generators in the brainstem and spinal cord. When provided with a structured auditory stimulus, the brain processes desired movement goals without consciously trying (Hoemberg & Thaut, 2014). Hoemberg and Thaut (2014) state the following:

> Central pattern generators (CPGs) are local spinal cord circuits that help to connect incoming sensory information to appropriate motor neurons that enable movement. The CPG is capable of producing coordinated movements of the limbs with no input from the brain. Therefore this magnet effect of auditory rhythm is synchronizing, and entraining movement patters occur even at levels below conscious perception and without cognitive learning. (p. 95-96)

As we've learned about how the brain and music are correlated, we can better provide therapeutic benefits for many populations. Because of the shared processing networks of music to various other systems of the brain, music has been used to achieve communication, cognitive, psychological, emotional, and motor movement goals of individuals with no prior musical experience. The field of Music Therapy is built on these concepts.

Music Therapy

Music Therapy is a research-based method that uses music to accomplish non-musical goals for individuals with emotional, social/communicative, cognitive, physical, psychological needs of individuals of all ages and abilities. A professional music therapist holds a bachelor's degree or higher in music therapy, has completed 1200 hours of clinical training, including a supervised internship, and obtained the credential MT-BC (Music Therapist- Board Certified) (AMTA, 2019). After an individual is referred to music therapy, the music therapist is responsible for assessing the current overall status of the client by identifying strengths and limitations (Hanser, 2018). After assessing the abilities and needs of individuals, the qualified music therapist identifies goals and provides treatment that may include listening to, singing, creating, and or moving to music. Through this process, client's abilities are strengthened and transferred to other areas of their life (AMTA, 2019).

While general Music Therapy aspires to treat many different aspects of patient's needs, NMT centers specifically around music and rhythm's physical effect on the brain and neuropathways. This is accomplished through specific NMT interventions which are applied in a consistent manner based on the goal of individuals (Hoemberg & Thaut, 2014). Neurologic music therapists are required to have completed a four day, 30-hour training in addition to the standard music therapy certification to maintain the NMT designation (Neurologic Music therapy Services of Arizona). This training is offered through the Academy of Neurologic Music Therapy, assuring that when NMT terminology is used, it is done so by a trained Neurologic Music Therapist (The Academy of Neurologic Music Therapy).

The five most important principles that define the basis of neurologic music therapy:

- It is defined as the therapeutic application of music to cognitive, sensory, and motor dysfunctions due to disease of the human nervous system.
- It is based on neuroscience models of music perception and the influence of music on changes in non-musical brain functions and behavior.
- Treatment techniques are based on data from scientific and clinical research and are directed toward non-musical therapeutic goals.
- Treatment techniques are standardized in terminology and application and are applied as therapeutic music interventions which are adaptable to a patient's needs.
- In addition to training in music and NMT, practitioners are educated in the areas of neuroanatomy and physiology, brain pathologies, medical terminology, and rehabilitation of cognitive, motor, speech, and language functions.

(Thaut, 2010)

Neurologic Music Therapy was developed by Dr. Michael Thaut and colleagues at Colorado State University and has been shown to benefit cognitive, sensory, and motor dysfunctions that occur due to neurologic disease of the human nervous system (Darrow, 2008). NMT has been shown to be effective in (1) neurological rehabilitation (individuals who have had a CVA, TBI, PD, MS, or Huntington's disease); (2) neuropediatric therapy (individuals with muscular dystrophy, cancer or surgery); (3) neurogeriatric therapy (individuals with Alzheimer's disease, and other dementias); (4) neurodevelopmental therapy (individuals have CP, Autism, developmental delays, and severe visual impairments) (Darrow, 2008). NMT's standardized clinical techniques provide structured and science-based protocol for speech/language training, cognitive training, and sensorimotor training in therapy (Hoemberg & Thaut, 2014).

Techniques used for Speech and Language training include Melodic Intonation Therapy, Symbolic Communication Training Through Music, Developmental Speech and Language Training Through Music, Therapeutic Singing, Oral Motor and Respiratory Exercises, Vocal Intonation Therapy, Rhythmic Speech Cueing, and Musical Speech Stimulation. Techniques used in Cognitive training include Musical Attention Control Training, Musical Executive Function Training, Associative Mood and Memory Training, Music Echoic Memory Training (MEM), Musical Mnemonics Training, Auditory Perception Training, Music Neglect Training, and Musical Sensory Orientation Training. Techniques used in Sensory Motor training include Therapeutic Instrument Music Performance, Patterned Sensory Enhancement, and Rhythmic Auditory Stimulation (Hoemberg & Thaut, 2014).

MIT is a structured rehabilitation program for the treatment of expressive Broca's aphasia, first described by Albert, Sparks, and Helm (1973). The Neurologic Music Therapy technique has shown to be effective among approximately 75% of non-fluent clients with aphasia with severe, long-term stable defects whom other forms of therapy had failed (Baker, 2000, & Albert, Sparks, & Helm, 1973). In a case study done by Slavin and Favus (2018), speech and expressive language skills using a modified MIT approach were examined. Within nine-months the examined individual's spontaneous utterances gradually increased and improved in length and complexity as measured by the Systematic Analysis of Language Transcripts (Slavin & Favus, 2018). MIT training protocol for non-fluent aphasic patients is as seen in Figure 1.

Step	Procedure
1	***Humming*** Therapist introduces the target phrase by showing a visual cue, humming the phrase 1x at a rate of 1 syllable/sec., then intoning (singing) the phrase 2x while tapping the patient's left hand 1x per syllable.
2	***Unison intoning*** Therapist and patient intone (sing) the target phrase together while the therapist taps the patient's left hand (1x/syllable).
3	***Unison intoning with fading*** Therapist and patient begin to intone (sing) and tap the target phrase together, but halfway through, the therapist fades out while the patient continues to sing the rest of the phrase accompanied by hand-tapping, but with no further verbal or oral/facial cueing.
4	***Immediate Repetition*** Therapist intones and taps the target phrase while the patient listens. The patient immediately repeats the phrase assisted only by the tapping of the left hand.
5	***Response to a probe question*** Immediately following the patient's successful repetition of the target phrase (Step 4), the therapist quickly intones a question (e.g., "*What did you say?*") and the patient answers by intoning the target phrase. Hand-tapping is the only assistance allowed.

(Norton, Zipse, Marchina, & Schlaug, 2009, Figure 3).
Figure 1. MIT procedure.

Musical Attention Control Training (MACT) is under the umbrella of cognitive training. MACT provides "structured active or receptive musical exercises involving precomposed performance or improvisation in which musical elements cue different musical responses to practice… attention function" (Thaut, 2005, p. 196). The MACT protocol instructs individuals to identify and count the number of times a word, or instrument occurs in a given song (Hoemberg & Thaut, 2014). MACT focuses on selective, and sustained attention and has demonstrated to be useful with patients who have experienced TBI, brain tumors, CVA, autism, dementia, PD, and Huntington's disease showing improvement in their ability to concentrate (Hoemberg & Thaut, 2014; Brandt & Van Dusseldorp, 2018). Patients experiencing psychosis have also found success with MACT (Van Alphan, Stams, & Hakvoort, 2019). Van Alphan, Stams, and Hakvoort (2019) state that "poor attention skills constitute a major problem for psychiatric patients with psychotic symptoms, and increase their chances of treatment drop-out." When patients were given 30-minute MACT sessions daily for six weeks, they outperformed the control group in selective, sustained, and alternating attention. Additionally, patients who had received MACT had a higher attendance (87.10%) than those in the control group (Van Alphan, Stams, & Hakvoort, 2019).

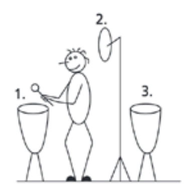
Therapeutic Instrument Music Performance (TIMP) has been shown to enhance control of both fine and gross motor movements within rehabilitative populations (Jo, Yeo, & Yang, 2016; Yoo, 2009). Target populations for TIMP include TBI including polytrauma, SCI with paraplegia syndrome, hypoxic brain damage, ischemic or hemorrhagic strokes, spina bifida, PD, Huntington's disease, muscular dystrophies, ataxiate-langiectasia, cerebral palsy, and poliomyelitis (Hoemberg & Thaut, 2014).

TIMP can be used in functional exercises that require the individual to alternate between or move toward target instruments (see Table 1). This technique allows the Neurologic Music Therapist to address functional needs of the patient just as leg and arm flexion/extension, strengthening of specific muscle groups, finger strength and dexterity, among other goals (Hoemberg & Thaut, 2014).

In a study by Jeehun Yoo (2009), six 35-minute TIMP music therapy sessions were provided for individuals post CVA. All participants in the study were three years post-stroke and exibited muscle rigidity, limited range of motion, poor muscle tone, and impaired motor control. After 30-minutes of intensive arm training, the therapist ended each session with 1-3 minutes of deep breathing for cool down. All participants decreased in movement time, and increased motor control and force (Yoo, 2009).

Entrainment is commonly referred to as rhythmic auditory cueing, rhythmic auditory stimulation, and external auditory cueing (Yoo & Kim, 2016). However, when gait training through entrainment is used by a board-certified neurologic music therapist, it is referred to as "Rhythmic Auditory Stimulation" or RAS.

Table 1. RAS exercises.

Movement	Instruments	Performance	Illustration
Flexion and extension of the trunk in a sitting position	1 standtom 1 cymbal/frame drum on a stand	Hold the mallet with both hands, bend forward and hit the drum in front of you, then stretch up and hit the cymbal standing behind you	
Rotation and erection of the trunk in a sitting and standing position	2 timpani 1 cymbal/frame drum on a stand	Stand between the instruments, hold the mallet with both hands, and hit the three instruments successively	
Rotation and erection of the trunk in a sitting position	1 standtom 1 cymbal/frame drum on a stand	Sit between the instruments, hold the mallet with both hands, hit the cymbal up next to you, and then cross the body in the midline and hit the drum on the other side	

(Hoemberg & Thaut, 2014, Table 10.1)

Rhythmic Auditory Stimulation

Rhythm has been represented significantly in motor neuroscience for enhancing, promoting, and eliciting motor movements. Music provides a timing aspect through its rhythmic component and has a strong influence on regulating movements. "Rhythm may be best described as a sensory timer that utilizes the physiologically very sensitive connection between the auditory and motor systems in the brain to influence time control in movement" (Thaut, 2005 p. 137).

Rhythmic Auditory Stimulation (RAS) is now considered to be part of the state-of-the-art repertoire in motor therapies (Thaut, 2010). Music therapy sessions containing RAS interventions focus on the rehabilitation of movements that are inherently biologically rhythmical. This technique is used to improve motor movements, most importantly gait, by using the physiological effects of rhythm on the motor system. The board-certified music therapist (MT-BC) will work with a physical therapist. The MT-BC commonly will play patient-preferred music while the patients walk on the beat and will increase the tempo as strides get longer, and stamina increases (O'Kelly et al., 2016). This stamina increase commonly allows patients to walk faster, balance more efficiently, and in some cases, bring some patients out of a frozen state (Sacks, 2010).

RAS protocol consists of six steps: Assessment of current gait parameters, resonant frequency entrainment and pre-gait exercises, frequency modulation at increments of five to ten percent, advanced gait exercises, diminishing of musical stimulus until independent, and reassessment of gait parameters (Hoemberg, & Thaut, 2014). All of the following steps for protocol have been referenced from *The Handbook of Neurologic Music Therapy* by Volker Hoemberg, & Michael Thaut (2014, p. 99-103).

Step 1: Assessment

Step one in the RAS gait training process beings with an assessment of baseline gait parameters. The client is instructed to walk 10-meters to calculate cadence (in steps/minute), velocity (in meters/minute), and stride length (in meters). Additionally, the Neurologic Music Therapist should evaluate the effective use of assistive walking devices, symmetry of gait, muscle weakness, heel strike, toe off, as well as single and double support time.

- Cadence= 60/time x number of steps
- Velocity= 60/ ___ time (in seconds) x 10 meter (distance)
- Stride length= velocity/cadence x 2

Step 2: Entrainment to RAS

Step two in the RAS gait training process is to provide a consistent rhythmic cue, through music, and/or a metronome and a strong 2/4 meter set at the same tempo as the client's internal baseline cadence. This should allow RAS to drive the movement patterns of the individual. The music therapist should use a metronome when doing RAS to avoid fluctuation in the tempo; however, the metronome does not need to be audible to the client.

Step 3: Frequency modulation and tempo increase

Once the entrainment process has occurred, the client will typically begin to normalize their gait pattern and will increase walking speed. The therapist will then increase the speed of the auditory stimulation (also known as the *tempo*) by five to 10 percent to bring gait cycle to a more normal range

Step 4: Change in direction, speed, and surfaces

After the client has become fluent in the more fundamental aspects of gait mobility, the more challenging obstacles such as changing in direction, speeding up and slowing down, stopping, and starting and walking on uneven surfaces can be addressed. Step four involves some of the following: Walking through obstacle course with different ground surfaces and objects to move around, walking backwards to a rhythmic cue, walking on beat to a fluctuating tempo, practice turning by walking in a circle, or figure of eight, walking outside on grass, sidewalks, etc., walking forward when the music stops, and stopping when the music stops.

Step 5: Fading the auditory stimulus

In step five of the RAS gait training process, the music is to be taken away to see whether the client can maintain the changes in their gait patters without the rhythmic cueing. The auditory stimulus is removed gradually by fading any stimulation provided.

Step 6: Reassessment

The final step in RAS gait training is to reassess clients using the gait parameter assessment tools found in step one.

CHAPTER 3

METHODS

A search was performed from August to November 2019. English-written articles published between 1990 and 2019 were identified from electronic databases. Keywords used in the electronic search included music therapy, gait, neurologic disability, stroke. Population-specific terms used: music, music therapy, and rhythmic auditory stimulation. Intervention-specific terms used: neurologic music therapy, rhythmic auditory stimulation, motor rehabilitation, gait, walking.

Inclusion Criteria

Articles addressing patients with a clinical diagnosis of a neurologic disorder were examined. Criteria for participants included research studies with a pre-test and post-test that examined stride length, velocity, and/or cadence. Quasi-experimental single group designs studies in which subjects served as their own control were included in data collection. Articles that compared post-test results to control groups were omitted from data. For the purpose of this study, the researcher collected data assessing population type (i.e TBI, SCI, MS, CVA), as well as auditory production methods including live feedback, metronome, and/or recorded music.

No demographic characteristics, including sex, age, cognitive level, or ethnicity, were limited. Articles were included if the intervention of "Rhythmic Auditory Stimulation" was done by a music therapist. To analyze the effects of RAS implemented by music therapists, studies that included other rhythmic auditory cueing for gait training implemented by physical therapists and/or neurologists were excluded in data collection. Data on stride length were excluded if left and right side were measured independently. Studies meeting criteria were further analyzed.

CHAPTER 4

RESULTS AND DISCUSSION

The initial search yielded 22 results (see Table 1 & 2). After reviewing titles and abstracts, the studies that did not meet the inclusion criteria were omitted. For potentially significant articles, full texts were retrieved and examined in terms of satisfaction of criteria. Five sources were found to have fit criteria.

Table 2. Article numbers.

Source	Number of Articles
Annals of physical & Rehabilitation Medicine	1
Austrailian Journal of Music Therapy	1
Clinical Rehabilitation	1
Encyclopedia of Neuropsychological Disorders	1
Frontiers of Neuroscience	2
Frontiers of Psychology	1
Gait & Posture	1
International Journal of Rehabilitation Research	1
Journal of Music Therapy	3
Journal of Neuroscience	2
Music Perception: An Interdisciplinary Journal	1
Music Therapy Perspectives	2
NeuroRehabilitation	1
Neurorehabilitation & Neural Repair	2
Parkinsonism & Related Disorders	1
University of North Dakota	1

Table 3. Articles used.

Article Title	Authors	Publisher/Journal	Date
Auditory feedback control for improvement of gait in patients	Baram & Miller	Parkinsonism & Related Disorders	2007
Neurologic music therapy training for mobility and stability rehabilitation with Parkinson's disease–A pilot study	Bukowska, Krezatek, Mirek, Bujas, & Marchewka	Frontiers in Human Neuroscience	2016
A Home-Based Walking Program Using Rhythmic Auditory Stimulation Improves Gait Performance in Patients With Multiple Sclerosis: A Pilot Study	Conklyn, Stough, Novak, Paczak, Chemali, & Bethoux	Neurorehabilitation and Neural Repair	2010
Rehabilitation, exercise therapy and music in patients with Parkinson's disease: a meta-analysis of the effects of music-based movement therapy on walking ability, balance and quality of life	De Dreu et al.	Parkinsonism & Related Disorders	2012
The effect of rhythmic auditory stimulation on the gait parameters of patients with incomplete spinal cord injury: an exploratory pilot study	De l'Etoile	International Journal of Rehabilitation Research	2008
The effects of auditory rhythms and instruction on walking patterns in individuals post stroke	Ford, Wagenaar, & Newell	Gait & Posture	2007
The encyclopedia of neuropsychological disorders	Horton, Dean, & Noggle	Springer Publishing Company.	2012

Table 3 – continued

Article Title	Authors	Publisher/Journal	Date
Rhythmic auditory stimulation in gait training for patients with traumatic brain injury	Hurt, Rice, McIntosh, & Thaut	Journal of Music Therapy	1998
Changes in gait patterns with rhythmic auditory stimulation in adults with cerebral palsy	Kim et al.	NeuroRehabilitation	2011
Collaborative Physical and Music Therapy Interventions for Impairments of Chronic Stroke: A Case Study	Leverington & Bell	University of North Dakota	2019
The use of rhythmic auditory stimulation of gait disturbance in patients with neurologic disorders	Lindaman & Abiru	Music Therapy Perspectives	2013
Editorial: Dialogues in music therapy and music neuroscience: Collaborative Understanding driving clinical advances	O'Kelly, Fachner, & Tervaniemi	Frontiers in Human Neuroscience	2016
Music therapy services in neurorehabilitation: An international survey	Pakdeesatitwara & Tamplin	Australian Journal of Music Therapy	2018
Musical motor feedback (MMF) in walking hemiparetic stroke patients: Randomized trials of gait improvement	Schauer & Mauritz	Clinical Rehabilitation	2003
Rhythmic auditory stimulation for gait training in persons with unilateral transtibial amputation: A randomized-controlled trial	Sohliya & Thomas	Annals of Physical and Rehabilitation Medicine	2018
Entrainment and the motor system	Thaut	Music Therapy Perspectives	2013

Table 3 – continued

Article Title	Authors	Publisher/Journal	Date
Rhythmic auditory stimulation in rehabilitation of movement disorders: A review of current research	Thaut & Abiru	Music Perception: An Interdisciplinary Journal	2010
Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial	Thaut et al.	Neurorehabilitation and Neural Repair	2007
Neurobiological foundations of neurologic music therapy: rhythmic entrainment and the motor system	Thaut McIntosh, & Hoemberg	Frontiers in psychology	2015
Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation	Thaut, Rice, & McIntosh	Journal of Neurological Sciences	1997
Analysis of EMG activity in biceps and triceps muscle in an upper extremity gross motor task under the influence of auditory rhythm	Thaut, Schleiffers, & Davis	Journal of Music Therapy	1991
Rhythmic auditory cueing in motor rehabilitation for stroke patients: Systematic review and meta-analysis	Yoo & Kim	Journal of Music Therapy	2016

The literature for RAS used clinically has included beats produced by metronome, metronome, and/or recording of music, metronome, and/or live music specially composed or modified for the patients with an emphasis on rhythmic aspects.

Using a metronome and recorded tapes, Hurt, Rice, McIntosh, and Thaut (1998) documented progress found in RAS goals for eight individuals with a TBI. The mean and standard deviation (SD) was provided in baseline data collection. Participants saw 18% increase in velocity, seven percent in stride length, and an eight percent increase in cadence after a single session. When Hurt, Rice McIntosh and Thaut (1998) used the same methods for five patients with a TBI over daily for five weeks, participants showed a 50% increase in velocity, a 29% increase in stride length, and 15% increase in cadence. Similarly, De L'Etoile (2008) used a metronome and recorded auditory production method over multiple sessions during RAS. However, De L’Etoile found no consistently positive effect across participants with incomplete spinal cord injuries. See Tables 3 for more details.

In a study done by Baram and Miller (2007), 14 randomly selected outpatients with MS and gait disturbances measured velocity (meters/second) and stride length (meters). Cadence was not measured. A range of participants baseline data was provided, and walking speed was converted from meters/second to meters/minute (see Table 3). Auditory cues were produced via live feedback. A motion detective device provided auditory stimulation by generating a tick each time the user took a step. Participants were told to attempt to walk at a steady pace. Walking speed residual improvement showed to increase by 18.75% on average; stride length residual improvement showed to increase by 9.93% on average. The length of study and the amount of time spent on gait training interventions was not found in this study.

Thaut, McIntosh, and Rice (1997) recorded the progress of velocity, stride length, and cadence of 20 individuals recovering from a stroke (CVA). Auditory stimulation was provided through the use of recorded music and metronome. The mean and standard deviation (SD) was provided in baseline data collection. Participants increased 164% in velocity, 88% in stride length, and 56% in cadence within six weeks or RAS gait training. Sessions occurred twice daily for 30 minutes.

Schauer and Mauritz (2003) provided RAS gait training with a live feedback method for individuals recovering from CVA. The mean and standard deviation (SD) was provided in baseline data collection. Baseline data was converted from meters/second to meters/minute and displayed in Table 3. Participants showed a 27% increase in velocity, 18% increase in stride length, and 4.6% difference in cadence.

Table 4. Article sessions.

Article	# of Participants	Population	Single-session	Multi-session	Intervention length	Length of Study
Baram & Miller (2007)	14	MS	–	4	–	–
De L'Etoile (2008)	17	SCI	✓	–	–	–
Hurt, Rice, McIntosh, & Thaut (1998) Experiment 1	8	TBI	✓	–	–	–
Hurt, Rice, McIntosh, & Thaut (1998) Experiment 2	5	TBI	–	Daily	–	5 Weeks
Schauer & Mauritz (2003)	23	CVA	–	15	20 min.	3 Weeks
Thaut, McIntosh, & Rice (1997)	20	CVA	–	Twice daily	30 min.	6 Weeks

Limitations

Research using live feedback as the primary auditory production method within rehabilitation was limited. However, Leonard (2019) found live music therapy interventions to show an important role in observed pain while individuals engaged in co-treating within rehabilitation populations. The researcher suggests more extensive research within the use of live feedback as the primary auditory production method.

Table 5. Baseline and increase.

Article	Velocity		Stride Length		Cadence	
	Baseline	% Increase	Baseline	% Increase	Baseline	% Increase
Baram & Miller (2007)	15.12- 82.86	18.75%	0.25 - 0.76	9.93%	–	–
De L'Etoile (2008)	13.18 ± 8.62	-2.20%	0.65 ± 0.16	-0.02%	38.06 ± 17.81	-0.47%
Hurt, Rice, McIntosh, & Thaut (1998) Trial 1	1.78 ± 19.05	18%	0.94 ± 0.30	7%	86.69 ± 21.57	8.0%
Hurt, Rice, McIntosh, & Thaut (1998) Trial 2	8.28 ± 16.08	50%	0.89 ± 0.22	29%	85.70 ± 26.56	15%
Schauer & Mauritz (2003)	38.40 ± 18	27%	0.84 ± 0.30	18%	45.5 ± 8.5	4.6%
Thaut, McIntosh, & Rice (1997)	19.7 ± 11	164%	0.64 ± 0.31	88%	63 ± 10	56%

Table 6. Auditory production.

Article	Live Feedback	Metronome	Recorded
Baram & Miller (2007)	✓	–	–
De L'Etoile (2008)	–	✓	✓
Hurt, Rice, McIntosh, & Thaut (1998) Experiment 1	–	✓	✓
Hurt, Rice, McIntosh, & Thaut (1998) Experiment 2	–	✓	✓
Schauer & Mauritz (2003)	✓	–	–
Thaut, McIntosh, & Rice (1997)	–	✓	✓

Music preferences of participants were not recorded in data collection; however, research seems to suggest preferred-music listening may decrease perceived exertion, increase positive mood, and decrease estimations of time duration of exercise in clients (MacNay, 1995). The researcher suggests further analysis of the benefits of patient preferred live-feedback in rehabilitative music therapy services.

Discussion

Limited research was focused on the success of live auditory stimulus within RAS gait training. This content analysis sought to (1) identify the types of neurologic disabilities that are successful in gait-related goal achievement through RAS gait training, and (2) identify the success of a live auditory stimulus production method within RAS gait training. Results revealed that five of the six studies (83.33%) in this content analysis saw an increase in the measured gait training functions. Live feedback as the primary auditory production method was used in two of the six (33.33%) studies found. Although live feedback was not seen as the primary auditory production method within the majority of the studies, positive results were seen within those using live feedback as their primary method. Results may provide a starting point for further, more in-depth research on the therapeutic benefits of RAS gait training with neurologic disorders and the use of live feedback as the primary auditory production method within rehabilitative populations.

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