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Rhythmic exercises as tools for rehabilitation following cerebellar stroke: A case study integrating music therapy and physiotherapy techniques

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ABSTRACT

Introduction: This article explores the use of music and multisensory stimuli in the construction of compensatory neural networks for motoric functioning in a patient recovering from cerebellar strokes (CS). This study aimed to address the real-world clinical concern of patients having a passive role in therapy, by arousing the client's interest and self-motivation in rehabilitation.

Method: The article presents a case study of a CS survivor, using data derived from rehabilitation sessions combining music therapy techniques with physiotherapy techniques to improve the fluency and accuracy of his motor performance. Qualitative and quantitative data are used to identify, describe, and evaluate the key elements of tasks used in the ten therapy sessions. Therapy focused particularly on facilitating the CS survivor to produce his own exact and fluent movement and generate his own vocal cues via rhythmic reciting and chanting.

Results: The CS survivor achieved his therapy goals, and the therapist was able to facilitate the CS survivor's increased motivation and ability to perform movements that were goal-directed, repetitive, functional, and progressive in complexity.

Discussion: Results support the need for further research on multisensory, rhythmical exercises within physiotherapy and music therapy work with stroke patients and others with neurological disorders. The use of self-generated vocal cues would be a particularly interesting focus for further research. Results are discussed in the context of current music therapy research and theory.

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KEYWORDS Music therapy; physiotherapy; cerebellar stroke; self-generated cues; rhythm; speech

Introduction

Cerebellum, cerebellar stroke, and physiotherapy

Cerebellar infarctions account for just 3–4% of strokes (Manto, 2010), and result in impairments which affect work and safety in daily life. The particular motoric and cognitive issues related to cerebellar stroke are not well known. Compared to cerebral stroke, minimal research has been published specifically about CS, representing an important gap in the literature.

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The cerebellum is perhaps best known as playing a crucial role in motor coordination, particularly in refining and adjusting motor behaviors outside of conscious awareness (Doya, 2000; Koziol et al., 2012). However, research has also shown that the cerebellum is involved in memory, learning and emotion (Adamaszek et al., 2017; Doya, 2000; Krakauer & Shadmehr, 2006), and that coactivation of the cerebellum and the prefrontal cortex underlies a close association between motor and cognitive development (Diamond, 2000). The cerebellum also appears to be involved in social functioning (Van Overwalle et al., 2014; Wang et al., 2014). The multifaceted role of the cerebellum is reflected in the symptoms of cerebellar stroke (CS), which impede daily life in a myriad of ways. While a typical stroke patient experiences muscular weakness and impaired sense on one side of the body, muscular activation is largely preserved following CS. CS survivors, however, have difficulties in motor coordination and sustaining of muscular force, as well as with both initiating and ending movements with proper scaling of force (Carr & Shepherd, 2010). Unlike typical stroke, CS results in more severe symptoms on the ipsilateral side, including impairments in speed and fine motor coordination (Harrington et al., 2004).

As stroke results in damage to the brain, rehabilitation for stroke survivors is usually aims to facilitate the redevelopment of damaged neural circuits which allow voluntary motor activation (Kiper et al., 2020). However, emotional and motivational factors are of significant importance for stroke survivors who frequently suffer from increased physical and mental fatigue and are at a greater risk of experiencing depression (Hackett et al., 2005; Staub & Bogousslavsky, 2001). Talvitie and Reunanen (2002) studied physiotherapists' sessions with stroke survivors and found that, despite arguments that it is important for patients to have an active role in therapy (Piirainen, 2006), therapists more often acted as an authority figure rather than facilitating self-motivation. These social and emotional factors may be particularly important for CS survivors, given the cerebellum's role not only in motor timing but in social and emotional functioning.

The most widely used physiotherapy method for stroke survivors in Finland is the Bobath Neuro-Developmental Treatment (NDT) which focuses on facilitating the client to produce key movements in a relaxed, sometimes passive state (Paci, 2003; Zanon et al., 2018). The Motor Learning Model, as developed by Carr and Shepherd (1989), requires more active involvement from the patient, and has been shown to be more effective than NDT in some cases (Pyöriä, 2007). However, these methods are aimed at typical stroke survivors who are paralyzed or paretic, such that they are less beneficial for CS survivors, whose needs involve motor timing and coordination along with cognitive and affective challenges. It is therefore useful to look beyond traditional physiotherapy to meet the needs of CS survivors.

Music, movement and music therapy in stroke rehabilitation

Humans have a remarkably advanced and flexible ability to synchronize their movements to a steady auditory beat (Christensen et al., 2017; Repp, 2005). Research shows that humans are able to synchronize their movements rhythmically to external stimuli, such as heard music or the click of a metronome at a wide range of tempos, and that to do so is among the most common responses to heard music (Lesaffre et al., 2008). Neural overlap exists between motor areas of the brain and those which process musical rhythm, suggesting the use of rhythm as a particularly useful tool in

neurological rehabilitation (Grahn, 2012). Sihvonen et al. (2017) suggest that this coupling of auditory and motor signals in the brain can be used to support motor learning in rehabilitation, due both to the personal motivating factors associated with music and because memory for musical structure can facilitate motor timing. The integration of music therapy methods into physiotherapy therefore has the potential to address some of the shortcomings of current methods described above for CS survivors.

Bruscia (2014) defines music therapy as a therapeutic process "using various facets of music experience and relationships formed through them as the impetus for change" (p. 36). In the rehabilitation of stroke, rhythm is often used in music therapy to guide movement. Neurologic Music Therapy (NMT), for example, capitalizes on overlaps between music and non-music functioning in the brain to facilitate timed movements and improve speech, often using a metronome as a stimulus (M. Thaut, 2005a; M. Thaut et al., 1997; Lim et al., 2013). Functional Music Therapy (FMT), developed by Swedish therapist Lars Hjelm is characterized by the client sitting at a drum set and playing along with the therapist's piano accompaniment. The client must use motor control, hand-eye coordination and use one or both upper limbs, reaching around 90 degrees in both direction (Ahonen-Eerikäinen, 1999). The Ronnie Gardiner Rhythm and Music Method (RGRMM) aims to stimulate cognitive function by engaging the client in tapping, stepping, and clapping while rhythmically reciting nonsense words (Pohl et al., 2013).

While each of these methods has shown positive results, when viewed from a physiotherapy perspective, the methods described in the above research could be improved by greater attention to functional, applicable movement and cognitive skills needed in daily life. The FMT model, for example, can be criticized for not sufficiently activating core muscles needed by the client for balance. In line with Sandström and Ahonen (2011), the first author has noted within her therapy practice the importance of facilitating the CS survivor's proprioception in the area of pelvis and lower limbs. It is also important to increase perception of the tactile sensation of the floor or chair while standing or sitting. A traditional drum set provides a limited context in which to develop this balance. While the Transformational Design Model (TDM), which provides the basis for NMT, describes a process of creating exercises that are functional and attenuated to client's specific needs (M. Thaut, 2005a), research on the gait-training NMT technique of Rhythmic Auditory Stimulation has focused almost exclusively on more basic features of gait such as velocity, cadence, and stride length (M. Thaut & Abiru, 2010; M. Thaut et al., 2007). Guidelines for RAS also do not address the integration of cognitive skills for daily life, such as the client's ability to multi-task while walking (e.g. engaging in conversations, looking in store windows; C. Thaut & Rice, 2014).

Movement-focused music therapy techniques for stroke survivors may also not adequately address the emotional and relational needs of these patients. This is particularly important for CS survivors, given the role of the cerebellum plays in social and emotional functioning (Adamaszek et al., 2017; Van Overwalle et al., 2014). Ahonen-Eerikäinen (1998) describes music as means of communication, expression, and reciprocal dialogue in a multisensory experience, providing a safe environment; that is, it facilitates the development of the therapeutic relationship. The therapeutic relationship is seen as a key element in many traditional forms of music therapy (MacDonald, 2013), with the musical interaction between therapist and client seen

as similar to the pre-verbal interaction of infant and parent (Aigen, 2014; Feldman, 2006; Trevarthen, 1999; Trevarthen & Aitken, 2001). Clayton (2012) defines entrainment as "the process by which independent rhythmic systems interact with each other" (p. 49); for example, two people tapping a steady beat together may make constant small adjustments to stay in time with each other (Repp, 2005). Not only do humans excel at sensorimotor entrainment, but, uniquely, are capable of physiological entrainment, as when the breathing and heart rate of an infant and parent become entrained during their interactions (Feldman, 2017). Although the mechanisms that mediate sensorimotor, physiological and emotional entrainment are not yet fully understood, multiple studies suggest strong links between these types of entrainment (Kirschner & Tomasello, 2009, 2010; Ogden & Hawkins, 2015; Phillips-Silver & Keller, 2012; Trost & Vuilleumier, 2013). For example, synchronization with others in the form of dance affects both emotional and cognitive aspects of social functioning, producing feelings of social closeness (Tarr et al., 2016) and improving memory for social stimuli (Woolhouse et al., 2016). Furthermore, a social context has been shown to facilitate sensorimotor entrainment in young children (Kirschner & Tomasello, 2009), suggesting a bidirectional relationship between social functioning and sensorimotor entrainment. Additionally, rhythmic entrainment of speech patterns appear to reflect successful interactions between conversation partners (Ogden & Hawkins, 2015).

Phillips-Silver and Keller (2012) have hypothesized that entrainment ability, and its relationship to social functioning, is rooted in early interactions between parent and infant, which are characterized by vocal and facial imitation, turn-taking and timing, and which have been described by Cross (2006) as "protomusicality." Trevarthen and Malloch (2000) have suggested that improvisational music therapy may be effective because it entails similar processes to early interaction. However, the role of entrainment in supporting social relationship in other music therapy contexts does not appear to have been discussed or examined in the music therapy literature.

Based on the above research regarding entrainment, rhythmic entrainment between the CS survivor and therapist may enhance the quality of the therapeutic relationship. However, while the relationship between entrainment and social functioning is addressed in music therapy literature dealing with patients with depression or autism (Amos, 2013; Erkkilä, 2014), it does not adequately address the importance of this for stroke survivors. This issue may be especially pertinent for CS, which is marked by difficulties in precise motor timing. In movement-focused rehabilitation, when a metronome is used and/or the client is expected to match the therapists' tempo, this mutual adjustment entailed by social entrainment is not possible (Phillips-Silver & Keller, 2012). This furthermore results in a similar "therapist-as-authority" social context, which has been previously described as problematic in physiotherapy treatment of neurological patients (Talvitie & Reunanen, 2002).

Other forms of music therapy have of course been successfully used to address psychosocial needs for clients, for example, to depression in adults (Erkkilä et al., 2008). Regarding stroke patients specifically, music therapy has been shown to improve mood and social interaction in patients with traumatic brain injury and stroke, and to help meet the emotional needs of stroke patients as they cope with and adjust to being faced with a sudden, severe loss of functional capacity (Forsblom et al., 2009; Nayak et al., 2000). Särkämö et al. (2008) have shown that listening to music after a stroke increased patients' levels of dopamine, a neurohormone which is crucial for mediating arousal, emotion, reward, motivation and memory among other faculties.

The aims and origins of this study

This article presents the case study of a unique music therapy process, which integrated elements of music therapy and physiotherapy for a patient who had experienced multiple cerebellar strokes (CS). The first author, an experienced physiotherapist, had noticed the unusual challenges faced by her patient who was a CS survivor. These observations motivated her to augment her rehabilitation tools in the unique trial as part of her Bachelor level training in music therapy. The first author, who was also the therapist in the case study, studied the therapy process with the aim of combining music therapy resources in the rehabilitation in such a way that the music's therapeutic effects and the patient's sensorimotor responses would work together to the reformation and reorganization of the stroke victim's brain network. The purpose of this article is to elucidate this approach to rehabilitation, developed for a specific CS survivor, in order to provide a basis for further clinical work and research into this topic. This helps to fill the gaps in the literature created by the comparative rarity of CS and the lack of discussion of it in music therapy research. The music therapy process addressed the CS survivor's functional needs while considering the importance of his emotional needs and active, motivated involvement in the therapy process. The therapy process drew on sensorimotor and affective entrainment in musical exercises and was characterized by: the use of rhythm and meter to guide the CS survivor's movements; encouraging the CS survivor to vocally provide his own rhythmic cues thorough chanting and singing; and the supportive therapeutic relationship between the CS survivor and therapist. Therapy was designed considering the psychological, physiological, and psychosocial needs of the CS survivor in an integrated way, reflecting involvement of the cerebellum not only in motor timing, but in cognitive, social and emotional functioning as well (Adamaszek et al., 2017; Harrington et al., 2004; Molinari et al., 2007; Van Overwalle et al., 2014). The ten-session therapy process described here took place in 2010 as part of the first author's Bachelor studies in music therapy. Video recordings and the notes taken during the process contributed data to the first author's Master Thesis in music therapy (2013). It was not planned at that time to develop a Master's thesis or article based on this work, but the data have been re-examined as part of both of these processes.

Methods

Description of the client and his history with the therapist

The CS patient, referred to as Jussi (age 56), had experienced six strokes on the right side of his cerebellum and one on the left side of the cerebellum. He was initially treated in hospital, where he received rehabilitation for a few weeks and was discharged with a referral to private physiotherapy with the first author as his therapist (hereafter "the therapist"). This therapy took place before the start of the music therapy process. During these 15 months of physiotherapy, Jussi's abilities improved, but he still struggled with balance, specifically activation of the core and gluteal muscles. His speech continued to be too fast and slurred, and tension in his vocal cords produced a "gravely" tone and frequent vocal cracks. He struggled with cognitive tasks such as reading the subtitles while watching foreign television or films. Because of the CS survivor's on-going needs following physiotherapy, and the unique character of his needs compared to those with typical stroke, the first author chose to invite the CS survivor to work with her as part of her music therapy training in her Bachelor studies.

Prior to his illness, Jussi had been involved with sports and was eager to engage in physical activity. However, because of the damage caused by his cerebellar strokes (CS), he had lost his natural, fluent movements and quickly became stressed when attempting movements. His personal strengths included his enormous motivation for getting well and a positive attitude. During the sessions he was courageous, brave, and reacted to difficulties with humor. Rather than becoming angry or frustrated when he made a mistake, he would laugh, make a joke, and try again. He was open to trying new tasks even if he could not immediately understand the purpose.

Ethical considerations

Jussi was invited to be involved as patient in a case study during the therapist's bachelor level studies in music therapy at the University of Jyväskylä, in September 2009 and provided his written informed consent. Jussi provided additional informed consent for the later analysis on 21 September 2019.

Methods Derived from Music Therapy and Physiotherapy

The case study included elements stressed by NMT: functional assessments, development of therapeutic goals, design of functional exercises, transfer learning to functional real-world applications (M. Thaut, 2005a). However, it also included novel elements to meet the specific needs of the CS patient, including having the CS patient generate his own rhythmic cues vocally, involving him more directly as a participant in the therapy process and simultaneously practicing oral motor skills. The therapy process also favored social entrainment processes over one-sided (metronomic) entrainment, such that the therapist and Jussi adjusted mutually to one another, more in line with early interaction models of music therapy rather than those typically used in neurological rehabilitation.

Collaborative development of the therapy goals

At the start of music therapy, Jussi said that he wished to learn to ski strongly "like a man"; that is, to be able to kick the ski strongly across the snow while simultaneously pressing down the ski pole with the opposite arm (as opposed to sliding the skis forward). His second wish was to learn to ride a bicycle safely while turning his head sideways to see the area and to talk with his wife. He also wished to walk in such a way that his condition as a CS survivor was not obvious to strangers. To work towards these practical goals, Jussi and the therapist agreed on the following therapeutic objectives:

1. To improve fluency of movements and coordination of movements in daily life; namely, maintaining stability and balance while moving and stopping on many kinds of surfaces
2. To improve fluency of speaking, addressing oral motor skills and use of the voice
3. To improve ability for multitasking in daily living, to focus in two or more tasks at the same time safely

Table 1 provides an overview of the challenges Jussi faced in multiple areas of functioning at the start of the therapy process. Although Jussi's goals focused on movement, speech and cognitive processes, the therapist noted that sensory

Table 1. Ares of difficulty forJussi at start of therapy

Cognition	Speech	Motor	Sensory	Psychosocial
Working memory	Slow speed	Coordination	Vestibular sense	Shame
Orientation	Stuttering	Balance	Sense of pressure	Low self-esteem
Conceptualization	Diphthongs	Timing	Sense of force	Loss of identity
Reading speed	Consonant clusters	Core activation		Worry
		Multitasking		Missing hobbies
				Social contact

difficulties with balance and proprioception would be necessary to address as part of these goals. She also expected that emotional issues such as low self-esteem, embarrassment about his symptoms, and anxiety leading to increased social isolation, would be necessary to take into consideration in addressing Jussi's goals within the therapy process.

Approach to research

Over the course of the sessions, the therapist aimed to understand and evaluate the essential factors which affected the therapy process. She kept detailed notes and descriptions of this process, so that she could afterwards examine the important elements. She additionally recorded 23 video clips of task performances. She aimed to make her research unambiguous, measurable, realistic, and consistent. This research is presented as a case study, due to its provision of an in-depth examination of a single therapy process in a natural context (Crowe et al., 2011). However, the process also included elements of action research, as the therapist aimed to develop and improve her own practice via the process. This is in line with Kananen (2013), who describes action research as a process for developing one's own work in which "the researcher is herself participating in the operations of the development object" (p. 44).

Implementation of therapy

Each of the ten therapy sessions followed the same structure:

1. *Opening discussion (≈5 min.)*: the therapist and Jussi discussed his feelings, state of health and whether he had been practicing therapy tasks at home. They processed any thoughts or emotions that arose from the previous session and discussed Jussi's desires for the current session.
2. *Whole body tasks (≈10-15 min.)*: Jussi completed tasks involving rhythmic walking, standing and sitting which focused on developing functional movement, for example, coordination, balance, and activation of vestibular and proprioceptive systems. Musical stimuli consisted of Jussi's own chanting of a chosen rhyme, the therapist's singing, or pre-recorded music of Jussi's preference.
3. *Upper body tasks (≈15 min.)*: Jussi performed tasks organized in 8-beat patterns, consisting of clapping hands, tapping knees, drumming with hands or mallets on a tabletop or overturned buckets, and stomping of feet. Tasks targeted not only timing and coordination, but short-term memory and multi-tasking, and

became progressively more challenging. Musical stimuli consisted of Jussi's own chanting, alone or along with the therapist, the therapist's singing, or pre-recorded music of the Jussi's preference. The therapist frequently provided a visual model for Jussi while he was completing the task.

4. *Relaxation (≈5-8 min.)*: Jussi listened to background music while sitting or lying down, focusing on breathing and reducing bodily tension. Guided imagery techniques were used to support relaxation.

Key elements of the therapy process

In the following sections, key aspects of the therapy process are highlighted. A comprehensive description of all activities used, all therapy tasks and the steps involved, transcriptions of notes from each session, and further details regarding therapist evaluation of tasks performances and sessions can be found in the first author's Master's thesis (Ruotsalainen, J. 2013).

Choice of rhyme and familiarization with metric structure

At the start of therapy, Jussi was asked to choose a rhyme which he would recite while performing rhythmic tasks. Jussi chose a rhyme he knew well, "Hämä hämä häkki" (The Itsy-Bitsy Spider), which is easy to divide into an eight-beat phrase. As Jussi became familiar with this structure, he was better able to complete tasks like taking eight steps forward and eight steps sideway, or swinging his arms as needed in walking. When pre-recorded music was used, Jussi preferred Irish folk music.

Progression of rhythmic tasks for upper limbs

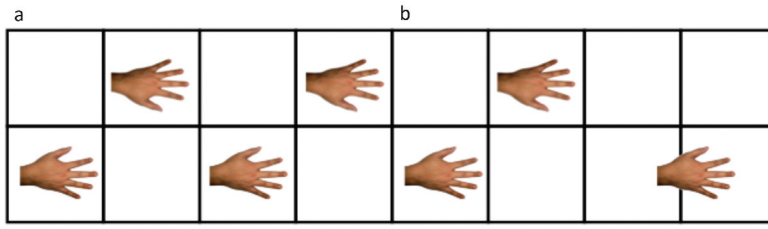
The main part of the session comprised combinations of hand movements performed standing or sitting on a stool. Jussi was guided to focus on feeling the even pressure of both sides of the body and limbs, and to activate his whole body to support his generation of fluent, natural motor performing. These tasks started slowly with tapping with one hand at the time on the table for eight counts along with the receipted rhyme (see Figure 1). This progressed to two taps with one hand at the time. Then the therapist increased the difficulty by adding taps, having Jussi cross the middle line with his tapping hand, and by changing the directions of taps, as with the warm-up waking task.

Later in the rehabilitation process, tapping was exchanged for drumming with mallets on overturned buckets (no "real" drums were accessible) or on colorful pieces of felt. At the beginning of each task the therapist gave instructions, modelled the movements, and in some tasks supported the client by providing a mirroring model. Difficulty was increased by altering (a) the number of targets to hit with the mallet; (b) the direction in which to hit; (c) the direction of drumming only with one hand; (d) adding simultaneous drumming with both hands in same direction, or simultaneous in mirroring direction etc.; (e) the distance of targets, and (f) changing the starting position, e.g. sitting, standing, or stepping simultaneously.

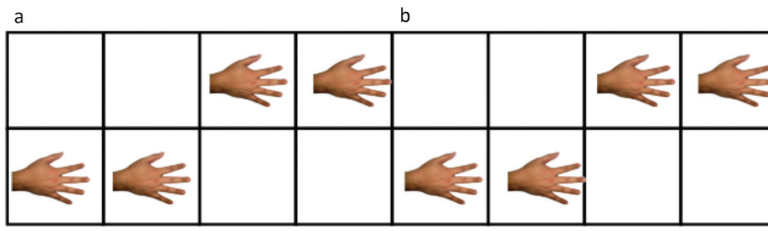
Focus on everyday functional movements

The therapist designed exercises meant to improve everyday functional movements. For example, walking comprises not only the lower limbs but also arm swing in the relative phase of 180° and the rotation of the thorax, which must be practiced as these

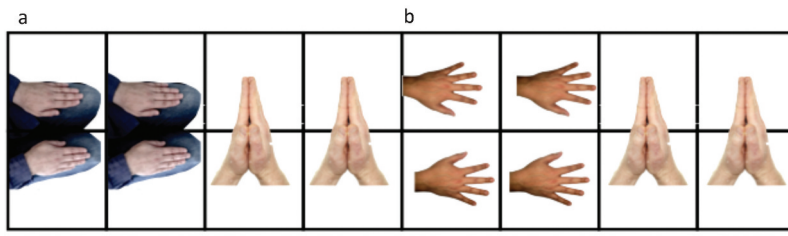
Task 1: DC/1T



Task 5: C/1T



Task 11: DC/3T



Task 15:C/3T

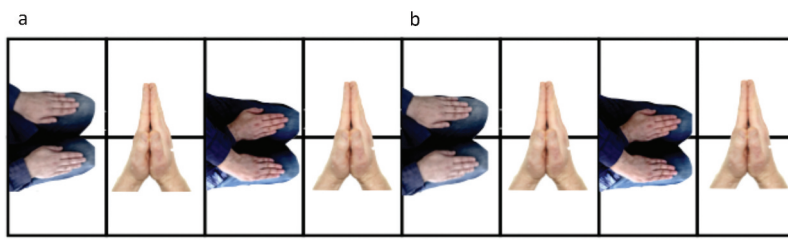


Figure 1. Examples of simple tapping tasks used in therapy. C = continuity (pattern A and pattern B are identical); DC = discontinuity (pattern A and pattern B differ); 1T = one tapping target; 3T = three tapping targets

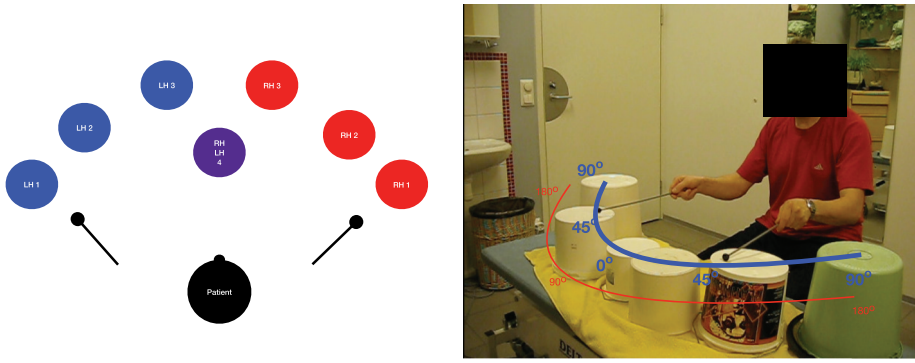


Figure 2. Drumming task. In this task, the client hit each drum twice in a row, his hands working simultaneously, mirroring as they moved from side towards middle line. The challenging aspect of the task was in moving the arms quickly from the midline to the far lateral sides to repeat the pattern at the start of the next cycle of 8-beats

elements of gait provide the walker with greater forward momentum. The therapist also targeted movements needed in directing the upper limbs towards a particular direction with the correct amounts of acceleration, force, and speed. Such movements are necessary, for example, while catching a ball or falling object. Drumming tasks (Figure 2) also mimicked the act of having to move an object with two hands, with the arms moving horizontally in the same direction. Daily functional movements require the upper limbs to move in turns or simultaneously clockwise or anticlockwise, in parallel coordination or mirroring symmetry. Drumming and tapping tasks with one or both limbs were training the right timing and muscle power in everyday functions, such as reaching to take a glass from the tray, to put something on a moving carriage, or to receive a ball and to bounce it. Walking tasks trained acceleration, force, and timing of the lower limbs in jumping and swerving.

Multi-modality of cues

Table 2 provides an overview of the multimodality of cuing used in the sessions. Multimodality was considered to be particularly important throughout the therapy process, in line with Sihvonen et al. (2017). Visual cues provided by the therapist included providing a model of tasks, allowing Jussi to imitate the therapist's rhythmic movements. The therapist also made use of Figure Notes, a method established by Kaikkonen and Uusitalo (Kaikkonen & Uusitalo, 2005) in which of using colorful dots,

Table 2. Multimodality of cues within the therapy sessions

Sensory Modality	Therapeutic stimulus
Visual	Movements demonstrated by therapist
	Viewing self in mirror or videoclips
	Figure Notes
Auditory	Client's voice
	Therapist's voice, musical stimuli
	Sounds of client's tapping, clapping
Tactile	Feeling of touch of target with skin or mallet
	Feeling of feet on the floor
Kinesthetic	Feeling of own movements
	Feeling of movements as assisted by the therapist

for example, on piano keys, to allow young children and those with cognitive delays to read music, which has yielded positive results relating to improved perception and processing of rhythm (Äystö, 2005).

The therapeutic relationship

At the time of collecting these data, the therapist was a novice professional in music therapy field. However, she had had, at the time, 34 years of experience as a physiotherapist working with neurological patients. Like in music therapy, physiotherapy education emphasizes the importance of the psychological and social relationship between patient and therapist. The therapist therefore strived to maintain the positive mood for the client during the whole process. If Jussi struggled with a particular task, she asked him to repeat the task he had most recently completed successfully in order to mitigate demand stress. For the same reason, each session was started with a successful task from the last session. Positive feedback was considered a highly important aspect of the session, due to the wide variety of disappointments and embarrassments that can be experienced daily by stroke patients. The therapist drew the client's attention to all possible positive moments in every session, which proved to be a powerful tool in rehabilitation. Any difficulties that occurred were discussed between the therapist and Jussi. Musically, the therapist and Jussi were frequently moving together in rhythm, as she provided a model for him to complete tasks during the session, which has been shown to support feelings of social closeness and even elevate pain thresholds (Tarr et al., 2016), enhancing the feeling of therapist and Jussi working together rather than the therapist acting as an authority.

Transcription of the notes, observations, and analysis of videos

Every session was strictly documented thoroughly by the therapist through her notes. She drew templates of the tasks used in the session. The therapist usually recorded Jussi's participation in sessions using video, which allowed him to view the video immediately and assess of his own performance. The therapist familiarized herself with her notes and description, and she evaluated and defined each session separately. The therapist analyzed Jussi's performances by making a list of the tasks assigning a grade of difficulty to each. Table 4 provides an example of this process from the tasks described in Figure 1.

In estimating the level of a challenge in the task, the therapist considered, for example, the number of targets the client was asked to hit, whether the first four and second four beats in the eight-count phrase were identical (= continuity) or different (discontinuity). Challenging elements also included the addition of half-notes along with quarter notes, as well as crossing midline. Jussi's performance on each task was assessed based on the steadiness of his tempo, the correct completion of the task, use and clearness of his own vocal cues, and whether his movements used appropriate amounts of force.

Results and Findings

Descriptions of Jussi's improvements

The following section provides narrative descriptions of Jussi's improvement in skills over the course of the ten-week therapy process.

Development of whole-body rhythmic movements

Jussi's ability to move rhythmically improved during the process. In the first session, he struggled with changing direction while walking in conjunction with the 8-beat structure, even if he counted aloud. He could not simultaneously step and clap and could not walk on a narrow pathwithout losing his balance. In the sixth session, the therapist asked Jussi to place the 4 step boards at an appropriate distance from each other, so that he would be able to march on every board and take one step in between every board while moving sideways. The therapist provided rhythm by singing the melody of "Kalle-Kustaan Muori" (The Battle Hymn of the Republic). In the first trial he successfully walked sideways to the left for two eight-beat patterns, clapping his hands on the 16th step, then walked sideways to the right, clapping on the 16th step. He successfully performed the pattern twice in a row. Jussi additionally developed an efficient and synchronized way of jumping, which required appropriate and synergistically timed activation of the whole body.

Development of upper body rhythmic movements

In the first session, tapping the table with each hand in turns was very problematic for Jussi. He attempted this several times without success. In the next session, however, he succeeded in performing this pattern while reciting "Hämä hämä häkki", four successive times a speed of 96 beats per minute (BPM). By the sixth session, Jussi had learned move his hands in a steady rhythm. He struggled with a task wherein he tapped two beats on the table and placed a third tap (two beats in length) over the midline but was able to complete it when the therapist sat in front of him and mirrored his movements, tapping and reciting in rhythm with him. With the additional visual cue, Jussi was able to perform the pattern four times at a tempo of 128 BPM. By the last session, Jussi was able to work with eight "drums." He could drum with hands or mallets, both hands together, alternating hands, tap one had multiple times, move his hands in mirror of each other, and move his arms in parallel clockwise and counterclockwise. While in the first session Jussi struggled to produce a steady pulse with his right hand, in the last sessions could maintain a steady beat even when required to move his both hands a distance of 70 cm over one beat. The hits with the right hand were well timed, however he still displayed some inconsistencies in force compared to the left hand. In the last session, Jussi was additionally able to "drum in the air" on the third beat. From a physiotherapy perspective, this is notable because the raising of the mallet required the activation of the muscle chain of the humero-scapula area. The peripheral movements in such a case need to be anchored in the proximal part of the body by activating the core muscles and the whole kinetic chain, which combine to allow movement of the upper limbs.

Quantitative description of improvements

Table 3 provides information about Jussi's skills in tapping and drumming tasks, measured in the beginning, in the middle of the process and in the end of the process. For example, he progressed from tapping with his left or right hand only to using both together, from having minimal bodily rotation to up to 180° rotation. His ability to remember patterns, and focus his attention appeared to improve, as he was able to perform a greater number of full patterns in a row without mistakes. The patterns became increasingly complex.

Table 3. Assessment of task difficulty within a session

Description	Areas Addressed	Challenges
Tapping and reciting, 1 tap per beat, with last tap lasting 2 beats	Verbal fluency, multi-tasking; memory and attention	Jussi struggled to remember the change in pattern B
Tapping 2 beats in a row with each hand	Motor fluency, balance, memory and attention	Jussi often tapped only once with his left hand. However, he completed the task perfectly after 2 minutes of trampoline jumping
Tapping 2 beats in a row, both hands on knees, hands together and hands on table	Multitasking, motor fluency, memory and attention	Jussi struggled to keep the beat steady while remembering the targets in order
Tapping 1 beat per target, no reciting, music on in the background	Multitasking, motor fluency, midline crossing, memory and attention	Crossing hands on the third beat of the pattern was initially difficult for Jussi

Achievement of therapy objectives

Jussi made gains in his functioning during the therapy process that went beyond what he achieved during his previous physiotherapy. Both the therapist and Jussi agreed that he had achieved his personal goals. He improved his fluency of movements through his completion of increasingly complex patterns requiring increasingly extensive motor planning (Objective 1). While reciting rhythmic rhymes during therapy tasks, Jussi had to make countless repetitions of various speech sounds, which helped him achieve his goal of improving the fluency of speech (Objective 2). According to the therapist's assessment, speech became slower with less slurring, and the quality of his voice improved and became more relaxed as evidenced by decreases in the voice breaking and decreases in a "gravelly" vocal quality.

Jussi additionally learned to perform bodily movements while simultaneously speaking (Objective 3). This, along with the multi-tasking that was integral to the majority of tasks used in the therapy session, allowed the client to not only to achieve his goal of being able to simultaneously ride a bike and chat with his wife, but also addressed the underlying emotional need for social connection and expression.

Transfer of skills to everyday life

Jussi and his wife provided reports about his improved skills outside of the therapy session. Jussi reported that he could correctly control the timing and force of his movements while skiing, such that skiing became more enjoyable for him. While walking outside in challenging circumstances, he was now able to simultaneously yield to passers-by and to direct his gaze to windows of shops and to chat with his wife. Taking bicycle trips with his wife became safer because of his improved coordination skills, as he was now able to turn his head to side but still to ride forwards. Jussi was able to walk and talk and additionally throw a ball rhythmically to his training partner. In Finland, foreign-language films and television are not dubbed, so it is necessary to read the Finnish subtitles quickly to follow foreign dialogue. Jussi reported that he had learned to keep up with the subtitles while watching foreign films or television and could even read the text aloud to his wife quickly enough that his wife could follow the program.

Table 4. Progression of tapping and drumming skills throughout the therapy

Session	1	6	9	9	10	10
Max n. targets	2	4	8	7	8	8
Mode	hands	hands	hands	mallets	mallets	mallets
L and R hands	separate	separate	separate	together	together	together
Pattern length	8 beats	8 beats	8 beats	8 beats	8 beats	8 beats
Description	7th beat longer length (2 beats)	crossing midline, 7th beat longer length hit by length	four taps in row, crossing midline	hands mirroring, double hits	crossing midline w/ both hands in same direction	hands mirroring, the 3rd hit in the air
Degree of rotation	0°	20°- 0°	180°-90°	45° –0- 45°	180°-90°-180°	0°- 45°- 0°
Max distance	n/a	~60 cm forwards, ~20 cm over midline	~70 cm	~50 cm	~70 cm	~50 cm
Max n. patterns	0	4	8	8	8	8
Speed at success	n/a	128 BPM	96 BPM	120 BPM	100 BPM	91 BPM*

*BPM = beats per minute. *Upon reviewing the video, the therapist reflected that she herself chose to sing a tempo that was slow, rather than matching Jussi's own tempo.*

Psychosocial aspects of the rehabilitation

Jussi's behavior showed that he responded to therapy with increased motivation and initiative to achieve his goals. For example, he recorded some of his own actions at home for to help him estimate his performing based on the visual feedback from the videos, as he had done in therapy. He told the therapist that he no longer felt timid when among strangers. After therapy, Jussi decided to join a group-gymnastics class for women (as he could not find a group for men), and additionally started to go to the gym. His mood was also improved. Jussi had not previously been aware of his own sense of rhythm, having discovered and developed this musical skill during therapy. In one session, Jussi showed his confidence in his new skills by spontaneously creating his own tapping task for the therapist to complete. These positive experiences of new-found musical competence and improvement of skills within therapy seemed to improve his self-confidence. Jussi state to the therapist that he had discovered new aspects in himself, and that he believed that the therapist had helped him to gain more competencies. The therapist also found that the therapeutic relationship between herself and the client was deeper as a result of the music therapy process.

Cognitive overload (fatigue) and "Rebooting the brain" in sessions

One interesting finding from the case study involved the problem of cognitive overload, which is a common problem for neurological patients (Baker et al., 2005). Instances of apparent cognitive overload challenged the therapist's aim to maintain the positive atmosphere and avoid frustration. She decided to try engaging Jussi in a distracting task to allow the difficult task to be forgotten. In between the cognitively stressful tasks, Jussi jumped rhythmically on the trampoline or to drew big circles with his hands on the table. The therapist called these tasks "brain rebooting." In as little as 30–60 seconds of these activities, fatigue and cognitive overload apparently decreased, and the client was often able to perform the previously problematic task well. This usually occurred in the last 15 minutes of sessions, suggesting that a 40-minute session may have been better than a 60-minute session.

Challenges during therapy

The therapist found it challenging to predict which aspects of a task would be difficult for Jussi; for example, while he quickly increased his ability to perform complex patterns, controlling right-handed movements remained challenging. His impairments in working memory often led to challenges as well. Later sessions included a task which demanded attention to a large visual area, when both hands were simultaneously reaching sideways, more than a meter apart. The therapist expected that this would be challenging, but he did not find it difficult. However, he struggled with the relative phase of arm movements. For example, he struggled in a task where the hands were moving simultaneously in the same direction, at a 90-degree angle to each other, rather than cyclically. This may be because the 90-degree angle between arms is rather seldom used in human motor performance and demands greater attention (Sandström & Ahonen, 2011).

Discussion

This case study examined the effectiveness of integrating music therapy and physiotherapy in treating a patient with multiple cerebellar strokes. Although there is not a consensus on when the use of music in rehabilitation should be considered music therapy (as opposed to, for example, music medicine; Aigen, 2014; Gold et al., 2011; M. Thaut, 2005b), the authors of this study find that Bruscia's (2014) definition fits the therapy process described, in that music and elements of music (rhythm, meter, structure, familiarity) were central to the client's development and improved wellbeing, and that the process was achieved within a therapeutic relationship. In addition, the first author/therapist was completing her bachelor's degree in music therapy as part of the therapy process.

Different aspects of music proved important to addressing Jussi's needs in different areas of functioning in an integrated way. While the main goal of the rhythmic tasks used in therapy was to rehabilitate coordinated, timed movement, Jussi was constantly engaging his working memory and attention through having to remember rhythmic patterns. While chanting "Hämä hämä häkki" during tasks Jussi was providing a rhythmic cue for himself to guide his own movements, but simultaneously exercising his oral-motor control, and facilitating his own relaxation through rhythmic breathing. The difficulties with speech Jussi experienced before therapy may have been due not only to difficulties in oral-motor control, but tension of the vocal fold; relaxed muscles in vocal apparatus are necessary for intonation and dynamics in the voice. It is possible that the positive mood created by the use of music helped Jussi to relax his vocal folds, facilitating better speech and greater emotional expression, similar to Baker et al. (2005)'s findings with clients with traumatic brain injuries. Only when relaxed can muscles in the vocal apparatus produce intonation and dynamics in the voice (Baker et al., 2005).

Therapy tasks engaged Jussi's vestibular system, which has been shown to itself play an active role in neural processing of rhythmic stimuli (Phillips-Silver & Trainor, 2007); this embodied engagement with music may have helped Jussi in the discovery of his understanding of rhythm and meter, which in turn provided him with greater self-confidence and understanding of himself as a musical person. In addition to the vestibular system, music activities have been shown in previous research to activate the dopaminergic mesolimbic system which regulates memory, attention, executive functions, mood, and motivation. Increased extracellular dopamine levels (associated with the experience of pleasure from music listening) could partly explain the cognitive-emotional gains induced by music with neurological patients such as Jussi (Sihvonen et al., 2017). These observations suggest that the cognitive, and emotional aspects of the therapeutic process as supported by music are not easily disentangled, in line with research showing that music activates many areas of the brain at once (Alluri et al., 2012).

One of the most important motivations for undertaking this study was to address the issues raised by Talvitie and Reunanen (2002), who found that physiotherapists often fail to empower neurological patients in therapy, acting as an authority rather than facilitating self-motivation. Jussi's self-motivation was evident both in and outside of therapy sessions. At home he practiced changing directions and turning while walking and reciting his chosen rhyme, showing that, although he did not previously consider himself musical, he had learned to see music as a tool he was himself competent to use on his own rather than a tool provided by the therapist. That Jussi

was willing to join an exercise group for women in order to continue to train along with music not only evidences his increased self-motivation but also his self-confidence was increased.

Learning to provide his own rhythmic cues vocally (and, possibly, internally – see, Schaefer, 2014, for a discussion of the effects of heard and imagined musical cuing) was one of several aspects influencing Jussi's motivation and empowerment. The authors feel this aspect of the therapy process deserves further exploration in music and physiotherapy research, as it has not to the authors' knowledge been studied earlier. Musical sounds *resulting from* timed movements, such as tapping or kicking a tambourine, play a role in models of music therapy such as FMT and NMT, but client-generated vocalizations meant to *as the impetus for* timed movements are not emphasized. However, studies focused on the use of singing in rehabilitating speech (e.g. Melodic Intonation Therapy) have found that singing engage an auditory-motor feedback loop in the brain more intensively than other music making activities such as instrumental playing (Wan et al., 2009). Despite this, in describing Therapeutical Musical Instrumental Performance (TIMP), Mertel (2014) cautions that "patients often wish to sing along with a familiar tune, which may interfere with their instrumental performance, especially in the case of children or patients who have attention problems" (p. 136). By contrast, results of this case study suggest that, for some CS survivors, the opposite may be true; singing could enhance therapeutic results not only by providing patients a sense of empowerment, but by facilitating relaxation through breathing. It is true that both vocalizing and simultaneously completing rhythmic tasks was at times challenging for Jussi, but the authors believe that challenging his ability for multi-tasking ultimately enhanced, rather than hindered, his progress and ability to transfer skills to everyday life scenarios.

The nature of the therapy demanded near constant rhythmic entrainment between the therapist and Jussi. Given previous research showing a relationship between rhythmic entrainment and social functioning (Rabinowitch, Cross, & Burnard, 2013; Tarr et al., 2016; Woolhouse et al., 2016), it is possible that this aspect of the therapy supported the positive therapeutic relationship between the therapist and Jussi. This study emphasized the CS patient generating his own cues through reciting and chanting, in addition to the cues provided by the therapist's singing. Phillips-Silver et al. (2010) distinguish between "social entrainment" referring to cases in which the stimuli to which one entrains come from another person, and "mutual social entrainment," cases in which both persons adjust to one another. Mutual social entrainment is impossible in the case of a metronomic or pre-recorded musical stimulus, and while it is certainly not impossible in cases in which the therapist is playing the piano in real time, it may be that asking the client to actively generate his own cues allowed mutual social entrainment to be more visible and intentional in the sessions described here. Given growing evidence that the cerebellum is highly implicated in social cognition (Van Overwalle et al., 2014), these aspects may be particularly important for CS survivors.

Jussi's case does not fit neatly into any one existing music or physiotherapy therapy theory, and thus raises the issue of the relationship between theory, research, and clinical experience in guiding rehabilitation. Although research on rehabilitation following CS is still lacking, following the work described here, the therapist/first author treated another CS patient and used the same techniques she first developed for the current case. This rehabilitation process was also successful, allowing this CS

patient to achieve his goal to relearn the multitasking, balance, and timing of his movements. He was again able to ride a motorcycle and to ski in the Alps, further suggesting that such therapeutic practices deserve attention in the literature. Karppi (2003) underlines clinical experience as an important foundation for qualified physiotherapy, describing that the methods chosen in the rehabilitation should be derived both from research evidence and clinical wisdom, neither being sufficient alone to provide the best possible care for the patient. In the context of music therapy, Lehtonen and Lehtonen (2008) has also argued for this pragmatic approach to clinical practice, describing music therapy theories as providing ideographic meaning to the therapy process, but also evaluating theories based on their practical value to patient care, stating that "that which works is true" (Lehtonen & Lehtonen, 2008).

Practical lessons derived from the case

A number of practical lessons for music therapists who may work with clients with CS can be derived from the current study. First, the importance of understanding the patient in an integrated, holistic way cannot be overstated. The integrated view of the patient can be, to borrow a term from Stige (Stige, 2015) "zoomed in" and "zoomed out." Not only are the patient's psychosocial and emotional needs directly relevant to the motoric rehabilitation, but when "zooming in" on the patient's motoric functioning, it is necessary to consider the body as a whole, such that the movement of the limbs are always inherently related to the support of the core, the perception of being grounded while sitting or standing, and the patient's breathing and level of relaxation (which, in turn, relate to the patient's emotional functioning). Second, multimodality of cuing, particularly incorporating visual stimuli via colored felt targets, and through the therapist's modeling movements, were particularly important to the CS patient's success. Additionally, video recording of the CS patient also proved to be very valuable, allowing him to analyze his own performances along with the therapist and to correct his position more easily. This technique should be used cautiously, as viewing of such videos may also risk that the person will feel disappointed and frustrated. Still, previous research supports self-evaluation of errors in motor learning (Wulf & Mornell, 2008). Finally, it is important to activate the CS patient's body awareness. Throughout therapy, Jussi was guided to pay attention to his bodily reactions, such as sensing the power of feet against the floor while standing, the straightening of his upper body while sitting, and activating the kinematic power chain by pressing the shoulders downwards and raising the head upwards.

Limitations

As this is a single-subject case study, one notable limitation of the current work is that the findings may not apply similarly to every CS patient, a limitation shared with all case studies (Aldridge, 1996). Additionally, qualitative research is inherently subjective, such that a different therapist and author may have made some different interpretation of the data. However, evaluations were based on the first author's clinical experience, such that the authors feel confident in their overall accuracy. According to Sihvonen et al. (2017) the limitations in most studies arise from small sample sizes and methodological heterogeneity in study design, and in the interventions and outcome measures used. Thus, it is important that the current findings be followed-up with additional research, including larger sample sizes and control conditions. However,

due to the relative rarity of cerebellar stroke, further case studies may also be necessary, and useful in bringing to light individual differences between CS patients and the relative complexity of cerebellar function. Further research on the therapeutic methods described here could benefit from more precise pre- and post-therapy measurements regarding the cognitive, physical and emotional gains of the CS patient. Future research should also be more systematic in the use of varied rhythmic patterns

Conclusion: The Future Requires Multidisciplinarity

Sihvonen et al. (2017) showed the need for novel rehabilitation strategies to replace or complement traditional methods because of a substantial proportion of the associated costs of long-term treatment and rehabilitation for patients with neurological diseases. MacDonald (2013), too, has described an "urgent need for cross-pollination of ideas" across disciplines in the research of music, health and wellbeing (p. 2). The therapy process described in this study benefited both from the incorporation of elements from music therapy and from its rootedness in the first author's many years of experience as a physiotherapist. Although music therapy may ideally take place within a multidisciplinary team, allowing music therapists to directly consult with physiotherapists (Street et al., 2019; M. Thaut et al., 1997), this is not always the case. Issues related to funding availability, especially as many countries worldwide face an aging population, may increase the burden on individual therapists to incorporate expertise from multiple disciplines within their own practice to provide their clients with the best care possible. As such, this findings may be relevant to, for example, to speech therapists, whose clients may benefit from physiotherapy methods which activate the kinetic muscular chain to support speech, and as well as to music therapists, who may consider integrating clients' self-generated vocal cuing into their practices.

Although further research is needed to provide evidence of the value of the described techniques for CS patients, the authors believe this findings are valuable despite their individual nature. Schaefer (2014) has observed that music's ability to improve motivation and emotional engagement in rehabilitation for clients is often cited as a reason for its inclusion in therapy, noting that, "if this reward is sufficient to lead to increased practice, other mechanisms may not even be necessary for better rehabilitation results" (p. 6). This observation provides an apt summary for this case. The rhythmic aspects of music indeed facilitated the motor timing and coordination, but it is clear that the motivating and emotional aspects of music were key to the success of the therapeutic process.

Disclosure statement

No potential conflict of interest was reported by the authors.

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