An Interdisciplinary, Neuroscience-Informed Music Therapy Early Intervention Research Program for Gait Atypicalities in Autistic Children

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ABSTRACT

An Interdisciplinary, Neuroscience-Informed Music Therapy Early Intervention Research Program for Gait Atypicalities in Autistic Children

Lianna Powers

The purpose of this study was to develop an interdisciplinary, neuroscience-informed music therapy intervention program targeting gait atypicalities in preschool aged children, 3-5 years old, diagnosed with autism spectrum disorder (ASD). While not currently a diagnostic feature of ASD, recent research is showing that gait atypicalities are present in 60 to 100% of autistic children. Given the significant impact of gait atypicalities on quality of life, including joint pain and fatigue, it is an important area to be targeted for early intervention, and given that music processing abilities remain intact, it seems that music therapy intervention may be an ideal approach. Some research on the gait atypicalities in ASD is beginning to come out in the fields of physical and occupational therapies but remains to be explored in the context of music therapy. This study, following the initial steps of intervention research design as outlined by Fraser, Richman, Galinsky, and Day (2009), provides guidelines for implementing a music therapy intervention program targeting gait atypicalities in autistic children, including important considerations to accommodate a younger age group. The intervention program is organized into four phases: Assessment and evaluation, deconstruction of gait and relearning of independent movements, reintegration into standard walking pattern, as well as reassessment and maintenance. Potential implications for practice and areas for future research are also discussed.

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Chapter 1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder, affecting the areas of social communication and interaction, and narrow, repetitive interests and/or patterns of behaviour. While motor deficits are not strictly necessary for a diagnosis of Autism Spectrum Disorder (ASD), they are cited in the 5th Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) as supporting features, specifically mentioning "odd gait" ("Associated features supporting diagnosis," para. 1, American Psychiatric Association, 2013). Calhoun et al. (2011) explain how this abnormal gait can lead to quality of life deficits, due to pain, fatigue, and joint stress. These atypicalities have been linked to various areas of the brain, including the basal ganglia, the fronto-striatal lobe, and the cerebellum, as well as potential inclusion of the thalamus (Rinehart et al., 2006; Rinehart, Bradshaw, Breton, & Tonge, 2001; Casartelli et al., 2017).

Similar gait atypicalities have been found in patients with Parkinson's disease (de Dreu, Kwakkel, & van Wegen, 2014), cerebral palsy (Efraimidou et al., 2016), and certain acquired brain injuries (Kim, Shin, Yoo, Chong, & Cho, 2013), with the neural areas involved in these conditions correlating to those found in the autistic brain. Given the neurological underpinnings of these atypicalities in motor functioning, it is pertinent to research whether neuroscience-informed music therapy methods, which have historically been focused on speech and sensory dysfunction with the autistic community, could be effectively applied to gait atypicalities within this population, as they have been in other populations with similar conditions.

Relevance to Music Therapy

A study by Quintin, Bhatara, Poissant, Fombonne, and Levitin (2013) found that while there were no superior processing abilities of music by autistic children and adolescents,as compared to a control group, there were also no significant differences between the two groups, identifying music processing as not having the same deficits found in other processing areas. This notion aligns with the findings of Whipple (2004) who found that music interventions had a positive impact on autistic children and adolescents, regardless of the purpose. Even practitioners in other fields, such as physiotherapy and kinesiology, are identifying the potential promise in music-based interventions for autistic individuals, including children (Bhat et al., 2011). In spite of these facts, Proffitt (2015) found, in a study that examined motor interventions in music therapy with autistic children, that many music therapists choose not to focus on motor goals

because they are addressed by other therapists, instead focusing more often on the areas of social skills, communication skills, academic skills and emotional/regulation skills. Thus, the present study aims to present a potential intervention program to target some of these motor atypicalities in autistic preschoolers.

Personal Relationship with the Topic

Throughout my music therapy work with autistic toddlers and preschool age children, I have observed abnormal gait patterns and delays in motor development. As an autistic individual myself, I have experienced these abnormal gait patterns, and have felt the pain joint stress, and repetitive strain injuries that these patterns can cause, as well as the overall negative impact they have had on my life. I have also experienced how little therapy focuses on gait impairments in autistic children and observed that while this is starting to change as I get older, there is still a significant gap in the services relating to the more physical symptoms of ASD. Music has had an important role in minimizing ongoing issues with my own gait, such as by listening to music at certain tempos while I am walking to cue the correct movement patterns. I believe that early intervention to attempt to correct some of the abnormal patterns, when the atypicalities are first observed in a child, may help avoid some of the negative impacts I have experienced.

Use of Identity-First Language

The American Psychological Association's recommendations for avoiding bias in language when referring to autistic individuals is to use person-first language (e.g., *person with autism*) over identity-first language (e.g., *autistic*), for the purpose of maintaining "the integrity (worth) of all individuals as human beings" (APA, 2010, p. 76). While the overall message in this statement is commendable, the use of person-first language to refer to autistic individuals tends to devalue these individuals as people. A study conducted by Kenny, Hattersley, Molins, Buckley, Povey, and Pellicano (2016) surveyed 3470 individuals in the UK autism community, and found that the majority of the autistic adults who participated in the survey (61%), as well as a number of parents (51%) and family members (52%) of autistic individuals, preferred identity-first language. The reasons varied but generally revolved around person-first language diminishing the positive aspects of autism and perpetuating the idea that being autistic is somehow inherently wrong. They also found that survey participants felt that their disorder is a central part of their identity that cannot be separated from their personhood. This finding is echoed in a study by Angulo-Jiménez and DeThorne (2019) who analyzed the narratives of

autism by autistic YouTube vloggers, where 62% of the vloggers, regardless of whether their discourse predominantly followed the medical model or the neurodiversity model[1], used language more identified with the neurodiversity model, such as identity-first language, when referring to autistic individuals. Thus, in order to respect the preferences of the majority of autistic individuals, identity-first language will be used herein.

Assumptions

The epistemological foundation of this research is post-positivism, which is defined as an assumption of current knowledge as being true, within the limitations imposed by the human nature of the researchers, until it is proven otherwise (Howell, 2013). The epistemological model underlying the specific Neurologic Music Therapy (NMT) techniques discussed is the Rational Scientific Mediating Model (Thaut, McIntosh, & Hoemberg, 2014), which is comprised of four steps that function essentially to translate the findings in neuroscience into clinically relevant interventions. The first step is to examine musical response models, the second is to compare musical response models to parallel non-musical response models, which is built upon in step three through the development and investigation of mediating models, and the final step translates the findings to clinical contexts.

Statement of Purpose

Given the effect that gait atypicalities can have on the quality of life of autistic children, and the similarities in the neurologic underpinnings of these gait atypicalities in comparison to gait atypicalities in other neurologic disorders, such as Parkinson's disease, cerebral palsy, and acquired brain injuries, the purpose of this study is to design a neuroscience-informed early intervention program to target gait atypicalities in autistic children through the use of neurologically-informed music therapy techniques used to target gait in the latter three.

Primary Research Question

How can an interdisciplinary early intervention program be designed to target the gait atypicalities seen in autistic children through the lens of neuroscience-informed music therapy?

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[1] In the simplest of terms, the medical model focuses on autism as a pathology, whereas the neurodiversity movement focuses on autism as a form of biodiversity, or a natural variation in neurology.

Key Terms

Autism Spectrum Disorder: A neurodevelopmental disorder characterized by deficits in the categories of social communication and interaction, and narrow, repetitive interests and/or patterns of behaviour, with motor deficits, including abnormal gait, being characteristics supporting a diagnosis (American Psychiatric Association, 2013).

Gait: Manner of walking, including parameters such as velocity, cadence, stride length, and posture ("gait," 2008).

Interdisciplinary: Working within a team setting, whereby two or more professionals of different disciplines work together on the same case, with the knowledge from each discipline being intertwined to create a single cohesive approach (Canadian Institutes for Health Research 2005; Choi & Pak, 2006).

Neurologic Music Therapy (NMT): Application of specific, well-defined, scientific research-based music-intervention techniques targeting non-musical goals in cognitive, affective, sensory, language, and motor deficits, caused by dysfunction of the human nervous system due to injury or disease (Thaut, McIntosh, & Hoemberg, 2014).

Neuroscience-Informed Music Therapy: A music therapy approach wherein the interventions used and the rationale behind their usage are informed by neuroscientific understanding of the presenting problem or disability and of music perception and cognition (Moore & Lagasse, 2018). These interventions may fall within the scope of NMT or other music therapy models/approaches but are not necessarily a part of the organized collection of interventions that comprise NMT.

Patterned Sensory Enhancement (PSE): PSE targets complex movements that are not intrinsically rhythmic. It uses patterned musical structures, such as an ascending and descending arpeggio passage, to represent and further facilitate processing of the steps in complex movements, in particular, spatial, force, and temporal aspects (Thaut, 2014).

Rhythmic Auditory Stimulation (RAS): At its core, RAS is a framework for the timing of movements through the use of rhythm, and seems to work through compensatory brain networks to bypass the defective internal timekeeper in certain brains (de Dreu, Kwakkel, & van Wegen, 2014).

Therapeutic Instrumental Music Performance (TIMP): TIMP is the use of musical instruments to help individuals practice impaired movements. The instruments chosen, the

spatial configuration of the instrument, and the manner in which they are played are the key to exercising these movements (Mertel, 2014).

Overview of Chapters

In this chapter, the relevance of developing an interdisciplinary, neuroscience-informed, early intervention music therapy program was introduced, including the purpose of the study and the research question, along with the key terms and perspectives that will be used throughout this thesis. In the second chapter, existing literature in the areas of neurologic music therapy, neural anatomy of autism and other disorders with similar neural atypicalities, as well as music as it relates to autistic individuals will be explored. The third chapter will discuss the design of the study, as well as delimitations, data collection, and analysis procedures. The fourth chapter will explore the risk and protective factors that may influence a neuroscience-informed music therapy early intervention program, the ideal goals of the proposed program, and the overall structure of the proposed program. Finally, the fifth chapter will discuss key factors of the program as outlined in the previous chapter, limitations of this study, potential implications for practice, as well as implications for future research and music therapy awareness.

Chapter 2. Related Literature

Autism is a disorder that has been the focus of multiple research studies in several fields. While there is a lack of research on music therapy to target motor atypicalities in autistic individuals, there have been several studies that point to the efficacy of music as a therapeutic medium in other domains, as well as research supporting the use of music therapy for motor difficulties in individuals with other diagnoses. Meanwhile, research in other domains, such as neuroscience, occupational therapy (OT), and physical therapy (PT), has explored the motor atypicalities in autistic individuals, including both causational factors, specifics of what these atypicalities are, and the similarities and differences to the motor atypicalities in other diagnoses. This chapter unifies existing research in motor dysfunction in autistic individuals, music interventions for autistic individuals, and neurologic music therapy and its application to related populations, into one cohesive document.

Motor Dysfunction in Autistic Individuals

Traits of motor dysfunction. The DSM-5 notes abnormal gait, clumsiness, motor stereotypies and other abnormal motor patterns such as walking on tiptoes as the motor features supporting a diagnosis of ASD (American Psychiatric Association, 2013). In addition to the above-mentioned characteristics, unusual postures and increased joint mobility, or hypotonia, have been found in at least a third of autistic children (Filipek et al., 1999; Tsai, 1996). Results of the Shetreat-Klein et al. (2014) study found that autistic children had a greater passive range of motion for the fingers, wrist, and ankle, though not for the elbow, than their typical peers in the control group. It was noted, however, that this hypotonia decreased with age, which seems to support the idea that joint mobility is not as pressing an issue to be targeted in terms of motor atypicalities than other aspects. Gait atypicalities of any type were found in 68% of the autistic children included in the study, compared with only 13% in the typically developing group (Shetreat-Klein et al., 2014). Hallet, Lebiedowska, Thomas et al. (as cited in Bhat et al., 2011) found characteristics of ataxic gait in autistic individuals, including instability, variability of stride length, and reduced range of motion at the ankle. Contrary to older studies, it is noted that there are significant motor impairments in autistic children, whether there was an associated cognitive delay or intellectual disability or not (Bhat et al., 2011). Sensory processing deficits are identified as possibly relating to motor atypicalities, particularly given that these deficits include input in the proprioceptive and vestibular categories (Bhat et al., 2011).

Poor upper and lower-limb coordination in older children and adults with autism appears to correlate with gross motor delays in sitting skills and with a delayed onset of walking in infants at risk for ASD, and autistic toddlers and preschoolers (Bhat et al., 2011). Shetreat-Klein et al. (2014) also noted a delay in the age of onset of walking, even in autistic individuals without a cognitive delay. Although these individuals do not show a clinically significant delay in the age of onset of walking, as the age still falls within the typical range, the average age of onset between these autistic children and their typical peers was still later by 1.6 months (Shetreat-Klein et al., 2014). Freitag et al. (2007) found that individuals on the autism spectrum have significant difficulty in the areas of dynamic balance control and diadochokinesis, the ability to make antagonistic movements in quick succession. It is clear that both of these characteristics may cause functional impairment in gait and walking ability. Pauk, Zawadzka, Wasilewska, and Godlewski (2017) found that the unique gait parameters in autistic children include a greater stance duration, longer step length, and shorter stride length, as well as a decrease in overall velocity. Calhoun, Longworth, and Chester (2011) found that the cadence of autistic individuals was higher than the control group of typically developing peers.

Neuroanatomy of motor dysfunction. While there appear to be some Parkinsonian features in the arm, head and neck posturing of autistic individuals, there does not appear to be the reduction in stride length typical of Parkinson's disease. This, in turn, seems to indicate involvement of the basal ganglia, as in Parkinson's, but with involvement of other areas of the brain (Rinehart et al., 2006a; Rinehart et al., 2006b). Gait atypicalities, including coordination, difficulty walking in a straight line, variability in stride length and velocity, and overall smoothness seem to correlate with cerebellar involvement, and all of the observed gait atypicalities may also indicate involvement of the thalamus (Rinehart et al., 2006*a*; Rinehart et al., 2006*b*). Rinehart, Bradshaw, Breton, and Tonge (2001) found significant atypicalities in movement preparation in autistic individuals, but an intact ability to carry out movements. This result implied involvement of the fronto-striatal area in the motor atypicalities of autistic individuals. This finding is reflected in a study by Casartelli et al. (2017), which found that given the second-order motor planning difficulties experienced by children with ASD and the intact second-order motor planning in an individual with cerebellar agenesis, cerebellar dysfunction is not the only cerebral region involved in the gait and motor atypicalities experienced by autistic individuals.

In summary, the areas that appear to be involved in the motor dysfunction of autistic individuals are the basal ganglia, cerebellum, thalamus, and fronto-striatal regions. In spite of the potential atypicalities in these areas, music processing appears to be intact in autistic individuals, thus making music therapy a promising mode of intervention for difficulties associated with ASD. Therefore, the following section will outline how music interventions are currently being used with autistic individuals.

Music Interventions for Autistic Individuals

In Whipple's (2004) meta-analysis of 12 studies involving music-based intervention methods for autistic children and adolescents, the effect size for all 12 studies were in a positive direction with the smallest effect size being .09 but the all others falling between .29 and 1.71, with an overall effect size of .77, indicating that almost all of the studies analyzed found music to be a useful mode of intervention for ASD. No difference in benefit was found regardless of "treatment design, age of subjects, music used, source of research, treatment methodology, or profession of the music provider" (Whipple, 2004, p. 99). Furthermore, while most of the studies involved in the meta-analysis focused on social, emotional, communication, and cognitive/attentional areas, it was found that one benefit of music in this population is enhanced body awareness and coordination (Whipple, 2004). Bhat et al. (2011) wrote that music-based interventions for autistic individuals appear promising, due to the joint action and imitation skills that naturally occur in these types of interventions. However, they noted that there was only limited evidence supporting this approach, and that "there is an urgent need to develop novel embodied interventions grounded in movement and motor learning principles for children with autism" (Bhat et al., 2011, p. 1116).

Quintin, Bhatara, Poissant, Fombonne, and Levitin, (2013) conducted a study using a modified version of a children's toy, called *MusicBlocks*, where five plastic cubes could be inserted into slots to play a segment of a melody. Participants were instructed to arrange the cubes into the correct slots based on auditory feedback. It is important to note that audiotemporal and audioconstructive processing are needed to complete these puzzles. The results of this study found that while there was not a superior processing ability for music in the autistic individuals, there were no significant differences between the autistic group and the control group, indicating that music processing does not show the deficit present in most other functions of the autistic brain (Quintin et al., 2013). This supports the conclusions of Whipple (2004) regarding the

efficacy of music interventions with autistic individuals. Even more strikingly, this suggests that the unimpaired audiotemporal processing abilities of autistic individuals may be instrumental in developing interventions that target the temporal parameters of gait atypicalities in autistic individuals.

In Proffitt's (2015) dissertation which surveyed music therapists (n = 168) on current music therapy practices involving motor goals for autistic children, it was found that a significant portion of therapists indicated addressing motor goals (76% of participants) . However this number may be influenced by survey respondents counting any movement activity as targeting a motor goal. In terms of the goals most commonly addressed within the autistic population, social skills, emotional regulation skills, speech/communication skills, and academic skills were all indicated, in this order (most to least targeted), with motor skills being the next most targeted (Proffitt, 2015). One of the responses written in by multiple respondents on the qualitative section of the survey on why motor goals were not addressed by a music therapist was that other goals were of higher priority in the mind of the music therapist (Proffitt, 2015). This is worrying, as the motor deficits observed in autistic individuals can "compromise a child's ability to perform activities of daily living, such as walking. An abnormal walking pattern can lead to pain, fatigue, and joint stress, which in turn, may affect a child's functional capabilities and quality of life" (Calhoun et al., 2011,; p. 200). Calhoun (2011) further explains that effective interventions for motor deficits and gait patterns can reduce health care costs and allow autistic individuals to reach their full potential.

Types of motor interventions in Proffitt's (2015) survey included instrument play, movement activities, dancing, and music games. Manipulatives such as scarves were also frequently used, and, together with instrument play, seem to be popular intervention techniques due to their ability to target both fine and gross motor skills in a single activity. The emphasis on these more creative interventions may be related to the fact that 96% of the respondents indicated that their autistic clients worked with various other professionals, such as occupational therapists and physical therapists, to address motor goals (Proffitt, 2015). Proffit (2015) further states that the fact that their autistic clients work with other professionals on motor goals was the main reason that music therapists stated they did not focus on motor goals. Given the unique music processing abilities of autistic individuals, which is at the same level as their typically developing peers, despite the deficits in most other areas of processing (Quintin et al., 2013), this

survey finding highlights a lack of understanding on the part of both music therapists and the teams in which they work, on the importance of or rationale for using music-based interventions with autistic individuals to increase the positive outcome of therapies. It may be that other modalities only teach imitation of a skill to autistic children, given their limited processing abilities in these domains, rather than giving an actual understanding of the skill that may be applied in other related situations. Proffitt (2015) surmised that many music therapists may feel they lack adequate training to target motor deficits in comparison with professionals in other modalities. However, this may be compensated for by collaborating with other professionals in an interdisciplinary manner. As Bhat et al. (2011) pointed out, given the complexity of autism spectrum disorder, an interdisciplinary team approach is clinically indicated to provide the most cohesive and comprehensive intervention possible. The next section will explore Neurologic Music Therapy (NMT), which is a specialized music therapy approach that is often realized in interdisciplinary contexts and that has been successfully applied in populations that show similar neuroanatomical atypicalities as autistic individuals.

Neurologic Music Therapy (NMT) & Application to Related Populations

NMT is a research-based system consisting of twenty standardized techniques that have been used effectively in neurorehabilitation, as well as in treating certain aspects of neurodevelopmental disorders. These twenty techniques are subcategorized into three areas: sensorimotor training, speech and language training, and cognitive training (Thaut, McIntosh, & Hoemberg, 2014). Three sensorimotor techniques targeting motor skills are used in NMT: Rhythmic Auditory Stimulation (RAS), Patterned Sensory Enhancement (PSE) and Therapeutic Instrumental Performance (TIMP) (Bukoswka, Krezalek, Mirek, Bujas, & Marchewka, 2016). The relevance of these three techniques for gait abnormalities in autistic individuals is discussed below.

Rhythmic auditory stimulation. RAS is used to target deficits in gait parameters and is most frequently used in the treatment of Parkinson's disease, stroke, traumatic brain injury, multiple sclerosis, and cerebral palsy, though most of the research is in individuals with Parkinson's disease (Thaut & Rice, 2014). Four neurological principles underlie RAS: rhythmic entrainment, priming, cueing of the movement period, and stepwise limit cycle entrainment. Rhythmic entrainment is the principle whereby auditory stimuli are paired with movement patterns within the motor system. Priming is the process whereby the external auditory stimulus

cues the motor neurons, thereby allowing entrainment to occur. Cueing of the movement period relates to the fact that rhythmic entrainment is connected to frequency entrainment instead of a synchronization between the external cue and the internal motor reaction. Finally, the step-wise limit cycle entrainment is the process where rhythmic entrainment is matched to the current optimal limit cycle of the client, the cadence of their steps, and gradually adjusting it to the ideal limit cycle (Thaut & Rice, 2014). In understanding these four principles, it begins to become clear how this technique might be useful for targeting the gait parameters of autistic individuals. At its core, RAS is a framework for the timing of movements and seems to work through compensatory brain networks to bypass the defective internal timekeeper in certain brains (de Dreu, Kwakkel, & van Wegen, 2014). Thaut et al. (2009) found that different aspects of rhythmic synchronizations are associated with different locations of neural activity within the cerebellum. This provides further support to the concept of RAS working through compensatory brain networks, particularly in bypassing the basal ganglia, which is often related to timekeeping mechanisms.

Kim, Shin, Yoo, Chong, and Cho (2016), found significant changes to the spatiotemporal parameters of gait in a group of adolescents (n=12) with acquired brain injuries receiving RAS treatment for 30 minutes, three times a week for four weeks. These findings suggest that RAS may be an effective intervention for gait atypicalities in this population. Of note, the locations of injury of individuals involved in the study were the cerebellum and brain stem (3 participants in each group), frontoparietotemporal cortex (2 participants in each group), and the basal ganglia (1 participant in each group; Kim et al., 2016). This correlates with the current theories on which neural atypicalities cause gait dysfunction in autistic individuals, namely the cerebellum and the basal ganglia. Efraimidou et al., (2016) highlight that the spastic hemiplegia, a type of cerebral palsy that affects only one half of the body, often causes asymmetric or ataxic walking, as well as difficulty in coordinating movements. This parallels some of the more prominent gait atypicalities in autistic individuals, as detailed above. RAS was found to be effective in these individuals as well, not only in terms of gait and balance parameters, but also in terms of positive effect on mood and self-esteem (Efraimidou et al., 2016).

Patterned Sensory Enhancement (PSE). PSE targets complex movements that are not intrinsically rhythmic, and thus tend to focus more on the upper body, where non-rhythmic movements are more common. The therapeutic mechanisms and principles underlying PSE are

the same as in RAS, in relation to timing and priming. However, it also uses patterned musical structures, such as an ascending and descending arpeggio passage, to represent and further facilitate processing of the steps in complex movements, in particular, spatial, force and temporal aspects (Thaut, 2014). Pitch is used to represent the spatial parameters of movement, as in the arpeggio example above, as are dynamics, such as through the use of crescendos and decrescendos. Less obvious musical aspects used to target the spatial parameters of movement through PSE include sound duration, timbre, and sound shape, such as using legato notes for more fluid movements, or staccato notes for more rigid movements. Interestingly, harmony can also be used to cue movement, for example by using a closed harmony for actions that are close to the body and an open harmony for actions that are further away from the body. As Thaut (2014) explains, the open or closed quality of certain harmonies, which can be easily understood in terms of voicing of a chord, can cue the spatial quality of whether a movement is more open, such as with the arms extended to the sides of the body, or close, such as with the arms crossed in front of the chest. Temporal cues in PSE follow the same principles as RAS. Finally, the force of a movement can be characterized through tempo, dynamics, and harmony in much the same way that these characteristics can be used for spatial parameters (Thaut, 2014).

Given that PSE tends to focus more on upper body motor deficits, most of the research is irrelevant in the discussion of gait parameters. That being said, Bukowska et al. (2016) ran a pilot study investigating the effect of a neurologic music therapy protocol using all three of the sensorimotor techniques, to target mobility and stability in patients with Parkinson's disease. The idea behind this combined approach was to lengthen the duration of the positive results from RAS alone. This is important in considering NMT approaches with autistic children, as, unlike Parkinson's disease, it is not degenerative in nature. Thus, further and more lasting improvements are more important for autistic children than may be the case in neurodegenerative disorders, where the main goal is maintenance of improvements. Another significant finding of this study is that there was significant improvement in all five gait parameters during a condition where the participants kept their eyes closed, which seems to indicate an improvement in proprioception (Bukowska et al., 2016). As Bhat et al. (2011) theorized, the sensory processing difficulties experienced by autistic individuals, in particular, proprioception, may be related to some of the gait and motor atypicalities seen in the same.

Therapeutic Instrumental Music Performance (TIMP). TIMP is the playing of instruments in different ways in order to stimulate and practice specific movements. In TIMP, the choice of instrument, the placement of the instrument, and the way in which it is being played, are all deliberate in order to exercise the particular targeted movement (Mertel, 2014). The therapeutic mechanisms underlying TIMP are similar to the other two sensorimotor NMT techniques, especially in terms of rhythmic entrainment. The key difference in TIMP, however, is the feedforward-feedback loop that is created, whereby a movement to play an instrument, or the feedforward portion of the loop, is followed by the auditory cue, the feedback portion of the loop (Mertel, 2014). Therefore, unlike RAS and PSE, the actual movement is producing the auditory cue, and they are more clearly linked, thus any interruption in the repetition or timing of the auditory cue is more easily perceived by the brain as being caused by an interruption in the repetition or timing of the movement itself. This may be of particular importance when taking into consideration the sensory processing difficulties in relation to the gait atypicalities of autistic individuals, as discussed by Bhat et al. (2011). As with PSE, possibly the most important reason for considering TIMP in relation to gait atypicalities is the possible improvement of results through the combination of all three sensorimotor NMT techniques, as mentioned in the Bukowska et al. (2016) pilot study.

Chapter Summary

Research in various disciplines has brought to light the motor difficulties of autistic individuals, including the gait parameters, and the long-term impact that this can have. As Calhoun et al. (2011) point out, these motor skills, and in particular, gait and posture, can have a significant effect on the quality of life, in preventing fatigue, pain and joint stress. Bhat et al. (2011) point to the growing emphasis in the occupational therapy field of the importance of motor interventions for autistic individuals and the need for an interdisciplinary approach to autism interventions, and an increase in research on the topic. Whipple (2004) makes a claim for the importance of music-based interventions within the autistic population, and Quintin et al. (2013) support this claim with evidence regarding typical music processing in autistic brains, in spite of atypical processing in other areas. Rinehart et al. (2001; 2006*a*; 2006*b*) point to motor impairments being localized in the fronto-striatal, cerebellar, and basal ganglia areas in the brain for autistic individuals. While no studies on neurologic music therapy interventions in autistic individuals have been published, studies have shown efficacy in gait rehabilitation and

development through the use of rhythmic auditory stimulation in individuals post-stroke, with Parkinson's disease, with acquired brain injuries, and even with cerebral palsy, all of which have had the motor impairment associated with their condition tied to at least one of the brain areas mentioned in the autistic deficits (Thaut & Rice, 2014; Kim et al., 2016; Efraimidou et al., 2016; Bukowska et al., 2016). Taken all together, this information seems to point towards the promise of NMT sensorimotor techniques as an intervention to target gait atypicalities in autistic children.

Chapter 3. Methodology

Design

The design of this study is the intervention research methodology as outlined by Fraser, Richman, Galinsky, and Day (2009). This type of research consists of five steps; however, this study will be delimited to the first step and the first half of the second step,steps in order to remain within the scope of a master's thesis. The first and second steps are to "specify the problem and develop a program theory" and to "create and revise program materials" (Fraser, Richman, Galinsky, & Day, 2009, p. 36). Future research completing the final three steps of this methodology, whereby the program components are refined, effectiveness is assessed in various settings, and finally, the program materials and findings are disseminated, will be required for the full development of this intervention program.

Participants

There are no participants in this study, as this study is delimited to the first and second steps of the five steps of intervention research, as described by Fraser, Richman, Galinsky, and Day (2009).

Materials

Relevant literature in the areas of autism spectrum disorder, neuroscience-informed music therapy, and the application of NMT sensorimotor techniques to gait in cases of neurologic disorders with similar neurologic atypicalities as those theorized as being involved in the gait of autistic individuals from the last 20 years were reviewed. The information found in this literature was used for the development of the program.

Delimitations

Due to the time and length restrictions of a master's thesis, the main delimitation was to only employ the first two steps of intervention research as described by Fraser, Richman, Galinsky, and Day (2009). The intervention program design is delimited to children between the ages of 3 and 5 years old, with official diagnoses of ASD, as autistic children are likely to be diagnosed by this age and will most likely already be walking (Shetreat-Klein, Shinnar, & Rapin, 2014). Thus, the intervention program is still an early intervention designed to meet needs as walking develops. The literature was delimited to include only what is directly related to autistic populations, and neurologic music therapy sensorimotor techniques used to target gait in

individuals with conditions that involved similar neuroanatomical deficits as in autistic individuals, within the last twenty years.

Data Collection and Analysis Procedures

The first stage of step one, as described by Fraser, Richman, Galinsky, and Day (2009) involves reviewing the existing literature in relation to the problem, in this case, gait atypicalities in autistic individuals, to develop the problem theory. Thus, literature was reviewed using keywords such as "gait," "ataxia," and "autism," and other professionals in related fields such as occupational therapy were consulted to help the researcher further conceptualize the problem as it presents in a functional setting. Sources were compiled in a binder, organized by population, approach/technique, and therapeutic modality. The second stage of the first step is to develop the program theory, through looking at risk factors, protective factors, the ideal outcome of the intervention, intervention activities, and other related factors. The literature was reviewed using terms such as "neurologic music therapy," "preschool motor interventions," "gait," "motor deficits," and "early intervention." Only the first stage of the second step was completed, which is the formulation of a first draft of the intervention manual and other materials (Fraser et al., 2009). Literature from each stage was then compiled into a problem theory, program theory, and draft of an intervention manual, respectively. In the development of the problem theory and program theory, a total of 28 publications were used. Of these, five were assessment tools, three of which where excluded due to the age they are designed for. Seventeen articles were looking at autistic individuals specifically, with two articles about autism and music/music therapy, five looking at neurology as it pertains to motricity, four looking at motor performance, three looking at both motor performance and neurology, two by autistic adults about their personal experiences with motor difficulties, and finally one article looking at age of diagnosis in preschoolers. A further four articles were not population-specific, with three looking at childhood neural and/or motor development, and one looking at neurology as it pertains to motricity in general. Finally, three studies using NMT were selected. All three articles were in populations with neurologic atypicalities similar to those seen in autism. One, conducted by Kim et al. (2016), focuses on adolescents with acquired brain injuries, and was the most comprehensive study of RAS with participants under the age of 18. The second, conducted by Efraimidou et al. (2016), was looking at adults with cerebral palsy, and was chosen due to the similarities in gait atypicalities with autistic individuals, such as irregularity of strides and balance difficulties. The final study,

conducted by Bukowska et al. (2016), was looking at adults with Parkinson's, and was chosen due to the unique program combining all three NMT sensorimotor techniques, as well as looking at the lasting effects of therapy several weeks after therapy has concluded.

Chapter 4. Results

In the previous chapters, the need for an intervention program targeting gait atypicalities in autistic children using a neuroscience-informed approach was established, and the methodology of intervention research as outlined by Fraser, Richman, Galinsky, and Day (2009) was chosen as being most appropriate for the development of this intervention program. This chapter explores the risk and protective factors in the development of gait atypicalities, as well as the various factors influencing the success of a potential intervention program. These factors include the target age group, the duration of the intervention, intervention agents and setting, and assessment procedures. Following discussion of these factors, the proposed intervention program guidelines are described.

Problem Theory

Prevalence of gait atypicalities in ASD. Given the relatively limited literature available that speaks specifically to gait atypicalities and autism spectrum disorder, it is difficult to give an accurate estimate of prevalence. Two studies in particular speak to the prevalence of gait atypicalities in autistic individuals, giving similar data points and limitations. Shetreat-Klein et al. (2014) state that 68% of the participants in their study showed any gait abnormality, including toe-walking, with 58% of participants showing any gait abnormality, excluding toe-walking. Limitations of this study, however, include brief video clips that may limit detection of more subtle gait atypicalities, a fairly small participant pool (n=38), and the exclusion of a large group of participants with potentially confounding comorbid diagnoses. Jansiewicz, Goldberg, Newschaffer, Denckla, Landa, and Mostofsky (2006) conducted a study on motor signs in children with higher functioning autism and their typical peers, further dividing the autism group into individuals taking stimulant medication and those not taking stimulant medication. Results of this study found 60% of autistic individuals not taking stimulant medication showed gait atypicalities, while 100% of autistic individuals taking stimulant medication showed gait atypicalities. Jansiewicz et al. (2006) theorize that the most likely reason behind this discrepancy is that individuals taking stimulant medications may be taking them to treat symptoms such as impulsivity, hyperactivity, and inattention, all of which may affect gait.

Risk and protective factors. Early research, as noted by Bhat et al. (2011), focused on motor impairments in autistic children who had a co-occurring cognitive delay. However, more recent research is showing that cognitive functioning and IQ level are not accurate indicators of

gait atypicalities but may be helpful in predicting the specific type of abnormality that is present. Pauk et al. (2017) conducted one of the first studies comparing the differences between high functioning and low functioning autism, defined by having an IQ score above or below 80, respectively, as well as to an age-matched control group. All children with a diagnosis of ASD had a diagnosis of plano-valgus, or flat-footedness, which may be a result of hypotonia. Additionally, greater maximum hip-flexion, reduced knee range of motion, and reduced plantarflexion movement were found in both autistic groups. The main difference found between the two autism groups were in terms of plantar pressure. Both groups had the lowest pressure distribution under the metatarsal heads, however the high functioning group had the highest pressure amplitudes under the heel while the highest pressure amplitudes were found under the toes (Pauk et al., 2017). This seems to suggest that while cognitive functioning is not indicative of the presence of gait atypicalities, a diagnosis of lower functioning autism spectrum disorder may be a risk factor for toe-walking.

Perhaps the greatest risk factor for pain, fatigue and joint stress caused by gait atypicalities, is the lack of access to therapies targeting gait for autistic children. Rinehart et al. (2006a) note that in spite of awareness of the effect that gait atypicalities can have on one's quality of life, "when combined with a complex psychiatric condition, such as autism, the clinical significance of the gait disorders is often overlooked, or seen as secondary to the more salient social-communicative symptomatology" (p. 261). Additionally, while the motor preparation of autistic individuals is abnormal, it is not considered greatly dysfunctional (Rinehart et al., 2001), which further contributes to gait atypicalities not being treated in therapies. Shetreat-Klein et al. (2014) mention that some gait atypicalities of autistic individuals may have been too poorly defined or subtle to have been detected in their study. This observation, taken in conjunction with the fact that gait atypicalities in autism are still an emerging area of study, especially in autistic individuals without a cognitive delay, may further limit access to therapies, as therapists may not be looking for these atypicalities or be aware of how they may present. That being said, the community of autistic adults who are advocating about their experiences is also emerging (Sequenzia, n.d.; Harrison & St-Charles, 2017). This may become a significant protective factor, as it provides a concrete illustration of the long-term impact of gait atypicalities that go untreated, as awareness and research into the motor dysfunction in autistic individuals becomes more widespread.

In terms of factors relevant to the success of a particular therapeutic intervention, perhaps the greatest risk factor is difficulty with motor learning, as mentioned by Bhat et al. (2011), as simple repetition and practice may not be sufficient to teach the new skill to the autistic individual. Thus, therapists may need to adjust their level and type of communication, including modeling the action, physically guiding the action, and verbally breaking down each step of the action (Bhat et al., 2011). There are, however, two protective factors that help counteract this risk factor. The first is the intact music processing ability found by Quintin et al. (2013), as this provides a framework wherein prompts are inherent, through rhythmic entrainment, and musical cueing. The second, and most important, protective factor is Rinehart et al.'s (2001) finding that while the movement preparation of autistic individuals is impaired, the actual ability to execute the movement is intact. Similarly, both Freitag et al. (2007) and Bhat et al. (2011) note that findings relating to dynamic balance skills, postural control and diadochokinesis suggest an impairment in the integration of various sensory and motor functions. This also aligns with the observation of Cassartelli et al. (2017) of impairment in second-order motor planning in autistic individuals. These three findings, while at first may appear to be more of a risk factor, clarify the specific area of need, and, like the Rinehart et al. (2001) study, suggest that the ability to execute the movement is still intact.

Program Theory

Target age group. While the specific parts of the brain responsible for gait atypicalities in autistic children remains uncertain, it is now understood that these motor atypicalities are likely neurologic in nature (Rinehart et al., 2001; Rinehart et al., 2006a; Rinehart et al., 2006b; Casartelli et al., 2017; Nayate, Bradshaw, & Rinehart, 2005; Allen, Müller, & Courchesne, 2004; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). It is also understood that younger brains tend to have greater plasticity, meaning that acquiring new skills and learning is more easily done for younger children, when the brain is still in its developmental stage (Shonkoff, J. P., & Richter, L., 2013). Thus, it follows most logically that an intervention targeting gait atypicalities would be most effective in younger children. Taken in conjunction with the average age of onset of walking for autistic children of 13.8 months (Shetreat-Klein et al., 2014), and the average age of diagnosis amongst autistic children in Canadian preschools of 38.2 months (Zwaigenbaum et al., 2019), the target age group for this intervention should be between 3 and 5 years of age. This allows for the children to have been walking for around one and a half years, minimum, takes

advantage of the increased neuroplasticity in early childhood, and takes into account the average age of diagnosis of ASD within the age group of early childhood.

Duration. In a real-world setting, the duration of this intervention program would be tailored to the child, ideally with follow-up maintenance sessions once a month after the established goals are met. This aligns with the current understanding of the length of the effects of NMT sensorimotor techniques lasting several weeks, which was confirmed in the Bukowska et al. (2016) study. Due to the relative newness of applying NMT sensorimotor techniques to autistic children, and especially to children so young, there is not much literature available to present the ideal timeline and schedule. In the three studies of NMT techniques in populations other than ASD, the duration and schedule of the therapies varied considerably, but overall time in therapy was 360 minutes (Kim et al., 2016), 720 minutes (Efraimidou et al., 2016) and 800 minutes (Bukowska et al., 2016). The two longer studies focused on adult populations, whereas the 360 minute study focused on adolescents in a rehabilitation setting post-brain injury. Thus, an average of the three durations was determined to be around 630 minutes of therapy time, and seems to take into account both the fact that the participants targeted by this intervention program are young children, as well as the fact that adjusting to the intervention team and the activities themselves is likely to be difficult for autistic children and may take longer than children in other groups. The schedule and division of these 630 minutes would be determined on a case by case basis, taking into account the age and attention span of each child, as well as their schedules in other therapies, so as not to overwork the child. Ideally, however, sessions would occur at least twice a week, which was again determined from the therapy schedules used in each of the three aforementioned studies, and should last no more than thirty minutes each, which takes into account the relatively short attention span of preschool age children (Neville, 2007).

Intervention agents. Given the interdisciplinary nature of this intervention, the intervention team should consist of a music therapist and either an occupational or physical therapist, depending on the staffing at a given site. The music therapist should have knowledge and understanding of neurology and basic physiology, particularly as it relates to autistic children and music. This combined approach allows the music therapist to ensure that music is being used in the best manner to promote entrainment, which is key to success of all three sensorimotor techniques and allows the occupational or physical therapist to ensure that the targeted

movements of the child are being performed correctly. This is of particular importance, as mentioned in the Proffitt (2015) study, because music therapists may not have adequate training to properly address motor goals. Conversely, occupational and physical therapists may not have adequate training to properly incorporate music-based interventions into their treatment. Thus, the combined approach allows both professionals to fill the gaps in the training of their co-facilitator. Both professionals also bring a unique skill set to other important elements of the program outside of gait, such as by providing motivation and ensuring that activities are age appropriate. For example, the music therapist may use music to structure the session and address emotional reactions, while the occupational therapist may be particularly well-skilled in turning functional exercises into fun games.

Intervention setting. The most important feature of the setting in which this intervention takes place is a large, hard surface. This is required to allow space for walking, and to prevent any undesired ankle flexion that may result from a softer surface such as a mat. Given the aforementioned requirements for the space, and the variety and size of instruments that may be needed, it is likely impractical for treatment to occur in the home environment, and thus the recommended intervention setting is within a stimulation center or rehabilitation clinic providing various services for children with disabilities. Due to the individualization of intervention protocol to each child, implementation of the program should take place in an individual session context.

Materials. Materials needed depend on the specific nature of the gait atypicality of the child, but would likely include guitar and/or piano for the music therapist to provide ongoing musical stimuli and rhythm, and various percussive instruments, such as a cymbal and bass drum with foot pedals, a tambourine or other similar instruments that can be held above the feet for the child to tap. Additionally, any assistive devices, such as athletic tape or wrap for help to increase proprioceptive awareness of the body, and a chair or stool, depending on the stability of the child, for earlier exercises, may also be needed. Alternative and augmentative communication devices may also be required, depending on the needs of the child.

Assessment and evaluation tools. Several evaluation scales for motor tasks were considered throughout the development of this intervention (Bruininks-Oseretsky Test of Motor Proficiency – second edition (Bruininks & Bruininks, 2005); Purdue Perceptual-Motor Survey (Roach & Kephart, 1966); Clinical Observations of motor and postural skills – second edition

(Wilson, Kaplan, Pollock, & Law, 2000), but were ultimately discarded, as they tended to focus on motor development in older children. This may negatively skew the assessment results in a younger child, as certain motor atypicalities are present even in typically developing children until they reach a certain age, due to their ongoing development. Ultimately, the Peabody Developmental Motor Scale 2 (PDMS-2; Folio & Fewell, 2000a; Folio & Fewell, 2000b) was chosen as being ideal for assessing the gait atypicalities targeted by this intervention. The PDMS-2 is a standardized assessment instrument designed to assess children from birth to age 5, and while it is not a free scale, it is used by many institutions working with children under the age of 5 and as the cost is at an institutional level, it is likely to be readily available to the intervention team. As it is designed specifically for use with children under the age of 5, the PDMS-2 allows for a more accurate assessment of motor challenges, regardless of the developmental stage of each child. It comprises of six subtests: reflexes, which applies only in children 11 months and under; stationary; locomotion; object manipulation; grasping; and visual-motor integration. More specifically, the stationary and locomotion subtests were chosen for assessment of gait in this intervention. The locomotion subtest, as the name implies, is directly correlated with gait, as it assesses how the child gets from one place to the other, whether that be walking, running, crawling, jumping or any other means. The stationary subtest is equally important, however, as it assesses the child's equilibrium and proprioception, which has been theorized as being relevant in relation to the gait atypicalities of autistic individuals, as mentioned by both Freitag et al. (2007) and Bhat et al. (2011). For the same reasons, a sensory profile of the child should be completed, using the Child Sensory Profile 2 (Dunn, 2014).

The Sensory Profile 2 is a set of questionnaires to assess sensory processing issues in children from birth to 14 years 11 months of age. Within this set, there are five different questionnaires based on age: the Infant Sensory Profile 2 for birth to 6 months, the Toddler Sensory profile for 7 to 35 months, the Child Sensory profile 2 for 3 to 14 years and 11 months, a Short Sensory Profile 2, also for children 3 to 14 years and 11 months, and the supplementary School Companion Sensory Profile 2, for children 3 to 14 years and 11 months. As with the PDMS-2, the Child Sensory Profile 2 is not a free scale, but cost is at an institutional level and is likely to be readily available to the intervention team. It is also worth noting that this scale is available in both English and French. Areas that should be given particular emphasis during

assessment are the vestibular and proprioceptive areas, as well as touch, to give an indication of how much of the ground underneath the child's feet is being registered.

Musical assessment tools include the music therapy intake interview for parents of young autistic children, indicated in Appendix A and the music therapy assessment protocol for young autistic children, found in Appendix B. These tools were created by this author due to a lack of available and relevant assessment protocols for autistic children under 5 years of age, and, in accordance with this type of intervention, was created using knowledge of both autistic neurology and the autistic experience. While there are limitations of using non-standardized tools, most significant of which being that reliability and validity have not been tested, there is also a significant strength in using an assessment protocol created by a professional with a more in-depth understanding of ASD than other professionals may have, due to lived experience. The parent questionnaire, included in Appendix A, provides information of musical preferences, as well as basic information regarding the ways in which their child communicates. This information can help the child stay engaged, as it makes the intervention a more desirable and accessible activity and provides valuable information for the structuring of the session where the music therapy assessment protocol for young autistic children is being conducted. The music therapy assessment protocol for young autistic children noted in Appendix B may indicate sensory aversions to certain sounds, thus allowing the intervention team to respect the sensory difficulties associated with autism. Additionally, it may provide a clearer picture of cognitive abilities and communication abilities and needs, which will allow the intervention team to better structure the child's program. Given the heterogenous nature of the disorder, the program should be assembled by the intervention team from the recommendations provided in the proposed intervention procedures below using dialogical processes to account for the individual experience and needs of each participant.

The final evaluation tool to be used is the weekly parent questionnaire, also created by the author, found in Appendix C. These questions were formulated with the needs of the child in mind, in order to both monitor progress, but also to monitor any discomfort, which may be useful in determining if movements are being completed correctly, or if the occupational or physical therapist needs to take a closer look at their movements. This questionnaire is designed to be filled in prior to each week's session, as the final question is in relation to affect on that day. While a therapist is trained to identify affect and modify session plans accordingly, in the case of

autistic children, knowing ahead of time may avoid a potential autistic meltdown[2], which can be difficult for the adults in the room and is very trying on the child.

Proposed Intervention Procedure

Referral and Intake. Children included in this program should be between 3 and 5 years of age, with a diagnosis of autism spectrum disorder. They must have been walking for at least one year, in order to have allowed the child to have a decent level of mastery over the skill of walking, thus having a more stable gait pattern with less falls (Adolph et al., 2012). The absence of obvious motor or gait atypicalities is not necessarily a reason for disqualification, as many of these atypicalities can only be seen when assessed in depth, and thus may not be seen by the family. Therefore, all children meeting the aforementioned criteria, whether or not they display evidence of motor or gait atypicalities, would be referred for potential participation in this program. Prior to the first assessment session, the music therapy intake questionnaire for parents of young autistic children, found in Appendix A, is to be completed and submitted to the intervention team, in order to provide pertinent background information.

Phase 1. Assessment and Evaluation. The goal of the first phase of intervention is to assess the specific needs and traits of the child in order to best tailor specific intervention strategies to meet said needs. Within this step, the intervention team, consisting of a music therapist and an occupational or physical therapist, assess the motor development of the child as it pertains to gait atypicalities, using the stationary and locomotion subsections of the Peabody Developmental Motor Scale (PDMS-2). Additional areas to be assessed in this phase include a sensory profile of the child using the Child Sensory Processing 2 scale (Dunn, 2014), as well as the Music Therapy Assessment Protocol using the aforementioned tool found in Appendix A. This phase should last approximately seventy minutes, with the division of that time depending on the attention span and needs of the child. Each of the two subtests on the PDMS-2 takes approximately twenty minutes to complete, which may comprise of one or two sessions, depending on appropriate session length for the child, and a final session is needed to complete the music therapy assessment protocol (see Appendix A). The specific division of assessment duties for each of the professionals on the intervention team can be found in Table 1. Following

[2] Meltdowns are a response to overwhelming situations, where the autistic individual loses control over their bodies, and, consequently, their behaviours (National Autistic Society, 2018)

this assessment, the intervention team will work together to assemble a program tailored to the specific needs of the child, including exercises using TIMP, which uses instrument playing to practice specific movements, PSE, which uses the characteristics of music such as direction, dynamics, and tempo, to cue non-rhythmic movements, and an RAS protocol, which uses the temporal cues of music to cue walking.

Table 1

Division of Assessment Tasks

Assessment Tool	Primary Professional
-PDMS-2	-Occupational/Physical Therapist
-Child Sensory Profile 2	-Joint
-Music Therapy Intake Questionnaire for Parents of Young Autistic Children	-Music Therapist
-Music Therapy Assessment Protocol for Young Autistic Children	-Music Therapist

Note: In the case of the Child Sensory Profile 2, the primary professional may be either the OT, PT or the certified music therapist (MTA or MT-BC), depending on the qualifications of the MTA. This test requires a certain qualification level, which includes being a member of a professional organization that covers training in the relevant area of assessment, or holds a degree or license to practice in the healthcare or allied healthcare fields. Thus, someone possessing solely an MTA status may not administer the assessment, but if they have other licensing, such as a psychotherapy licence, they would hold the necessary qualification level (Pearson, 2020). The MT should provide more input in the area of auditory processing, with the OT and/or PT providing more input in other areas of the assessment.

Phase 2. Deconstruction of gait and relearning of independent movements. The goal of the second phase of intervention is to reteach each of the specific movements in gait by breaking each step down to its most basic component. For example, if the presenting issue is a lack of heel-to-toe pattern, exercises would target dorsiflexion and contact of the heel with the floor, as well as plantar flexion and contact of the toe with the floor when the heel is already in contact with the floor, using each foot independently. These may include a combination of TIMP

and PSE exercises, depending on whether each specific step of the movement is rhythmic or not, and PSE exercises may be useful in connecting each of the steps together. Thus, in the aforementioned heel-to-toe example, the movements may be paired with a musical representation, with emphasis being put on the step that is the most difficult for the child. This would not yet be RAS, as even though the steps would be combined, there would still be distinct cues for each specific part of the walking pattern, rather than on the overall fluidity of the motions and evening out of the step and stride lengths. In order to maintain the interest and motivation of the child, exercises should, where possible, be paired with preferred songs and instruments. This phase should last between 200 and 300 minutes in session, depending on the specific stage of locomotion development of the child, and the duration of each session, which will be further discussed in the following chapter. Progress will be tracked using parental feedback from time between sessions, gathered through the weekly parent questionnaire (see Appendix C) and may include the creation and review of video recordings of each session by the intervention team. When the child is confidently able to complete all of the motions that were identified and targeted in the exercises for their program, it is time to move onto phase three, which reintegrates all of the steps of movement that were broken down at the beginning of this phase.

Phase 3. Reintegration into standard walking pattern. The goal of the third phase of intervention is to focus on the fluidity of walking motion, and to tie together all of the steps from the previous phase and pair them to a single cue for each foot. Thus, what may have eight cues per stride in phase two, four for each foot, would then be condensed down to two cues, one for each foot. As in the previous phase, and contrary to a traditional RAS protocol, where the main emphasis is on the rhythm of the music rather than the preferences of the client, there needs to be some consideration of what music is used to maintain the interest and motivation of the child.

Phase 4. Reassessment and maintenance. The goal of this final phase is to reassess the gait atypicalities of the child. In the reassessment, only the PDMS-2 locomotion and stationary subtests and the vestibular and proprioception sections of the sensory profile need to be completed. The time from the beginning of the intervention protocol may vary from child to child, but overall time in therapy should be about 580 minutes prior to progressing to this final stage, with the final 60 minutes of intervention time being used for reassessment. Progress should be noted, and a decision should be made of whether the child needs to continue on the

more intensive schedule determined in the assessment phase, or if they have reached all of their gait-related goals. If it is determined that the child needs to continue the more intensive schedule, the child's specific program should be redesigned by the intervention team in order to ensure that emphasis is being placed on the areas that continue to cause the most difficulty. If it is determined that the child has reached all of their gait-related goals, then one maintenance session around once a month should be provided moving forward for at least a year, in order to solidify the learning and maintain the benefits of the NMT intervention until the learning has truly been consolidated in the child's brain.

Table 2

Proposed Intervention Procedures

Treatment Phase	Number of Minutes	Interventions	Evaluation Procedures
Referral and Intake	Pre-treatment	n/a	Music Therapy Intake Questionnaire for Parents of Young Autistic Children
Phase 1. Assessment and Evaluation	~70 minutes	Administration of assessment tools	PDMS-2 Childhood Sensory Profile 2 Music Therapy Intake Questionnaire for Parents of Young Autistic Children (Appendix A) Music Therapy Assessment Protocol (Appendix B)
Phase 2. Deconstruction of gait and relearning of	~200-300 minutes (depending on needs of child)	-warm up and greeting song -TIMP	Weekly Parent Questionnaire (Appendix C)

independent movements		-PSE -Favourite activity and goodbye song	Progress notes following SOAP, DART, or format recommended by institution
Phase 3. Reintegration into standard walking pattern	~200-300 minutes (depending on needs of child)	-Warm up and greeting song -RAS -Favourite activity and goodbye song	Weekly Parent Questionnaire (Appendix C) Progress notes following SOAP, DART, or format recommended by institution
Phase 4. Reassessment and Maintenance	~60 minutes	Readministration of PDMS-2 and Child Sensory Profile 2	PDMS-2 Child Sensory Profile 2

Note: The intervention agents for each phase are specified in the descriptions of each phase presented in Table 1. Additionally, interventions in phase 2 and 3 will be adapted to the immediate needs of each child, as is typical for therapists, particularly when working with such young children.

Chapter Summary

In this chapter, several risk and protective factors, implicated in the development and type of gait atypicalities found in autistic children, were explored. Risk factors for the development of gait atypicalities include physiologic atypicalities (Pauk et al., 2017) and lack of access to therapies targeting gait atypicalities in autistic children (Rinehart et al., 2006a). Bhat et al. (2011) identify difficulty with motor learning in autistic individuals, which becomes a risk factor in relation to the success of a particular therapeutic intervention, however this is counteracted with two significant protective factors: intact music processing ability in autistic individuals (Quintin et al., 2013), and an intact ability to execute movements, in spite of the impairment in movement preparation of autistic individuals (Rinehart et al., 2001). Finally, early intervention may be a

significant promotive factor, due to the increased neuro-plasticity of younger children (Shonkoff, & Richter, 2013). Upon review of literature regarding autistic gait atypicalities, including instability, variability of stride length, poor upper and lower limb coordination, dynamic balance control and diadochokinesis, the key causal factors for these atypicalities could be traced to five key factors. These five factors include increased incidence of flat-footedness, greater maximum hip flexion, reduced knee range of motion, reduced ankle range of motion, and difficulty with motor planning (Pauk et al., 2017; Bhat et al., 2011; Cassartelli et al., 2017). Using the risk and protective factors and five factors outlined above, guidelines for a neuroscience-informed music therapy intervention procedure for children between 3 and 5 years of age was proposed. The proposed program lasts approximately 630 minutes in total duration, and incorporates TIMP, PSE, and RAS as primary intervention procedures. It was split into four distinct phases of intervention: (1) assessment and evaluation, (2) deconstruction of gait and relearning of independent movements, (3) reintegration into standard walking pattern, and (4) reassessment and maintenance.

Chapter 5. Discussion

The purpose of this study was to develop an interdisciplinary, neuroscience-informed music therapy intervention program to address the gait atypicalities seen in the majority of autistic children. The program was designed to be used primarily in pediatric stimulation centres and rehabilitation clinics, in an individual treatment setting. Due to the interdisciplinary nature of this intervention, it was determined that a combined approach using a music therapist and either an occupational therapist or physical therapist, which is not uncommon in the type of setting outlined above. There are two important factors in the implementation of the intervention protocol proposed in the previous chapter that are to be addressed in this chapter: flexibility and division of timing, and interdisciplinarity. Both of these factors hold particular relevance in working with autistic individuals, given the heterogenous nature of the disorder and the multiple ways that it can affect an individual.

Flexibility and Division of Timing

There is an oft-repeated saying in the autism community that says "if you've met one person with autism, you've met one person with autism" (Shore, 2018). This quote is meant to highlight the true level of diversity across the autism spectrum, as the specifics of characteristics and needs that an autistic individual may have are often unique, in spite of the overarching shared traits that define the disorder. For example, sensory processing issues have been noted across the spectrum, but the type of sensory processing issue may be increased proprioception in one individual, and decreased proprioception in another. For this reason, flexibility in the development of this intervention was of utmost importance, in order to meet the unique needs of each child, in spite of the common presentation of gait atypicalities.

Several areas of flexibility have been noted in the proposed intervention procedures, but perhaps the most obvious is the span of the recommended duration of each phase. Namely, whether the majority of the intervention time will be spent in phase two, where walking is broken down into distinct separate movements and each movement is worked on individually, or phase three, where the movements practiced in the second phase are all reintegrated into a cohesive walking pattern. If a child has been walking for a long time, there may need to be more time spent in the second phase, as the child will need to unlearn the way that they have been walking, which will be quite engrained in their muscle memory, before relearning the adapted way of walking. If the child is still learning to walk and has not necessarily solidified their

muscle memory, then the time in the second phase may be shorter, since the abnormal walking pattern is not yet engrained, however more time may need to be spent in the third phase, as the child may not have as much stability when combining movements into a cohesive walking pattern. Further research on the difference in time division between these two phases, depending on stage of walking development, is pertinent.

Other key areas of flexibility include the duration of each session and how the time in each session is divided. While the proposed guidelines place a suggested limit of 30 minutes per session, this time may be much shorter, depending on the attention span of the child. While it is ideal that the time of each session be broken down with about a third of each session spent on opening and closing activities as well as transitions, combined, and two thirds of the time being spent on gait work, it is also important for the therapists to remember that it is difficult for an autistic child to handle new situations. Thus, especially for the first few sessions, more time may be spent on gaining familiarity with the new surroundings, people, instruments, and schedule. It is imperative that the child is not pushed beyond their comfort zone too soon, or they may not be able to cope with the therapy sessions. Overall, the most important thing for professionals to remember is that it may take more time for an autistic child to acclimatize to this new situation than it may take a typically developing child, and that patience and listening to the cues from the child are more important than diving into the therapeutic interventions. This approach lines up with the anti-oppression framework that many therapists work within by honouring the lived experience and needs of the autistic child without making potential oppressive assumptions about their needs (Shera, 2003; Baines, 2013).

Interdisciplinarity

As mentioned above, the needs of an autistic child are diverse and vary from child to child. Their needs span several areas, including motor atypicalities, social difficulties, sensory processing difficulties, communication difficulties, and cognitive delays, among others. Given the diversity and breadth of these needs, it is impractical for a single therapist to try and meet all the needs of the child. This is why interdisciplinary teams in general are the ideal approach to intervention for autistic children; providing various types of intervention with several different therapists for different needs allows more of their needs to be met. Having each therapist focus on a specific area of need also allows each need to be met more comprehensively.

In regards to this intervention program, the importance for interdisciplinarity goes further than that. In Proffitt's (2015) study, at least one music therapist named feelings of inadequate training as justification for why they did not focus on motor goals. This is problematic, given the intact music processing abilities of autistic individuals found in Quintin et al.'s (2013) study, in spite of the difficulties in other processing areas. Music has proven itself to be a highly effective intervention method for autistic children, time and time again, and it should be applied in all areas of need, including motor atypicalities. That being said, it is also true that occupational therapists and physical therapists are not trained on the employment of music in interventions. While many may use music with good intentions, it is also possible that they may misuse music. In order to bridge this gap in the training and knowledge in both fields, so as to provide the best care to the autistic child, it is necessary for therapists in these fields to work together, complementing each other's knowledge.

Limitations

The most significant limitation is the lack of existing literature on gait with autistic individuals, particularly in terms of music-based interventions. Thus, much of the information used in the design of this intervention program was inferred from research in other disabilities which seem to hold similar neurologic underpinnings but does not give a clear picture of the effectiveness of translating these findings to the ASD population. Delimitation to the first two steps of intervention research also furthers this limitation due to the program not yet being tested, which means that the translational assumptions have not yet been tested, let alone the effectiveness of the proposed intervention procedures.

Future Research Implications

Given the limitation of solely completing the first two steps of intervention research, it is important that the final three steps of intervention research, as defined by Fraser et al. (2009), be completed. This means that future research to evaluate the effectiveness of the intervention and to make any modifications needed to ensure maximum benefit is warranted. Longitudinal studies to examine the long term effects of this intervention may also be pertinent. Finally, future research outside of the continued development of this intervention protocol could focus on the application of the three neurologic music therapy sensorimotor techniques in autistic individuals, to target the motor atypicalities that are beginning to be recognized as characteristic of the disorder.

Implications for Practice

The greatest implication for music therapy practice in the development of this intervention is the potential for more emphasis to be placed on motor atypicalities in autistic children, particularly in view of the resultant joint pain and fatigue that may occur if these atypicalities are not adjusted. It is hoped that this intervention program will bring these motor difficulties to the attention of the early intervention teams working with autistic children, and that it will be acknowledged that this area is just as important as social skills, cognitive development, and communication, when planning interventions for these children. Another potential implication for music therapy practice is increased training in the area of targeting motor difficulties to allow music therapists to more fully meet the needs of their clients, especially their autistic clients, for whom other types of therapy may prove more difficult due to their neurology.

Conclusion

This intervention program addressed the gait atypicalities of autistic children by using the intact music processing abilities to bridge the neurologic weaknesses and strengths underlying each of these facets of functioning. Literature in the areas of gait atypicalities in both the autistic population and populations with similar neurologic underpinnings as autism, was reviewed, as was the use of neurologic music therapy within these populations. The findings from this review of the literature were then used to mold the proposed intervention procedure, using an interdisciplinary approach. The procedure was split into four distinct phases: assessment, deconstruction of gait and relearning of specific movements, reintegration into standard walking patterns, and reassessment and maintenance. Specific care was given to the flexibility of the intervention and the importance of the interdisciplinarity, in order to best meet the needs of the autistic child. While the scope of this intervention is based on the most relevant existing literature, it is important to remember that the area of motor atypicalities in autistic individuals remains a relatively new field of research and continues to be the focus of new studies. Thus, information in this area is constantly changing, and the intervention protocol outlined in this paper needs to be assessed with this in mind. It is the intention of the author to continue to contribute to the development of knowledge on this topic through subsequent research endeavors, including the completion of all of the stages of intervention research as proposed by Fraser et al. (2009).

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Appendix A

Music Therapy Intake Questionnaire for Parents of Young Autistic Children

Discussion with parents/guardians:

The first phase of assessment with young autistic children is to gather information from parents/guardians about their child. Information gathered in this step is not to be taken at face value, but rather used to guide interactions and assessment activities in future steps. Important questions to ask include:

a) Does your child communicate verbally, or do they use another method of communication?
b) How does your child typically react to hearing music playing around them, either live or recorded?
c) Does your child have any musical preferences you're aware of? These may include songs, genres, or instruments that they either enjoy or display aversive reactions to.
d) Does your child have any sensory processing difficulties? These may include hypersensitivities and/or hyposensitivities. Auditory sensory difficulties are of particular importance in relation to music therapy, but other sensory difficulties including touch and visual difficulties are also important to be aware of.

Appendix B

Music Therapy Assessment Protocol for Young Autistic Children

1. Instrument exploration:

This second phase of assessment with young autistic children is to assess their reactions to different instruments, as well as their willingness to explore novel instruments. Instruments being explored should vary in timbre and volume as much as possible, to help with the assessment of auditory processing particularities. An example of a sufficiently diverse set of instruments would be a metallophone, such as a glockenspiel, a tambourine, a drum, a shaker, a guitar, and a piano. If there seems to be aversion to an instrument prior to making any sound with it, the aversion may be due to size, and thus it is advisable to modify the specific instrument chosen. For example, if a child demonstrates an aversion to the guitar prior to any sound being made, it is worth attempting to explore a ukulele with the child, as the smaller size may be less imposing. Pay attention to both facial expression and body language, as this may help provide clues about how the child is experiencing an instrument. For example, if they are smiling but covering their ears when hearing the drum, they may enjoy aspects such as the timbre but find the volume too loud, and adjustments to instruments can be done based on these observations.

1. Follow the leader activity:

This third phase of assessment with young autistic children is to assess their cognitive abilities for following directions, and how these may differ depending on how the direction or request is presented. Ideally, words will not be used during the first couple trials of this activity, as verbal processing is often the weakest area for autistic children. Transitioning to this activity is easily done by starting as the "follower" rather than the leader, mimicking the sounds the child is making once they are more comfortable with the instruments. This may be done either vocally or with instruments, depending on the comfort level of the child and what their preferences appear to be. However, if the therapist is mimicking vocal sounds that may be stimulatory in nature, and the child appears distressed, it is recommended to use instruments more exclusively. If the child shows awareness of being copied, the next step is to begin to slightly modify the response to the child's sounds. In this way, the therapist will often become the "leader" in a natural way, communicating the instructions of what is expected without using words. Modifications to further trials can be made based on the reactions of the child to this first trial.

2. Playing favourite songs:

This final phase of assessment with young autistic children is to assess whether any identified preferred songs from the first phase are indeed preferred songs, or if there is an aspect of a particular song that they prefer, other than the song itself. As parents often do not have musical training, the child may have a preference for a particular aspect of a recording, such as a riff, instrument, chord structure, timbre or sound effect, that is found in a particular recording, rather than simply a preference for the song itself. For example, a parent may say the child loves "Wheels on the Bus." If the child reacts positively to the therapist playing the song live, then it is likely the song itself that the child enjoys. If the child does not react positively to the therapist playing the song live, or seems indifferent, then it is recommended that the child's favourite recording of the song be played. In assessing and comparing the reactions to the two different versions of the same song, the music therapist is able to gather significant information about the true preference of the child. Finally, this activity also acts as a reward for participating throughout the assessment process, and can establish itself thusly as motivation for continued participation in sessions throughout the therapeutic process.

Finally, it is important to note that while all of these activities should be completed, they do not necessarily need to occur in a linear fashion. The first phase needs to be first, however movement between the last three activities may be in a different order or may be more fluid, moving from one activity to the next and back again. It is more important to listen to what the child is communicating at any given point, rather than working to the therapist's predetermined schedule.

Appendix C

Weekly Parent Progress Questionnaire

1) Has your child displayed any signs of discomfort when walking or moving limbs? If so, please specify.
2) Has your child seemed to connect their walking with rhythm or music? Examples of this may include singing to themselves or tapping a rhythm while locomoting, or locomoting more when they are listening to music.
3) Has your child practiced or seemed to be trying to practice any of their session exercises?
4) Have you noticed any increase in heel-to-toe pattern in your child's walking? If so, please specify.
5) Are there any other new observations that may be pertinent for the therapists to be aware of? This may be specifically regarding motor skills and/or locomotion, or may be related to energy/sensitivities, so that the therapists can make any necessary modifications to today's session plan. If so, please specify.