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Efficacy of Rhythmic Acquisition on Gait Performance Among Individuals with Parkinson's Disease

Demian L. Kogutek, *The University of Western Ontario*

Supervisor: Holmes, Jeffrey D., *The University of Western Ontario*
Co-Supervisor: Grahn, Jessica, A., *The University of Western Ontario*
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Abstract

The purpose of this study was to identify the ability of individuals with Parkinson's disease (PD) to acquire different rhythmic complexity levels through individual home-based Improvised Active Music Therapy (IAMT) sessions. The study aimed to identify whether higher acquisition of rhythmic complexity levels improved gait performance, as well as beat perception and production abilities. In this single subject multiple baseline design, the study measured the ability of four right-handed participants with PD to acquire greater density of syncopation, as a measure of rhythmic complexity levels, while playing uninterrupted improvised music on a simplified electronic drum-set. An accredited music therapist led each session with an acoustic guitar. The study described how higher density of syncopation levels presented in participants' playing related to not only gait performance, and beat perception and production abilities, but also to other music measurements. The participants' music content was transformed into digital music data in real time using Musical Instrument Digital Interface (MIDI). MIDI data was analyzed to determine density of syncopation, note count, velocity, and asynchrony during baseline and treatment IAMT intervention. Results from visual analyses and Pearson correlations indicated partial evidence for the ability of individuals with PD to acquire different rhythmic complexity levels through IAMT. Partial evidence was also found to support the overall effectiveness of IAMT sessions in increasing participant's mean gait velocity and stride length, and reducing step time and stride length variability. The findings of the current study indicate that IAMT sessions could be an effective strategy to increase physical mobility among individuals with PD. Using MIDI in the IAMT approach can yield data to evaluate treatment effectiveness and assess patient progress, providing daily measures and analysis of data using statistical analyses alongside visual analysis. This method has the potential to lead to new evidence-based interventions modeled in music therapy.

Keywords

Improvised Active Music Therapy, Parkinson's disease, Rhythmic complexity, Gait, Musical Instrument Digital Interface

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Chapter 1

1 Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder associated with dopamine depletion in the basal ganglia (Benazzouz, Mamad, Abedi, Bouali-Benazzouz, & Chetrit, 2014). In 1817, James Parkinson first described PD as a syndrome that predominantly affected the motor system (Parkinson, 2002). Since then, PD has also been clarified as a syndrome that may also involve abnormalities in behavior, cognition, and emotion (Callesen, Scheel-Krüger, Kringelbach, & Møller, 2013). PD currently affects more than 1% of individuals over the age of 65 years, affecting an estimated 100,000 Canadians (Wong, Gilmour, & Ramage-Morin, 2014) with approximately 5,500 new cases being diagnosed each year (Pringsheim, Jette, Frolkis, & Steeves, 2014). The incidence is similar worldwide (Belin & Westerlund, 2008). This number will continue to increase as the population ages (Bodnar, 2008). Dysfunction of the basal ganglia has been studied intensively as it pertains to motor control (A. Nelson & Kreitzer, 2014), as dopamine decreases, tremors can develop, muscle movements become slower and more rigid, and reflexes become impaired (Wong et al., 2014). These impairments to motor control progressively impairs the ability to execute steady actions such as, walking, speaking, or handwriting (Schwartze, Keller, Patel, & Kotz, 2011). Major morbidity and mortality in PD has been closely linked to problems arising from falling (Morita et al., 2014). Moreover, when compared to other medical conditions, PD has been found to be the leading cause of falls in the elderly (Teno, Kiel, & Mor, 1990). Roller, Glatt, Vetere-Overfield, and Hassanein (1989) reported 13% of individuals with PD fall more than once a week, 13% of them experience fractures, 18% of them are hospitalized, and 3% of them are confined to a wheelchair (Roller et al., 1989).

Gait impairments lead to limitations in functional activities such as self-care and mobility, and ultimately restrict participation in domestic life and social activities (Keus, Bloem, Hendriks, Bredero-Cohen, & Munneke, 2007). As the disease progresses, individuals with PD may be left dependent upon others to provide their basic needs, and they may feel powerless in their lack of control over loss of independence (Altenmüller & Schlaug, 2013; Cummings, 1992). Dependency and the decline in functional abilities are often manifested in emotions of anger, frustration, and sadness (Lindgren, 1996).

While pharmacotherapy treatment with levodopa remains the mainstay of treatment for PD as the most commonly used drug in improving motor symptoms (DeMaagd & Philip, 2015; Tomlinson et al., 2010), long-term levodopa therapy frequently leads to disabling side effects. Motor fluctuations such as the wearing-off or on-off phenomena and dyskinesia are reported to strongly correlate to duration and dose of levodopa exposure (Davie, 2008; Kulkantrakorn, Tiamkao, Pongchaiyakul, & Pulkes, 2006). Furthermore, supplementary use of other pharmacotherapy treatments, such as dopaminergic agonists, are generally only effective early on in the disease. Agonist pharmacotherapy is no longer recommended later on in the disease because of their poor overall benefit to risk ratio when compared with initial levodopa monotherapy (Hauser et al., 2007). Pleuropulmonary or cardiac valvular fibrosis have been identified as life-threatening additional risks of dopaminergic agonists use (Antonini, Tolosa, Mizuno, Yamamoto, & Poewe, 2009). Moreover, up to 30% of patients taking dopamine agonists also experience daytime drowsiness (Homann et al., 2002). Patients with advance PD responding unsatisfactorily to adjustments of or with serious adverse effects to pharmacotherapy treatment are sometimes effectively treated by deep brain stimulation (Odekerken et al., 2015). Although deep brain stimulation has been shown to improve motor functions (Group, 2001),

these invasive techniques are expensive, carry a certain degree of risk, and are generally recommended only for a small subset of patients as a last resort, when all other treatment options have failed (Bronstein et al., 2011). Overall, pharmacotherapy and surgical management strategies improve some of the symptoms of PD, but cannot fully restore motor performance (Morita et al., 2014), leading to a deterioration of the patients' quality of life as the disease progresses (Schrag, Jahanshahi, & Quinn, 2000).

Moreover, despite a growing body of literature demonstrating the benefits of exercise and rehabilitation for individuals with PD, it is not part of standard practice to refer patients for rehabilitation services (Ellis et al., 2008). Those patients in rehabilitation programs receiving physiotherapy, occupational therapy, and speech language pathology (Broadley et al., 2014) may find participation in such practices to be challenging. Factors such as pain, fear, anxiety, or lack of motivation may serve as barriers to participation and prevent individuals from receiving the benefits of these strategies (Paul & Ramsey, 2000). It is perhaps not surprising, then, that a 2001 survey of outpatient PD clinics in the United States found that nearly 40 % of patients were using complementary and alternative medicine practices (Bega, Gonzalez-Latapi, Zadikoff, & Simuni, 2014; Ghaffari & Kluger, 2014).

The inadequate response rate to current medications and the chronic nature of this disease suggest a critical need for the development of alternative treatment strategies (Morita et al., 2014). Thus, evaluating alternative rehabilitation strategies should continue as they are an important adjunct to medical treatment (de Dreu, van der Wilk, Poppe, Kwakkel, & van Wegen, 2012). Music therapy (MT) is a popular and evidence-based alternative treatment option that has recently been embraced as an effective adjunct to conventional rehabilitation programs for individuals with PD (Altenmüller & Schlaug, 2013).

1.1. Music Therapy (MT)

Music therapy (MT) is a discipline in which credentialed professionals use music purposefully within therapeutic relationships to address human needs within cognitive, communicative, emotional, physical, social, and spiritual domains (Canadian Association of Music Therapists, 2016). There are two main branches of MT in neurological rehabilitation with adults, active and passive (Frohne-Hagemann, 2007; Oliveri et al., 2013; Pacchetti et al., 2000; Raglio et al., 2015; Weller & Baker, 2011). In brief, active MT involves patients engaging in the production of music by using instruments or voice (Kogutek, Holmes, Grahn, Lutz, & Ready, 2016). In passive MT, on the other hand, the therapist does not encourage the patient to play or sing (Frohne-Hagemann, 2007; Pacchetti, Aglieri, Mancini, Martignoni, & Nappi, 1998). Instead, with passive MT the patient listens to recorded or live music for relaxation purposes, for song lyric discussion, or for reminiscence to promote reflection (D. Grocke, 2015; D. E. Grocke, Grocke, & Wigram, 2007; Marconato, Munhoz, Menim, & Albach, 2001; Wheeler, 2005). The delivery of MT interventions in both active and passive approaches, is facilitated in individual and group sessions (Darrow, 2004; Davis, Gfeller, & Thaut, 2008).

Active approaches in MT are generating interest in the rehabilitation science field (Weller & Baker, 2011). MT is believed to be particularly beneficial in facilitating cognitive processes in populations with neurological impairments because of the many skills and cognitive processes that music requires (Altenmüller et al., 2012; Pacchetti et al., 2000; Zatorre, 2003). In the last 10 years, a number of studies have demonstrated that music listening, and to a greater extent music production activate a multitude of brain structures involved in cognitive, sensorimotor, and emotional processing (Abdul-Kareem, Stancak, Parkes, & Sluming, 2011; Grahn & Brett, 2007; Koelsch, 2014; Salimpoor, Zald, Zatorre, Dagher, & McIntosh, 2015; Zatorre, Chen, & Penhune,

2007). For example, music production requires a host of brain functions, including (1) reading a complex symbolic system (musical notation), and translating it into sequential, bimanual motor activity dependent on multisensory feedback; (2) developing fine and gross motor skills coupled with metric precision; (3) memorizing long musical passages; and (4) improvising within given musical parameters (Wan & Schlaug, 2010).

According to Altenmüller et al. (2012), the multimodal effects of music production, together with music's ability to tap into the emotion and reward systems in the brain—such as in the frontal and parietal lobes, cingulate gyrus, amygdala, hippocampus, and midbrain—can facilitate the physical therapeutic benefits of neurological rehabilitation. Although the implications of active MT are generating great interest in the field, limited research to date has been published in the literature on active MT interventions that target physical improvements in neurological rehabilitation with adults (Kogutek et al., 2016; Weller & Baker, 2011). In recent years, three MT approaches have shown promise for improving motor impairments within neurological populations including; 1) Music-Supported Therapy (MST), 2) Therapeutic Instrument Music Performance (TIMP), and 3) Improvised Active MT (IAMT) (Kogutek et al., 2016).

1.1.1. Music Supported Therapy (MST)

MST was developed for inducing motor recovery after stroke (Schneider et al., 2007). Integrating the following four principles: i) massive repetition, ii) auditory-motor coupling and integration, iii) shaping, and iv) emotion-motivation effects (Ripollés et al., 2016). MST is comprised of individual sessions that are generally 25 to 30 minutes in duration, and focus on musical training of melodies. Participants are trained to produce tones, scales, and simple melodies on an electronic piano and/or an 8-pad electronic drum-set that produces the sounds A,

B, C, D, E, F, and G (Fujioka, Ween, Jamali, Stuss, & Ross, 2012; Schneider, Münte, Rodriguez-Fornells, Sailer, & Altenmüller, 2010). When using the drum-set, the 8 drum pads are arranged from left to right in a half circle so that the patient can reach all from a central position (Altenmüller, Marco-Pallares, Münte, & Schneider, 2009). Both the drum-set and piano are programmed using a Musical Instrument Digital Interface (MIDI) and software. The music that is made is digitally transferred via the MIDI, such that notes from each instrument are recorded as data on a scale of sound loudness, from 1 to 127 based on how fast the instrument is struck, wherein larger values equal greater loudness. Benefits of implementing the MST technique include the ability to assess and train both fine and gross motor skills and that no specific formal training is required to deliver MST (Chong, Cho, & Kim, 2014). In Chong et al. (2014), musical training involved participants with brain injury making music on a Yamaha electronic keyboard during two 25-minute sessions per week for 4 to 6 weeks. To allow individuals to participate who had no previous music experience or keyboard training, the authors marked the keyboard with numbered stickers and used a numbering system to indicate finger sequence. During each session, participants played simple melodic patterns that were based on repeated movements of a single finger such as thumb-thumb-thumb-thumb, and successive movements of adjacent fingers, such as thumb-index-middle-ring-little. As each participant became accustomed to keyboard playing, random movements of the fingers or combinations of more than 2 finger movements were executed. More recently, in Ripollés et al. (2016), musical training involved 20 participants with chronic stroke making music on an electronic keyboard and on a drum-set during two 30-minute sessions per week for 4 weeks. For drum training, study participants were seated on a chair without armrests in front of the drum-set. Each exercise was first played by the therapist and was subsequently repeated by the individual with chronic stroke. Participants had to hit the

different pads with the affected hand (using only the hand; no drum sticks were used). The therapist stood behind the participant and provided physical support for the affected extremity if necessary. Similarly, for keyboard training, study participants were seated in front of the keyboard with the therapist standing next to them (on the affected side). Again, an exercise was first performed by the therapist and then repeated by the participant.

In most research studies that have utilized the MST approach, the training intervention was conducted by individuals who were not trained as accredited music therapists. One study, Chong et al. (2014), was conducted by an accredited music therapist while other studies were conducted by therapists from other disciplines such as faculty in music and drama, (Altenmüller et al., 2009; Schneider et al., 2010; Schneider, Schönle, Altenmüller, & Münte, 2007), physical therapists (Villeneuve & Lamontagne, 2013) occupational therapists (Grau-Sanchez et al., 2013), and neurophysiologists (Ripollés et al., 2016; Rojo et al., 2011). Furthermore, Fujioka et al. (2012) did not report on the professional background of the instructor who delivered the intervention (Fujioka et al., 2012). The length and duration of the MST sessions ranged from two to five 30-minute sessions per week over the course of 5 weeks for a total of 15 sessions (Fujioka et al., 2012) to two to five 30-minute sessions per week over the course of 5 weeks for a total of 25 sessions (Chong et al., 2014). Participants included those recovering from a stroke (Altenmüller et al., 2009; Fujioka et al., 2012; Grau-Sanchez et al., 2013; Ripollés et al., 2016; Rojo et al., 2011; Schneider et al., 2010; Schneider et al., 2007; Villeneuve & Lamontagne, 2013), or those who had received an acquired brain injury (Chong et al., 2014). Several studies compared groups receiving occupational therapy, physiotherapy, conventional treatment and healthy control groups against a MT group (Altenmüller et al., 2009; Schneider et al., 2010; Schneider et al., 2007; Villeneuve & Lamontagne, 2013), whereas other studies did not include

group comparisons (Chong et al., 2014; Fujioka et al., 2012; Grau-Sanchez et al., 2013; Rojo et al., 2011). Studies employed repeated measures designs (Chong et al., 2014; Fujioka et al., 2012; Grau-Sanchez et al., 2013; Villeneuve & Lamontagne, 2013), controlled, single-blinded design (Schneider et al., 2010), pseudorandomized, controlled design (Schneider et al., 2007), a case study (Rojo et al., 2011), and a prospective cohort study (Altenmüller et al., 2009). The MST outcome measures predominantly focused on changes in the pressing velocity of the fingers and on hand function (Chong et al., 2014), fine and gross motor skills, (Altenmüller et al., 2009; Rojo et al., 2011; Schneider et al., 2010; Schneider et al., 2007; Villeneuve & Lamontagne, 2013), and changes in the sensorimotor representations underlying motor gains (Grau-Sanchez et al., 2013). Those outcomes were measured by employing the Grip and Pinch Strength Test (Chong et al., 2014), Box and Block Test of Manual Dexterity (Altenmüller et al., 2009; Chong et al., 2014; Grau-Sanchez et al., 2013; Rojo et al., 2011; Schneider et al., 2010; Schneider et al., 2007; Villeneuve & Lamontagne, 2013), Jebsen-Taylor Hand Function Test (Chong et al., 2014; Villeneuve & Lamontagne, 2013), 9-Hole Pegboard Test, (Altenmüller et al., 2009; Grau-Sanchez et al., 2013; Rojo et al., 2011; Schneider et al., 2010; Villeneuve & Lamontagne, 2013), Action Research Arm Test, (Fujioka et al., 2012; Grau-Sanchez et al., 2013; Rojo et al., 2011; Schneider et al., 2010; Schneider et al., 2007), and Arm Paresis Score (Altenmüller et al., 2009; Grau-Sanchez et al., 2013; Rojo et al., 2011; Schneider et al., 2010). A meta-analysis conducted by Zhang et al. (2016) which included 10 studies (13 analyses), and nearly 400 subjects, suggests that MST has a positive effect on motor function.

1.1.2. Therapeutic Instrument Music Performance (TIMP)

The TIMP technique from the Neurologic Music Therapy (NMT) program designed by Michael Thaut comprises 30- to 40-minute individual sessions and uses instruments to reinforce

functional motor patterns (Thaut & Hoemberg, 2014). In this approach, instruments are used not only to produce musical output but also to facilitate movement associated with nonmusical rehabilitative purposes. For example, the therapist might place various sizes of drums at different heights and direct a patient to extend his or her arm to play the drum at different spatial locations. The aim of this approach is to help to train eye-hand coordination; increase motor planning and coordination of the upper extremities bilaterally; improve range of motion of the elbow, shoulder, and wrist; and increase muscular strength and endurance (Thaut, 2005). To deliver the TIMP approach, one must obtain a recognized MT bachelor's degree or graduate certificate and have successfully completed the accreditation process for their provincial or federal agency, and he or she must receive certification as a master in NMT (LaGasse & Thaut, 2013).

To date it is believed that only two studies have been conducted wherein the TIMP approach has been investigated for the purpose of facilitating physical improvements within a neurologic population (Kogutek et al., 2016; Weller & Baker, 2011). The first investigation that used the TIMP approach was conducted by H. A. Lim, Miller, and Fabian (2011) and involved participants completing a functional target moving task. Participants included 35 individuals who had physical impairments due to neurologic disorders or orthopedic surgeries. Eight participants were diagnosed with strokes, one participant was diagnosed with Parkinson's disease, and 16 participants had orthopedic surgeries including total hip arthroplasty, total knee arthroplasty, and knee amputation. Study protocol required participants to be in a seated position with full elbow flexion or extension with the shoulder flexed to 90 degrees. A light mallet with a 1-pound weight was added to the patient's wrist, targeting a paddle drum. With an assistant holding the paddle drum directly above eye level so that the participant's shoulder was flexed to 90 degrees, the

investigator demonstrated the target movement by flexing to tap his or her own shoulder, extending to strike the drum, then repeating the sequence. The participant was instructed to touch his or her shoulder, hit the drum, and then repeat the sequence at a comfortable pace. The music and exercise were stopped when the patient stated that he or she was too fatigued or in too much pain to continue. For one specific intervention in their study, H. A. Lim et al. (2011) arranged a 7-minute instrumental version of 3 songs: the traditional "I've Been Working on the Railroad," Stephen Foster's "Swanee River," and Irving Berlin's "Alexander's Ragtime Band." The arrangements were recorded and played through a Yamaha keyboard, and the music was arranged with strong emphasis on the down beats, especially specific metric and rhythmic features, to facilitate the desired movements. The investigator measured and recorded the number of repetitions of the movement sequences as well as the duration of the exercise. No difference in endurance was found between TIMP and traditional occupational therapy treatment. TIMP resulted in significantly lower levels of perceived fatigue and exertion than traditional occupational therapy.

The second study that investigated the TIMP approach was conducted by Chong, Cho, Jeong, and Kim (2013). In this investigation, five adults aged 20 to 39 with cerebral palsy completed two 30-minute training sessions per week for a maximum of nine weeks. The music used for training was selected based on the preference of the participants, taking the melodic line as the main theme to be played repeatedly with their fingers. In the first half of the training, repeated pressing (finger no. 1-5), sequential playing (ascending 1, 2, 3, 4, 5; descending 5, 4, 3, 2, 1), and simultaneous pressing (1.2, 1.3, 1.4, 1.5, 3.4, 3.5, 4.5) were measured. In the second half of the training, extended melody was played in order to maximize the range of motion among the fingers. Following TIMP training, velocity of key pressing for each digit improved;

however, the pre-post differences were not statistically significant. Velocity of key pressing for the second and fifth fingers was significantly increased.

These two studies have clinically examined the effectiveness of utilizing the TIMP approach and both studies were conducted by an accredited music therapist (Chong et al., 2013; H. A. Lim et al., 2011). The length and duration of the TIMP sessions and programs consisted of biweekly 30-minute sessions in the course of 3 months (Chong et al., 2013). H. A. Lim et al. (2011) did not report the length of sessions. Participants included those with cerebral palsy (Chong et al., 2013) and those who had general physical deconditioning (H. A. Lim et al., 2011). One study compared groups receiving occupational therapy against an MT group (H. A. Lim et al., 2011), whereas the other study did not include group comparisons (Chong et al., 2013). One study employed repeated measures designs (Chong et al., 2013), whereas the other one employed a randomized, controlled, single-blinded design (H. A. Lim et al., 2011). The TIMP outcome measures focused on changes in hand functioning (Chong et al., 2013), endurance, self-perceived fatigue, and self-perceived exertion (H. A. Lim et al., 2011). Those outcomes were measured using the MIDI (Chong et al., 2013), analyzing video sessions, and having participants complete the Patient Perceived Fatigue Scale and Ratings of Perceived Exertion (H. A. Lim et al., 2011).

1.1.3. Improvised Active Music Therapy (IAMT)

Historically, this approach began with the work of Nordoff and Robbins (1977) with children with severe to profound developmental disabilities, by encouraging them to musically communicate meaningfully with the therapist (Aldridge, Gustorff, & Neugebauer, 1995). The approach is based primarily on the musical interaction, where the patient is encouraged to play a variety of instruments such as, drums, xylophones, bells, and/or produce vocals (i.e., sing) while being accompanied by a music therapist who is simultaneously engaged in music making either

with instruments or voice. IAMT rests on the assumption that every individual, regardless of ability or disability, has an inborn musicality and musical sensitivity (Nordoff & Robbins, 1977). According to Lee (2003), the mere act of engaging in this type of musical experience is the primary means of attaining therapeutic aims. Although many music therapists exclusively use this approach (Schmid, 2013), only one study (Pacchetti et al., 2000), targeting physical improvements in neurological rehabilitation has been conducted to evaluate its effectiveness (Kogutek et al., 2016; Schmid, 2013; Weller & Baker, 2011). In their investigation, Pacchetti et al. (2000) used a structured 13-week program to deliver weekly 2-hour sessions to groups of 8 participants. During each therapy session, participants engaged in a variety of activities, including listening and relaxation exercises, movement to music, vocalization exercises, instrument playing, and improvisations. Although structured, the therapist was afforded some flexibility in the design and implementation of the interventions delivered. For this approach, it was recommended that a session room be of sufficient size for participants to hear and move easily. Typically, the central area of the room was left empty so that room for movement activities was available as well as space to place the instruments during improvisations. The equipment required typically included a piano, an organ, percussion instruments, a Hi-Fi system with record and compact disc player, a mixer, an audio recording system and microphones, and a video camera for recording. At the beginning of each session, participants were first invited to sit comfortably for a listening and relaxation intervention. They listened to music and visualized peaceful images for approximately 10 to 15 minutes. During that time, they were asked to breathe continuously without inspiratory or expiratory pauses, as though their breathing was part of the music. The therapist then invited the group to stand up, and he or she led the stretching of muscles and joints. Movements were always synchronized to the music. The music used for this

section was usually from the new age genre. A wide variety of styles of new age music exists, but, very often, the music is associated with nature, featuring sounds of waterfalls, ocean waves, and animals combined with Celtic harps, sitars, and digital synthesizers. It tends to be slow (Newport, 1998). Following the listening and relaxation intervention, participants were then invited to accompany music with hand gestures; their hands were moved up and down the body from the abdomen to the head. Subsequently, participants were invited to make vocal sounds, onomatopoetic sounds, and extreme sounds (high-low) and to perceive corresponding points of bodily vibration. While singing, participants were also invited to activate and exaggerate the use of their muscles for facial expressions by shouting, whispering, and pronouncing the notes. Other techniques were employed, such as adjusting the pitch to match other voices and listening to the self and others to achieve euphony and produce collective vocal harmonies. The main part of each session was based on improvisation. First, all participants were allowed to practice freely using instruments and voice, play music games, and use free expression with the body. Then, they needed to seek to interact with one another. The therapist acted as a conductor, stimulating the group, suggesting short rhythmic-melodic ideas. Finally, the therapist left the group free to reach a musically uncontrolled conclusion based on the spontaneous contribution of each instrumentalist. The aim of the exercise was to create a musical sound progressively with a strong element of emotional involvement, where every person shared his or her own physical and psychological sensations with the group. Each improvisation lasted on average for 30- or 40-minutes.

In their study (Pacchetti et al., 2000), trained music therapists who had obtained a recognized bachelor's degree or graduate certificate and had successfully completed the accreditation process for their provincial or federal agency delivered the group MT intervention.

Each of the sessions were 90-minutes in duration and occurred weekly in the course of 3 months (Pacchetti et al., 2000). Participants were individuals with PD and the instruments used were metallophones, xylophones, drums, wood block, and cymbals. The study compared a control physiotherapy group with the MT group. The study (Pacchetti et al., 2000) was randomized, controlled, and single-blinded. Although the study provided some details on how the MT session was designed and applied, the level of detail was not sufficiently specific, thus leaving open the possibility for interpretation. No long-term follow-up beyond 2 months was reported in the study. The outcome measures focused on the changes in the number of physical responses during the musical activities by assessing motor functions, including bradykinesia and rigidity using the unified PD rating motor scale (Pacchetti et al., 2000).

Overall, the small number of articles in the literature suggests that a limited amount of research has occurred on the effectiveness of active MT treatments in addressing physical mobility (Kogutek et al., 2016). Similar conclusions were also drawn from a systematic review conducted by Weller and Baker (2011), which examined the role of MT in physical rehabilitation that included both active and passive approaches. Furthermore, the only research study on a group MT intervention was performed 14 years ago, and, since then, most of the individual MT interventions investigated MST, wherein the intervention was conducted by individuals who were not trained as accredited music therapists. This occurrence can likely be attributed to the fact that there are a relatively small number of music therapists as compared with individuals in other health professions (Abrams, 2010) or by the difficulties of standardized treatment when most MT interventions are based on the therapeutic relationship (Davis et al., 2008) and are modified according to patients' responses (Edwards, 2005). In some instances, evidence-based methods investigating clinical areas in MT have been questioned and discouraged (Aigen, 2015).

Although the majority of studies in the literature did not yield statistically significant results to demonstrate that active MT was superior to other treatments, the findings of Kogutek et al. (2016) provide insight into the breadth of research on the topic and can inform future research in the area. This information is particularly important as many music therapists exclusively employ approaches using improvisational live music in neurological rehabilitation, despite there being relatively few published studies in the area (Schmid, 2013). The literature also demonstrated a dearth of published research findings from studies that examined individual IAMT, where participants actively play and improvise music (Nordoff & Robbins, 1977) without combining the approach with other interventions such as relaxation or music and movement. Individual IAMT, as well as TIMP, MST, and other new designs need to evolve to optimize the components of the interventions, test specific outcome measures, and assign individual or small groups of participants randomly to intervention or control groups. As such, they can build toward and inform the design of more rigorous protocols, which then can establish the generalized efficacy of the intervention across sites as well as of different treatment intensities, thus leading to new evidence-based interventions modeled in MT. Active MT, applied to physical rehabilitation, is still a relatively new treatment modality. Only a limited number of studies have been conducted concerning its clinical effectiveness to date. In addition, the variability in the application with the use of different MT approaches to achieve a variety of outcomes makes analysis of studies into its effectiveness difficult, as often the interventions are different.

1.2. Gait Impairments in Parkinson's Disease

Among motor symptoms, gait disturbance represents one of the main impairments of PD. Gait dysfunction in PD is characterized by a slow, shuffling walking pattern, with short stride, diminished arm swing, and flexed forward posture (Bugalho, Alves, & Miguel, 2013; Hanakawa

et al., 1999). The correlation between cognitive decline and gait disturbance becomes more obvious as the disease progresses. In the early stages of disease, examination of gait may lead to inconclusive results because slow and small-stepped walking is often unspecific and can be related to age, depressive mood, or other conditions (Naugle, Hass, Joyner, Coombes, & Janelle, 2011). In early to middle stages of PD, abnormal slowness of gait is the main symptom that has been consistently reported in group comparisons between healthy and PD participants (Jankovic, 2008). As the disease progresses, further complex disturbance of gait such as motor blocks, festination, and disequilibrium become major determinants of disability (Ebersbach, Moreau, Gandor, Defebvre, & Devos, 2013). For example, Bugalho et al. (2013) assessed 40 individuals with PD, all on dopaminergic treatment, during a straight line 10-minute timed walking test (10 m forward, turn, and backward). Participants were instructed to walk at their preferred speed. Results suggest that loss of balance, short stride, and slowness were among the most prevalent features in PD. This is in accordance with most studies that have identified short stride and slower gait among individuals with PD (Bugalho et al., 2013). This is supported by Morris, Iansek, Matyas, and Summers (1994), who also found that the preferred walking pattern of individuals with PD was considerably slower than normal. Similar results were obtained by Hanakawa et al. (1999) who reported that ten individuals with PD had significantly higher cadence and shorter stride length than the controls.

Rahman, Griffin, Quinn, and Jahanshahi (2008) highlighted the importance of mobility problems to quality of life in PD. Falls are very common and begin relatively early in the course of PD. Bloem, Grimbergen, Cramer, Willemsen, and Zwinderman (2001) reported that during a six month timeframe, more than 200 falls occurred in 59 individuals with PD, 50% of the patients fell at least once, and about 35% suffered recurrent or injurious falls. Variability of

temporal characteristics such as step time, and spatial characteristics such has stride length, have been consistently associated with falling, with increased variability being associated with fall risk (Hausdorff, 2009). In many instances, injuries from falling results in hospitalization (Wielinski, Erickson-Davis, Wichmann, Walde-Douglas, & Parashos, 2005). Fear of falling has been identified as one of the major factors that contribute to the decline in activities of daily living and is one of the predictors of future recurrent falls in individuals with PD (Mak & Pang, 2009). Factors such as, social stigma and embarrassment from falling in public, can lead to depression and anxiety, directly affecting quality of life (Brozova, Stochl, Roth, & Ruzicka, 2009).

While pharmacological management has proven to be an effective strategy in mitigating some symptoms of PD, it has minimal effects on improving postural stability (Bloem, 1992) and in fact has in some cases been found to exacerbate gait impairment (Bloem, Hausdorff, Visser, & Giladi, 2004; Lamberti et al., 1997). As a consequence of the shortcomings with pharmacological management, researchers have recently focused their attention on non-pharmacological strategies. For example, Rhythmic Auditory Stimulation (RAS) has drawn considerable attention from both the research and clinical community as a promising option to help normalize gait patterns (Bloem et al., 2004).

1.3. Rhythmic Auditory Stimulation in the Treatment of Gait Impairments in PD

Rhythmic Auditory Stimulation (RAS) delivered in the form of a music stimulus has been reported to lead to significant improvements in spatiotemporal parameters of gait. For example, Thaut et al. (1996), investigated the effects of a 3 week home-based gait training program focused on improving mobility via auditory music cueing among 15 individuals who demonstrated gait impairment secondary to PD. In their investigation, participants underwent a

pre-test and post-test assessment, which involved measurement of their stride length without RAS present at their normal speed (preferred speed). During the training period, participants walked daily for 30-minute with RAS. The RAS program consisted of walking on a flat surface, stair stepping, and stop-and-go exercises to rhythmically accentuated music. Participants walked at three different tempos, one for each third of the exercise time. Participants could select from four short instrumental music pieces in four different familiar styles (folk, classical, jazz, country). Each selection was composed in 2/4 or 4/4 meter, and 32 measures in length. Rhythmic on-beats were enhanced by overlaying the click-function of the sequencer over the musical beat structure. For the first week of training, the normal speed was the pre-test cadence, the quick tempo was 5 to 10% faster, and the fast tempo an additional 5 to 10% faster. After each week, each tempo increased by 5 to l0%, such that the normal speed tempo became quick tempo etc. The rate of increase was also based on the participants' ability to match the tempos. Participants used portable tape players with headsets. Each musical selection was recorded for 30-minute on tapes in the laboratory. Participants exercised on their own or with spousal assistance at home or in the community. Study findings suggest that RAS training improved gait velocity, cadence, and stride length significantly after only 3 weeks. Furthermore, results showed gait velocity improved significantly by 25% with an increase in stride length (12%), and cadence (10%).

After this initial investigation, several studies on RAS in PD have been conducted (Hausdorff et al., 2007; Hove, Suzuki, Uchitomi, Orimo, & Miyake, 2012; I. Lim et al., 2005; Thaut & Abiru, 2010). Subsequently, utilizing similar RAS stimuli, McIntosh, Brown, Rice, and Thaut (1997) demonstrated that most individuals with PD in the absence of dopaminergic medication were still able to access auditory-motor synchronization to improve their gait patterns. They compared ten individuals with PD ON medication versus ten individuals with PD

OFF medication, and ten healthy age-matched participants as a control group. Participant walked initially at free velocity for baseline condition. Then, participants walked with RAS matched to the free velocity cadence and then with RAS 10% faster than baseline. Their results suggest that RAS produced significant improvements in mean gait velocity, cadence, and stride length over walking without RAS in all groups. Furthermore, the improvement rate for velocity was 36% in the PD on medication group, and 25% in the PD off medication group. Close rhythmic synchronization between RAS and step frequency for the PD group suggests participants' ability to utilize auditory rhythmic input to improve gait function (McIntosh et al., 1997). More recently, de Bruin et al. (2010) implemented a 13-week home-based music and walking program for 33 individuals with PD. Participants walked at least 30-minute, three times a week at a comfortable pace whilst listening to an individualized music playlist through head/ear-phones on an iPod. The tempo of each musical piece was carefully evaluated to ensure that it closely matched the preferred walking cadence of the respective participants. In agreement with aforementioned related studies, their findings also indicated that individuals with PD improved overall gait performance (de Bruin et al., 2010).

A systematic review of randomized clinical trials and quasi-randomized clinical trials conducted by Rocha, Porfírio, Ferraz, and Trevisani (2014), analyzed the effectiveness of RAS on gait parameters of individuals with PD. They concluded that RAS is effective for improving the gait parameters in elderly individuals with PD, whether participants were female or male, with walkers or without aid, and on or off medication.

It is believed the promising results afforded by RAS are based on the neurological principal of rhythmic entrainment. Rhythmic entrainment is the ability of the motor system to couple with the auditory system to drive movement patterns (Thaut & Hoemberg, 2014).

Entrainment has been identified as one of the most important underlying mechanisms for the successful application of MT in neurological rehabilitation (Thaut, 2015).

1.4. Entrainment

Entrainment is defined as a phenomenon in which two or more independent rhythmic or frequency processes interact with each other in such a way that they adjust towards, and eventually synchronize, with each other (Clayton, Sager, & Will, 2005; Lakatos, Karmos, Mehta, Ulbert, & Schroeder, 2008; Merker, Madison, & Eckerdal, 2009; Repp, 2005). Entrainment is a universal phenomenon that can be observed in biological and physical systems (Ancona & Chong, 1996). In nature, for example, human circadian rhythms (e.g., sleep–wake cycle) entrain with various environmental rhythms such as the daily light– dark cycle (Bruce, 1960). In physical systems, we can observe how pendulum clocks, in proximity, tend to synchronize with each other over time (Huygens, 1986; Rosenblum & Pikovsky, 2003). For example, the mechanism transforms the potential energy of the lifted weight into the oscillatory motion of the pendulum. These features are typical not only of clocks, but also of many oscillating objects of diverse nature (Huygens, 1986; Rosenblum & Pikovsky, 2003). Different amounts of energy are transferred between two oscillating objects, until they start oscillating at the same frequency, in synchrony (Pikovsky, Rosenblum, & Kurths, 2003). The stronger oscillator locks the weaker into its frequency until gradually eliminating the difference to zero, when both moving bodies move in resonant frequency or synchrony (Aschoff, 1979). In our brain, the cerebral cortex generates different types of synchronized oscillation with ensembles of neurons (Nunez, Amzica, & Steriade, 1993), oscillating at particular frequencies (Llinas, Grace, & Yarom, 1991). These auto-rhythmic oscillatory properties of neurons are a consequence of their electrochemical properties. External rhythmic signal and/or music functions as an external oscillator entraining our internal

oscillators (Clayton et al., 2005; Large & Grondin, 2008). Consequentially, Thaut, McIntosh, and Hoemberg (2014) suggests that the firing rates of auditory neurons, triggered by a rhythmic signal or music, entrain the firing patterns of motor neurons. The auditory rhythmic signal may directly impact the motor system through auditory-spinal facilitation due to the observed coupling between the stimulus and motor response (Rossignol & Jones, 1976). Investigations during synchronization tasks in healthy individuals describe the auditory cortex projections to the supplementary motor area and the premotor cortex via reticulospinal connections, projections to the cerebellum via the pontine nuclei (Stephan et al., 2002), and projections to the basal ganglia via thalamic nuclei (Hardy & LaGasse, 2013). The electrophysiological properties of cortical projection neurons serve as both, the sole output from and the largest input system of the cortex through patterns of synaptic connectivity (Han & Šestan, 2013; Marín, 2012).

Through these auditory cortex projections to motor areas of the brain, listeners around the world are able to effortlessly clap, tap, dance or otherwise move in time with music (Hannon, Soley, & Levine, 2011). Likewise, musicians synchronize with each other to produce music (Fachner, 2007). When individuals synchronize to music, they enter into a form of temporal coordination that is among the most elaborate observed in nature (Large & Grondin, 2008). Motor synchronization is generally quickly achieved and maintained (Drake, Penel, & Bigand, 2000; LaGasse & Knight, 2011), and takes place despite the interference of most pathologic processes (Hardy & LaGasse, 2013). In most cases, it is possible to even synchronize without attention or expertise, and its considered by some as a fundamental human ability (Bouwer, Van Zuijen, & Honing, 2014). Yet, there are notable exceptions. Some individuals are described as weak beat-perceivers who have more difficulty in synchronizing their footsteps (Leow, Parrott, & Grahn, 2014), body movements, or finger tapping to the beat of music (Dalla Bella &

Sowiński, 2015). One of the simplest tasks to study synchronization is finger tapping. In this task, participants are instructed to tap in synchrony with a periodic sequence of brief tones or the beat of music. Given that no single response is perfectly aligned in time with the corresponding stimulus (Bavassi, Tagliazucchi, & Laje, 2013), synchronization performance can be examined by recording the time difference between each response and its corresponding stimulus (Repp & Su, 2013). Despite its simplicity, this task helps to unveil interesting features of the underlying neural processes such as time perception, interval comparison, error detection, time production, and motor execution (Repp, 2005).

Anticipation plays a critical role during entrainment. The brain calculates how much time has elapsed and how much time is left between tones or musical beats (Thaut, Miller, & Schauer, 1998) and the tapping responses. When desynchronization occurs, there is a rapid correction and adjustment, followed by resynchronization of the time difference between auditory stimulus interval and response interval (LaGasse & Knight, 2011). Thus, understanding the neural basis of tapping can inform us about auditory-motor interactions relevant to changes in motor control (Kung, Chen, Zatorre, & Penhune, 2013), motor planning, and motor execution (Thaut, McIntosh, et al., 2014). For example, Balasubramaniam, Wing, and Daffertshofer (2004) recruited eight healthy adults aged 25-37 years who had some musical training to examine their ability to synchronize to a metronome at higher frequencies. Participants were asked to perform repetitive index finger movements in the absence and presence of an auditory metronome. The trajectory form and accuracy of timing in movements were analyzed and compared with a three-camera motion capture system. Results demonstrated that participants made more rapid movements of shorter duration, greater trajectory asymmetry, and better timing accuracy in the presence of the auditory metronome. In another study, Whitall, Waller, Silver, and Macko (2000)

used repetitive bilateral arm training with metronome cueing where 16 patients with chronic hemiparetic arm dysfunction post-stroke underwent 20-minutes of training, three times per week, for six weeks (18 sessions). The apparatus consisted of two independent T-bar handles that moved, nearly friction free, in the transverse plane (perpendicular to the participant). Participants grasped the handles or the affected hand was strapped to the handle, depending on the severity of the deficits, and performed reaching and retrieving actions for 5-minute periods of training interspersed with 10-minute rest periods. Significant improvements between pre-test and post-test were found in the Fugl-Meyer Upper Extremity Motor Performance Section and the Wolf Motor Function Tests.

Temporal processing and the recognition of temporal regularity are crucial for anticipation, which in turn is necessary to temporally align periodic actions to events in the environment (Schwartze et al., 2011). Therefore, the temporal characteristics of music and rhythm must be examined in depth in order to be purposefully utilized in MT clinical practice. For example, to develop an effective intervention it is important to understand whether entrainment is best facilitated by music, a metronome, or frequency tones. Schaefer (2014) suggests that whereas metronomes are clear and unambiguous pacing signals, music has more rhythmic complexity, a moderate amount of which may create more engaging rhythms (Schaefer, 2014). However, in an earlier review, Wittwer, Webster, and Hill (2013b) did not find evidence of differences between the effects of synchronizing walking to rhythmic music versus a metronome. The clarity of the beat in music (i.e., beat salience) is associated with a musical characteristic called “groove” (Madison, 2006). Madison (2006) defined groove music as wanting to move some part of the body in relation to some aspect of the sound pattern. In a survey of 215 patients, the most strongly endorsed items for groove music encompassed concepts

of movement, positive emotion, a sense of integration with the music, and the presence of salient beats (Janata, Tomic, & Haberman, 2012). High-groove music and metronome cues generally resulted in better synchronization than low-groove music in healthy participants (Leow et al., 2014). Stupacher, Hove, Novembre, Schutz-Bosbach, and Keller (2013) investigated the difference between musicians and non-musicians listening to high-groove music and low-groove music while receiving single-pulse transcranial magnetic stimulation over the primary motor cortex. Their results indicate that listening to high-groove music modulated corticospinal excitability, increasingly engaging the motor system, but not listening to low-groove music. Other research suggests that the emotional and motivational effects of familiar music may also mediate a stronger response than from metronome cues, as long as the rhythmic characteristics of the music has a recognizable strong beat (Patel & Iversen, 2014). Motivation can then play a crucial factor in music cuing versus metronome because entrainment can be enhanced by individuals' music preference. For example, using fMRI, Kornysheva, von Cramon, Jacobsen, and Schubotz (2010) instructed eighteen semi-professional musicians to attend to presented musical rhythms composed of drum sounds and to decide whether or not the presented stimulus was beautiful (aesthetic judgment). Results demonstrated that attention to preferred musical rhythms correlated with activity increase in a network of motor-related areas (Kornysheva et al., 2010). Drake, Penel, et al. (2000) investigated synchronization with expressive performance of musical excerpts on the way in which the listener comprehends the metric structure. Musicians and non-musicians were required to tap in time with three versions of six musical excerpts: mechanical version, accented version (mechanical version containing intensity accents on the first beat of the measure), and expressive version (performed by an expert pianist). Results indicate that the expressive version was somewhat more difficult to synchronize with than the

temporally regular and accented versions, whatever the level of musical training, indicating that the expressive version containing rubato was more difficult to synchronize to. Rubato refers to the expressive and rhythmic freedom by a slight speeding up and then slowing down of the tempo of a piece at the discretion of the soloist or the conductor (Randel, 2003). Another interesting aspect of this research is that most synchronization occurred either at the quarter-note level or measure levels. Drake, Penel, et al. (2000) considered five categories of metrical level; 1) tapping below the quarter-note level, 2) tapping at the quarter-note level, 3) tapping between the quarter-note level and the measure level, 4) tapping at the measure level, and 5) tapping above the measure level. Non-musicians tended to tap at the quarter-note level while musicians tapped at the measure level. Thus, the slower tapping of musicians compared with non-musicians was derived from them tapping at a higher metrical level. According to Drake, Penel, et al. (2000), using a slower referent level reflects the ability of musicians to organize events perceptually over longer time spans than non-musicians (Drake, Penel, et al., 2000). Therefore, in order to understand what musical qualities best induce entrainment, it is important not only to consider individual's preferences, but also to examine the rhythmical structure of music and participant's music competence.

1.4.1. The influence of rhythmic complexity on entrainment

To synchronize movements to music, a listener must perceive its meter, which is subjectively experienced as an underlying pattern of strong and weak beats (Wittwer, Webster, & Hill, 2013a). For example, a *waltz* has a repeating cycle of three beats whereas a *march* has a repeating cycle of four beats in groups of two. For London (2012), meter is possible only because of entrainment. Meter is a specifically musical instance of a more general perceptual facility of temporal attunement or entrainment (London, 2012). Depending on the distribution of

strong and weak beats along the measure, the metric ratio structure may range from simple to complex (Large, 2000). Western ‘‘simple’’ musical meters are dominated by an even, or isochronous, beat that can be subdivided or multiplied by simple integers to produce other levels of a metrical hierarchy. Because rhythmic events tend to occur on metrically strong positions, rhythms that conform to simple meters tend to have long and short temporal intervals related by simple-integer ratios such as 2:1 (march) or 3:1 (waltz). Complex meters, on the other hand, are dominated by a non-isochronous beat of alternating long and short durations such as 3:2 or 7:4. (London, 1995). Several reports within the literature on rhythmic performance report preferences for isochronous and relatively simple meters over relatively complex meters (Collier & Wright, 1995; Keller & Schubert, 2011; Povel, 1981). This is supported by Essens (1986) who indicated that temporal patterns are easily represented hierarchically for isochronous and relatively simple ratio (i.e., 2:1, 3:1, and 3:2) over relatively complex ratio timings (i.e., 2.72:1). Patterns containing subdivisions with integer ratios formed the integer condition while patterns containing subdivisions not in integer ratios formed the noninteger condition. Accurate reproduction was found when the unit was subdivided into parts that formed ratios that were simple integers. If parts did not form integer ratios, reproduction was inaccurate. Similarly, Deutsch (1983) instructed participants to tap with the right forefinger in synchrony with tones that were delivered to the right ear, and with the left forefinger in synchrony with the tones delivered to the left ear. The stimuli consisted of trains of 50-msec sine-wave tones presented through headphones. Results suggest that performance levels in polyrhythm (3 against 2) contexts were substantially lower than in simple rhythm contexts. Consistent with the literature, Grahn and Brett (2007) found that healthy participants were able to reproduce simple meters more easily than complex meters while synchronizing to tones. In their study, they used three

kinds of stimuli, simple metric (values are multiples of isochronous pulse with emphasis on 4/4 downbeat), complex metric (underlying pulse with ambiguous meter/syncopation), and non-metric (no steady underlying pulse). Furthermore, Collier and Wright (1995), revealed that three musically experienced participants performed complex meters with more difficulty than simple ones. Four (relatively) simple ratios (2:1, 3:1, 4:1, and 3:2), and three (relatively) complex ratios (2.72:1, 3.33:1, and 1.82:1) were used. Although there was modest evidence that performance of complex meters improves with practice, improvement was slow. Yet, when considering multicultural differences, the ease with which listeners perceive and produce rhythmic patterns depends heavily on their culture-specific exposure.

1.4.2. Cross-cultural differences and entrainment

Robust cross-cultural differences in perception and production of temporal information among adult listeners have been found (Ullal-Gupta, Hannon, & Snyder, 2014). For example, Ullal-Gupta et al. (2014) recruited 51 college students from Las Vegas, Nevada, USA and 51 college students from Bangalore, India. Participants were asked to tap to three different rhythmic patterns, simple duple, simple triple, and complex. Simple duple pattern consisted on subdivided the inter-target interval into six groups of two by alternating between one strong and one weak beat (2+2+2+2+2+2). The simple triple pattern consisted on the subdivision of the inter-target interval into four groups of three by alternating between one strong and two weak beats (3+3+3+3). The third, complex pattern, consisted on the subdivision the inter-target interval into a pattern of groups of two and three beats (3+2+2+3+2). Their result demonstrated that Western listeners more accurately perceived and produced rhythmic patterns containing simple ratios than those containing complex ratios. Whereas Indian participants readily synchronized to simple and complex meter tone trials. North American participants, whose experience was almost

exclusively limited to simple meters, were better at and faster to synchronize during simple than complex meter trials. Because musical meters vary across cultures, the ease with which listeners perceive and produce rhythmic patterns depends on their cultural music (Ullal-Gupta et al., 2014). Not surprisingly, Indian music contains more complex meters than those found in Western music (Srinivasamurthy, Subramanian, Tronel, & Chordia, 2012). Thus, difficulties in perceiving and producing complex ratio rhythms may arise not from universal, innate constraints, but rather from learned expectations about Western meter and rhythm that are acquired during infancy. Hannon, Soley, and Ullal (2012) also compared American and Turkish listeners. Americans in the simple condition showed the highest accuracy, whereas performance was lower and generally indistinguishable across complex and highly complex conditions. Turkish listeners, on the other hand, were as good at detecting disruptions in the context of simple or complex meter, both of which are familiar in their culture with isochronous and nonisochronous meters (Bates, 2011). Hannon et al. (2012) also demonstrated that Americans were equally poor at discriminating unfamiliar rhythmic patterns, presumably because patterns utilized did not conform to Western metrical structures. Likewise, Turkish listeners were as good at detecting disruptions in the context of simple or complex meter (Hannon et al., 2012). Previously in a similar study, Hannon and Trehub (2005) investigated the extent to which rhythm perception is influenced by universal, culture-general constraints on temporal processing, or by conformity to acquired, culture specific cognitive representations of meter. Participants were first-or second-generation immigrants from Bulgaria or Macedonia, for whom isochronous and nonisochronous meters are both culturally familiar. Participants correctly rated disrupted variations as less similar in both simple- and complex-ratio conditions. The temporal perception and production of North American adults arise from extended exposure to the simple metrical

structures that predominate in Western music (Hannon & Trehub, 2005). This provides evidence that familiarity and not meter complexity may be the most important factor influencing rhythm synchronization among multicultural listeners (Hannon et al., 2012). Throughout development, perceptual and cognitive networks become increasingly specialized for encoding the musical structure of a particular culture (Hannon & Trainor, 2007). Therefore, familiarity might be the primary factor in entrainment (Hannon et al., 2011). Yet, other aspects of the rhythmical structure of music such as syncopation may also play an important role when considering its influence on entrainment.

1.4.3. The influence of syncopation

Syncopation is characterized by the emphasis of weak locations (off beat) in metric structure and de-emphasis of strong metric locations. Generally, syncopation causes a momentary violation of the listener's temporal expectancies by the degree to which accented events do or do not correspond to the location of the inferred pulse (Randel, 2003). Syncopation occurs when a sound onset coincides with a weak metric location (i.e., between beats) and no sound onset occurs at the next strong metric location (London, 2012). Given that syncopation is typically defined by the degree to which accented events do or do not correspond to the location of the inferred metrical pulse, syncopation can only occur when the listener has inferred a meter (Jackendoff, 1985). Using a web-based rating survey, Witek, Clarke, Wallentin, Kringelbach, and Vuust (2014) recruited 66 participants aged between 17 and 63 years, from countries in Europe, Oceania, Africa, America, and Asia. The stimuli consisted of 50 drum-breaks with a different degree of syncopation. Each 16 seconds of drum-breaks consisted of a two-bar phrase looped four times in 4/4 time at 120 beats per minutes (bpm). Results found an inverted U-shaped correlation between degree of syncopation and pleasure ratings, indicating that

intermediate degrees of syncopation elicit the most desire to move and pleasure in music. As the syncopation in the drum-breaks increased, ratings increased accordingly, but only to an optimal point, after which a continued increase in syncopation caused decreasing movement desire and pleasure. This is supported by a study conducted by Keller and Schubert (2011) who examined the cognitive and affective responses to musical rhythms that varied in degree of syncopation (syncopated vs. unsyncopated) by controlling for familiarity. Thirty-five upper level undergraduate music students rated melodies consisting of two 4-bar phrases in quadruple meter. The melodic pitch series repeated across both phrases while the rhythm changed. Four types of rhythmic change were possible; a) from an unsyncopated rhythm to a syncopated rhythm, b) from a syncopated rhythm to an unsyncopated rhythm, c) from one unsyncopated rhythm to another unsyncopated rhythm, and d) from one syncopated rhythm to another syncopated rhythm. Results indicated that perceived complexity increases when a melody moves from unsyncopated to syncopated. However, the reverse is not true, unsyncopated melodies were rated as statistically equivalent in complexity to syncopated melodies when they followed the syncopated melodies. Syncopated patterns were rated happier than unsyncopated patterns, indicating that syncopated rhythms are enjoyed more than unsyncopated patterns (Keller & Schubert, 2011). Fitch and Rosenfeld (2007), demonstrated that sixteen undergraduate student participants' accuracy in tapping to the beat along with the target rhythms decreased as the rhythms' syncopation indices increased. Highly syncopated rhythms were difficult to reproduce and remember. Participants were significantly more likely to switch from tapping the pulse to tapping closer to the syncopated, offbeat pulse. This suggests that participants shift their inferred pulse to match the implied syncopated pulse with highly syncopated rhythms, indicating that syncopated patterns are more structurally complex than unsyncopated patterns. Unfortunately,

definitions of rhythm and consequently the design of rhythmic stimuli are not consistent across studies, making the comparisons between experimental rhythm conditions difficult at times (Thaut, Trimarchi, & Parsons, 2014). The exact process involved in auditory–motor entrainment remains unclear (LaGasse & Thaut, 2013). More research studies are needed in order to assess the effectiveness of entrainment during active MT sessions.

1.5. Parkinson's Disease and the Influence of Music

Motor impairment in PD is associated with deficient internal timing, which is the mechanism that coordinates movement. If deficient, these timing processes lead to overall impaired motor performance (Schwartze et al., 2011). The literature strongly suggests that motor impairments in PD are caused by functional deficiency of the basal ganglia (Obeso et al., 2000). The basal ganglia are a set of deep forebrain nuclei consisting of the striatum (caudate and putamen), globus pallidus (internal and external segments), subthalamic nucleus, and substantia nigra (pars reticulata and pars compacta) (Baladron & Hamker, 2015). Along with other brain regions, including the cerebral cortex, thalamus, and several brainstem nuclei, the basal ganglia is involved in the control of motor behavior, mood, and cognition (A. Nelson & Kreitzer, 2014). These regions form a network containing loops in the cortico-basal ganglia-thalamic system (Seger et al., 2013). It has been proposed that this system consists of four loops: the motor, the executive, the visual, and the motivational loop (Seger et al., 2013). These loops are considered to work in segregated and parallel functions with partial overlap of projections (Marsland, Pressman, & Cohen, 2007). The motor component of the basal ganglia is incorporated in the loop originating in the motor cortex and terminating in the supplementary motor area and pre-motor area. Information is processed from the motor cortex through the basal ganglia and back to the supplementary motor area and pre-motor area. Studies have shown that the supplementary motor

area is involved in running movement sequences where execution of each movement component is conditional upon the preceding movement (Georgiou et al., 1993). Projections from the basal ganglia to the cerebral cortex through the thalamus control the learned movements of hands, eye movements, trunk movements, locomotion, mastication, vocalization, and higher brain functions (Ikemoto, Yang, & Tan, 2015). Cortico-basal ganglia-thalamic circuits are also critically involved in a wide range of sensorimotor processes that are closely associated with executive functions (Haleem, 2015).

Studies of the neural basis of synchronization corroborate some aforementioned functions of the basal ganglia. Neuroimaging studies have shown that the basal ganglia are active in finger tapping (Barber, 2012; Lewis, Wing, Pope, Praamstra, & Miall, 2004; Moritz, Meyerand, Cordes, & Haughton, 2000) and passive music listening (Chapin et al., 2010). This suggests that similar basal ganglia resources are recruited during both perception and production of rhythms (Kung et al., 2013). For example, Chapin et al. (2010) observed activity in the basal ganglia only after the rhythms were presented a sufficient number of times for the listener to perceive a pulse, thus concluding that attention is necessary for the basal ganglia to remain active during rhythm rehearsal and for participants to improve their synchrony performance (Jueptner & Weiller, 1998). This indicates that involvement is related to basic timing and sequencing aspects of rhythmic motor performance (Thaut, Demartin, & Sanes, 2008), interacting with working memory retrieval mechanisms in the frontal lobe (Kung et al., 2013). Grahn and Rowe (2013) found greater activity in the basal ganglia for beat continuation than beat finding, across all levels of musical experience. This finding suggests that the basal ganglia do not respond preferentially to the discovery of regular beat structure but instead reflects the prediction or internal generation of future beats continuing after the temporal structure has been found. This is

supported by Danielsen, Otnaess, Jensen, Williams, and Østberg (2014) who interjected groove music stimulus with drum-breaks at uneven intervals (not possible to predict) and did not find increased activation in the basal ganglia. Therefore, the basal ganglia might be involved in generating hierarchy of interval patterns encoding musical meter (Trost et al., 2014). For example, Grahn and Brett (2007) found that listening to simple meters significantly increased activity in the basal ganglia compared to complex meters and nonmetric conditions. Consistent with the literature, musically trained participants exhibited decreased activation in the basal ganglia during polyrhythm (3 against 2) production (Thaut et al., 2008). This is supported by Fujioka, Zendel, and Ross (2010) who found larger responses of basal ganglia for march than waltz meter. These findings may be associated with the perceptual advantage of binary meter of march over ternary meter of waltz or more complex metric structures, possibly related to the symmetrical nature of our locomotion system or musical experience in Western culture, in which binary meter is more prevalent (Fujioka et al., 2010). Other studies have reached conflicting results. For example, Kung et al. (2013) did not find correlation between the basal ganglia activity when participants tapped the beat of rhythms that varied across four levels of metrical regularity. Yet, in this study, participants were not presented with different metrical ratios, but, instead, with repetitions of single rhythms (i.e., easily identifiable beat) versus weakly metrical rhythms, where the beat was difficult to identify because of syncopation and ties over measures. On the other hand, Grahn and Rowe (2013) found activation in the basal ganglia in participants while listening to beat rhythms compared with non-beat rhythms, suggesting that basal ganglia activity is not necessarily correlated with the ‘‘strength’’ of beat but rather with having established a predictable sense of the beat.

Within the literature, individuals with PD are reported to be less able than healthy individuals to accurately synchronize their movements to external auditory cues (Freeman, Cody, & Schady, 1993; Thaut et al., 1996) and encounter difficulties at rhythm discrimination tasks (Cameron, Pickett, Earhart, & Grahn, 2016; Grahn & Rowe, 2013). This is likely caused by the disruption of dopaminergic pathways from the substantia nigra to the basal ganglia (Jones & Jahanshahi, 2014). The deficiency of dopamine interferes with the normal function of the basal ganglia in establishing a functional loop that maintains adequate temporal preparation for movements (Nombela, Hughes, Owen, & Grahn, 2013). This deficiency ultimately affects the ability to execute steady periodic actions (Schwartze et al., 2011). Dopamine is a neurotransmitter that plays a central role in the regulation and control of movement, motivation, and cognition (Booth et al., 2015). The emerging theory is that dopamine does not function as a 'pleasure' neurochemical directly, but rather regulates motivation behaviors, playing a critical role in the prediction and learning related to future rewarding events (Chanda & Levitin, 2013). Mazzoni, Hristova, and Krakauer (2007) introduced the idea that the motor system has its own motivation circuit. They found that individuals with PD were able to move as fast as age-matched controls without any compromise in endpoint accuracy, trajectory quality, or energy expenditure when energetic demands of a movement task were low. Individuals with PD were, on the other hand, more likely than controls to move slowly when the energetic demands of a movement task increased. This suggests that this motor motivation works outside of awareness and governs automatic and spontaneous behavior, such as the speed of a reaching movement. It has been suggested that the dopaminergic modulation of information flows across the cortico-basal ganglia-thalamic circuits as part of the neural mechanism for temporal processing in a variety of circumstances, including motor and perceptual interval timing. This indicates that the

deterioration of the dopaminergic input to cortico-basal ganglia-thalamic circuits produces a profound disruption in temporal processing in individuals with PD (Merchant, Luciana, Hooper, Majestic, & Tuite, 2008). Increased dopaminergic signaling in the sensorimotor cortico-basal ganglia-thalamic network produces the opposite effect (Yin, 2014). This is supported by O'Boyle, Freeman, and Cody (1996), who observed that a single normal dose of levodopa medication (precursor to the neurotransmitters dopamine) caused a significant decrease in total tapping variance during synchronization tasks. During the off-medication condition, values were significantly higher than control values. Thaut, McIntosh, McIntosh, and Hoemberg (2001) reached a similar conclusion during synchronization tasks in that PD participants showed slightly higher variability measures compared to the healthy controls, with unmedicated patients performing slightly worse than medicated ones.

The internal timing mechanism in PD can be remediated by incorporating external rhythmical cues. For example, Georgiou et al. (1993) recruited ten participants with PD and ten controls. Mounted upon a response board (480 x100 mm) were two parallel rows of ten target buttons. Each button could be illuminated by a light-emitting diode (LED) set into its base. A computer recorded the time that each button was held down, the time between the release of one button and the depression of the next, and the sequence to be followed at each successive two-way choice point. Participants followed a specified pathway down the board with visual cues. The pathway was shown as an illuminated sequence of all ten relevant buttons. Each participant first learned a pathway by repeating the same sequence ten times with visual cues present (i.e., lights remaining on). The first eight trials were practice, to ensure that participants had fully learned the sequence. Participants were instructed to reproduce the pathway 'as best they could'. No specific instruction was given to participants regarding the required speed of movement.

After the sixteenth such trial without external cues, metronome cues were presented, via earphones. Participants were to repeat the same sequence (i.e., with visual cues absent), this time keeping in time as best they could with each beat of the metronome. This study demonstrated that when a long sequence has to be run entirely from memory, the provision of auditory cues greatly improved patients' performance. On the other hand, the absence of auditory cues, had relatively little effect upon controls' performance (Georgiou et al., 1993).

Similarly, Freeman et al. (1993) studied the sudden withdrawal of auditory cues. Healthy participants were able, in the presence of auditory cues, to duplicate target frequencies accurately over the range investigated both in terms of mean tapping rate and in regularity of tapping. Individuals with PD, on the other hand, were less accurate under these conditions. Healthy participants were able to sustain tapping rhythms well following suppression of auditory signals. By contrast, withdrawal of external timing cues resulted in marked impairment of the individuals with PD in rhythm generation.

The mere act of listening to music modulates the dopaminergic and functional activity of mesolimbic (dopamine pathway) structures in rats (Tasset et al., 2012) and humans (Salimpoor et al., 2013). Similar activity of mesolimbic structures, along with pleasure experiences, occurs while eating or receiving money (Egerton et al., 2009). This might be the reason why pleasant music, compared to unpleasant music, produces stronger activation of the mesolimbic system and the basal ganglia. In their study, Trost et al. (2014) recruited one group of 18 young adults to take part in an fMRI experiment. Participants listened to ten pieces of piano music with a binary metrical structure. The piano pieces were chosen from the music literature (not specified), taking into account their potential entraining power and rhythmic stability. The pieces were played by a professional pianist on an electric MIDI piano and recorded using GarageBand on a

MacBookPro. The recordings were edited in LogicPro where a dissonant version was created for all ten pieces. To create a dissonant version, the pitch of the highest voice was shifted one semitone up and the pitch of the lowest voice was shifted one semitone down. Their results indicate that consonant, relative to dissonant music, produced higher activations not only in the right ventral caudate nucleus, a region of the basal ganglia, but also in somatosensory and primary motor cortices (Trost et al., 2014). These studies collectively suggest that dopamine may play a distinct but related role in musical experiences which is the desire and anticipation of hearing expected sound events (with highly familiar music) and positive prediction (with less familiar music). Individuals begin to like previously unheard music, indicating that the positive prediction arise when outcomes are better than expected. Both familiar music and pleasurable music are associated with increased activity of the mesolimbic system and the basal ganglia (Salimpoor et al., 2015). Although limited research has been conducted on the subject, the emerging hypothesis supports that dopamine activation from musical involvement can potentially favour the cortico-basal ganglia-thalamic network at establishing functional loops. The combination of this release of dopamine and the external rhythmic cue techniques might be the reason for why the temporal processing of the basal ganglia is effectively impacted in individuals with PD in preparation for periodic actions during synchronization tasks.

1.6. Assessing the Potential Use of IAMT Sessions

Unlike other active MT approaches, in IAMT, the music therapist improvises music with the patient and encourages him or her to create a musical interaction, stimulating the initiative and the active participation of the patient (Formisano et al., 2001). The music therapist first follows the patient's rhythm course and music production in order to create a non-verbal way of communication (Raglio et al., 2015). This approach differs from other active MT approaches in

that the client and therapist meet and get to know one another through the musical improvisation that is created jointly and spontaneously together (Forinash, 1992). Within the neurological rehabilitation setting, the function of IAMT introduces a further step. In IAMT, the music cannot only be changed according to the patient's musical preferences and responses, but can also be designed to address specific therapeutic aims.

Due to the lack of research conducted in IAMT, to effectively assess the potential benefits of IAMT, it is essential to explore and collect information from a wide range of disciplines to inform us about the musical process. Entrainment is one of the most important underlying mechanisms for the successful application of MT in neurological rehabilitation (Thaut, 2015). Through this mechanism of synchronicity, rhythmic auditory cue techniques can be successfully applied to improve the timing of the motor system (Nombela et al., 2013), range of motion, muscle strength, and endurance (Thaut, 1988). Based on the literature of entrainment, we can then infer that the patient can be entrained by the music produced by the therapist during IAMT sessions. Therefore, understanding how entrainment is best achieved can then inform us how to best facilitate the musical experience to achieve clinical aims. For example, if in order to entrain, a patient must perceive the meter (Wittwer et al., 2013a), the therapist should utilize music with the purposeful intent of establishing a clear meter. The meter should be of a simple ratio such as 4/4, as demonstrated in the literature of synchronization (Grahn & Brett, 2007). Only once the patient has inferred a simple metrical pulse (Ullal-Gupta et al., 2014), the therapist can introduce syncopation in the improvisation. Otherwise, the patient might not be able to synchronize, as shown in the literature on finger tapping (Repp & Su, 2013). Even when the musical interaction takes a definite musical form, the therapist should always consider the complexity of the meter and syncopation, because patients may face difficulties when playing

these complex rhythms (Collier & Wright, 1995; Witek et al., 2014). Yet, the therapist's incorporation of more complex rhythms should be introduced during the therapeutic process, because it has been indicated that performance improves with practice (Collier & Wright, 1995; Povel, 1981). Therefore, therapists should gradually increase the complexity of the rhythmic structure within and throughout the sessions.

Neuroimaging studies suggests that similar basal ganglia resources are recruited during both perception and production of rhythms (Grahn, 2009; Kung et al., 2013; Patel, 2006; Zatorre, 2003). The incorporation of different rhythmic structures is vital for the MT treatment of individuals with PD because the basal ganglia mechanisms are active during rhythm processing (Biswas, Jhunjhunwala, Pal, & Hegde, 2015; Grahn, 2009; Grahn & Rowe, 2009) and production (Kung et al., 2013; Schwartze et al., 2011; Zatorre et al., 2007). For example, activation in the basal ganglia was found in individuals while listening to continuous rhythms (Grahn & Rowe, 2013), while listening to piano music (Trost et al., 2014), and while tapping to the beat of musical rhythms (Kung et al., 2013). Together, these experiments suggests that the basal ganglia is involved while encoding musical meter (Trost et al., 2014), which is subjectively experienced as an underlying pattern of strong and weak beats (Wittwer et al., 2013a). We can then infer that the basal ganglia are active during IAMT sessions.

Therefore, during IAMT, music therapists can possibly utilize different rhythmic complexities to stimulate the basal ganglia. Thus, understanding how the basal ganglia is involved during music perception and production can then inform us how to best utilize musical structures to stimulate the basal ganglia. Since the basal ganglia is involved in generating prediction of hierarchy of rhythmic structures (Trost et al., 2014), the therapists could utilize them accordingly. For example, activation of the basal ganglia occurs after a sufficient number

of times for the listener to perceive a pulse (Jueptner & Weiller, 1998). Thus, the therapist could maintain the rhythmical structure of the improvisation until patients are able to synchronize to the beat. Since the basal ganglia requires attention to remain active (Jueptner & Weiller, 1998), the therapist may only alter the rhythmic structure once patients become accustomed to it. As the basal ganglia are active in continuing the beat, the therapist could make alterations in the hierarchy of the metrical structure to maintain a predictable pulse. The therapist could also utilize small increments of metrical complexities because simple meters significantly increase activity in the basal ganglia compared to complex meters (Grahn & Brett, 2007). Yet, it might be necessary to alter the rhythmic complexity in order to maintain the necessary attention to activate the basal ganglia. If changes in the rhythmic structure occur rapidly, the patient would concentrate on finding the beat, which is not correlated with activation of the basal ganglia (Grahn & Rowe, 2013). Rhythmic structures can then be purposefully utilized to stimulate the basal ganglia during IAMT sessions. More research is needed in order to inform clinical practice about the effectiveness of this technique and to further the understanding of the exact mechanisms activated in the basal ganglia during music production.

Individuals with PD are less able than healthy subjects in their ability to accurately execute steady periodic actions. This is likely caused by the disruption of the dopaminergic pathway in the basal ganglia (Jones & Jahanshahi, 2014). The potential use of IAMT relies on the patient's inherent motivation towards an active musical experience. Patient's motivation plays a crucial role since music involvement modulates the dopaminergic and functional activity of mesolimbic system (i.e., dopaminergic pathway in the brain). Similar activity of mesolimbic structures also occurs through the reward system (Egerton et al., 2009). Stronger activation of the mesolimbic system was observed while experiencing pleasant and familiar music (Trost et al.,

2014). Dopaminergic signaling flows across the cortico-basal ganglia-thalamic loop circuits as part of the neural mechanism for temporal processing. Deterioration of the dopaminergic input to the cortico-basal ganglia-thalamic circuit produces a profound disruption in this processing (Merchant et al., 2008). IAMT techniques could potentially favour the cortico-basal ganglia-thalamic network at establishing functional loops through the modulation of the dopaminergic and functional activity of mesolimbic system (Salimpoor et al., 2013). Although there is limited research on the subject, the emerging hypothesis supports that dopamine activation from musical involvement could potentially favour the basal ganglia at establishing functional activity. This hypothesis likely holds true in the earlier stages of the disease process wherein up to 70% of dopaminergic producing cells remain intact (Cheng, Ulane, & Burke, 2010). However, as the disease progresses and cell loss continues, RAS is understood to maintain its therapeutic benefit by enhancing general timing as a means of facilitating performance in tasks that involve perceptual and motor timing. This process is believed to be supported by neural circuitry less affected by PD, and likely involves cortico-basal ganglia-thalamic circuitry (Kotz & Schwartze, 2010; Nombela et al., 2013; Schwartze et al., 2011).

1.7. Need for Further Research

Recently, Kogutek (2014) conducted a grounded theory qualitative investigation that provided information regarding the implication and application (Kogutek, 2015) of tango style in IAMT. Four patients living in a long-term care home, ranging in age from 46 to 87 years old, were recruited to experience tango music during individual IAMT sessions. Patients had different diagnoses including Alzheimer's dementia, dissociative identity disorder, and chronic obstructive pulmonary disease. The intervention consisted of one session per week for 30-minutes of uninterrupted music for eight weeks. Patients played on the tenor metallophone while

accompanied by a music therapist on classical guitar. After approximately five to ten minutes of improvisation, the music therapist transitioned into tango style. After approximately two to five minutes of tango improvisation, the music therapist transitioned back to the original style of improvisation that was based on the patient's mood, and then continued with the clinical improvisation intervention. Audio and video recordings were the primary sources of data collection. For each patient, the tango portion of the improvisation was selected and transcribed from the audio recording using Finale software. Thirty seconds before and after the tango portion were selected and transcribed. These two 30-second portions were used to compare the tango portion with the surrounding musical style of the improvisation. The results yielded two main categories, each with subcategories, developed from the transcribed musical analyses; a) music qualities (tempo and dynamics), and b) incorporation of stylistic components (syncopation). In the category of music qualities, the tango style showed certain implications in all patients' musical responses. During tango style, patients showed an increase in their dynamics and tempo. In the category of incorporation of stylistic components, patients incorporated syncopation to their playing, altering from simple rhythms of quarter and eighth notes before and after the incorporation of tango style, to more complex combinations of rhythmic structure during tango style. Playing syncopated rhythms in music, that is, playing a strong note off the beat, has been found by Fraisse, Ehrlich, and Repp (2009) to be more difficult than playing notes on the beat. Results of music education studies indicate that some individuals, but not all, are capable of playing syncopated rhythms (Fraisse et al., 2009; Volman & Geuze, 2000), and that rhythmic ability improves with age (Gilbert, 1980; Groves, 1969; Smoll, 1974). Yet, improvement in rhythmic ability has been found to be limited without training and practice after the age of seven (Drake, 1993; Reifinger Jr, 2006).

Playing rhythms has been considered an important factor in development and in learning and performance of motor skills. Music education research found that rhythm performance increased linearly with age (Fraisse et al., 2009; Groves, 1969; Reifinger Jr, 2006; Sims, 1985; Smoll, 1974). Significant age-related differences in the synchronization and syncopation abilities of school-age children (Volman & Geuze, 2000), adult musicians and adult non-musicians (Drake, 1993) were identified. Collectively, these studies suggest that performance of simple rhythmic patterns improves significantly with age (Drake, 1993; Fraisse et al., 2009; Volman & Geuze, 2000). The ability to play on the beat is the first and most fundamental rhythmic skill (Reifinger Jr, 2006). This motor skill can emerge after the age of one (Moog, 1976)), but most children become competent between the ages of three and five (Sims, 1985). By age six, children can discriminate different simple meters. By age seven, children develop sufficient motor control to reproduce different simple meters (Gérard & Drake, 1990), but encounter difficulties at playing syncopated rhythms (Volman & Geuze, 2000). By age nine, children are able to reproduce syncopated rhythms, but the number of unsuccessful attempts is rather high (Volman & Geuze, 2000). Adult non-musicians are capable of playing syncopated rhythms, but their rhythmic ability becomes precise only while tapping to simple integer sequences (Fraisse et al., 2009).

Individuals can acquire and improve rhythmic skills by maturation, acculturation, and active learning (Drake, Jones, & Baruch, 2000; Upitis, 1987; Volman & Geuze, 2000). With regard to maturation, it has been found that most musical skills stabilize during childhood and do not continue to develop without further training (Tsapakidou, Zachopoulou, & Gini, 2001; Volman & Geuze, 2000). For example, Drake (1993) demonstrated that adult non-musicians were not statistically different at tapping to different rhythms than nine-year-old children,

implying that maturation and acculturation alone does not improve rhythm performance after a certain age (Drake, 1993). Thus, according to the literature of music education, motor skill development is necessary to be able to play higher complexity of rhythms (Drake, Jones, et al., 2000; Upitis, 1987; Volman & Geuze, 2000).

The finding of Kogutek (2014) is particularly important as it was demonstrated that syncopation could be quantified during IAMT sessions, thus providing an objective metric to quantify patient's rhythmic ability performance. To date there has been a paucity of research conducted supporting the extent to which acquisition of rhythmic complexity levels influence motor skills (Tsapakidou et al., 2001), with most resources that relate to IAMT improvisation focusing on techniques that support the client's musical intention (Bruscia, 1987; Lee, 2003; Ruud, 1998). Specifically, no investigations have attempted to examine patient's acquisition of rhythmic complexity levels through entrainment during IAMT sessions and draw correlations as a means to improve motor performance outcome measures.

Thus, given previous research findings that suggest syncopation is an important factor that elicits a desire to move and the most pleasure, research is warranted to examine whether IAMT sessions that introduce syncopation could help facilitate individuals to acquire higher rhythmic complexity levels, and whether this acquisition can positively impact motor control in PD.

1.8. Purpose of the Research

The purpose of this research was twofold: i) to identify the ability of individuals with PD to acquire different rhythmic complexity levels through IAMT individual sessions; and ii) to identify whether higher acquisition of rhythmic complexity levels improves gait performance. For the purpose of this research, a higher rhythmic complexity level was defined as an increase

in density of syncopation, as described by Huron (2002), exhibited in the participant's musical responses throughout IAMT sessions.

1.9. Hypotheses

i) Participants' density of syncopation exhibited in their musical responses will increase from baseline to treatment conditions.

ii) Participants who acquire higher density of syncopation during the treatment condition will demonstrate an increase in gait velocity and stride length and a decrease in step time and stride length variability compared to participants who do not demonstrate higher density of syncopation.

Chapter 2

2. Methods

2.1. Methodology Background

The methodology of this study was Single Subject Multiple Baseline Design Across Subjects (Zhan & Ottenbacher, 2001). Researchers in the field of rehabilitation science have advocated for, and used, single-subject research designs to examine the efficacy of various interventions (Connell, 1986). This design represents an alternative to traditional group-comparison and case-study procedures (Nourbakhsh & Ottenbacher, 1994) in that group-comparison approaches need a large number of participants (Zhan & Ottenbacher, 2001) and case-studies provide a detailed description of a single participant (Backman, Harris, Chisholm, & Monette, 1997). The difficulty of obtaining large homogeneous samples of participants with similar disorders, and the high cost of clinical research, make group-comparison designs difficult to implement (Zhan & Ottenbacher, 2001) during the length of a PhD study. On the other hand, case-studies provide a detailed description of a participant and the participant's responses to treatment, but there is no attempt to define and manipulate an independent variable to examine its effects on a dependent variable, as is required in experimental studies (Backman et al., 1997). In contrast, the Single Subject Multiple Baseline Across Subjects design gathers empirical data on the effects of a treatment, similar to that of group-comparison design (McReynolds & Kearns, 1983), by identifying the active components of treatment that are responsible for behavior change (Ward-Horner & Sturmey, 2010).

To demonstrate experimental control with this methodology, the investigator first collects baseline data across three to five participants (Tawney & Gast, 1984). The basic underlying principle is that control for extraneous variables is demonstrated within the individual

participant. The behavior (dependent variable) of each participant during baseline conditions is compared with the participant's behavior during treatment (independent variable). Initially, measures for frequency and duration of the target behaviors of each participant under baseline conditions are examined, until a stable trend and levels are established for each (Nourbakhsh & Ottenbacher, 1994). Once the target behavior under baseline has demonstrated a stable trend (i.e., plateau, or demonstrated an upward or downward trend) in Participant 1 (P1), the intervention is introduced to P1, while all other participants continue to be monitored under baseline conditions. If the target behavior does not plateau or demonstrate an upward or downward trend at a certain level, the intervention cannot be introduced and the baseline period needs to be extended (Zhan & Ottenbacher, 2001). When the target behavior of P1 is responding differently under the treatment phase, the intervention is then introduced to the second participant, while again all other participants (P2, P3, P4, and P5), continue to be monitored under baseline conditions (Gast & Ledford, 2009). Therefore, the length of the baseline is first predetermined as a fixed schedule with staggered entry, but it can be extended according to participant's aptitudes to establish a stable trend. Once the intervention is introduced to all participants, each participant remains in the treatment phase until the requisite timeframe is completed (i.e., x week intervention). In order to monitor participant's behavior, the dependent variable needs to be measured repeatedly, both when the treatment is in effect and when it is not (McReynolds & Thompson, 1986). This systematic and sequential introduction of the independent variable continues until all participants have been enrolled in the treatment phase (Tawney & Gast, 1984). The reasoning behind the Single Subject Multiple Baseline Design Across Subjects is that any effect of the intervention on the participants should be observed at approximately the same time-point (i.e., introduction to treatment) within each participant.

2.2. Participants

Four right-handed participants with PD (3 men and 1 woman) with an average age of 72.5 (SD = 5.06, range 69-80 years) were recruited to participate in the study (see Table 1). Individuals were recruited to participate by advertisements that were: placed within a newsletter distributed by Parkinson Society Southwestern Ontario, posted to the website kijiji within the volunteer opportunities advertisement section, and on Facebook. Recruitment efforts also involved in-person information sessions being delivered to Parkinson support groups, and at local events such as the Walk it for Parkinson's fundraiser, and a local area Parkinson's related conference. In order to participate in this research individuals were required to meet the following inclusion criteria: 1) have clinical diagnosis of Parkinson's disease; 2) be at least 50 years of age; 3) be capable of walking 40 feet with or without the use of an assistive device; 4) be able to sit independently for 30 minutes at a time; 5) be willing to play on an electronic drum-set and engage in weekly home-based MT sessions. Participants were not eligible to participate if they: 1) were cognitively impaired as determined by receiving a score of less than 26/30 on the Montreal Cognitive Assessment [1]; 2) were experiencing major back or lower limb pathology that may influence sitting or gait; 3) if they were an experienced musician as defined by having the skill or knowledge as a result of active participation or practice, or if they were currently learning to play a musical instrument. The review board for health sciences research involving human subjects approved this study (HSREB File Number: 108090), and informed consent was obtained from all participants.

[1] Montreal Cognitive Assessment (MOCA) has been demonstrated to have excellent sensitivity for detecting mild cognitive impairment in PD (Gill, Freshman, Blender, & Ravina, 2008)

Table 1. *Demographic Characteristics of Participants*

	Gender	Age	Medication	Modified Hoehm and Yarh Scale
Participant 1	M	71	Levodopa	2
Participant 2	M	69	None during the research period	3
Participant 3	M	80	Levodopa	2.5
Participant 4	F	70	Levodopa	2

2.3. Procedures

Participants received individual home-based IAMT sessions consisting of 25 minutes of uninterrupted improvised music, twice a week. Participants played music on a simplified electronic drum-set (Roland TD-11K V-Compact Kit) with two drum pedals, two drum pads, and a cymbal. The accredited music therapist and Ph.D. candidate, Demian Kogutek (DK), led each session with an acoustic guitar (MIDI Godin Guitars - Multiac Nylon). Figure 1 shows the IAMT equipment required for the sessions. All sessions took place between 10:30 and 11 am, approximately 3 hours after participants took their usual medication as to ensure consistency with participants' medication schedule.

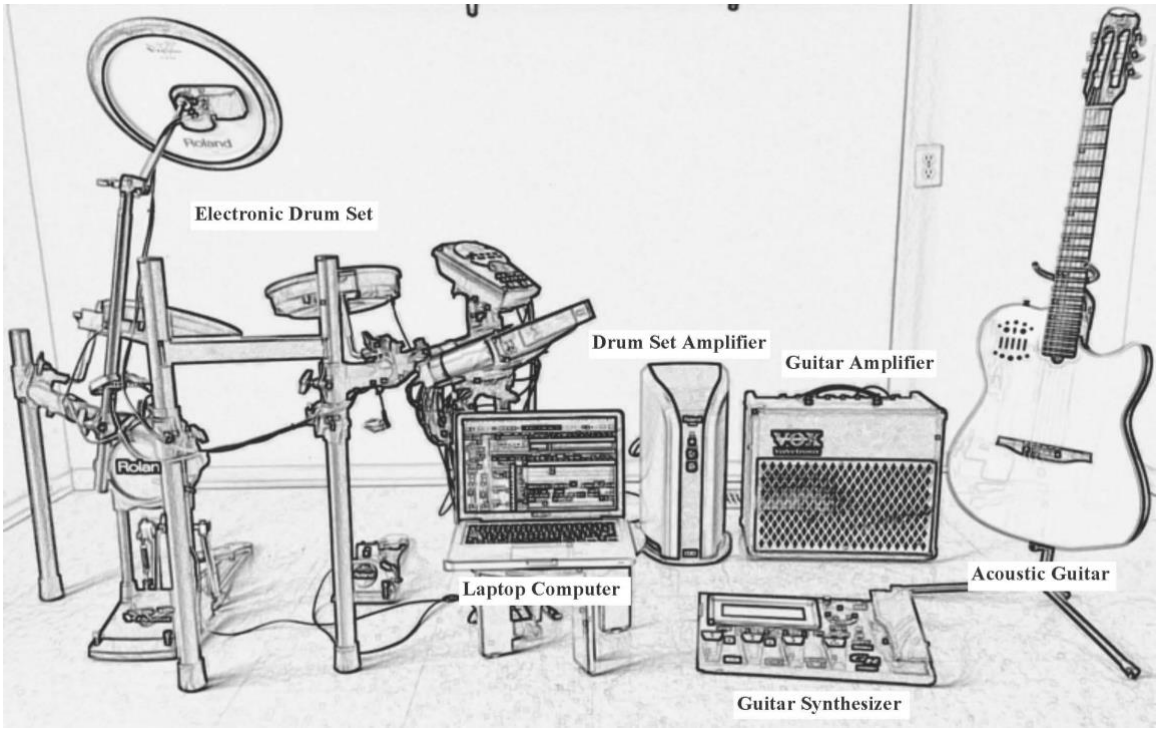

Figure 1. IAMT session equipment setup, including electronic drum-set, acoustic guitar, drum-set amplifier, guitar amplifier, guitar synthesizer, and computer laptop

The behavior under examination was the participant's ability to acquire a higher density of syncopation. During baseline, DK played rhythms with low-moderate density of syncopation. During treatment, in contrast, DK introduced rhythms with moderate-high density of syncopation. For the purpose of this study, low-moderate density of syncopation was operationally defined as scores within the range of 0.05 - 0.21, and moderate-high density of syncopation was operationally defined as scores within the range of 0.22 - 0.5. The density of syncopation trend of each participant during baseline conditions was compared with the participant's density of syncopation trend during treatment conditions. (McReynolds & Thompson, 1986). All participants completed the data collection timeline with the exception of P2 who only completed 6 out of 8 weeks of treatment due to vacation. The baseline sessions

range from four baseline sessions for P1 over two weeks, to eight baseline sessions over four weeks for participant P4 (see Table 2)

Table 2. *Amount of weeks' participants underwent IAMT sessions by condition*

	Weeks of Baseline	Weeks of Intervention
Participant 1	2	8
Participant 2	2 ½	6
Participant 3	3	8
Participant 4	4	8

2.4. Outcome Measures (Laboratory Tests)

Participants underwent laboratory-based gait, beat perception, and beat production tests before the start of the individual home-based IAMT sessions. These tests were completed four times throughout the study (pre-baseline, post-baseline, post-treatment, follow-up) and took place at the Health & Human Performance Laboratory, Elborn College, Western University. Follow-up tests took place four weeks after the end of the last treatment session. All laboratory tests were scheduled to start between 10:30 and 11 am to maintain consistency with medication schedule and IAMT sessions. Gait parameters were measured on an instrumented GAITRite mat system (Inc, 2013) and beat perception and production were assessed using the Beat Alignment Test (BAT) (Iversen & Patel, 2008). Each participant underwent a short semi-structured interview before the pre-baseline testing session began during which they were asked two general questions regarding their music preferences; a) What are your favorite songs or artists? b) Do you have any music preferences? This information was later utilized to individualize the session's musical content according to participant's musical preferences. For example, if participants reported enjoying a certain composer, songwriter, and/or musical style, DK incorporated these preferences into the improvised musical content of the sessions. The

incorporation of participant's musical preference is a standard procedure in MT interventions in order to maximize participant's enjoyment, engagement, and emotional connection (Aldridge, 1993; Craig, 2013).

2.4.1. Gait test

The gait test was performed using a GAITRite System. The GAITRite System consists of a 20-foot computerized sensor walkway that measures both temporal (timing) and spatial (two-dimension geometric position) gait parameters. The spatial and temporal parameters of gait that were measured included walking speed (velocity), stride length, step time variability and stride length variability, all of which were captured as participants ambulated across the walkway. For the current investigation, participants were instructed to complete a series of five walking trials in which they were asked to walk the length of the mat at a comfortable pace, turn and walk back. The GAITRite System has been reported to be a valid and reliable tool for measuring gait in both healthy adults and individuals with PD (Chien et al., 2006; McDonough, Batavia, Chen, Kwon, & Ziai, 2001; A. J. Nelson et al., 2002). The GAITRite software transforms raw pressure sensor data into spatiotemporal gait parameters, and quantifies variability by way of calculating the coefficient of variation (CoV) using the formula [(SD/mean) x 100].

2.4.2. Beat Alignment Test

The BAT is a standardized test aimed at quantifying the musical beat perception and synchronization abilities in the general population. The BAT was implemented on a laptop with noise cancelling headphones to reduce auditory feedback from the self-generated sound of the finger taps. The following beat perception and production tasks of the BAT were tested; a) perceptual test of beat perception in musical passages, and b) synchronization to musical passages test. The BAT requires participants to judge whether or not beeps superimposed on

musical excerpts were on the beat in the perceptual test, and requires participants to tap in synchrony with the beat of music in the production test. Thus, the BAT was designed to allow the possibility of dissociation between perceptual and motor aspects of beat processing (Miyazaki, Hiraga, Adachi, Nakajima, & Tsuzaki, 2008). The BAT uses the same set of musical instrumental excerpts from pop, orchestral, jazz, and rock songs in both the perception and production tasks. In the perceptual test, participants hear 17 excerpts with a series of regular beeps superimposed. Participants decide whether metronome beeps superimposed over the music excerpts were correctly aligned with the perceptual beat of that clip (the superimposed beeps are either on or off the beat). The beeps may coincide with the beat (aligned condition N=4), may be at the wrong rate (period error condition N=8), or may be at the correct rate, but consistently just before or just after the actual beat (phase error condition N=5). The tempo of the musical pieces varied between 85 and 165 beats per minute. Six of the musical pieces were in duple meter while three items (one from each genre) were in triple meter. Participants pressed the 'Y' key if the beep was perceived to be *on* the beat of the music, and the 'N' key if it was not. Participants then rated how certain they felt about their answer: 3 = very certain, 2 = somewhat certain, and 1 = guessing. Participants completed three practice trials and 17 test trials. For further information regarding the musical excerpts, procedures, or analysis, please see Miyazaki et al. (2008).

The second part of the BAT assesses participants' ability to tap with the beat of music (production). For this task, participants listened to each excerpt (with no superimposed beeps) two times (in a row) and were instructed to tap the spacebar to the perceived beat. Tap times were collected and the accuracy and variability of synchronization were measured (Fujii & Schlaug, 2013). Instructions for each test were presented visually to each participant, and read from the screen for them prior to beginning the test as to ensure that all participants understood

the nature of the test that they were about to undertake. Each music clip was followed by a familiarity rating: 1 = never heard it, 2 = somewhat familiar, and 3 = very familiar. Participants were allowed to ask questions during the practice trials of each test, but were explicitly told to remain silent during the testing period. BAT instructions are included in Appendix A.

In the perceptual test, scores are calculated as the percentage of correct answers from all 17 trials. In the production test, three outcome measures are identified, the Coefficient of Variability (CoV), Coefficient of Deviation trial by trial (CDEV-T), and Asynchrony. CoV is a measure of the steadiness of an individual's tapping (how variable the taps are, but does not take into account whether the taps are synchronized with the stimulus). CoV is calculated by dividing the SD of the intertap interval (ITI) by the average ITI ($CoV = SD_{ITI}/MEAN_{ITI}$). All values are then averaged across trials. CDEV-T measures how close each ITI is to the nearest interbeat interval (IBI) in the stimulus, (taking the difference between each ITI and the corresponding IBI). CDEV-T is calculated by taking the average of the absolute difference between the participant's tap times and the beat time and dividing that value by the average of the participant's tap times. Thus, each intertap interval in the trial is subtracted from the nearest corresponding IBI in the music, then the absolute value of the difference is taken. These differences are averaged across a trial, and divided by the average ITI on that trial, yielding a single value per trial. Therefore, $CDEV\text{-}T = MEAN_{ABS(ITI-IBI)}/MEAN_{ITI}$. All values are then averaged across trials.

Asynchrony indicates a phase error, that is, the number of milliseconds that the participant tapped before or after the beat. All the above statistical measures take into account the difference between the participant's tap times and music's beat times. Asynchrony scores are measured by taking tap times of the participant and comparing them with the closest beat times.

Participant's cumulative tap times and the cumulative beat times are then calculated. The absolute difference between the participant's cumulative tap times and the cumulative beat times is calculated by taking the average of the absolute difference between the participant's accumulative tap times and the accumulative beat time and dividing that value by the average of the participant's tap times ($ASYNCHRONY = MEAN_{ABS(TAP-BEAT)}/MEAN_{ITI}$). All values are then averaged across trials.

2.5. Data Collection Timeline

After the semi-structured interview, participants underwent laboratory-based pre-baseline gait and BAT testing as described above. Participants returned to the lab to complete the gait and BAT tests immediately after completing the individual home-based IAMT baseline sessions (post-baseline), and after completing the treatment sessions (post-treatment). An optional follow-up gait and BAT test session was also performed four weeks after the IAMT treatment sessions concluded. The pre-baseline gait testing identified participant's baseline gait parameters. Post-baseline gait testing served to identify whether low-moderate density of syncopation impacted gait, as comparisons were drawn between post-baseline and pre-baseline scores. Post-treatment gait testing served to identify whether moderate-high density of syncopation impacted gait performance, as comparisons were drawn between post-treatment and post-baseline scores. Similarly, the completion of the BAT at the various time points served to identify if improvements in participants' beat perception and production abilities occurred over the course of the study. Finally, follow-up gait and BAT testing provided information about whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Figure 2 shows the outline of the data collection timeline of the methodology.

Figure 2. The data collection timeline including gait and BAT tests throughout the study, as well as the amount of weeks of staggered baseline condition, the amount of weeks of treatment condition, and the amount of weeks of follow up

2.6. Home-Based Music Therapy Sessions

2.6.1. Instructions to participants

At the onset of the study, participants were informed that the research would investigate motor skill improvements through participant's active music playing and that the overall idea was for them to play music with DK. Participants were informed of the length of the sessions as well as their ability to request breaks throughout to avoid pain or fatigue. Furthermore, participants were advised that playing on the drum-set can be a challenging task because it requires the incorporation and synchronization of all limbs. Thus, participants were encouraged to incorporate all limbs if and whenever possible, reassuring that there were no musical expectations from them. Moreover, participants were told that playing on the drum-set is similar to that of other exercise programs, in that it requires some level of effort from them. Participants

were encouraged and instructed to follow along the music that is being played by DK, but they were also reminded to play as they feel or want at any moment. Providing loose instructions required participants' personal interpretation of the task at hand, allowing for later analysis of the different ways participants decided to play the drum-set. During the first baseline session, or as requested by participants, a simple demonstration of the different sounds that each drum-set part produces was offered. Also, as requested, a simple demonstration of the different possible simple patterns to play on the drum-set was provided. For example, alternating foot pedals, alternating left foot pedal and right pad, or both feet or hands at the same time. Participants were encouraged to explore the drum-set and to find patterns to include in their improvised music. Participants played with two drumsticks, one in each hand. A simple technique demonstration on how to properly hold the drum sticks for maximal control was also provided (Marucci, 2010).

2.6.2. Musical content of improvisation

The music styles utilized within the IAMT sessions included pop, jazz, rock, rock and roll, folk, Flamenco, and Argentinean folklore music. DK purposefully created rhythmic structures intended to establish a clear music meter, generally 4/4, as a means to facilitate participant's entrainment. Rhythmic phrases within the rhythmic structures created by DK consisted of one or two measures in length. These rhythmic structures were maintained in blocks of 2-3 minutes. This allowed DK to assess whether participants were able to synchronize to the beat or to the rhythmic structure before switching to a different rhythmic structure. Once participants became accustomed to the rhythmic structure or in order to maintain their attention, the density of syncopation was altered.

While improvisation can be described as the process by which one spontaneously creates "new" music, the material does not rely on pre-composed music. Extemporization, on the other

hand, is to improvise on some existing composed music material (Randel, 2003). Thus, during sessions, the improvisation not only contained new creative music material based in the aforementioned music genres, but also incorporated several familiar pieces of music in which DK extemporized on. These were: “You Are My Sunshine”, “Pack Up Your Troubles in Your Old Kit-Bag, and Smile, Smile, Smile”, “My Bonnie Lies Over the Ocean”, “Hound Dog”, “Hey Jude”, and “Shake, Rattle and Roll”. The extemporization of these songs focused on maintaining the aforementioned rhythmic structures throughout the songs (same in length, between 2-3 minutes). For example, after establishing a 4/4 metric simple rhythmic sequence of 312211114 (with numbers denoting relative lengths of intervals in the rhythm, and 1 corresponding to the quarter note), DK would sing the song “You Are My Sunshine” maintaining this specific rhythmic structure throughout the entire song. This provided familiarity within the improvisation while maintaining the rhythmic structure. When singing, DK’s voice was purposely not prominent in the improvisation to avoid the influence of the rhythmic structure within the melody line (singing). For example, the song “Hound Dog” contains moderate-high syncopated rhythms in the melody line that can interfere with the controlled experiment, especially during baseline conditions where the rhythmic structure of the improvisation should only contain low-moderate density of syncopation. Therefore, the utilization of voice was carefully administered by regulating for dynamics (loudness), duration, and frequency of its use throughout the sessions.

2.7. Data Acquisition of IAMT Sessions (Music Measures)

To determine participant’s ability to incorporate density of syncopation into their music playing, the music content was transformed into digital music data in real time using MIDI, recorded on software (Logic Pro X 10.2) installed on a laptop (Apple MacBook Pro) that was connected to the drum-kit. MIDI automatically displayed the music played by participants and

DK into the recording music software, carrying event messages that specified parameters such as note count (each drum-set part is designated its own note), velocity (striking force), note ON and Note OFF messages (equivalent to down stroke and up stroke release events in msec) for asynchrony measures, in both music notation and numerical binary code (Glatt, 2004). The digital music data of every session provided the necessary information to process the following seven measures: 1) density of syncopation played by participants, 2) density of syncopation played by DK, 3) note count, 4) velocity, 5) asynchrony, 6) notes ON beat, 7) notes OFF beat. While density of syncopation was the primary variable of interest, the relationship between the other music measures was considered important to capture as they provide context regarding acquisition of rhythmic complexity levels and the overall music behaviour presented by participants.

2.7.1. Density of syncopation data acquisition

MIDI has widely been used as the standard for controlling communication between electronic musical instruments and computers (Tanaka & Ishida, 1993). Although many attempts have been done to produce an acceptable automated music notation with MIDI from a music performance (Cemgil & Kappen, 2002; Grohganz, Clausen, & Müller, 2014), the task becomes increasingly difficult in the presence of musical expression (i.e., systematic variations in timing of notes and in tempo). For example, musician(s) tend to play accelerando (to accelerate), ritardando (to slow down), or rubato (to use expressive rhythmic freedom by a slight speeding up and then slowing down of the tempo of a piece) (Randel, 2003) during unconstrained performance conditions. Thus, under unconstrained performance conditions, automated music notation with MIDI is inaccurate and remains an unsolved engineering problem (Moore, 1988). The consequence of this is that in order for the music software to accurately display the content

of the music, users are required and restricted to play along with a fixed metronome and without temporal expression (Cemgil, Desain, & Kappen, 2000). Therefore, using an in-ear headphone, DK listened to the click track (recording metronome) of the music software throughout the session. The recording metronome tempo was set at 120 bmp during baseline and at 110 bpm during treatment conditions (interbeat interval of 500 and 545 msec, respectively), which falls within the optimal perception and production of rhythmic tempo in human perception, which is typically between 100 bpm and 120 bpm (500-600 msec) (Moelants, 2002; Parncutt, 1994; Repp, Windsor, & Desain, 2002). The difference in the metronome tempo between baseline and treatment conditions allowed for the manipulation of the density of syncopation with more ease. During baseline, the tempo was required to be faster in order to entrain participants with simple down beat guitar strum rhythms. During treatment, on the other hand, the incorporation of moderate-high density of syncopation required the utilization of slower tempo to accommodate for the increased number of notes as a result of the increasing complexity of the subdivisions of the rhythmic structure. The task of improvising with high density of syncopation became more difficult at 120 bpm metronome tempo than 110 bpm. This conclusion was formulated by DK by first exploring tempo changes in the beginning of each condition with participants P1 and P3 (first participants to enter the experiment) until reaching an optimal tempo that promote entrainment (based on DK's expertise as music therapist). The first participant entering the study was P3. Metronome changes for P3 during baseline: session 1 (100 bpm), session 2 (100 bpm), session 3 (100 bpm), session 4 (110 bpm), session 5 (110 bpm), session 6 (112 bpm), and treatment session 7 (120 bpm) until reaching the finalized tempo on session 8 (110 bpm). P1 entered the study a few sessions after P3. Metronome changes for P1 during baseline: session 1 (108 bpm), session 2 (112 bpm), session 3 (115 bpm) until reaching the finalized tempo on

session 4 (120 bpm). All other sessions were recorded as aforementioned, 120 bpm during baseline and at 110 bpm during treatment conditions.

2.7.2. Note count data acquisition

The note count feature in MIDI automatically displayed the total number of notes in the track for all the tracks of the session (i.e., drum-set parts and guitar) in the music software's Piano Roll view (see Figure 3). The notes in the Piano Roll view are displayed in the independent tracks as colored bars in a time grid. On the grid, a note's horizontal axis indicates time, while its vertical axis indicates its pitch. A keyboard graphic along the left edge of the Piano Roll view provides an easy guide to the pitches of notes. Each drum-set part is automatically designated a different pitch. Figure 3 shows a portion of Piano Roll view of an example trial session. The right drum pedal is assigned to note C1 (Kick), left drum pedal is assigned G#1 (Hi-Hat Foot Close), right drum pad is assigned G1 (Low Tom), left drum pad is assigned two notes, depending on the striking section (two sensors), to D1 and E1 (Snare Center and Snare Rimshot respectively). Whenever the rim of the left pad is struck, the note displayed is E1, and whenever the center of the left pad is struck, the note displayed is D1. These two striking sections of the left pad provide different sounds as they are struck. Similarly, the cymbal is assigned two notes, D#2 and F2 (Ring Out and Ride Bell respectively) depending on the striking section of the cymbal pad. Whenever the edge of the cymbal is struck, the note displayed is D#2, and whenever the center of the cymbal is struck, the note displayed is F2.

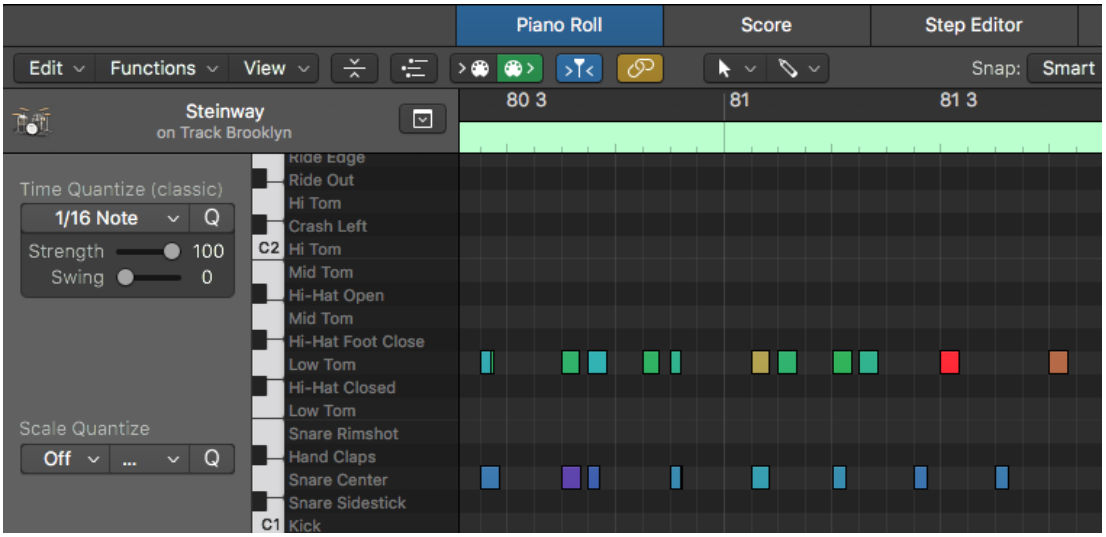

Figure 3. Sample Piano Roll view displaying drum-set notes on a grid played during a trial session.

2.7.3. Velocity data acquisition

Among the digitally transferred data obtained from MIDI, the velocity of notes was also collected, processed, and analyzed. The velocity of each note played is indicated on a scale of sound loudness, from 1 to 127, measuring how fast the drum is struck (striking force). Individual notes are displayed as colored bars varying in intensity of color with tone intensity. An example can be found in note G1track (Low Tom) on Figure 3. The higher the MIDI velocity value, the more the blue of soft tones turns into red. Furthermore, by clicking on a colored note bars, its velocity, in numerical symbol is shown.

MIDI velocity measurement has been identified in previous literature on hand rehabilitation as a reliable parameter for measuring finger strength (Chong et al., 2014; Goebl & Palmer, 2008; Salmon & Newmark, 1989). Although MIDI velocity is an indicator of dynamic level, loudness, or striking force, MIDI does not specify exactly how velocity should be interpreted. The velocity measure from 1 to 127 does not directly translate to any other type of

velocity or force unit, nor are they comparable across different instruments (Dannenberg, 2006). Nonetheless, it provides an objective metric to quantify striking force.

2.7.4. Asynchrony data acquisition

Asynchrony (also called synchronization error) is the basic data in any sensorimotor synchronization study using tapping as the response (Repp, 2005). Asynchrony is defined as the difference between the time of a tap and the time of the corresponding event onset in the external rhythm. In the Piano Roll view, timing deviations are displayed against the timing grid. For example, a note occurring too early is displaced leftwards and a note occurring too late is displaced rightward from the corresponding timing grid.

The tempo of the external rhythm is usually measured in terms of interonset interval (Repp & Su, 2013). Researchers have previously noted that taps tend to precede the onset of external rhythm events by a few tens of milliseconds, rather than being distributed symmetrically around the tone interonset interval (Repp & Su, 2013). This anticipation tendency has been named the negative mean asynchrony and it is found in most sensorimotor synchronization studies in the literature (Repp, 2005). For example, Repp (2005) demonstrated that musically trained participants showed a smaller negative mean asynchrony than do college students participants in tapping synchrony task with tones. Asynchrony measurement from MIDI has been identified in previous literature on sensorimotor synchronization as a reliable parameter (Keller & Appel, 2010; Snyder, Hannon, Large, & Christiansen, 2006).

2.7.5. Notes ON vs OFF beat data acquisition

Among the digitally transferred data obtained by MIDI, the amount of notes played by participants' ON the beat and notes played OFF the beat was calculated. Note, these are not the

MIDI note events of note ON and note OFF. Instead, this measure represents the amount of notes played by participants ON the beat versus the amount of notes played OFF the beat.

2.8. Data Processing of IAMT Sessions (Music Measures)

Whilst it is possible to identify the music measures of each independent drum-set part, it is not possible to identify whether the pad or cymbal was struck with the right or left upper extremity (UE). It was possible, however, to identify whether the right foot (RF) or left foot (LF) was played since participant's feet position was fixed during the entire session and therefore there was no possibility for a cross over to occur (i.e., pressing the right pedal with the left foot or vice versa). UE combined the sum of both drum pads and cymbal. The availability of these music measurements through MIDI is semi-automatic with the exception of density of syncopation. Processing density of syncopation required a programming language software (detailed below) to obtain measurements, therefore, due to its complexity, it was not divided by extremity.

2.8.1. Density of syncopation data processing

After being recorded on Logic Pro X 10.2., the drum-set track (i.e., participants' data from playing on the drum-set) and the guitar track (i.e., DK's data from playing on the guitar) were exported separately from the music software as MusicXML. MusicXML format is designed to be a universal translator for programs that understand common Western musical notation (Good & Actor, 2003). The MusicXML file was then loaded and processed through a software called Humdrum Toolkit (Huron, 1994). Detail description of Humdrum Toolkit can be found in Huron (2002). David Huron created the software in the 1980s in Python, a well-established programming language, to facilitate musical analysis in the musicology field (Cook, 2004). This program detects specific inner mechanisms of music and important trends by searching and

analyzing different aspects of music (Jan, 2004). A special-purpose computer script (see Appendix B) was written to identify syncopation rhythmic moments within a MusicXML file. For more information regarding the definition of syncopated moments see Huron and Ommen (2006).

For the purpose of this study, the Humdrum Toolkit was assigned to detect syncopation moments according to the beat resolution of sixteenth notes (see 4). The Humdrum Toolkit distinguishes single syncopation rhythmic moment at the beat level. On every beat, the Humdrum Toolkit can identify up to two syncopation moments. The first syncopation moment is identified when the downbeat note is missing (first sixteenth rest), and the second sixteenth note is present (see Figure 5.a). Another single syncopation moment is identified by the Humdrum Toolkit when the upbeat note is missing (third sixteenth rest), and the fourth sixteenth note is present (see Figure 5.b). Lastly, the Humdrum Toolkit identify two syncopation moments in a single beat, when both, the downbeat and the upbeat notes are missing, and are followed by a sixteenth note (see Figure 5.c). The density of syncopation measure derives from adding the total number of syncopation moments identified by the Humdrum Toolkit, over the total number of beats contained in the entire IAMT session.

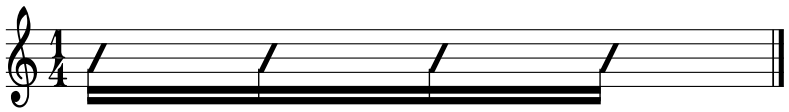

Figure 4. Sixteenth notes resolution assigned to Humdrum Toolkit

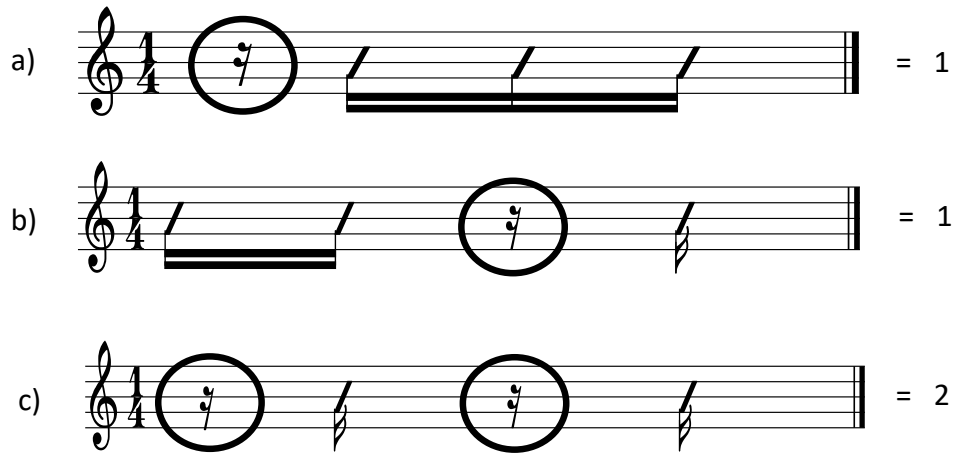

Figure 5. Examples of syncopation moments identified by Humdrum Toolkit at the beat level

2.8.2. Note count data processing

Note count was extracted directly from the music software Piano Roll view and tabulated using Excel software. The total amount of notes played by participants was identified as well as, the total amount of notes played with EU, the total amount of notes played with LF, and the total amount of notes played RF in each session.

2.8.3. Velocity data processing

Each MIDI file was first converted to a text file using the MF2T program (van Oostrum, 1995) and then extracted and tabulated using Excel software. In general, MIDI Channel 10 is reserved for percussion sets. The list of 47 possible percussion instruments is assigned to each MIDI note number. For example, acoustic bass drum corresponds to note number 35, while open triangle corresponds to note number 81 (#60, high bongo is the key for middle-C). The numbers are assigned according to sound (pitch), where lower pitch instrument (from the many sounds available in MIDI) are assigned to lower numbers and higher pitch instruments are assigned to higher numbers. The right drum pedal was assigned to number 36, left drum pedal was assigned

44, right drum pad was assigned 43, left drum pad was assigned two numbers 38 and 40, depending on the striking section. Whenever the rim of the left pad was struck, the number displayed was 40, and whenever the center of the left pad was struck, the number displayed was 38. Similarly, the cymbal was assigned two numbers 51 and 53. Whenever the edge of the cymbal was struck, the number displayed was 51, and whenever the center of the cymbal was struck, the number displayed was 53. The mean and standard deviation of the velocity of the all notes played by participants were identified as well as the mean and standard deviation of the velocity of notes played by participants with UE, with LF, and with RF.

2.8.4. Asynchrony data processing

Each MIDI file was converted to a text file using the MF2T program (van Oostrum, 1995), and then tabulated and processed using Excel worksheet. Participants' notes played OFF beat were filtered and erased from the matrix. The asynchrony calculation employed an algorithm which subtracts the difference between participants' notes played ON beat and each metronome onset distance (heard only by DK while playing the guitar) (Elliott, Welchman, & Wing, 2009).

One caveat regarding the exportation of MIDI data is that MIDI time duration events are not recorded in milliseconds, but rather in tick units. A MIDI tick is a subdivision of a beat; in the study described herein, the greatest temporal precision used was 480 ticks per beat or quarter-note. A tempo of 120 bpm implies that a metronome's interval is 500 msec and a tempo 110 bmp implies that the metronome's interval is 545.45 msec (Collyer, Boatright-Horowitz, & Hooper, 1997). Therefore, conversion from MIDI ticks to milliseconds was calculated by dividing 500/480 (metronome interval speed/ticks per beat). The result indicates 1.04 msec per tick duration during baseline condition and 545.45/480 = 1.13 msec per tick duration during

treatment condition. The mean asynchrony that resulted from the average of all distances in ticks was subsequently converted into milliseconds. Similarly, the asynchrony standard deviation was also calculated, converted, and utilized as an index of stability (Repp & Su, 2013). The temporal resolution of a MIDI system is limited to approximately 1 msec (Collyer et al., 1997).

The data was extracted and tabulated using Excel software to calculate the total mean and standard deviation asynchrony as well as, the mean and standard deviation asynchrony played by participants with UE, with LF, and with RF.

2.8.5. Notes ON vs OFF beat data processing

Processing asynchrony required the differentiation between notes played by participants ON vs OFF beat. Using Excel worksheet, these scores were tabulated and processed. The total score of all notes played by participants ON and OFF beat were identified.

2.9. Data Analysis

Visual inspection has been the traditional method of data analysis for single-subject designs (Fisch, 1998) and was the method used to analyze graphed, gait parameters, and BAT measures, density of syncopation, note count, velocity, and asynchrony results. To identify the ability of participants to acquire density of syncopation between baseline to treatment conditions (hypothesis (i)), visual inspection of the graphs was employed. The baseline and treatment conditions were separated in the graph by a vertical line to differentiate between the two conditions. Similarly, visual inspection of the graphs was employed to identify whether higher density of syncopation throughout IAMT sessions improves gait performance (hypothesis (ii)) by comparing the pre-baseline, post-baseline, and post-treatment results. The reliability of visual inspection of graphical data has been questioned at times. Interrater agreement using visual inspection has been found to be moderate. Depending on the magnitude of any change associated

with the level, trend, and variability of the data path within and across conditions, visual inspection can be straightforward, but at other times it may be more difficult to differentiate. For example, Danov and Symons (2008) results showed relatively moderate interrater agreement (0.63) among raters when using visual inspection. In response, some researchers suggested the use of celeration lines to improve the accuracy and reliability of visual analysis. Yet, researchers have not found significant difference in decision accuracy between charts with celeration lines and charts without celeration lines (Normand & Bailey, 2006; Stocks & Williams, 1995). Although statistical methods have been developed for single-subject designs and some researchers tend to recommend statistical analysis as a supplement for visual analysis in some cases (Brossart, Parker, Olson, & Mahadevan, 2006), none of these analyses were appropriate for the current study. For example, a simple method called time-series analysis (Tryon, 1982) can only be applied with at least eight observations per condition. The current study contains less than eight data points in the baseline condition, excluding the utilization of time-series analysis for this study. Despite this limitations, visual inspection has been the most commonly used method to determine intervention effect and has long been recommended as the only method for evaluating single subject data (Busk & Marascuilo, 2015). A graph of participants' scores on each measure was created using Microsoft Excel to enable visual inspection.

Visual analysis was completed using the four-step process recommended by What Works Clearinghouse (WWC) (Kratochwill et al., 2010). First, the baseline data pattern was analyzed for stability. Baselines were considered stable and predictable if the baseline trend was neutral or in the opposite direction of the expected behavior change. Second, the treatment condition data were examined to identify predictable patterns of the dependent variables. Following this step, the baseline and treatment conditions were compared to determine if density of syncopation

differed between conditions and whether it was associated with any changes in music and outcome measures. Finally, visual analysis integrated all the information from both conditions of the study to determine whether there were at least three demonstrations of a treatment effect at different points in time. To analyze and compare conditions in the four steps listed above, three variables were additionally examined. These variables included the level (i.e., mean), trend (i.e., slope), variability (i.e., range or standard deviation of data) in each phase (Kratochwill et al., 2010).

Finally, correlational analyses amongst all music measurements was performed using Pearson product moment correlation *(r)* statistics displayed in a 6x6 matrix. All statistical analyses were performed using SPSS.

Chapter 3

3. Results

This chapter presents the data collected through the current study in order to address the two research questions. The first research question investigated whether participants' density of syncopation exhibited in their musical responses would increase from baseline to treatment conditions. These changes were measured via MIDI, exported as MusicXML files, and processed through Humdrum Toolkit. The second research question queried whether participants who acquired higher density of syncopation during treatment condition would demonstrate an increase in gait velocity and stride length, and a decrease in step time and stride length variability compared to participants who do not demonstrate higher acquisition of density of syncopation during treatment condition. These changes were measured using a GAITRite System.

All but one participant completed the entire data collection protocol, including the home-based IAMT baseline and treatment sessions, and gait and BAT laboratory tests. P2 completed only six out of the eight weeks of treatment due to vacationing. Furthermore, P2 and P3 were not available for the optional follow-up gait and BAT tests due to personal reasons, unrelated to the study.

Visual analysis results for each participant are discussed for the following music measures (dependent variables): density of syncopation played by participant and density of syncopation played by DK, total note count and note count by extremity, average velocity and average velocity by extremity, total asynchrony and total asynchrony by extremity, and notes played ON vs OFF beat. Visual analysis results for each participant are also discussed for the outcome measures: gait velocity and stride length, and step time and stride length variability (GAITRite System), and beat perception and production (BAT). Discussion of results for each

music and outcome measure is accompanied by figures displaying the multiple-baseline graphs across participants for the baseline and treatment conditions. In addition, descriptive statistics (i.e., mean, range, SD) are presented in tables for each measure.

3.1. IAMT Sessions Results (Music Measures)

3.1.1. Density of syncopation results for DK

The hypothesis predicted that the density of syncopation exhibited in the participant's musical responses would increase from baseline to treatment conditions throughout IAMT sessions. Before testing this hypothesis, the density of syncopation played by DK requires a distinctive difference between baseline and treatment conditions. A specific criterion was utilized for calculating the density of syncopation. The density of syncopation equaled the number of the total syncopated moments over the total amount of beats contained in the entire IAMT session. Table 3 shows the density of syncopation results by DK across conditions. These results are consistent with the control experiment with the exception of P3's baseline sessions (which scores were higher than the other three participants'). On average, DK's density of syncopation in P1, P2, and P4 sessions were higher during treatment than during baseline conditions. DK's density of syncopation in P3, on the other hand, was higher during baseline than during treatment conditions. DK's density of syncopation in P1's sessions was 0.24 (range 0.11 - 0.51) during baseline compared to 0.35 (range 0.22 - 0.46) during treatment condition, an increase of 45.8%. DK's density of syncopation in P2's sessions was 0.11 (range 0.08 - 0.14) during baseline compared to 0.25 (range 0.19 - 0.34) during treatment condition, an increase of 127.3%. DK's density of syncopation in P4's sessions was 0.18 (range 0.12 - 0.35) during baseline compared to 0.3 (range 0.21 - 0.4) during treatment condition, an increase of 66.7%. DK's density of syncopation in P3's sessions, in contrast, was 0.4 (range 0.19 - 0.54) during baseline compared to

0.36 (range 0.25 - 0.5) during treatment condition, a decrease of 10%. Overall, analysis of the changes in DK's density of syncopation scores suggested at least three demonstrations of an increase from baseline to treatment conditions. This suggests that in fact, DK's density of syncopation was low-moderate during baseline and moderate-high during treatment IAMT sessions. The lack of distinction between conditions in P3's baseline sessions and P1's first baseline sessions might have been related to the development and mastering of the baseline condition as described in Chapter 2.

Table 3. *Density of syncopation scores by DK across conditions*

	P1	P2	P3	P4
Baseline 1	0.51	0.09	0.39	0.18
Baseline 2	0.20	0.12	0.48	0.35
Baseline 3	0.14	0.14	0.54	0.13
Baseline 4	0.11	0.08	0.40	0.18
Baseline 5		0.12	0.40	0.21
Baseline 6			0.19	0.14
Baseline 7				0.15
Baseline 8				0.12
Treatment 1	0.30	0.34	0.30	0.27
Treatment 2	0.38	0.21	0.32	0.33
Treatment 3	0.36	0.2	0.29	0.25
Treatment 4	0.46	0.26	0.31	0.36
Treatment 5	0.22	0.26	0.31	0.34
Treatment 6	0.29	0.31	0.29	0.34
Treatment 7	0.35	0.23	0.50	0.34
Treatment 8	0.34	0.24	0.25	0.38
Treatment 9	0.34	0.32	0.42	0.40
Treatment 10	0.44	0.29	0.32	0.33
Treatment 11	0.38	0.19	0.42	0.23
Treatment 12	0.39	0.21	0.42	0.30
Treatment 13	0.40		0.33	0.23
Treatment 14	0.33		0.44	0.21
Treatment 15	0.40		0.40	0.30
Treatment 16	0.35		0.47	0.33
Average Baseline	0.24	0.11	0.40	0.18

Average Treatment	0.35	0.25	0.36	0.30
Total Average	0.33	0.21	0.37	0.26

3.1.2. Density of syncopation results for participants

The hypothesis predicted that the density of syncopation exhibited in the participant's musical responses would increase from baseline to treatment conditions throughout IAMT sessions. Figure 6 shows the patterns of density of syncopation for each participant across baseline and treatment conditions. In accordance with the Single Subject Multiple Baseline Design Across Subjects it was hypothesized that, even though the four baselines vary in length from 2 to 4 weeks, the scores would plateau at a low level (neutral) or would demonstrate a downward trend over baseline (opposite direction of behavior change). The density of syncopation would only be increased and demonstrate an upward trend after treatment condition was introduced. Visual inspection shows this pattern for P1, P2, and P4, but not for P3 during baseline condition. Baseline levels demonstrated a downward trend only for P1 and P2, whereas P4 exhibited a stable trend with higher variability than P1, P2, and P3. P3's baseline levels, in contrast, demonstrated an upward trend, in the opposite direction of the expected level change.

The hypothesis then predicted that the density of syncopation exhibited in the participants' musical responses would increase from baseline to treatment conditions. The results are not consistent with the hypothesis. The density of syncopation initially increased only for P2, whereas remained stable for P1, and decreased for P3 and P4. Furthermore, P1, P2, and P4 demonstrated a slight downward trend, in the opposite direction expected, throughout treatment condition. P3, in contrast, demonstrated a slight upward trend during treatment condition, in the direction expected.

Table 4 shows the density of syncopation results by participant across conditions. These results are not consistent with the hypothesis. On average, P1 and P4 scored a higher density of syncopation during baseline than during treatment conditions. P1 scored 0.23 (range 0.19 - 0.3) during baseline compared to 0.19 (range 0.13 - 0.23) during treatment condition, a decrease of 17.4%. P4 scored 0.28 (range 0.18 - 0.35) during baseline compared to 0.25 (range 0.18 - 0.34) during treatment conditions, a decrease of 10.7%. P2 and P3, in contrast, scored slightly lower density of syncopation during baseline than during treatment conditions. P2 scored 0.19 (range 0.15 - 0.22) during baseline compared to 0.21 (range 0.17 - 0.23) during treatment conditions, an increase of 10.5%. P3 scored 0.28 (range 0.24 - 0.34) during baseline compared to 0.29 (range 0.26 - 0.34) during treatment conditions, an increase of 3.4%. Overall, analysis of changes in density of syncopation scores suggests that one demonstration of a treatment effect was observed across the four participants. This suggests that participants' acquisition of rhythmic complexity did not increase in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation during IAMT sessions.

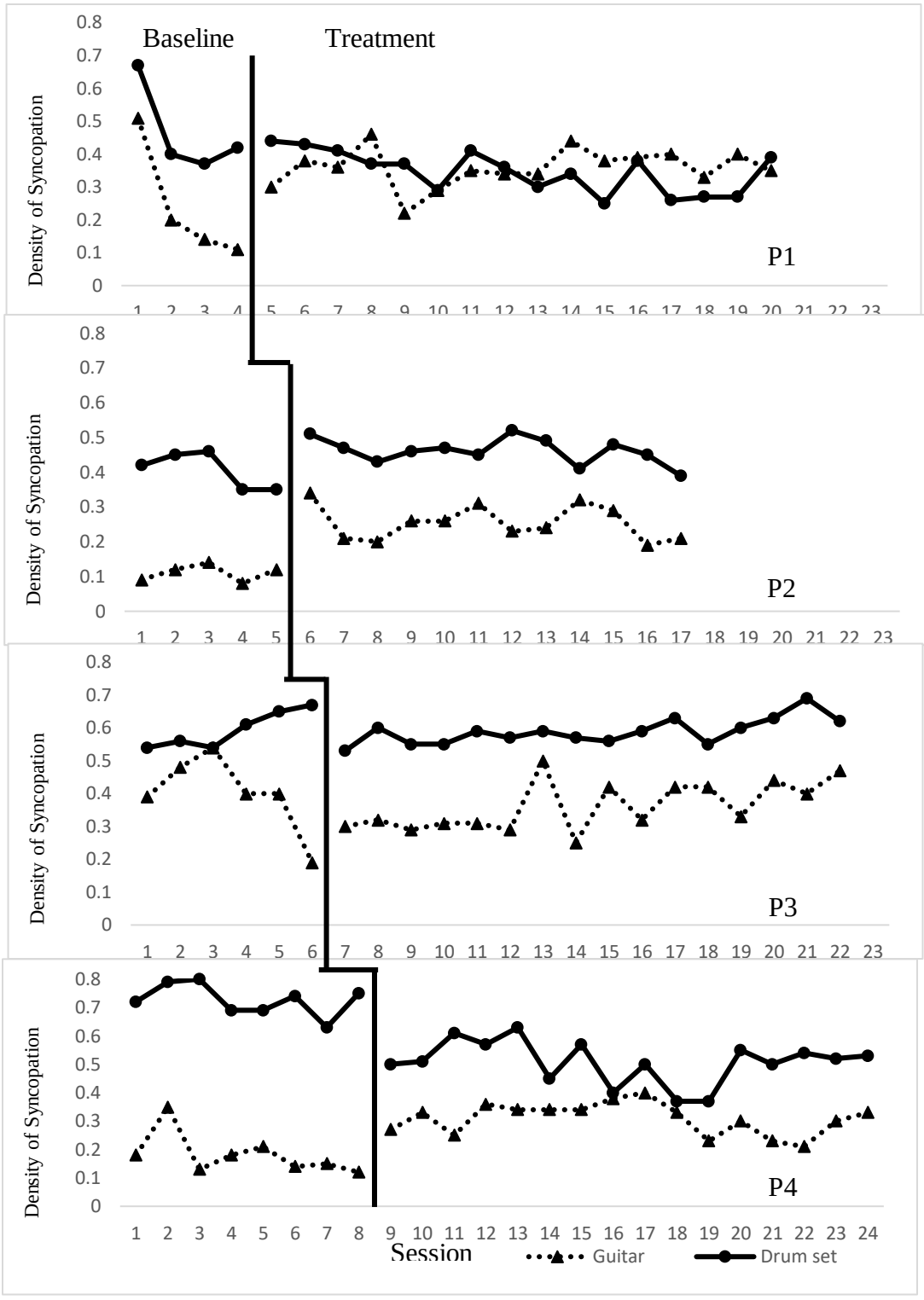

Figure 6. Participants' (drum-set) and DK's (guitar) patterns of density of syncopation across conditions

Table 4. *Density of syncopation scores by participant across conditions*

	P1	P2	P3	P4
Baseline 1	0.67	0.42	0.45	0.72
Baseline 2	0.40	0.45	0.56	0.79
Baseline 3	0.37	0.46	0.54	0.80
Baseline 4	0.42	0.35	0.61	0.69
Baseline 5		0.35	0.65	0.69
Baseline 6			0.67	0.74
Baseline 7				0.63
Baseline 8				0.75
Treatment 1	0.44	0.51	0.53	0.50
Treatment 2	0.43	0.47	0.60	0.51
Treatment 3	0.41	0.43	0.55	0.61
Treatment 4	0.37	0.46	0.55	0.57
Treatment 5	0.37	0.47	0.59	0.63
Treatment 6	0.29	0.45	0.57	0.45
Treatment 7	0.41	0.52	0.59	0.57
Treatment 8	0.36	0.49	0.57	0.40
Treatment 9	0.30	0.41	0.56	0.50
Treatment 10	0.34	0.48	0.59	0.37
Treatment 11	0.25	0.45	0.63	0.37
Treatment 12	0.38	0.39	0.55	0.55
Treatment 13	0.26		0.60	0.50
Treatment 14	0.27		0.63	0.54
Treatment 15	0.27		0.69	0.52
Treatment 16	0.39		0.62	0.53
Average Baseline	0.46	0.40	0.59	0.72
Average Treatment	0.34	0.46	0.58	0.50
Total Average	0.37	0.44	0.59	0.58

3.1.3. Note count results

Note count was extracted directly from the music software Piano Roll view and tabulated using Excel software. Figure 7 shows the patterns of the total note count trend for each participant across conditions. Visual inspection shows that P1, P2, and P4 exhibited an upward trend during baseline condition. In contrast, P3 exhibited a stable trend with high variability across baseline and treatment conditions. P2 demonstrated a considerable increase in scores with

slight upward trend during treatment condition. In contrast, P1, P3, and P4 demonstrated a stable trend during treatment condition. Overall, analysis of changes in note count scores suggest only one demonstration of treatment effect was observed across the four participants. This suggests that participants' note count scores did not increase in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

3.1.3.1. Note count results by extremity.

Figure 8 shows the patterns of the total note count trend by extremity for each participant across conditions. Visual inspection of Figure 8 shows that all participants played more notes with UE across conditions than with LF or RF. Furthermore, P1, P2, and P3 played more notes with RF than with LF across conditions. In contrast, P4 played more notes with LF than with RF across conditions. Moreover, P4's LF note count pattern demonstrated high variability across conditions, as indicated by a range of 3 notes played at the first baseline session to 4093 at the eleventh treatment session (see Appendix F). Similarly, P2 exhibited high variability of note count with RF, but only during treatment condition, as indicated by a range of 234 notes played at the third treatment session to 2788 at the ninth treatment session (see Appendix D). On average, all participants played more notes during treatment condition than during baseline condition, with the exception of P2 and P3, whose LF note count was lower during treatment than during baseline conditions.

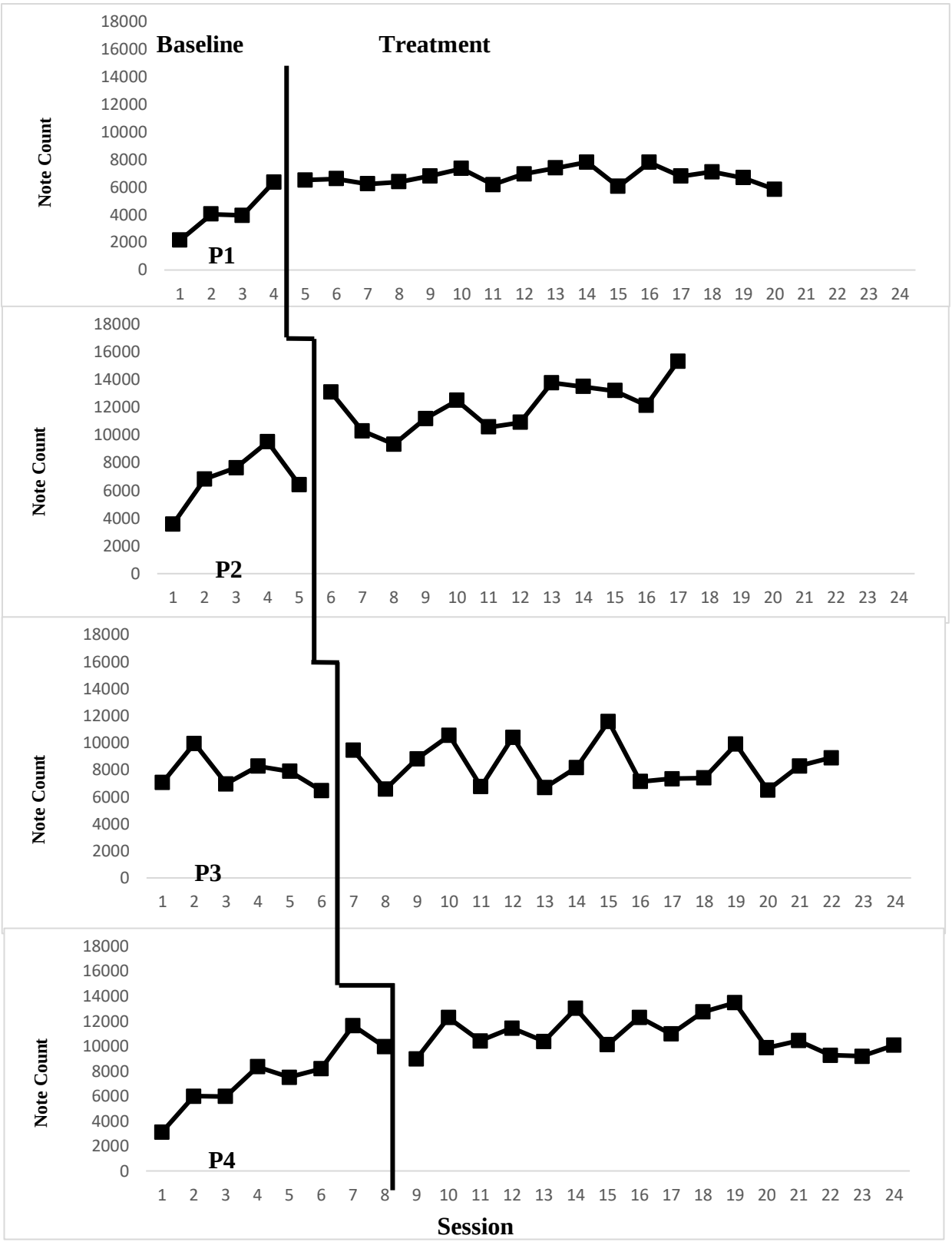

Figure 7. The patterns of note count by participant across conditions

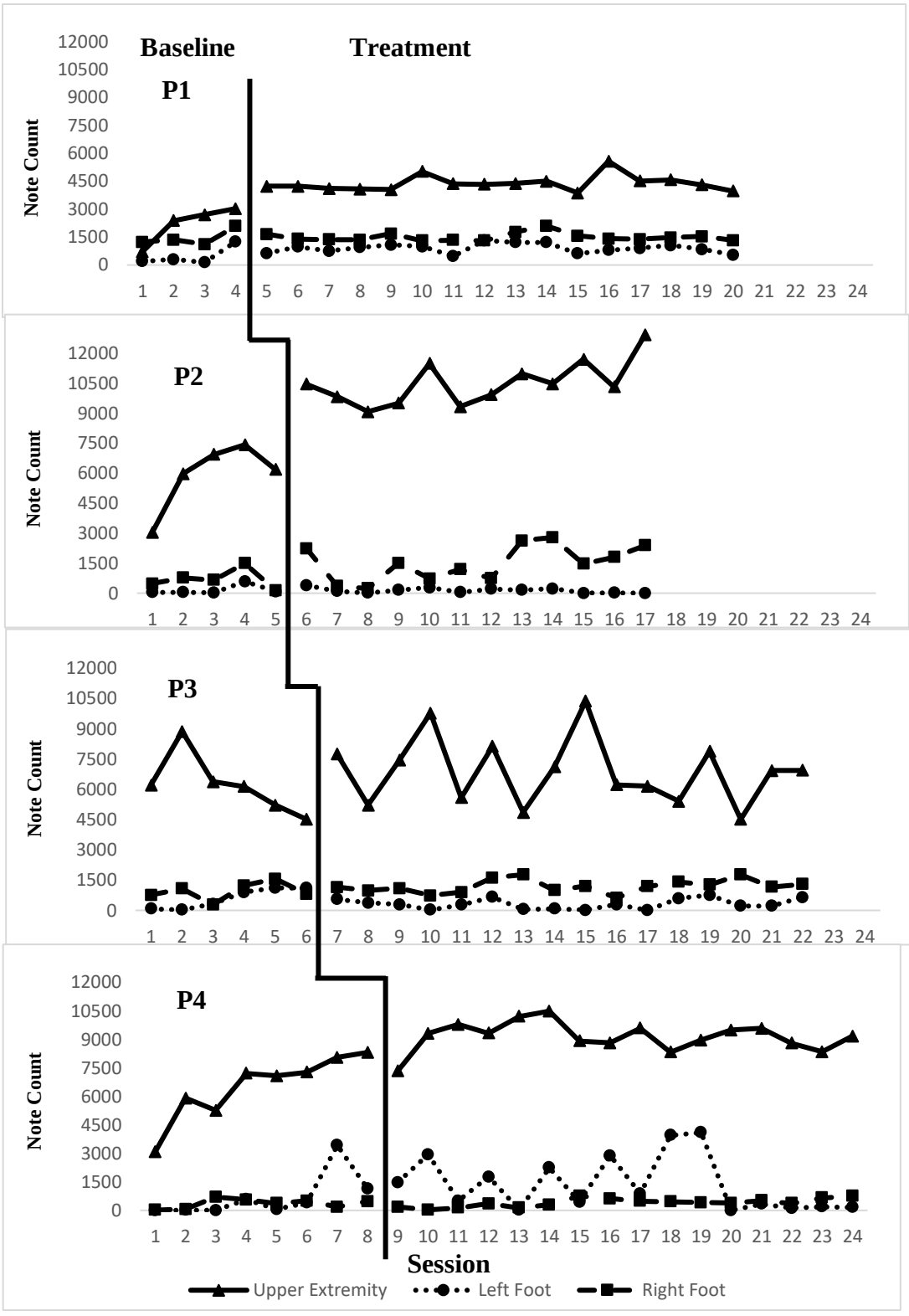

Figure 8. The patterns of note count scores per extremity for each participant across conditions

On average, P1 played 4130 notes (range 2151 - 6373) during baseline and played 6781 notes (range 5848 - 7812) during treatment conditions, an increase of 64%. On average, P1 played 2210 notes (range 717 - 3031) with UE during baseline and played 4384 notes (range 3872 - 5577) with UE during treatment conditions, an increase of 98%. On average, P1 played 475 notes (range 203 - 1258) with LF during baseline and played 900 notes (range 476 - 1325) with LF during treatment conditions, an increase of 90%. On average, P1 played 1446 notes (range 1117 - 2084) with RF during baseline and played 1498 notes (range 132 - 2092) with RF during treatment conditions, an increase of 3.5%. In total (combining baseline and treatment sessions), on average, P1 played 6252 notes per session, 3949 (63%) notes with UE, 815 (13%) notes with LF, and 1487 (24%) notes with RF (see Appendix C).

On average, P2 played 6785 notes (range 3571 - 9504) during baseline and played,12142 notes (range 9335 - 15320) during treatment conditions, an increase of 79%. On average, P2 played 5916 notes (range 3045 - 7424) with UE during baseline and played 10502 notes (range 9082 - 12928) with UE during treatment conditions, an increase of 78%. On average, P2 played 159 notes (range 24 - 587) with LF during baseline and played 134 notes (range 4 - 395) with LF during treatment conditions, a decrease of 16%. On average, P2 played 710 notes (range 140 - 1493) with RF during baseline and played 1506 notes (range 234 - 2788) with RF during treatment conditions, an increase of 112%. In total, on average, P2 played 10567 notes per session, 9153 (87%) notes with UE, 141 (1.3%) notes with LF, and 1271 (12%) notes with RF (see Appendix D).

On average, P3 played 7765 notes (range 6445 - 9966) during baseline and played 8405 notes (range 6500 - 11592) during treatment conditions, an increase of 8.2%. On average, P3 played 6219 notes (range 4519 - 8867) with UE during baseline and played 6890 notes (range

4510 - 10367) with UE during treatment conditions, an increase of 11%. On average, P3 played 590 notes (range 20 - 1117) with LF during baseline and played 317 notes (range 3 - 754) with LF during treatment conditions, a decrease of 46%. On average, P3 played 955 notes (range 272 - 1563) with RF during baseline and played 1197 notes (range 618 - 1766) with RF during treatment conditions, an increase of 25%. In total, on average, P3 played 8230 notes per session, 6707 (82%) notes with UE, 392 (4.8%) notes with LF, and 1131 (14%) notes with RF (see Appendix E).

On average, P4 played 7579 notes (range 3108 - 11635) during baseline and played 10929 notes (range 8986 - 13460) during treatment conditions, an increase of 44%. On average, P4 played 6518 notes (range 3090 - 8309) with UE during baseline and played 9147 notes (range 7335 - 10480) with UE during treatment conditions, an increase of 40%. On average, P4 played 703 notes (range 3 - 3418) with LF during baseline and played 1375 notes (range 0 - 4093) with LF during treatment conditions, an increase of 95%. On average, P4 played 358 notes (range 15 - 702) with RF during baseline and played 407 notes (range 30 - 753) with RF during treatment conditions, an increase of 14%. In total, on average, P4 played 9812 notes per session, 8271 (84%) notes with UE, 1151 (12%) notes with LF, and 391 (4%) notes with RF (see Appendix F).

3.1.3.2. Velocity results.

Visual inspection of Figure 9 shows that P1 and P4 exhibited a stable trend on overall mean velocity scores across baseline and treatment conditions. In contrast, P2 and P3 exhibited an upward trend during baseline condition and a stable trend during treatment condition. All participants scored similar total mean velocity results between baseline and treatment conditions. This suggests that participants' mean velocity trend was not influenced by the presence of low-moderate density of syncopation compared to moderate-high density of syncopation. Yet,

analysis of changes in the trend in velocity scores suggests that two demonstrations of a baseline effect were observed across the four participants, suggesting a possible increase in velocity scores during low-moderate density of syncopation.

3.1.3.3. Velocity results by extremity.

Figure 10 shows participants' mean velocity scores per extremity across conditions. Visual inspection shows that P1 exhibited greater variability across baseline and treatment conditions than P2, P3, and P4. P1 demonstrated a stable trend in UE and RF throughout baseline and treatment condition, but LF exhibited high variability scores, fluctuating over and under the mean scores of UE and RF scores, throughout baseline and treatment condition. P4 and P2 consistently scored higher mean velocity scores with UE than with LF and RF throughout baseline and treatment condition. P4 also exhibited LF variability scores fluctuating between and above the mean scores of UE and RF throughout baseline and treatment condition. P3 exhibited an upward trend in all extremities during baseline condition and a stable trend during treatment condition with little variability amongst extremities during treatment condition. P2 exhibited higher mean scores in UE than lower extremities (LE) throughout baseline and treatment condition, with higher differences during baseline condition. Considering velocity as a measure of the intensity of striking the drum-set, we can infer that on average P1 struck the drum-set with more intensity than P2, P3, and P4. Results suggest that there are not visible differences in mean velocity between the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

When averaged across all extremities, P1, P2, and P4 played with less velocity during treatment than during baseline condition; however, P1 and P4 demonstrated an increase in velocity during treatment with their RF and LF, respectively. P3, in contrast, scored higher mean

velocity during treatment condition with the exception of LF. Analysis of changes in the mean velocity scores suggests one demonstration of a treatment effect was observed across the four participants. This suggests that participants' mean velocity scores did not increase in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

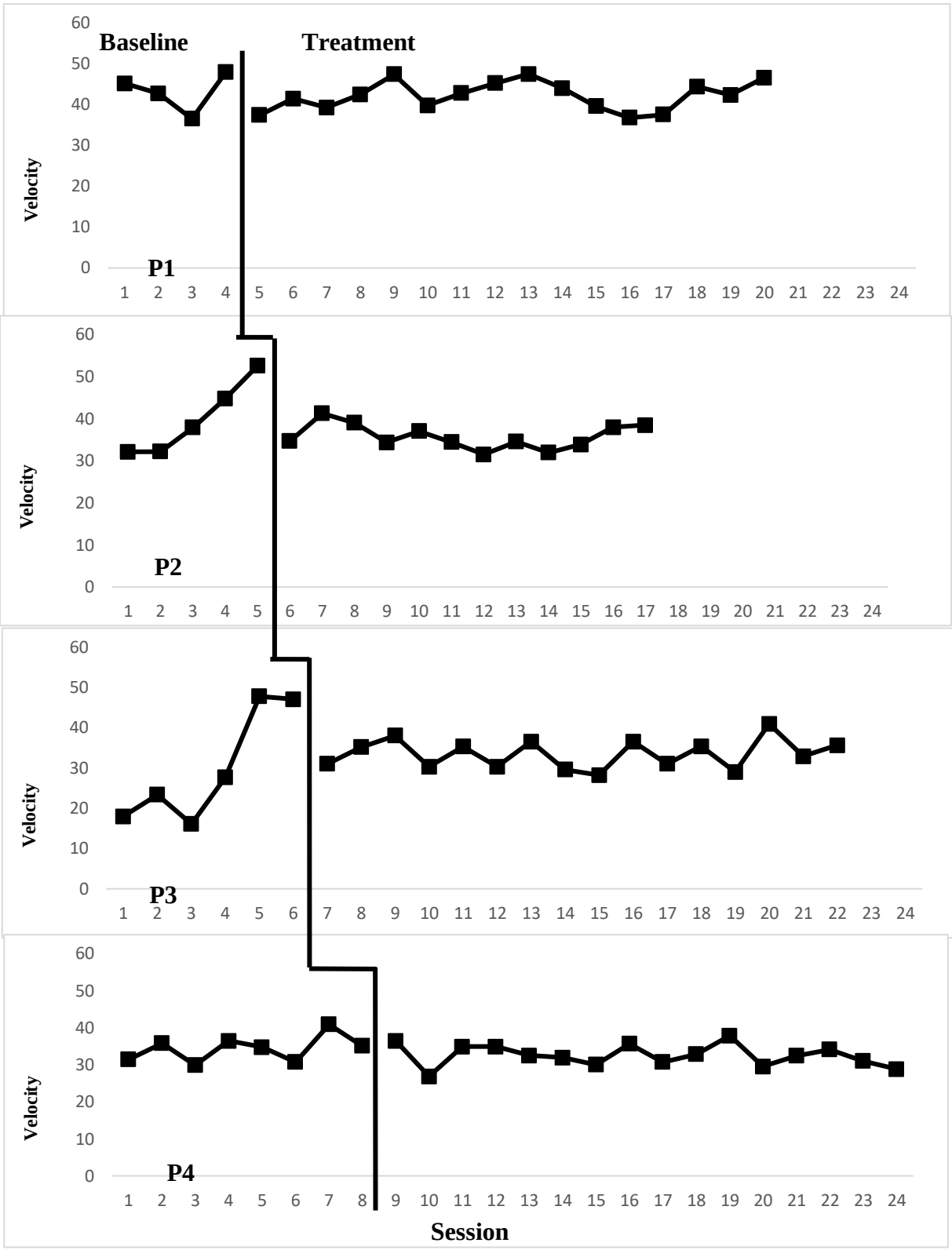

Figure 9. The patterns of mean velocity by participant across conditions

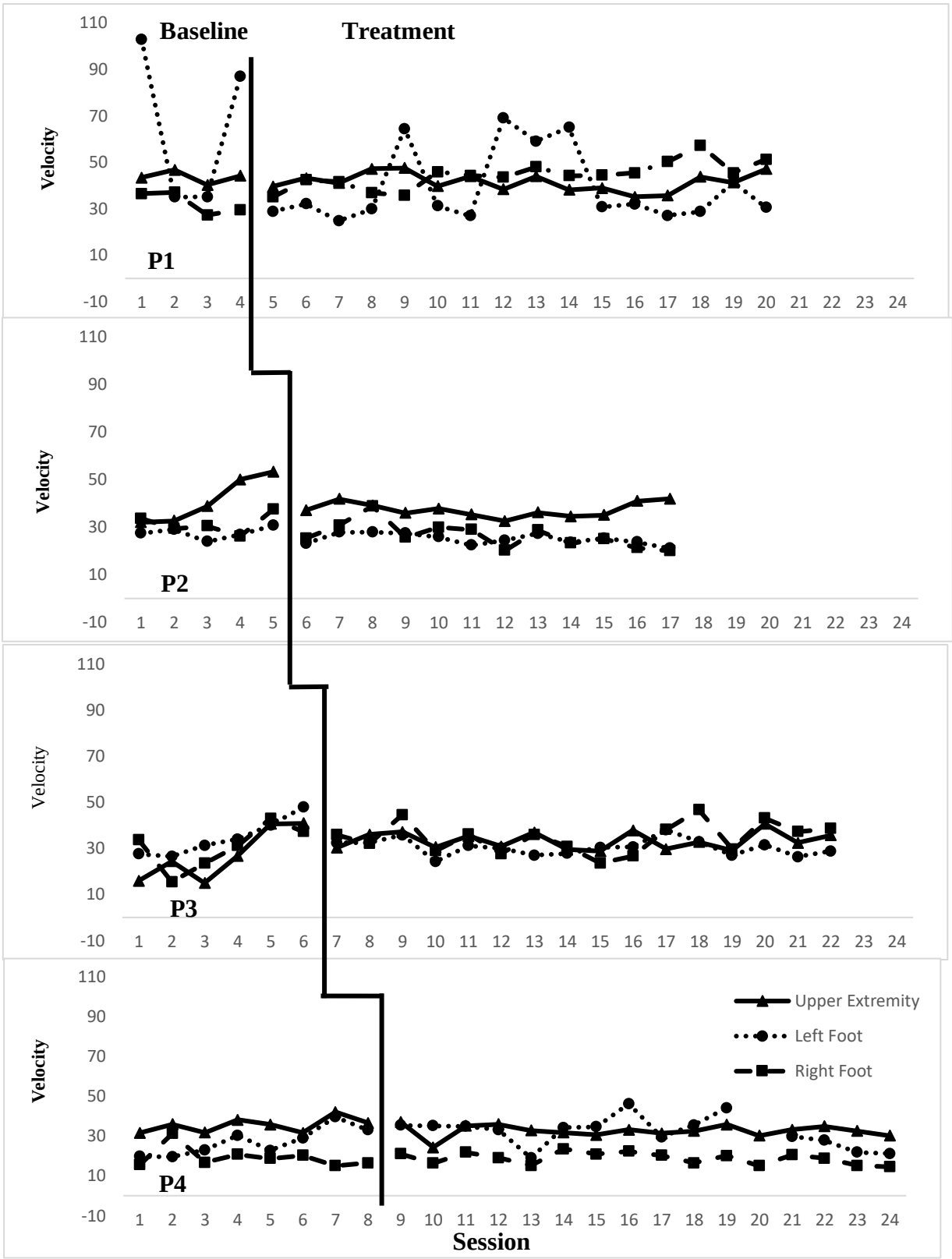

Figure 10. The patterns of mean velocity by participant per extremity across conditions

P1 mean velocity score was 43.04 ± 19.87 (range 36.49 – 47.87) during baseline and mean velocity score was 42.11 ± 17.11 (range 36.75 – 47.45) during treatment conditions, a decrease of 2.2%. P1 UE mean velocity score was 43.66 ± 14.57 (range 40.28 – 46.78) during baseline and UE mean velocity score was 41.55 ± 16.49 (range 35.2 – 47.53) with during treatment conditions, a decrease of 4.8%. P1 LF mean velocity score was 65.01 ± 17.93 (range 35 – 102.92) during baseline and LF mean velocity score was 38.91 ± 15.73 (range 24.81 – 69.07) during treatment conditions, a decrease of 40.1%. P1 RF mean velocity score was 32.62 ± 13.29 (range 27.3 – 37.05) during baseline and RF mean velocity score was 44.5 ± 11.85 (range 35.08 – 57.28) during treatment conditions, an increase of 36.4%. In total (combining baseline and treatment conditions), P1 mean velocity score was 42.3 ± 17.66 per session, 41.98 ± 16.1 with UE, 44.13 ± 16.17 with LF, and 42.12 ± 12.13 with RF (see Appendix G).

P2 mean velocity score was 39.93 ± 19.41 (range 32.15 – 52.59) during baseline and mean velocity score was 35.78 ± 17.48 (range 31.54 – 41.28) during treatment conditions, a decrease of 10.4%. P2 UE mean velocity score was 41.3 ± 19.64 (range 32.01 – 53.24) during baseline and UE mean velocity score was 37.32 ± 17.68 (range 32.55 – 41.92) during treatment conditions, a decrease of 9.6%. P2 LF mean velocity score was 27.54 ± 9.57 (range 23.83 – 30.65) during baseline and LF mean velocity score was 24.98 ± 7.71 (range 21 – 27.89) during treatment conditions, a decrease of 9.3%. P2 RF mean velocity score was 31.38 ± 12.28 (range 26.21 – 37.43) during baseline and RF mean velocity score was 26.47 ± 11.64 (range 19.97 – 38.79) during treatment conditions, a decrease of 15.6%. In total (combining baseline and treatment conditions), P2 mean velocity score was 37 ± 18.05 per session, 38.49 ± 18.26 with UE, 25.73 ± 8.26 with LF, and 27.91 ± 11.83 with RF (see Appendix H).

P3's mean velocity score was 29.97 ± 16.56 (range 16.08 – 47.74) during baseline and mean velocity score was 33.47 ± 16.25 (range 28.22 – 40.92) during treatment conditions, an increase of 11.7%. P3's UE mean velocity score was 27.2 ± 16.27 (range 14.92 – 40.76) during baseline and UE mean velocity score was 33.28 ± 16.44 (range 28.76 – 40.55) during treatment conditions, an increase of 22.3%. P3's LF mean velocity score was 34.5 ± 13.92 (range 26.45 – 47.87) during baseline and LF mean velocity score was 30.35 ± 10.82 (range 24.15 – 38) during treatment conditions, a decrease of 12%. P3's RF mean velocity score was 30.62 ± 13.76 (range 15.4 – 42.97) during baseline and RF mean velocity score was 34.7 ± 15.03 (range 23.58 – 46.62) during treatment conditions, an increase of 13.3%. In total (combining baseline and treatment conditions), P3's mean velocity score was 32.52 ± 16.33 per session, 31.63 ± 16.39 with UE, 31.48 ± 11.66 with LF, and 33.59 ± 14.68 with RF (see Appendix I).

P4's mean velocity score was 34.47 ± 11.88 (range 29.88 – 40.85) during baseline and mean velocity score was 32.53 ± 10.44 (range 26.85 – 37.85) during treatment conditions, a decrease of 5.6%. P4's UE mean velocity score was 35.37 ± 11.22 (range 31.52 – 42.01) during baseline and UE mean velocity score was 32.54 ± 9.74 (range 24.28 – 37.05) during treatment conditions, a decrease of 8%. P4's LF mean velocity score was 27.03 ± 8.27 (range 19.52 – 39.47) during baseline and LF mean velocity score was 32.1 ± 9.18 (range 18.91 – 46.15) during treatment conditions, an increase of 18.8%. P4's RF mean velocity score was 19.27 ± 9.17 (range 15.5 – 31.12) during baseline and RF mean velocity score was 18.77 ± 8.91 (range 14.45 – 23.48) during treatment conditions, a decrease of 2.6%. In total (combining baseline and treatment conditions), P4's mean velocity score was 33.14 ± 10.92 per session, 33.48 ± 10.23 with UE, 30.34 ± 8.86 with LF, and 18.93 ± 8.99 with RF (see Appendix J).

3.1.4. Asynchrony results

The difference between the time of participants' notes ON beat and each corresponding metronome onset (listened to by only DK during the session while playing the guitar) were tabulated on Excel. Visual inspection of Figure 11 shows that P1 and P2 exhibited negative mean asynchrony scores, whereas P3 and P4 exhibited positive mean asynchrony during baseline. Furthermore, P1, P2, and P3 exhibited a stable trend during baseline condition, whereas P3 exhibited a sharp increase on session two and a sharp decreased for the remainder baseline sessions. During the treatment condition, P1 demonstrated a downward trend, whereas P2, P3, and P4 demonstrated a stable trend with high variability. Negative asynchrony suggests that the drum-set was struck preceding the metronome onset, while positive asynchrony can be interpreted as reacting to the music, after the metronome onset. Analysis of changes in asynchrony scores suggest that three demonstrations of a treatment effect was observed across the four participants. This suggests that participants' asynchrony scores increased in variability in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

3.1.4.1. Asynchrony results by extremity.

Figure 12 shows participants' mean asynchrony scores per extremity across conditions. Visual inspection shows that all participants exhibited lower mean asynchrony scores with UE extremity across conditions than LE. P2, P3, and, P4 exhibited high variability scores in LF, fluctuating over and under the UE and RF mean scores throughout baseline and treatment conditions. P1's mean asynchrony scores demonstrated a stable downward trend throughout baseline and treatment conditions with small variability. Analysis of changes in mean asynchrony scores suggest only one demonstration of a treatment effect was observed across the

four participants. This suggests that participants' mean asynchrony with UE scores maintained more stability in the presence of moderate-high and low-moderate density of syncopation compared to LE.

On average, P1 and P3 scored lower mean asynchrony during treatment than during baseline condition in all extremities. P2 and P4, in contrast, scored higher mean asynchrony during treatment than during baseline conditions in all extremities. Analysis of changes in mean asynchrony scores suggest two demonstrations of a treatment effect were observed across the four participants. This suggests inconclusive results as to whether participant's mean asynchrony scores in all extremities decreased or increased in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

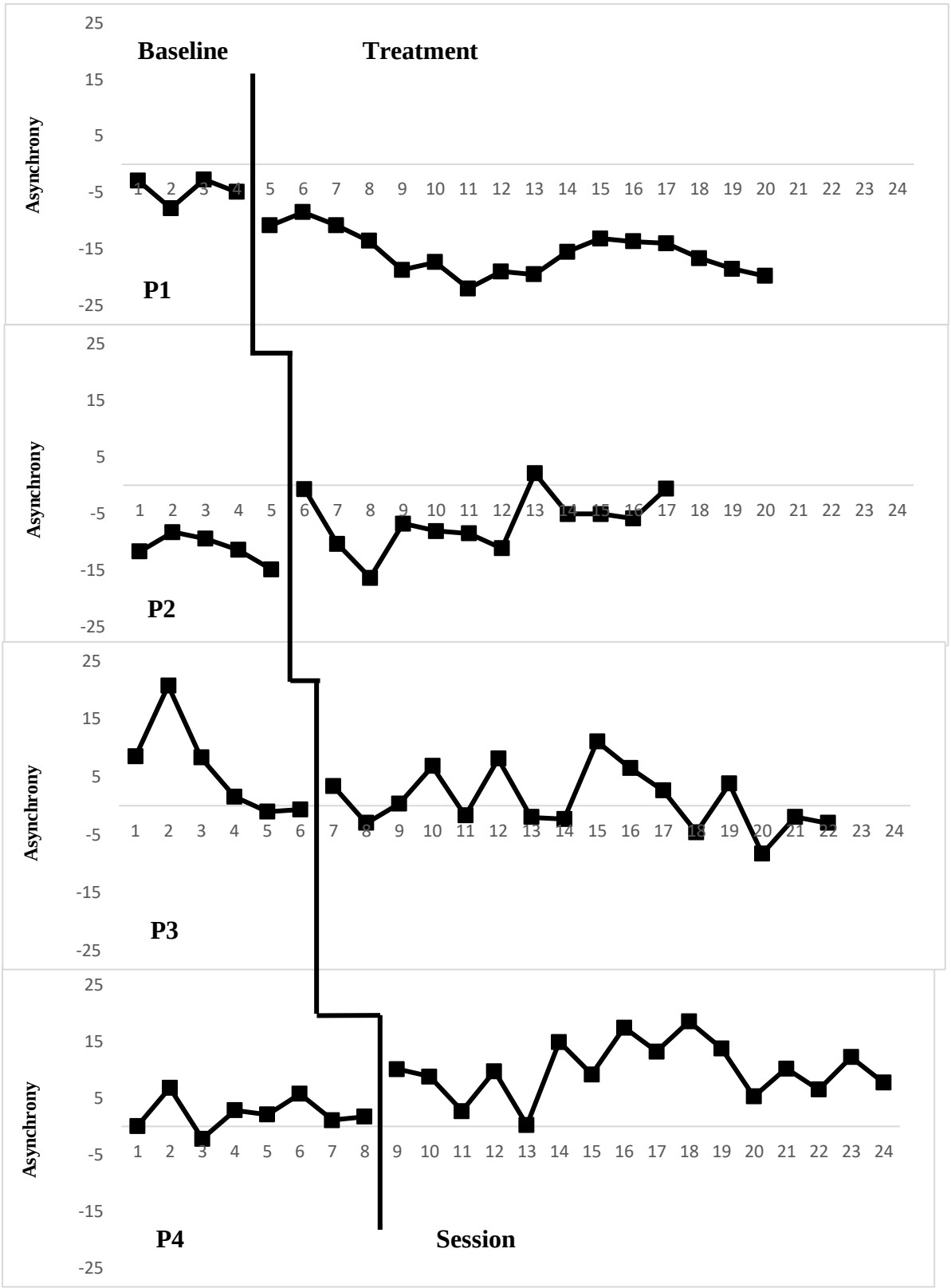

Figure 11. The patterns of mean asynchrony scores by participant across conditions

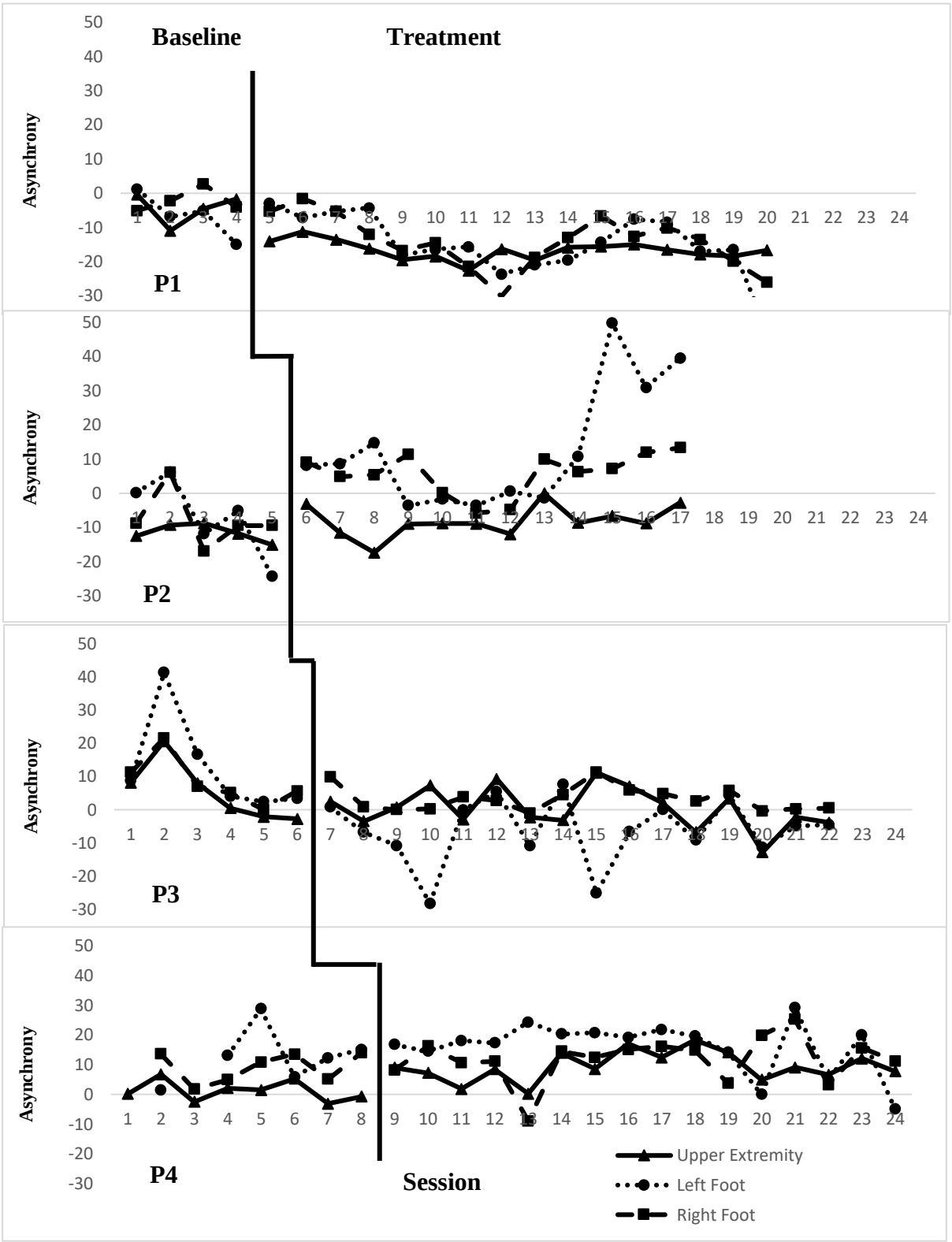

Figure 12. The patterns of mean asynchrony scores per extremity across conditions

P1's total mean asynchrony score was -4.6 ± 35.8 (range -7.8 – - 2.9) during baseline and total mean asynchrony score was -15.7 ± 35.1 (range -22 – -8.5) during treatment conditions, a decrease of 242%. P1's UE mean asynchrony score was -4.3 ± 34.6 (range -10.9 – -0.37) during baseline and UE mean asynchrony score was -16.7 ± 34.1 (range -22.6 – -11.2) with during treatment conditions, a decrease of 281%. P1's LF mean asynchrony score was -6.4 ± 33.7 (range -14.9 – 1.2) during baseline and LF mean asynchrony score was -14.9 ± 38 (range -40.1 – -2.8) during treatment conditions, a decrease of 131%. P1's RF mean asynchrony score was -2.1 ± 37.6 (range -5.1 – 2.7) during baseline and RF mean asynchrony score was -14.2 ± 35.8 (range -30.1 – -1.6) during treatment conditions, a decrease of 560%. In total (combining baseline and treatment conditions), P's1 mean asynchrony score was -13.5 ± 35.2 per session, -14.2 ± 34.2 with UE, -13.2 ± 37.2 with LF, and -11.8 ± 36.2 with RF (see Appendix K).

P2's total mean asynchrony score was -11.2 ± 34.6 (range -14.9 – -8.3) during baseline and total mean asynchrony score was -6.4 ± 37.9 (range -11.2 – 2.1) during treatment conditions, an increase of 42.9%. P2's UE mean asynchrony score was -11.5 ± 34.1 (range -15 – -8.7) during baseline and UE mean asynchrony score was -8.1 ± 37 (range -17.3 – -0.03) with during treatment conditions, an increase of 29.2%. P2's LF mean asynchrony score was -7 ± 35.3 (range -24.3 – 6.1) during baseline and LF mean asynchrony score was 12.7 ± 33 (range -3.6 – 39.5) during treatment conditions, an increase of 282%. P2's RF mean asynchrony score was -7.7 ± 36 (range -16.8 – 6.1) during baseline and RF mean asynchrony score was 5.8 ± 41 (range -5.8 – 13.3) during treatment conditions, an increase of 175%. In total (combining baseline and treatment conditions), P2's mean asynchrony score was -7.8 ± 36.9 per session, -9.1 ± 36.2 with UE, 6.9 ± 33.6 with LF, and 1.8 ± 39.6 with RF (see Appendix L).

P3's total mean asynchrony score was 6.2 ± 39.6 (range -1 – 20.7) during baseline and

total mean asynchrony score was 1 ± 41.9 (range -4.6 – 11.1) during treatment conditions, a decrease of 84.2%. P3's UE mean asynchrony score was 5.4 ± 39.9 (range -2.7 – 20.6) during baseline and UE mean asynchrony score was 0.36 ± 42.6 (range -12.8 – 11.2) with during treatment conditions, a decrease of 93.3%. P3's LF mean asynchrony score was 12.7 ± 39 (range 2.3 – 41.2) during baseline and LF mean asynchrony score was -6.3 ± 35.1 (range -28.2 – 7.6) during treatment conditions, a decrease of 149.4%. P3's RF mean asynchrony score was 8.4 ± 36.9 (range -0.01 – 21.6) during baseline and RF mean asynchrony score was 3.2 ± 36.1 (range -1 – 11.3) during treatment conditions, a decrease of 61.8%. In total (combining baseline and treatment conditions), P3's mean asynchrony score was 2.4 ± 41.3 per session, 1.7 ± 41.9 with UE, -1.1 ± 36.1 with LF, and 4.6 ± 36.3 with RF (see Appendix M).

P4's total mean asynchrony score was 2.3 ± 40.7 (range -2.2 – 6.8) during baseline and total mean asynchrony score was 10.1 ± 40.9 (range 0.23 – 18.6) during treatment conditions, an increase of 339.3%. P4's UE mean asynchrony score was 1.2 ± 40.8 (range -3.1 – 6.8) during baseline and UE mean asynchrony score was 9.5 ± 40.8 (range 0.23 – 18.3) with during treatment conditions, an increase of 708.5%. P4's LF mean asynchrony score was 12.7 ± 35.5 (range 1.4 – 28.7) during baseline and LF mean asynchrony score was 16 ± 37.5 (range -5 – 29.2) during treatment conditions, an increase of 25.6%. P4's RF mean asynchrony score was 9.1 ± 39.2 (range 1.8 – 13.9) during baseline and RF mean asynchrony score was 11.8 ± 39.4 (range -9 – 25.2) during treatment conditions, an increase of 29.7%. In total (combining baseline and treatment conditions), P4's mean asynchrony score was 7.5 ± 40.9 per session, 6.7 ± 40.8 with UE, 15.1 ± 36.9 with LF, and 11 ± 39.3 with RF (see Appendix N).

3.1.5. Notes ON vs OFF beat results

P1's, P2's, and P3's percentage of notes ON beat decreased from baseline to treatment conditions, whereas P4's percentage of notes ON beat increase from baseline to treatment conditions. In total, on average, P1 played 2281 (36.5%) notes ON beat and 3969 (63.5%) notes OFF beat per session. P1 played 1799 (43.5%) notes ON beat and 2331 (56.5%) notes OFF beat during baseline, and 2402 (35%) notes ON beat and 4379 (64.5%) notes OFF beat during treatment condition. In total, on average, P2 played 10566 notes per session with 2305 (21.8%) notes ON beat and 8261 (78.2%) notes OFF beat. P2 played 2047 (30.1%) notes ON beat and 4738 (69.9%) notes OFF beat during baseline, and 2413 (19.8%) notes ON beat and 9729 (80.2%) notes OFF beat during treatment condition. In total, on average, P3 played 8230 notes per session with 1316 (16%) notes ON beat and 6913 (84%) notes OFF beat. P3 played 1353 (17.4%) notes ON beat and 6411 (82.6%) notes OFF beat during baseline, and 1302 (15.5%) notes ON beat and 7101 (84.5%) notes OFF beat during treatment condition. In total, on average, P4 played 9812 notes per session with 2189 (22.6%) notes ON beat and 7622 (77.4%) notes OFF beat. P4 played 1631 (21.5%) notes ON beat and 5947 (78.5%) notes OFF beat during baseline, and 2468 (22.5%) notes ON beat and 8460 (77.4%) notes OFF beat during treatment condition (see Table 5). Analysis of changes in the percentage of notes played ON vs OFF beat suggests three demonstrations of a treatment effect were observed across the four participants. This suggests that participants' percentage of notes played ON beat decreased in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation.

Table 5. *Participants' notes played ON vs OFF beat*

P1		P2		P3		P4	
ON	OFF	ON	OFF	ON	OFF	ON	OFF

Baseline 1	590	1561	1236	2335	1213	5842	724	2384
Baseline 2	1771	2277	2285	4524	1864	8102	1385	4604
Baseline 3	1982	1967	2308	5315	1347	5614	1040	4919
Baseline 4	2854	3519	2272	7232	1467	6797	2098	6234
Baseline 5			2134	4285	1400	6497	1723	5777
Baseline 6					831	5614	1736	6440
Baseline 7							2405	9230
Baseline 8							1938	7994
Treatment 1	2150	4370	2413	10676	1472	7977	2118	6868
Treatment 2	2526	4075	2030	8255	1183	5381	2627	9646
Treatment 3	2188	4044	2340	6995	1490	7323	2392	8011
Treatment 4	2334	4047	2184	8995	1620	8925	2506	8935
Treatment 5	2022	4795	2637	9856	1201	5558	2471	7899
Treatment 6	2416	4928	2573	7985	1446	8972	2839	10172
Treatment 7	1893	4295	2215	8675	1118	5557	2242	7870
Treatment 8	1779	5181	2291	11465	1246	6931	2652	9647
Treatment 9	2231	5150	2789	10699	1722	9870	2375	8586
Treatment 10	2428	5384	2507	10674	1301	5827	2769	9965
Treatment 11	3227	2823	2330	9806	1095	6256	2898	10562
Treatment 12	2468	5325	2652	12668	1402	6004	2470	7392
Treatment 13	3082	3710			1335	8568	2620	7810
Treatment 14	2810	4296			1056	5444	2217	7053
Treatment 15	2885	3800			1027	7268	2166	7020
Treatment 16	1998	3850			1130	7769	2141	7924
Average Baseline	1799	2331	2047	4738	1353	6411	1631	5947
Average Treatment	2402	4379	2413	9729	1302	7101	2468	8460
Total Average	2281	3969	2305	8261	1316	6913	2189	7622

3.1.6. Music measures correlations

Pearson's Correlations (r) among music measures are presented on Table 6. P1's density of syncopation scores was found to be marginal negatively correlated with note count (r= -0.664, n= 20, p= 0.01), with asynchrony (r=0.545, n=20, p=0.013) and strongly negatively correlated with the number of notes ON beat (r= -0.81, n= 20, p= 0.00). No correlation was found between density of syncopation and velocity, notes OFF beat, and DK's density of syncopation for P1. P2's density of syncopation scores revealed a marginal negative

correlation with velocity (r= -0.656, n= 17, p= 0.004), and a positively correlation with DK's density of syncopation (r=0.559, n=17, p=0.02). No correlation was found between density of syncopation and note count, asynchrony, and notes ON and notes OFF beat for P2. P3's density of syncopation was found to marginally correlate with velocity (r= 0.599, n= 22, p= 0.003), with asynchrony (r= -0.472, n= 22, p= 0.027), and with notes ON beat (r=-0.644, n= 22, p= 0.001). No correlation was found between density of syncopation and note count, notes OFF beat, and DK's density of syncopation for P3. P4's density of syncopation was found to negatively correlate with note count (r= -0.781, n= 24, p= 0.00), asynchrony (r= -0.837, n= 24, p= 0.00), notes ON (r= -0.816, n= 24, p= 0.00), notes OFF (r= -0.76, n= 24, p= 0.00) beat, and positively correlate with DK's density of syncopation (r=-0.566, n=24, p=0.004). No correlation was found between density of syncopation and velocity for P4. Note count was found to negatively correlate with asynchrony for P1 (r= -0.654, n= 20, p= 0.002) and positively correlate for P2 (r= 0.77, n= 17, p= 0.00), for P3 (r= 0.540, n= 22, p= 0.009), and for P4 (r= 0.634, n= 24, p= 0.001). Note count was found to be correlated to notes ON beat for P1 (r= 0.656, n= 20, p= 0.002), for P2 (r= 0.754, n= 17, p= 0.00), for P3 (r= 0.738, n= 22, p= 0.00), and for P4 (r= 0.959, n= 24, p= 0.00), and strongly correlated to notes OFF beat for P1 (r= 0.917, n=20, p= 0.00), for P2 (r= 0.997, n=17, p= 0.00), for P3 (r= 0.993, n=22, p= 0.00), and for P4 (r= 0.997, n= 24, p= 0.00). Note count was found to be positively correlated to DK's density of syncopation for P2 (r=0.741, n=17, p=0.001), and negative correlated for P4 (r=0.433, n=24, p=0.035). No correlation was found between note count and velocity for any participant, and P1 and P3 note count and DK's density of syncopation. P3's velocity was found to negative correlate with asynchrony (r= -0.642, n= 22, p= 0.001). No correlation was found between velocity and asynchrony for P1, P2, or P4. Furthermore, velocity was not correlated with notes ON and OFF beat or DK's density of

syncopation for any participants. P3s' and P4s' asynchrony was found to correlate with notes ON beat (r= 0.692, n= 22, p= 0.00) and (r= 0.638, n= 24, p= 0.001) respectively. No correlation was found between asynchrony and notes ON beat for P1 and P2. Asynchrony was found to negatively correlate with notes OFF beat for P1(r= -0.708, n= 20, p= 0.00) and to positively correlate for P2 (r= 0.785, n=17, p= 0.00), for P3 (r= 0.484, n= 22, p= 0.023), and for P4 (r= 0.624, n=24, p= 0.001). Asynchrony was found to correlate with DK's density of syncopation for P2 (r=0.582, n=17, p=0.014) and P4 (r=0.646, n=24, p=0.001). No correlation was found between asynchrony and DK's density of syncopation for P1 and P3. Furthermore, notes ON beat was found to positively correlate with notes OFF beat for P2 (r= 0.699, n= 17, p= 0.002), for P3 (r= 0.651, n= 22, p= 0.001), and for P4 (r= 0.933, n= 24, p= 0.00). No correlation was found between notes ON and notes OFF beat for P1. Notes ON beat was found to positively correlate to DK's density of syncopation for P2 (r=0.606, n=17, p=0.01) and P4 (r=0.483, n=24, p=0.017). No correlation was found between notes ON beat and DK's density of syncopation for P1 and P3. Finally, notes OFF beat was found to positively correlate to DK's density of syncopation for P2 (r=0.733, n=17, p=0.001) and P4 (r=0.413, n=24, p=0.045). No correlation was found between notes OFF beat and DK's density of syncopation for P1 and P3.

Table 6. *Correlations (r) and significance levels (P) between density of syncopation, note count, velocity, asynchrony, and notes ON and notes OFF beat for every participant during baseline and treatment conditions combined*

Music Measures	Note Count *r (P)*	Velocity *r (P)*	Asynchrony *r (P)*	Notes ON *r (P)*	Notes OFF *r (P)*	DK' Syncopation
Syncopation						
P1	-0.664 (0.01)*	0.165 (0.487)	0.545 (0.013)**	-0.810 (0.00)*	-0.41 (0.72)	0.119 (0.618)
P2	0.308 (0.229)	-0.656 (0.004)*	0.406 (0.106)	0.065 (0.804)	0.327 (0.2)	0.559 (0.02)**
P3	-0.333 (0.130)	0.599 (0.003)*	-0.472 (0.027)**	-0.644 (0.001)*	-0.26 (0.243)	-0.057 (0.801)
P4	-0.781 (0.00)*	0.14 (0.947)	-0.837 (0.00)*	-0.816 (0.00)*	-0.76 (0.00)*	-0.566 (0.004)*
Note Count						
P1		0.001 (0.996)	-0.654 (0.002)*	0.656 (0.002)*	0.917 (0.00)*	0.078 (0.744)
P2		-0.219 (0.39)	0.77 (0.00)*	0.754 (0.00)*	0.997 (0.00)*	0.741 (0.001)*
P3		-0.284 (0.2)	0.540 (0.009)*	0.738 (0.00)*	0.993 (0.00)*	-0.067 (0.768)
P4		0.123 (0.566)	0.634 (0.001)*	0.959 (0.00)*	0.997 (0.00)*	0.433 (0.035)**
Velocity						
P1			-0.282 (0.229)	-0.249 (0.289)	0.134 (0.575)	-0.076 (0.749)
P2			-0.444 (0.74)	-0.46 (0.862)	-0.232 (0.369)	-0.455 (0.067)

P3	-0.642 (0.001)*	-0.413 (0.056)	-0.246 (0.269)	-0.362 (0.098)
P4	-0.40 (0.854)	0.120 (0.577)	0.122 (0.569)	-0.278 (0.188)
Asynchrony				
P1		-0.224 (0.342)	-0.708 (0.00)*	-0.24 (0.309)
P2		0.430 (0.085)	0.785 (0.00)*	0.582 (0.014)**
P3		0.692 (0.00)*	0.484 (0.023)*	0.176 (0.434)
P4		0.638 (0.001)*	0.624 (0.001)*	0.646 (0.001)*
Notes ON				
P1			0.299 (0.20)	-0.098 (0.682)
P2			0.699 (0.002)*	0.606 (0.01)*
P3			0.651 (0.001)*	0.154 (0.493)
P4			0.933 (0.00)*	0.483 (0.017)**
Notes OFF				
P1				0.150 (0.527)
P2				0.733 (0.001)*
P3				-0.102 (0.65)
P4				0.413 (0.045)**

Significant at the *p< 0.01 **p< 0.05

3.2. Outcome Measures (Laboratory Tests)

3.2.1. Gait test results

In order to test the hypothesis that participants with PD who acquire higher density of syncopation during IAMT sessions would increase gait velocity and stride length, and decrease step time and stride length variability, participant's pre-baseline and post-baseline gait parameters were compared. This served to identify whether acquisition of low-moderate density of syncopation through IAMT sessions can impact gait parameters. In order to test the hypothesis, participant's post-baseline and post-treatment gait velocity, stride length, and step time and stride length variability parameters were compared. This served to identify whether acquisition of moderate-high density of syncopation can additionally impact gait performance by comparing it to post-baseline measurements.

3.2.1.1. Gait velocity results.

Results indicate that all participants increased gait velocity from pre-baseline to post-baseline measurements (see Figure 13). All participants increased gait velocity after baseline conditions. P1 increased mean velocity from 105.1cm/s to 114cm/s (or an increase of 8.9cm/s), P2 increased mean velocity from 82.1cm/s to 86.1cm/s (or an increase of 4cm/s), P3 increased

mean velocity from 120.3cm/s to 126.7cm/s (or an increase of 6.4cm/s), and P4 increased mean velocity from 72.2cm/s to 78.8cm/s (or an increase of 6.6cm/s). Analysis of changes in mean gait velocity scores suggests that all demonstrations of baseline effect were observed across the four participants. This suggests that participant's gait velocity can be increased when low-moderate density of syncopation is administered during IAMT sessions. Table 7 contains gait test results by participant across conditions.

Post-treatment gait measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact gait velocity by comparing it to post-baseline measurements. Results indicate that P1, P2, and P3 decreased gait velocity, whereas P4 additionally increased gait velocity from post-baseline to post-treatment measurements. P1 decreased mean velocity from 114cm/s to 106.8cm/s (or a decrease of 7.2cm/s), P2 slightly decreased mean velocity from 86.1cm/s to 85.6cm/s (or a decrease of 0.5cm/s), and P3 decreased mean velocity from 126.7cm/s to 118.3cm/s (or a decrease of 8.4cm/s). P4, on the other hand, demonstrated an increase mean velocity from 78.8cm/s to 86.9cm/s (or an increase of 8.1cm/s). Analysis of changes in mean gait velocity scores suggests that one demonstration of treatment effect was observed across the four participants. This suggests that there is little evidence to suggest that participant's gait velocity is increased when moderate-high density of syncopation is administered during IAMT sessions. These results contradict the hypothesis. All participants increased their gait velocity after baseline IAMT sessions were administered, but only one participant further increased gait velocity after treatment IAMT sessions were administered.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions combined), pre-baseline and post-treatment gait velocity measurements were compared. Results indicate that P1, P2, and P4 increased gait velocity, whereas P3

decreased gait velocity from pre-baseline to post-treatment measurements. P1 slightly increased mean velocity from 105.1cm/s to 106.8cm/s (or an increase of 1.7cm/s), P2 increased mean velocity from 82.1cm/s to 85.6cm/s (or an increase of 3.5cm/s), and P4 increased mean velocity from 72.2cm/s to 86.9cm/s (or an increase of 14.7cm/s). P3, on the other hand, demonstrated a decrease mean velocity from 120.3cm/s to 118.3cm/s (or a decrease of 2cm/s). Analysis of changes in mean gait velocity scores suggests that three demonstrations of overall IAMT session effect were observed across the four participants. This suggests that participant's gait velocity could potentially be increased when IAMT sessions are administered.

Follow-up gait measurements provided information as to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Both participants P1 and P4 increased mean gait velocity from post-treatment scores. P1 increased mean velocity from post-treatment scores 106.8cm/s to follow-up scores of 123.3cm/s (or an increase of 16.5cm/s) and P4 increased mean velocity from post-treatment scores of 86.9cm/s to follow-up scores of 88cm/s (or an increase of 1.1cm/s). Analysis of changes in mean gait velocity scores suggests that two demonstrations of follow-up effect were observed across the two participants. This suggests that some participant's gait velocity kept increasing four weeks after completion of IAMT sessions.

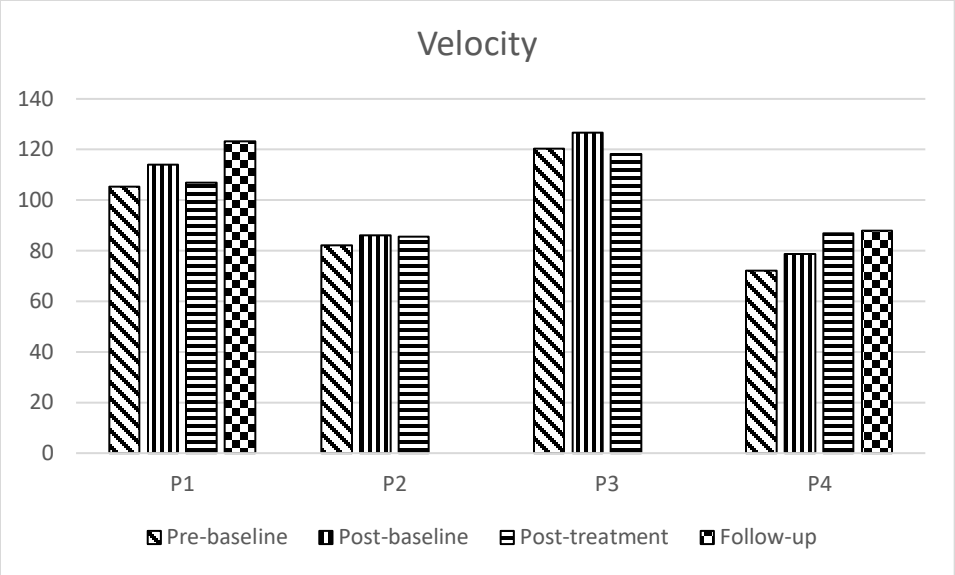

Figure 13. The patterns of gait velocity scores by participant across conditions

3.2.1.2. Step time variability results.

Results indicate that P2 and P3 decreased step time variability, whereas P1 and P4 increased step time variability from pre-baseline to post-baseline measurements (see Figure 14). P2 decreased step time variability from 10.1% to 6.7% (or a decrease of 3.4%) and P3 decreased step time variability from 4.6% to 4.1% (or a decrease of 0.5%). P1, on the other hand, increased step time variability from 3.2% to 3.35% (or an increase of 0.15%), and P4 increased step time variability from 4.55% to 6.1% (or an increase of 1.55%). Analysis of changes in step time variability scores suggests that two demonstrations of baseline effect were observed across the four participants. Suggesting inconclusive results to whether participant's step time variability increase or decrease when low-moderate density of syncopation is administered during IAMT sessions. Table 7 contains gait test results by participant across conditions.

Post-treatment gait measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact step time variability by comparing it to post-baseline measurements. Results indicate that all participants decreased step time variability from

post-baseline to post-treatment measurements. P1 decreased step time variability from 3.35% to 2.6% (or a decrease of 0.75%), P2 decreased step time variability from 6.7% to 5.65% (or a decrease of 1.05%), P3 decreased step time variability from 4.1% to 3.95% (or a decrease of 0.15%), and P4 decreased step time variability from 6.1% to 4.25% (or a decrease of 1.85%). Analysis of changes in step time variability scores suggests that four demonstration of treatment effect was observed across the four participants. This suggests that step time variability can be decreased when moderate-high density of syncopation is administered during IAMT sessions. These results support the hypothesis.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions combined), pre-baseline and post-treatment step time variability measurements were compared. Results indicate that all participants decreased step time variability from pre-baseline to post-treatment measurements. P1 decreased step time variability from 3.2% to 2.6% (or a decrease of 0.6%), P2 decreased step time variability from 10.1% to 5.65% (or a decrease of 4.45%), P3 decreased step time variability from 4.6% to 3.95% (or a decrease of 0.65%), and P4 decreased step time variability from 4.55% to 4.25% (or a decrease of 0.3%). Analysis of changes in step time variability scores suggests that four demonstrations of overall IAMT session effect were observed across the four participants. This suggests that participant's step time variability can be decreased when IAMT sessions are administered.

Follow-up gait measurements provided information as to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Results indicate that P1 slightly increased step time variability scores from 2.6% at post-treatment to 2.8% (or an increase of 0.2%) at follow up. P4, on the other hand, decreased step time variability from 4.25% at post-treatment to 3.35% (or a decrease of 0.9%) at follow up.

Analysis of changes in step time variability scores suggests that one demonstration of a follow-up effect was observed across the two participants. This suggests inconclusive results as to whether participant's step time variability kept increasing or decreasing four weeks after completion of IAMT sessions.

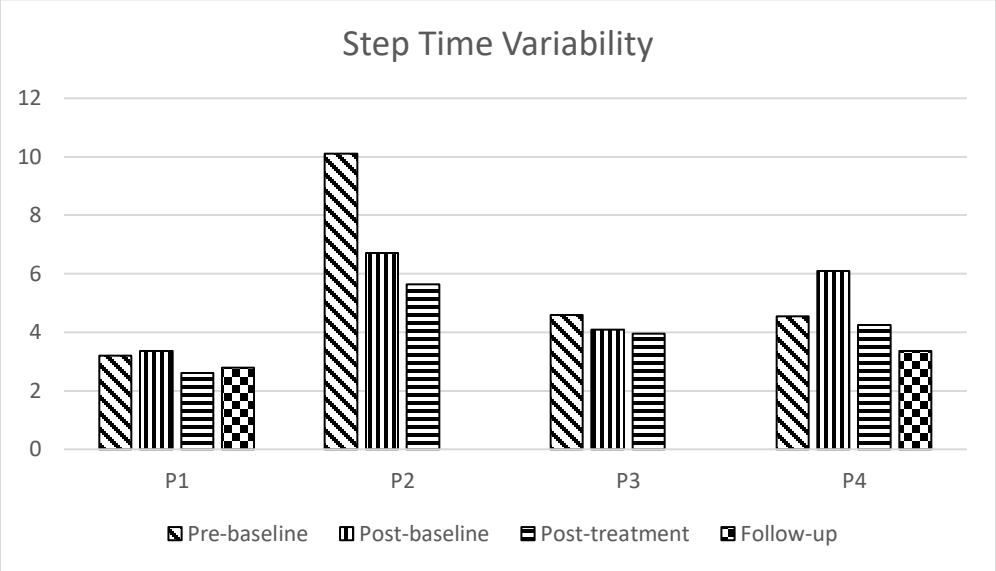

Figure 14. The patterns of step time variability scores by participant across conditions

3.2.1.3. Gait stride length results.

Gait stride length results indicate that P1, P3, and P4 increased their stride length, whereas P2 slightly decrease stride length from pre-baseline to post-baseline measurements (see Figure 15). P1 increased mean stride length from 123.2cm to 131.4cm (or an increase of 8.2cm), P3 increased mean stride length from 118.2cm to 124.8cm (or an increase of 6.6cm), and P4 increased mean stride length from 80.8cm to 91.5cm (or an increase of 10.7cm). P2, on the other hand, decreased mean stride length from 93.6cm to 91.2cm (or a decrease of 2.4cm). Analysis of changes in mean stride length scores suggests that three demonstrations of baseline effect were observed across the four participants. This suggests that participant's stride length could

potentially be increased when low-moderate density of syncopation is administered during IAMT sessions. Table 7 contains gait test results by participant across conditions.

Post-treatment gait measurements served to identify whether acquisition of moderate-high density of syncopation can impact stride length by comparing it to post-baseline measurements. Results indicate that P2 and P4 increased mean stride length, whereas P1 and P3 decreased mean stride length from post-baseline to post-treatment measurements. P2 increased mean stride length from 91.2cm to 95.6cm (or an increase of 4.4cm) and P4 additionally increased mean stride length from 91.5cm to 96.6cm (or an increase of 5.1cm). P1, on the other hand, decreased mean stride length from 131.4cm to 123.8cm (or a decrease of 7.4cm), and P3 decreased mean stride length from 124.8cm to 113.8cm (or a decrease of 11cm). Analysis of changes in mean stride length scores suggests that two demonstrations of treatment effect were observed across the four participants. This suggests inconclusive results to whether participant's stride length increase or decrease when moderate-high density of syncopation is administered during IAMT sessions. The results contradict the hypothesis. Most participants increased stride length after baseline IAMT sessions were administered, but only two participants increased stride length after treatment IAMT sessions were administered.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions), pre-baseline and post-treatment stride length measurements were compared. Results indicate that P1, P2, and P4 increased stride length from pre-baseline to post-treatment measurements, whereas P3 decreased stride length from pre-baseline to post-treatment measurements. P1 slightly increased mean stride length from 123.2cm to 123.8cm (or an increase of 0.64cm), P2 increased mean stride length from 93.6cm to 95.6cm (or an increase of 2cm), and P4 increased mean stride length from 80.8cm to 96.6cm (or an increase of 15.8cm). P3, on the

other hand, demonstrated a decrease on mean stride length from 118.2cm to 113.8cm (or a decrease of 4.4cm). Analysis of changes in mean stride length scores suggests that three demonstrations of overall IAMT session effect were observed across the four participants. This suggests that participant's stride length could potentially be increased when IAMT sessions are administered.

Follow-up gait measurements provided information to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Both participants P1 and P4 increased mean stride length from post-treatment scores. P1 increased mean stride length from post-treatment scores of 123.8cm to follow-up scores of 136.1cm (or an increase of 12.3cm) and P4 increased mean stride length from post-treatment scores of 96.6cm to follow-up scores of 97.5cm (or an increase of 0.96cm). Analysis of changes in mean stride length scores suggests that two demonstrations of follow-up effect were observed across the two participants. This suggests that some participant's gait stride length kept increasing four weeks after completion of IAMT sessions. Table 7 shows stride length scores by participant across conditions.

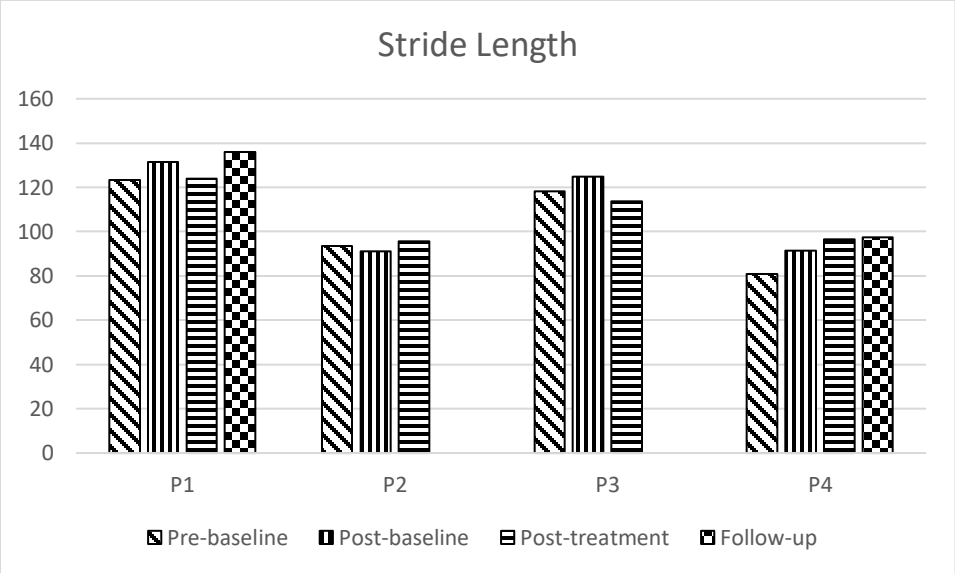

Figure 15. The patterns of gait stride length scores by participant across conditions

3.2.1.4. Stride length variability results.

Results indicate that P1 decreased stride length variability from pre-baseline to post-baseline measurements, whereas, P2 and P4 increased stride length variability. P3, on the other hand, maintained the same stride length variability scores from pre-baseline to post-baseline measurements (see Figure 16). P1 decreased stride length variability from 6.4% to 3.85% (or a decrease of 2.55%), P2 increased stride length variability from 6.65% to 8.05% (or an increase of 1.4%), P4 increased stride length variability from 6.05% to 6.4% (or an increase of 0.35%), and P3 maintained stride length variability at 4.55%. Analysis of changes in stride length variability scores suggests that one demonstration of baseline effect was observed across the four participants. This suggests that there is little evidence to suggest that participant's stride length variability can be decreased when low-moderate density of syncopation is administered during IAMT sessions. Table 7 contains gait test results by participant across conditions.

Post-treatment gait measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact stride length variability by comparing it to post-baseline measurements. Results indicate that P1 increased stride length variability, whereas P2, P3, and P4 decreased stride length variability from post-baseline to post-treatment measurements. P1 increased stride length variability from 3.85% to 6.2% (or an increase of 2.35%). P2, on the other hand, decreased stride length variability from 8.05% to 6.45% (or a decrease of 1.6%), P3 decreased stride length variability from 4.55% to 3.55% (or a decrease of 1%), and P4 decrease stride length variability from 6.4% to 4.95% (or a decrease of 1.45%). Analysis of changes in stride length variability scores suggests that three demonstration of treatment effect was observed across the four participants. This suggests that participant's stride

length variability could potentially be decreased when moderate-high density of syncopation is administered during IAMT sessions. These results support the hypothesis.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions combined), pre-baseline and post-treatment stride length variability measurements were compared. Results indicate that all participants decreased stride length variability from pre-baseline to post-treatment measurements. P1 slightly decreased stride length variability from 6.4% to 6.2% (or a decrease of 0.2%), P2 slightly decreased stride length variability from 6.65% to 6.45% (or a decrease of 0.2%), P3 decreased stride length variability from 4.55% to 3.55% (or a decrease of 1%), and P4 decreased stride length variability from 6.05% to 4.95% (or a decrease of 1.1%). Analysis of changes in stride length variability scores suggests that four demonstrations of overall IAMT session effect were observed across the four participants. This suggests that participant's stride length variability can be decreased when IAMT sessions are administered.

Follow-up gait measurements provided information as to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Both participants, P1 and P4 decreased stride length variability from post-treatment scores. P1 decreased stride length variability from post-treatment scores of 6.2% to follow-up scores of 3.9% (or a decrease of 2.3%) and P4 decreased stride length variability from post-treatment scores of 4.95% to follow-up scores of 2.7% (or a decrease of 2.25%). Analysis of changes in stride length variability scores suggests that two demonstrations of follow-up effect were observed across the two participants. This suggests that participant's stride length variability kept decreasing four weeks after completion of IAMT sessions.

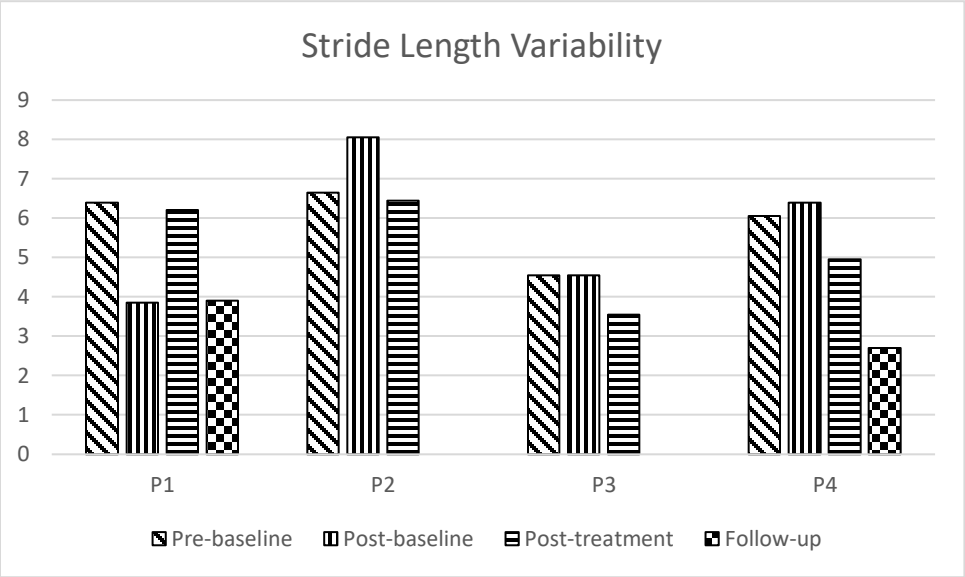

Figure 16. The patterns of stride length variability scores by participant across conditions

Table 7. *Gait scores by participant across conditions*

		Velocity cm/s	Stride Length cm	Step Time (%)	Stride Length (%)
P1					
	Pre-baseline	105.1	123.2	3.2	6.4
	Post-baseline	114.0	131.4	3.35	3.85
	Post-treatment	106.8	123.8	2.6	6.2
	Follow-up	123.3	136.1	2.8	3.9
P2					
	Pre-baseline	82.1	93.6	10.1	6.65
	Post-baseline	86.1	91.2	6.7	8.05
	Post-treatment	85.6	95.6	5.65	6.45
P3					
	Pre-baseline	120.3	118.2	4.6	4.55
	Post-baseline	126.7	124.8	4.1	4.55
	Post-treatment	118.3	113.8	3.95	3.55

P4				
Pre-baseline	72.2	80.8	4.55	6.05
Post-baseline	78.8	91.5	6.1	6.4
Post-treatment	86.9	96.6	4.25	4.95
Follow-up	88.0	97.5	3.35	2.7

3.2.2. Beat Alignment Test results

3.2.2.1. Perceptual test.

In the perceptual test, scores were calculated as the percentage of correct answers from all 17 trials. Figure 17 shows the BAT perceptual test scores by participants across conditions. In order to measure participants' improvement in beat perception, or lack of, pre-baseline and post-baseline BAT perceptual test scores were compared. This served to identify whether acquisition of low-moderate density of syncopation during baseline condition can impact BAT perceptual test scores. Results indicate that P2, P3, and P4 decreased beat perception scores from pre-baseline to post-baseline measurements, whereas P1 increased beat perception scores from pre-baseline to post-baseline measurements. P2 decreased from 52.9% to 41.2% (or a decrease of 11.7%), P3 decreased from 58.8% to 41.2% (or a decrease of 17.6%), and P4 decreased from 76.5% to 64.7% (or a decrease of 11.8%). P1, on the other hand, increased from 58.8% to 76.5% (or an increase of 17.7%). Analysis of changes in beat perception scores suggests that one demonstration of baseline effect was observed across the four participants. This suggests that there is little evidence that participant's beat perception abilities are increased when low-moderate density of syncopation is administered during IAMT sessions (see Table 8).

Post-treatment beat perception measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact beat perception by comparing it to post-baseline measurements. Results indicate that P1, P2, and P3 increased beat perception

scores from post-baseline to post-treatment measurements, whereas P4 decreased beat perception scores from post-baseline to post-treatment measurements. P1 increased from 76.5% to 82.3% (or an increase of 5.8%), P2 increased from 41.2% to 64.7% (or an increase of 23.5%), and P3 increased from 41.2% to 64.7% (or an increase of 23.5%). P4, on the other hand, decreased scores from 64.7% to 52.9% (or a decrease of 11.8%). Analysis of changes in beat perception scores suggests that three demonstrations of treatment effect were observed across the four participants. This suggests that participant's beat perception could potentially be increased when moderate-high density of syncopation is administered during IAMT sessions.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions), pre-baseline and post-treatment beat perception abilities scores were compared. Results indicate that P1, P2 and P3 increased beat perception scores, whereas P4 decreased beat perception scores from pre-baseline to post-treatment beat perception scores. P1 increased beat perception from 58.8% to 82.3% (or an increase of 23.5%), P2 increased beat perception from 52.9% to 64.7% (or an increase of 11.8%), and P3 increased beat perception from 58.8% to 64.7% (or an increase of 5.9%). P4, on the other hand, demonstrated a decrease on beat perception from 76.5 to 52.9% (or a decrease of 23.6%). Analysis of changes in beat perception scores suggests that three demonstrations of overall IAMT effect were observed across the four participants. This suggests that participant's beat perception could potentially be increased when IAMT sessions are administered.

Follow-up beat perception measurements provided information as to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Results indicate that P1 decreased beat perception scores from 82.3% at post-treatment to 64.7% (or a decrease of 17.6%) at follow up. P4, on the other hand, increased

beat perception from 52.9% at post-treatment to 64.7% (or an increase of 11.8%) at follow up. Analysis of changes in beat perception scores suggests that one demonstration of a follow-up effect was observed across the two participants. This suggests inconclusive results as to whether participant's beat perception kept increasing or decreasing four weeks after completion of IAMT sessions.

Table 8. *Beat alignment perceptual test scores by participant across conditions*

	P1	P2	P3	P4
Pre-baseline	58.8%	52.9%	58.8%	76.5%
Post-baseline	76.5%	41.2%	41.2%	64.7%
Post-treatment	82.3%	64.7%	64.7%	52.9%
Follow-up	64.7%			64.7%

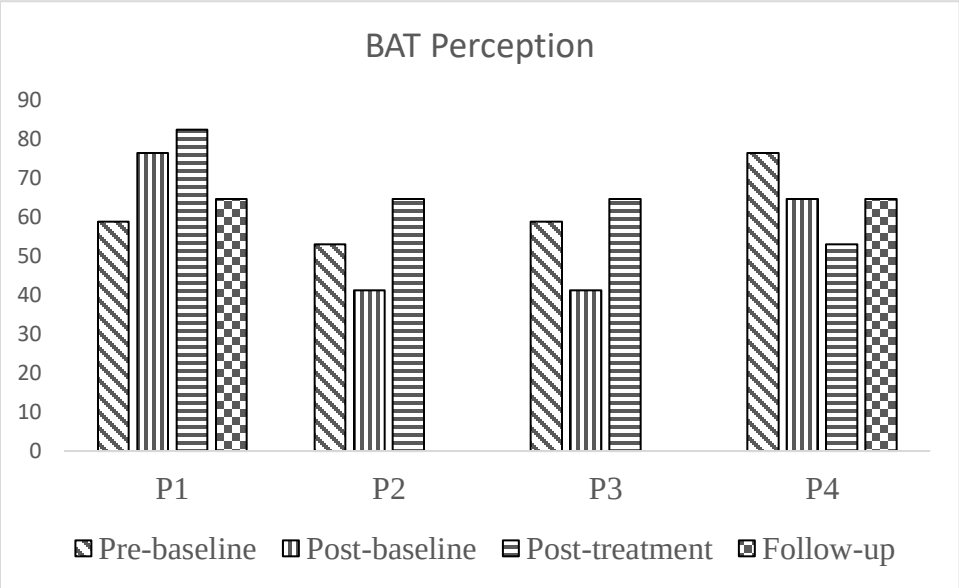

Figure 17. The patterns of BAT perceptual scores by participant across conditions

3.2.2.2. Production test.

In the production test, three measures were identified, the Coefficient of Variability (CoV), Coefficients of Deviation (CDEV-T), and Asynchrony. In order to measure participants'

improvement in synchronization, or lack thereof, pre-baseline and post-baseline BAT production test scores were compared. This served to identify whether acquisition of low-moderate density of syncopation during baseline condition can impact BAT production test scores. Figure 18 shows the BAT production test scores by participants across conditions.

3.2.2.2.1. Coefficient of variability results.

Results indicate that P1, P2, and P4 slightly increased CoV scores from pre-baseline to post-baseline measurements, whereas P3 decreased CoV scores from pre-baseline to post-baseline measurements. P1 increased from 0.073 to 0.094 (or an increase of 0.021), P2 from 0.174 to 0.187 (or an increase of 0.013), and P4 from 0.097 to 0.113 (or an increase of 0.016). P3, on the other hand, decreased from 0.228 to 0.145 (or a decrease of 0.083). Analysis of changes in CoV scores suggests that one demonstration of baseline effect was observed across the four participants. There is little evidence to suggest that participant's tapping variability can be decreased when low-moderate density of syncopation is administered during IAMT sessions (see Table 9).

Post-treatment CoV measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact tapping variability by comparing it to post-baseline measurements. Results also indicate that P1, P2, and P4 slightly decreased CoV scores from post-baseline to post-treatment measurements, whereas P3 slightly increased CoV scores from post-baseline to post-treatment measurements. P1 decreased from 0.094 to 0.087 (or a decrease of 0.007), P2 from 0.187 to 0.148 (or a decrease of 0.039), and P4 from 0.113 to 0.088 (or a decrease of 0.025). P3's score increased from 0.145 to 0.172 (or an increase of 0.027). Analysis of changes in CoV scores suggests that three demonstrations of treatment effect were observed across the four participants. This suggests that participant's tapping variability can

potentially be decreased when moderate-high density of syncopation is administered during IAMT sessions.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions), pre-baseline and post-treatment CoV scores were compared. Results indicate that P2, P3 and P4 decreased CoV scores, whereas P1 increased CoV scores from pre-baseline to post-treatment scores. P2 decreased CoV scores from 0.174 to 0.148 (or a decrease of 0.026), P3 decreased CoV scores from 0.228 to 0.172 (or a decrease of 0.056), and P4 decreased CoV scores from 0.097 to 0.088 (or a decrease of 0.009). P1, on the other hand, demonstrated an increase on CoV scores from 0.073 to 0.087 (or an increase of 0.014). Analysis of changes in CoV scores suggests that three demonstrations of overall IAMT effect were observed across the four participants. This suggests that participant's tapping variability could potentially be decreased when IAMT sessions are administered.

Follow-up CoV measurements provided information to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Follow up scores indicate that P1 and P4 increased CoV scores from post-treatment to follow-up scores. P1 increased CoV scores from 0.087 at post-treatment to 0.112 (or an increase of 0.025) at follow up and P4 increased CoV scores from 0.088 at post-treatment to 0.103 (or an increase of 0.015) at follow up. Analysis of changes in CoV scores suggests that no demonstrations of follow-up effect were observed across the two participants. This suggests that participant's tapping variability performance was not maintained four weeks after completion of IAMT sessions.

3.2.2.2.2. Coefficient of deviation results (trial-by-trial).

Results indicate that P1, P2, and P4 increased CDEV-T scores from pre-baseline to post-baseline measurements while P3 decreased CDEV-T scores from pre-baseline to post-baseline measurements. P1 increased from 0.072 to 0.093 (or an increase of 0.021), P2 a considerable increased from 0.182 to 0.346 (or an increase of 0.164), and P4 increased from 0.09 to 0.145 (or an increase of 0.055). P3, in contrast, considerably decreased scores from 0.278 to 0.125 (or a decrease of 0.153). Analysis of changes in CDEV-T scores suggests that one demonstration of baseline effect was observed across the four participants. This suggests that there is little evidence that participant's tapping deviation (how close each ITI is to the nearest IBI) is decrease when low-moderate density of syncopation is administered during IAMT sessions.

Post-treatment CDEV-T measurements served to identify whether acquisition of moderate-high density of syncopation can impact tapping deviation by comparing it to post-baseline measurements. Results also indicate that P1, P2, and P4 decreased CDEV-T scores from post-baseline to post-treatment measurements, while P3 increased CDEV-T scores from post-baseline to post-treatment measurements. P1 decreased from 0.093 to 0.085 (or a decrease of 0.008), P2 a considerable decrease from 0.346 to 0.179 (or a decrease of 0.167), and P4 from 0.145 to 0.1 (or a decrease of 0.045). P3's score, in contrast increased from 0.125 to 0.164 (or an increase of 0.039). Analysis of changes in CDEV-T scores suggests that three demonstrations of treatment effect were observed across the four participants. This suggests that participant's tapping deviation could potentially be decreased when moderate-high density of syncopation is administered during IAMT sessions.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions), pre-baseline and post-treatment CDEV-T scores were compared. Results

indicate that P2 and P3 decreased CDEV-T scores, whereas P1 and P4 increased CDEV-T scores from pre-baseline to post-treatment scores. P2 decreased CDEV-T scores from 0.182 to 0.179 (or a decrease of 0.003) and P3 decreased CDEV-T scores from 0.278 to 0.164 (or a decrease of 0.114). P1, on the other hand, demonstrated an increase on CDEV-T scores from 0.072 to 0.085 (or an increase of 0.013) and P4 increased CDEV-T scores from 0.09 to 0.1 (or an increase of 0.01). Analysis of changes in CDEV-T scores suggests that two demonstrations of overall IAMT effect were observed across the four participants. This suggests inconclusive results to whether participant's tapping deviation can be increased or decreased after IAMT sessions were administered.

Follow-up CDEV-T measurements provided information to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Results indicate that P1 and P4 increased CDEV-T scores from post-treatment to follow-up scores. P1 increased CDEV-T scores from 0.085 at post-treatment to 0.111 (or an increase of 0.026) at follow up. P4 increased CDEV-T scores from 0.1 at post-treatment to 0.146 (or an increase of 0.046) at follow up. Analysis of changes in CDEV-T scores suggests that no demonstrations of follow-up effect were observed across the two participants. This suggests that participant's tapping deviation performance was not maintained four weeks after completion of IAMT sessions.

3.2.2.2.3. Asynchrony results.

Results indicate that all participants increased Asynchrony scores from pre-baseline to post-baseline measurements. P1 increased from 0.12 to 0.15 (or an increase of 0.3), P2 a considerable increased from 0.118 to 0.208 (or an increase of 0.09), P3 increased from 0.07 to 0.088 (or an increase of 0.018), and P4 a slight increased from 0.165 to 0.173 (or an increase of

0.008). Analysis of changes in Asynchrony (participants' trend from tapping before or after the beat) scores suggest that no demonstrations of baseline effect were observed across the four participants. This suggests that participant's Asynchrony could not be decreased when low-moderate density of syncopation is administered during IAMT sessions.

Post-treatment Asynchrony measurements served to identify whether acquisition of moderate-high density of syncopation can additionally impact Asynchrony by comparing it to post-baseline measurements. Results also indicate that P1 and P3 slightly increased Asynchrony scores from post-baseline to post-treatment measurements, whereas P2 and P4 decreased Asynchrony scores from post-baseline to post-treatment measurements. P1 increased from 0.15 to 0.16 (or an increase of 0.1) and P3 increased from 0.088 to 0.096 (or an increase of 0.08). P2, in contrast, decreased considerably from 0.208 to 0.136 (or a decrease of 0.072), and P4 a slight decreased from 0.173 to 0.161 (or a decrease of 0.012). Analysis of changes in Asynchrony scores suggest that two demonstrations of treatment effect were observed across the four participants. This suggests inconclusive results as to whether participant's Asynchrony can be increased or decreased after of IAMT treatment sessions.

In order to determine the effectiveness of the overall IAMT sessions (both baseline and treatment conditions), pre-baseline and post-treatment Asynchrony scores were compared. Results indicate that P1, P2 and P3 increased Asynchrony scores, whereas P4 decreased Asynchrony scores from pre-baseline to post-treatment scores. P1 increased Asynchrony scores from 0.12 to 0.16 (or an increase of 0.04), P2 increased Asynchrony scores from 0.118 to 0.136 (or an increase of 0.018), and P3 increased Asynchrony scores from 0.07 to 0.096 (or an increase of 0.026). P4, on the other hand, demonstrated a decrease on Asynchrony scores from 0.165 to 0.161 (or an increase of 0.004). Analysis of changes in Asynchrony scores suggest that one

demonstrations of overall IAMT effect was observed across the four participants. This suggests that there is little evidence that participant's Asynchrony can be decrease when IAMT sessions are administered.

Follow-up Asynchrony measurements provided information to whether participants were able to maintain the anticipated improved performance four weeks after completing treatment condition. Results indicate that P1 and P4 increased Asynchrony scores from post-treatment to follow-up scores. P1 increased Asynchrony scores from 0.16 at post-treatment to 0.179 (or an increase of 0.019) at follow up. P4 increased Asynchrony scores from 0.161 at post-treatment to 0.312 (or an increase of 0.151) at follow up. Analysis of changes in Asynchrony scores suggest that no demonstrations of follow-up effect were observed across the two participants. This suggests that participant's Asynchrony performance was not maintained four weeks after completion of IAMT sessions.

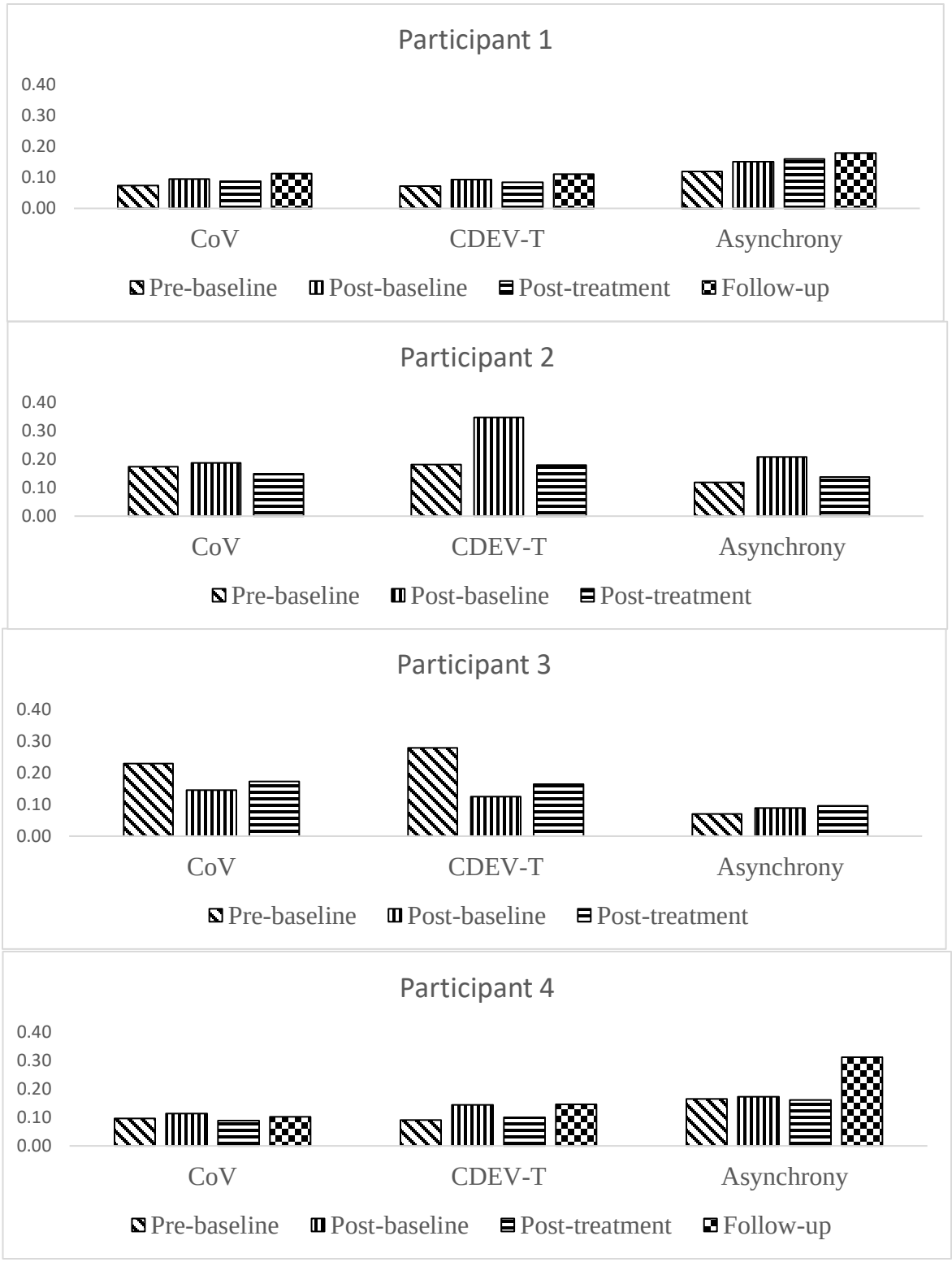

Figure 18. The patterns of BAT production test results by participant across conditions

Table 9. *Beat alignment production test scores by participant across conditions*

		CoV	CDEV-T	Asynchrony
P1	Pre-baseline	0.073	0.072	0.120
	Post-baseline	0.094	0.093	0.150
	Post-treatment	0.087	0.085	0.160
	Follow-up	0.112	0.111	0.179
P2	Pre-baseline	0.174	0.182	0.118
	Post-baseline	0.187	0.346	0.208
	Post-treatment	0.148	0.179	0.136
P3	Pre-baseline	0.228	0.278	0.070
	Post-baseline	0.145	0.125	0.088
	Post-treatment	0.172	0.164	0.096
P4	Pre-baseline	0.097	0.090	0.165
	Post-baseline	0.113	0.145	0.173
	Post-treatment	0.088	0.100	0.161
	Follow-up	0.103	0.146	0.312

Note. CDEV-T, coefficient of deviation trial-by-trial; CoV, coefficient of variability.

Chapter 4

4. Discussion

Until now, the implications of acquisition of rhythmic complexity levels on gait performance for individuals with PD in IAMT has not been studied. Currently there is no information in the literature about specific benefits and limitations of acquisition of rhythmic complexity levels and its impact on motor control in neurological rehabilitation. The IAMT approach has the potential to improve the timing of the motor system, muscle strength, and endurance. The purpose of this study was to contribute to the literature by investigating the efficacy of rhythmic acquisition on gait performance among individuals with PD. Using Single Subject Multiple Baseline Across Subjects design, the study described the impact of acquisition of density of syncopation (as a measure of rhythmic complexity) on gait velocity, on stride length, on step time and stride length variability, on beat perception and production abilities, and on other music measurements. Two hypotheses were tested to determine whether acquisition of rhythmic complexity improves gait performance. This chapter includes a discussion of the results related to the research hypotheses, followed by a presentation of the limitations of the study, ideas for future research, and implications for clinical practice.

4.1. Hypothesis 1

4.1.1. Density of syncopation

i) Participants' density of syncopation exhibited in their musical responses will increase from baseline to treatment conditions.

Even though the four baselines vary in length from 2 to 4 weeks, most participants' density of syncopation exhibited the expected level change. Visual inspection of baseline condition suggests that P2 and P4 demonstrated a stable trend, and P1 demonstrated a downward

trend. P3, on the other hand, demonstrated an upward trend. The upward trend exhibited by P3, opposite direction of the expected level, might be attributed to the high levels presented in DK's density of syncopation during P3's baseline sessions. According to the research methodology, DK's density of syncopation levels should have been considerably lower during baseline than treatment condition. DK's density of syncopation levels during P3's baseline sessions, however, had a similar density of syncopation levels as during treatment sessions. One of the reasons for this may be that P3 was the first participant entering the study, in the development stages of the intervention. During this developing process (P3's first six baseline sessions and P1's first three baseline sessions), DK analyzed the function of the music related to the effectiveness of entraining participants with low-moderate density of syncopation. DK relied on subjective opinion based on professional experience and knowledge regarding appropriate clinical music application (Wigram, 2004) in order to assess the functionality of the music. The purpose of this adjustment period was centered on finding the optimal tempo to maintain participants' entrainment with low-moderate density of syncopation rhythms with simple guitar strumming. The tempo was therefore incrementally increased from the premeditated speed of 100 bpm until reaching the desired tempo of 120 bpm. The initial speed of 100 bpm was established during two short trial sessions with two healthy subjects. This developmental period of the study might explain the high levels in density of syncopation exhibited by DK throughout P3's baseline condition and in P1's first session. DK's density of syncopation demonstrated low levels in the remaining sessions throughout baseline, as designed. Visual inspection suggests that P1's, P2's, and P4's density of syncopation trends during baseline condition were similar to DK's density of syncopation trends. These three participants demonstrated higher levels of syncopation than DK, but with similar trends. This indicates that, although participants did not increase their density of

syncopation levels when DK played low-moderate density of syncopation levels, density of syncopation trends shared similar characteristics between the DK and the participants throughout baseline condition.

The hypothesis also predicted that the density of syncopation exhibited in the participants' musical responses would increase from baseline to treatment conditions. The results from this study were not consistent with this hypothesis. The density of syncopation levels initially increased only for P2, whereas they remained stable for P1, and decreased for P3 and P4. DK's increase in density of syncopation during the treatment condition was not reflected in most of participants' density of syncopation as expected. This suggests that the study participants did not necessarily acquire higher levels of density of syncopation with DK's increased density of syncopation levels. Furthermore, throughout the treatment condition, P2, P3, and P4 demonstrated a stable trend scoring consistently higher levels than DK's density of syncopation. In contrast, P1 demonstrated a slight downward trend with similar density of syncopation levels as DK's. This finding suggests that participants did not necessarily acquire higher density of syncopation over time, even when DK maintained moderate-high density of syncopation levels throughout treatment sessions. This indicates that most study participants did not acquire higher rhythmic complexity levels as predicted.

Pearson's Correlation revealed that, in fact, there is an intricate relationship between participants' density of syncopation and DK's density of syncopation throughout conditions. For instance, P2's and P4's density of syncopation was found to significantly correlate with DK's density of syncopation, yet this relationship was in different directions for each participant. P2's density of syncopation levels positively correlated with DK's, whereas P4's levels negatively correlated. No correlation was found between P1's and P3's density of syncopation and DK's

density of syncopation, results suggests that the relationships are not consistent between the two measures. This suggests that while some participants exhibited acquisition of rhythmic complexity levels when exposed to higher density of syncopation levels, others showed an opposite behavior. The acquisition of rhythmic complexity, therefore, may be influenced by other factors.

In order to further interpret the results from this study, it is necessary to examine participants' personal interpretation of the task at hand (i.e., the different ways participants decided to play the drum-set). Only a handful of studies have investigated the way in which musicians and non-musicians synchronize their motor activities to music without or with loose instructions. In a study conducted by Drake, Penel, et al. (2000), for example, participants were asked to finger tap at their own spontaneous speed, that is, at the rate that seemed most appropriate to musical excerpts being listened to. Not all the participants tapped at the same rate. A number of participants tapped at the beat level, whereas others tapped at the measure level, at the two-measure level, or at less easily defined rates. Musicians tended to spontaneously synchronize at measure levels and non-musicians tended to synchronize at the beat or the binary subdivisions of that beat (eighth notes). In general, those with higher music proficiency used slower rhythmic referent than those with no music training.

Results from this study corroborate the results reported by Drake, Penel, et al. (2000) in that participants played mostly at the beat level or at the subdivision level, using distinctive interpretations of how they played the drum-set. In general, playing a drum-set requires bilateral movement (both limbs moving in unison), unilateral movement (one limb moving at a time), and alternating movement (alternating limbs) (Taylor, 2017). Participants performed a combination of these movements. P1 tended to follow the beat by alternating foot pedals, similar to marching

to a beat. At times, P1 would perform the same alternating motion by incorporating the UE in parallel motion with LE (i.e., right hand and foot simultaneously striking every other beat and left hand and foot following the other beat). P1 would occasionally follow/imitate the rhythmic structure exclusively with UE, but only after being confident at maintaining the beat while alternating LE. This interpretation of playing the drum-set might explain the slight downward trend exhibited in density of syncopation throughout conditions; P1 was mostly trying to synchronize to the beat instead of following the rhythmic structure, reducing the possibility of acquiring higher rhythmic complexity levels. P2, P3, and P4, on the other hand, imitated the rhythmic structure with mostly UE. P2 and P3 played with alternating movement with UE, whereas P4 played bilateral movement with UE. At times, P3 would only play unilateral movement with right UE. The LE of these three participants exhibited an intermittent unrecognizable rhythmic pattern, with unilateral, bilateral, and alternating movement patterns, which appeared to intermittently follow the beat, or at times, the rhythmic structure. Considering DK's guitar strumming as one source of density of syncopation, the drum-set can add more density of syncopation because there are four limbs involved in the production of the syncopation compared to a single guitar. The difference in instrumental features between the guitar and drum-set might explain why P2's, P3's, and P4's density of syncopation levels were consistently higher than DK's throughout the conditions, as these participants mostly followed the rhythmic structure. It is not clear, however, why P4's density of syncopation would exhibit a negative correlation with DK's density of syncopation, nor the reason why P4 demonstrated lower density of syncopation levels during treatment than during baseline conditions. Interestingly, P1 was the only participant who reported having some music training background, corroborating the results reported by Drake, Penel, et al. (2000) in that participants with higher

music training tapped at a slower reference than non-musicians. Overall, the participants' density of syncopation levels demonstrated a significant correlation with other music measures as well. In order to further understand the phenomenon of acquisition of rhythmic complexity levels, it is necessary to closely inspect how these music measures interact with each other.

4.1.2. Note count and notes played ON vs OFF beat

Visual inspection of the results from this study suggests that participants' note count scores did not increase or decrease in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation. Rather, the note count increased during baseline until reaching a plateau at treatment condition. One explanation of the upward trend during baseline and a stable trend during treatment condition in three participants is simply practice. As participants practice with the drum-set throughout baseline sessions, they become more comfortable with the task and increase their note count until reaching a plateau.

P1 and P4 exhibited significant negative correlations between their density of syncopation levels and note count results. This suggests that when participants played more notes, it reduced the number of possible density of syncopation moments as described by Huron and Ommen (2006). This result strengthens the internal validity of the Humdrum Toolkit because the results are somewhat expected. For example, if participants would play all sixteenth or thirty-second notes continuously, there would be a high note count without any density of syncopation level.

The participants' note count was also found to be significantly correlated with DK's density of syncopation. P2 and P4 demonstrated a significant positive correlation. This suggests that density of syncopation levels played by DK influenced the amount of notes played by participants. For example, P2, P3, and P4, who tended to follow the rhythmic structure, scored

on average 10566, 8230, and 9812 notes per session, respectively. P1, on the other hand, who tended to synchronize to the beat, scored on average 6251 per session. Relating back to the way participants played the drum-set, these results provide evidence that for most participants who attempted to follow the rhythmic structure, note count was influenced by DK's density of syncopation levels, compared to P1 who attempted to synchronize with the beat. Note count and note position within the rhythmic structure played by participants can provide further evidence of the aforementioned differences of how participants played the drum-set and how these differences were affected by DK's density of syncopation. For example, comparing each participant's percentage of notes played ON beat versus notes played OFF beat can provide further clues as to whether participants, in fact, tended to follow the beat or the rhythmic structure. For instance, P1 played on average 36.5% of notes ON beat and 63.5% notes OFF beat, whereas, P2 played 21.8% of notes ON beat and 78.2% of notes OFF beat, P3 played P3 16% of notes ON beat and 84% of notes OFF beat, and P4 played 22.6% of notes ON beat and 77.4% of notes OFF beat. This indicates that P1 played notes ON beat considerably more than P2, P3, and P4. This also implies the tendency of P1 to follow the beat compared to the tendency of P2, P3, and P4 to imitate the rhythmic structure.

P1's, P3's, and P4's density of syncopation scores was significantly negatively correlated with notes played ON beat, indicating that the more the participants played ON beat, the lower their density of syncopation. This result further corroborates the internal validity of the Humdrum Toolkit because playing ON beat would reduce the possibility of syncopation moments as described by Huron and Ommen (2006). Lastly, participants' note count had a significant positive correlation with notes played ON and OFF beat. This correlation was expected by the researcher because both measures, notes played ON and notes played OFF beat,

should increase as note count increases, unless participants exclusively attempt to play notes only ON or only OFF the beat, which was not the case with any of the participants in this study.

4.1.3. Velocity

In the present study, MIDI velocity provided a score between 1-127 for every note, measuring how fast the drum-set was struck with UE, LF, and RF. Visual inspection showed that P1 and P4 exhibited stable mean velocity scores across conditions. In contrast, P2 and P3 exhibited an upward trend during baseline, and a stable trend during the treatment condition. All participants scored similar total mean velocity scores between baseline and treatment conditions. This suggests that participants' mean velocity was not influenced by the presence of a moderate-high density of syncopation, but possibly the velocity scores increased during the baseline condition because of a practice effect, similar to the increase in note count scores.

P2's density of syncopation scores revealed a significant negative correlation with velocity, and P3's density of syncopation scores revealed a significant positive correlation with velocity. These results suggest that P2 tended to play with less striking force while playing higher density of syncopation levels, whereas P3 tended to play with more striking force while playing higher density of syncopation levels. This result may indicate that the participants' attempts at playing higher rhythmic complexity levels influenced their force. Yet, this relationship differs across two participants. No major differences were observed between the ways P2 and P3 decided to play the drum-set, indicating that the correlation between participants' velocity scores and rhythmic complexity levels might be influenced by other unknown factors. Furthermore, no correlation was found between DK's density of syncopation and participants' velocity. This suggests that the participants' striking force was not altered through the manipulation of rhythmic complexity levels introduced by DK.

Visual inspection of participants' mean velocity scores per extremity across conditions demonstrated higher variability in LF scores for P1 and P4, fluctuating above and below their mean scores of their UE and RF throughout conditions. The two possible techniques were described in the literature for the use of the pedal (Romero et al., 2016; Salvalaio et al., 2011). In the Heel Toe technique, the heel remains in contact with the pedal and the movements are performed mainly in the ankle joint (initial position: ankle on dorsiflexion; end position: neutral ankle). In the Toe Pivot technique, on the other hand, the heel is raised, and the toe touches the pedal (starting position: hip and knee flexion, neutral ankle and foot eversion; end position: hip and knee extension, neutral ankle and foot inversion). The two possible techniques for the use of pedals may have impacted velocity scores, providing a possible explanation for these fluctuations. While all participants' RF were observed to be utilizing the Heel Toe technique, P1's and P4's LF was observed to switch between two pedal techniques throughout sessions. The Toe Pivot technique has been suggested to produce higher muscle activity, covering more muscular areas (Salvalaio, Silva, Pinho, & Pohlmann, 2011), and producing higher striking force than the Heel Toe technique. The shifting in techniques of the LF might explain the variability in these two participants. This is corroborated by Carson and Riek (1998) who indicated that joint position in general had a significant impact on the control and stability of coordination movement patterns when subjects were required to synchronise finger tapping with a regular pacing signal (Carson & Riek, 1998). A difference in technique for the use of the pedals might provide an explanation of velocity fluctuations LF, but the use of these techniques can be also related to the asymmetrical unilateral motor symptoms in PD (Djaldetti, Ziv, & Melamed, 2006) which was reported by all participants. This may suggest that the more affected left side reported by participants influenced the striking force exhibited as velocity variability throughout sessions.

More research needs to be conducted regarding the biomechanics of playing a drum-set and its impact on motor control and coordination in individuals with PD.

4.1.4. Asynchrony

Until now, there is a lack of research in the ability of individuals with PD to synchronize extremities while playing a drum-set during IAMT. Freeman et al. (1993) reported that individuals with PD are less able than healthy subjects to accurately synchronize their finger tapping to external timing cues. None of the patients tested in this study showed a dominant tempo in their tapping behavior such as would be expected if a powerful entrainment occurred (Freeman et al., 1993).

Healthy subjects demonstrated a decrease in finger tapping accuracy during synchronization task to the beat as the rhythms' syncopation indices increased (Fitch & Rosenfeld, 2007). This is likely because syncopated rhythms have an accent structure in opposition to the beat, thus listeners have more difficulty in maintaining an internal representation of the beat in the presence of even moderately syncopated rhythms (Fitch & Rosenfeld, 2007). The current study corroborates the results reported by Fitch and Rosenfeld (2007) in that asynchrony scores revealed a significant positive correlation with DK's density of syncopation for P2 and for P4. These results suggest that as DK's density of syncopation increased, participants became less synchronized. Furthermore, the participants' density of syncopation scores revealed a significant positive correlation with asynchrony scores for P1, a negative correlation for P3 and P4. This suggests that the more syncopated rhythms played by P1, the less synchronized P1 became. For P3 and P4, an opposite effect occurred; the more syncopated rhythms these participants played, the more synchronized they became. Relating back to the way participants played the drum-set, it can be assumed that whenever P1, who

mainly attempted to follow the beat, tried to play syncopated rhythms, synchronicity was compromised. For P3 and P4, who mainly attempted to imitate the rhythmic structure, the more syncopated rhythms they successfully followed, the better their synchronization became.

Asynchrony was also significantly correlated with note count. Note count scores revealed a significant negative correlation with asynchrony for P1, and positive correlations for P2, P3, and P4. Synchronization is therefore affected by the amount of notes participants played during the intervention. This relationship, however, may be influenced by the way participants played the drum-set. For P1, who attempted to follow the beat, an increase in note count enhanced synchronization. On the other hand, for P2, P3, and P4, who attempted to follow the rhythmic structure, the more notes they played, the less synchronized they became. This suggests that synchronization may be possibly impacted by the degree to which participants tended to follow the beat compared to the rhythmic structure.

The literature of sensorimotor synchronization demonstrates that finger tapping tends to precede the beat of the music by a few tens of milliseconds, rather than being distributed symmetrically around beat (Repp, 2005). In general, musicians are known to have superior synchronization skills to non-musicians, with smaller mean asynchronies (Krause, Pollok, & Schnitzler, 2010). Repp (2010) reported that musicians' mean asynchrony was -26 ms, which for non-musicians was -47.9 ms during a synchronization finger tapping task to isochronous tones. Other studies have showed hardly any negative mean asynchrony, but a fluctuation between positive and negative mean asynchrony scores (Aschersleben, 2002; Repp & Penel, 2002). Furthermore, rhythmic complexity has been found to reduce or eliminate negative mean asynchrony (Patel, Iversen, Chen, & Repp, 2005). Individuals with PD were, in general, less precise than healthy subjects in replicating and in producing evenly paced tones (Freeman et al.,

1993). Yet, in this study, Freeman et al. (1993) did not include measurements of asynchrony, making any comparison to the current study rather difficult. The current study is consistent with the literature in that participants' mean asynchrony scores were both negative and positive, and influenced by music proficiency. P1's mean negative asynchrony score was -13.5ms, with P2's being -7.79ms, P3's being 2.4ms, and P4's being 7.47ms, across conditions. These results are harder to interpret if the implications of DK's asynchrony are taken into consideration. DK was the only one listening to the metronome, therefore it might be necessary to account for his asynchrony before reaching a conclusion. For example, if the literature suggests that musicians tend to have a mean asynchrony of -26ms, this asynchrony may need to be taken into consideration as the participants' mean asynchrony scores may be lower than the scores reported. The current study does provide evidence to indicate whether the participants played ahead or behind the beat, but does not take into account the implications of DK's asynchrony. Despite this, however, the results do suggest that P1's and P2's negative mean asynchrony scores indicate an anticipation of the beat, whereas, P3's and P4's positive mean asynchrony scores indicate a reactive behavior to the beat. This suggests that P1 and P2 had better synchronization abilities that P3 and P4 during IAMT sessions.

All participants exhibited lower mean asynchrony scores with UE extremity across conditions than LE. This result corroborates the results reported by Aschersleben and Prinz (1995); Fujii et al. (2011); Sims (1985) in that participant's synchronizing during IAMT was shown to be more difficult with the feet than with the hand. Furthermore, Aschersleben and Prinz (1995) reported no asynchrony differences between the use of limb's side (left vs right). Contrary to the results reported by Aschersleben and Prinz (1995), the current study found LE

side difference in three participants, where LF shown more asynchrony scores variability than RF across conditions.

4.2. Hypothesis 2

ii) Participants who acquire higher density of syncopation during treatment condition will demonstrate an increase in gait velocity and stride length compared to participants who do not demonstrate higher density of syncopation.

4.2.1. Gait test

The small number of participants in this study led to large variability, making the interpretation of results somewhat inconclusive. Results indicate that most participants had an increase in gait velocity and stride length from pre-baseline to post-baseline measurements. The participants' gait velocity and stride length, however, decreased after a moderate-high density of syncopation was administered, contrary to the hypothesis. Results also indicate that most participants had a decrease in step time and stride length variability from post-baseline to post-treatment measures, supporting the hypothesis. This suggests that gait variability measures decreased when moderate-high density of syncopation was administered. While the effectiveness of the overall IAMT sessions (both baseline and treatment conditions combined) suggest an overall improvement effect in participants' mean gait velocity, stride length, and step time and stride length variability, these changes may not be significant, or due to the IAMT sessions.

Another important aspect of the results is that gait velocity and stride length demonstrated the largest improvement from pre-baseline to post-baseline measurements, compared to improvements seen over the entire IAMT intervention. The average velocity score across participants at pre-baseline was 94.95cm/s and at post-baseline was 101.4cm/s, or an increase of 6.8%. Similarly, the average stride length score across participants at pre-baseline

was 103.9cm and at post-baseline was 109.7cm, or an increase of 5.6%. This indicates that participant's gait performance may be additionally enhanced when low-moderate density of syncopation is administered compared to when moderate-high density of syncopation is administered during IAMT sessions. However, it is also possible that participants were making gains that were not directly related to the influence of the low-moderate density of syncopation IAMT, but were more used to the testing situation during the second gait session than the first.

Results also indicate that participants had a decrease step time and stride length variability from post-baseline to post-treatment measurements. These results support the hypothesis in that step time and stride length variability can be decreased when moderate-high density of syncopation is administered during IAMT sessions. Furthermore, results also indicate that participants decreased step time and stride length variability overall during IAMT sessions (both baseline and treatment conditions combined). These results suggest that moderate-high density of syncopation administered during IAMT sessions positively impacted gait variability measures. On the other hand, low-moderate density of syncopation administered during IAMT sessions positively impacted gait velocity and stride length. Overall, IAMT sessions (both baseline and treatment conditions combined) has demonstrated to have a positive impact on all gait measures analyzed in this study. Three demonstrations of the overall IAMT sessions were found to improve gait velocity and stride length, whereas, all participants decreased step time and stride length variability. This suggests that IAMT sessions can potentially improve gait performance among individuals with PD.

In order to determine the degree of effectiveness of the overall IAMT interventions, a comparison to other studies in the literature may be useful. In, the de Bruin et al. (2010) study with individuals with PD, efficacy of 13-week walking intervention that incorporated a music

cueing program was examined. Participants walked at least 30 minutes, three times a week at a comfortable pace whilst listening to an individualized music playlist through head/ear-phones on an iPod. Spatiotemporal parameters of gait were assessed pre- and post-intervention. Participants walked the length of a 10-metre GAITRite mat walkway at a self-selected pace. Individuals with PD made significant improvements in gait velocity and stride length, reporting a change in gait velocity of 2.3% and a change in stride length of 1% (de Bruin et al., 2010). In the current study, results indicate that the overall IAMT intervention may have increased gait velocity and stride length. The average velocity score across participants at pre-baseline was 94.95cm/s and at post-treatment was 99.4cm/s, or an increase of 4.7%. Similarly, the average stride length score across participants at pre-baseline was 103.9cm and at post-treatment was 107.47cm, or an increase of 3.4%. Results of this study do provide larger differences than improvements reported by de Bruin et al. (2010). This suggests that IAMT sessions can potentially improve gait performance among individuals with PD, however, it cannot be conclusively stated that acquisition of rhythmic complexity during IAMT is what led to the difference, as no significant improvements were seen from post-baseline to post-treatment.

4.2.2. Beat Alignment Test

4.2.2.1. Perceptual test.

The results obtained in the BAT perceptual task are generally consistent with the range of values reported in previous studies in PD (Biswas, Hegde, Jhunjhunwala, & Pal, 2016). The variability scores among non-musicians across studies has showed lower accuracy compared to musicians, and individuals with PD perform significantly poorer than healthy subjects. For example, in a test battery including 147,633 healthy subjects, Müllensiefen, Gingras, Musil, and Stewart (2014) reported mean accuracy for the beat perception task of 77% (SD = 16).

Furthermore, Bouwer, Werner, Knetemann, and Honing (2016) also reported similar results of 79% (SD = 17) in 34 healthy subjects (23 women). In a study by Bouwer et al. (2016), the average accuracy reported on the BAT perception test scores were correlated to the musical training subscale, finding that musical training is related to better beat perception scores. Biswas et al. (2016) reported that BAT perception test scores of individuals with PD (10 male and 11 female) was 60% (Biswas et al., 2016). In another study, Roberts (2017) utilized the median perception score to classify healthy older adults as poor beat perceivers or good beat perceivers. In this study, of 98 healthy older adults, the BAT perception scores ranged from 17% to 100%. The median score was 64%. On average, the poor beat perceivers had significantly fewer years of music training than the good beat perceivers (Roberts, 2017), corroborating the results reported by Bouwer et al. (2016). Results of the BAT perceptual task in the current study corroborate results in the aforementioned studies. On average across conditions, P1, who reported some music training, scored 70%, higher than P2 (52%), P3 (54%), and P4 (64%). This suggests that P1 may be a good beat perceiver, whereas P2, P3, and P4 may be poor beat perceivers. These results also corroborate the aforementioned participants' differences in playing the drum-set. P1 played at a slower metric level than the rest of the participants, which also correlates with musical training. Furthermore, only P1 demonstrated an increase in performance throughout conditions, whereas P2, P3, and P4 demonstrated some fluctuations, but around and below the median scores of 64%. This suggests that IAMT sessions might improve beat perception abilities only in participants with previous music training.

4.2.2.2. Production test.

The literature suggests a significant, weak negative correlation between BAT perception scores and tapping variability in the production test scores, indicating that individuals with better

performance on the beat perception task have lower tapping variability in the production task (Dalla Bella et al., 2017). The results of the current study are consistent with this correlation. P1 scored the highest in the perception task and also demonstrated the lowest average tapping variability on the production task. Furthermore, P4 scored second highest percentage in the perception task and exhibited the second lowest average tapping variability.

BAT asynchrony scores in the production task, on the other hand, were not associated with perception task scores or tapping variability. For example, P3 exhibited the lowest BAT asynchrony score amongst participants. Differences between and within participants across conditions, however, were low. Furthermore, participants did not demonstrate a clear increase in performance throughout conditions, this suggests that IAMT sessions do not improve beat production abilities.

4.3. Summary of Findings

After four individuals diagnosed with PD participated in IAMT sessions, partial evidence of a treatment effect was found for one of four participants. Participants' personal interpretation of playing the drum-set and music proficiency partially influenced not only the dependent variable (participant's density of syncopation) and the outcome measures, but also other music measures. Only one participant's density of syncopation increased from baseline to treatment conditions, however, during the treatment condition demonstrated a slight downward trend, in the opposite direction expected. The remaining participants demonstrated a predictable trend during the baseline condition, however, during the treatment condition, a slight downward trend, in the opposite direction expected, was observed. This suggests that participants' acquisition of rhythmic complexity did not increase in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation during IAMT sessions.

Visual analysis of changes in note count scores suggest that the participants' note count scores did not increase in the presence of moderate-high density of syncopation compared to low-moderate density of syncopation levels. One explanation of this upward trend in note count during the baseline and a stable trend during treatment in three demonstrations, is that note count can be impacted by practice. Participants learned to play the drum-set throughout baseline sessions, becoming more comfortable with the task at hand, thus increasing their note count until reaching a plateau. Yet, Pearson's correlations amongst music measures revealed that DK's density of syncopation was significantly positively correlated with the participants' note count. This indicates that a higher density of syncopation may lead to participants playing more notes. The participants' note count, however, was also found to have a significant negative correlation to their density of syncopation. This suggests that DK's density of syncopation can increase the amount of notes the participants played. When the participants played more notes, however, it also reduced their density of syncopation level.

All the participants played more notes with UE across conditions than with LF or RF. The note count pattern demonstrated high variability across conditions with LE. On average, most participants played more notes with all extremities during the treatment condition than during the baseline condition. Note count and note position within the rhythmic structure played by participants provided further evidence of the differences of how participants played the drum-set. Comparing each participant's percentage of notes played ON beat versus notes played OFF beat provided evidence to the degree at which participants tended to follow the beat (more notes ON beat) or the rhythmic structure (more notes OFF beat). Results confirm that one participant tended to follow the beat considerably more than the rest, who mainly aimed to imitate the rhythmic structure.

Visual analysis of changes in mean velocity scores shows an increase in striking force during the baseline condition for two participants. This suggests that the participants' mean velocity trend was not influenced by the presence of a moderate-high density of syncopation, but was possibly influenced again by a practice effect. Similarly, to note count, the upward trend during the baseline condition and a stable trend during treatment condition in two demonstrations indicates that as participants learned to play the drum-set throughout baseline sessions, their striking force increased until reaching a plateau. Furthermore, the participants' density of syncopation scores revealed a significant correlation with velocity for two participants. One participant, however, exhibited a negative correlation between density of syncopation and velocity, whereas, another participant exhibited a positive correlation. This suggests that the participants' striking force increased or decreased with the increasing density of syncopation levels. This further suggests that attempting to play a higher density of syncopation can impact striking force differently for participants. Interestingly, these two participants shared similar music behavior while playing the drum-set without previous music proficiency. This fact may suggest that striking force might not be influenced by the participants' personal interpretation of playing the drum-set or music proficiency, but by other factors. Moreover, no correlation was found between DK's density of syncopation and the participants' velocity. This suggests that the participants striking force was not altered by the manipulation of density of syncopation levels played by DK. Visual inspection of the participants' mean velocity scores per extremity across conditions demonstrated higher variability with LF in two participants. A difference in technique for the use of the pedals might provide an explanation for these fluctuations, but the use of these techniques can be also related to the asymmetrical unilateral motor symptoms in PD (Djaldetti et al., 2006) reported by all participants. This suggests that the more affected left side reported by

participants influenced the striking force throughout sessions.

The participants' density of syncopation scores revealed a statistical correlation with asynchrony in three participants. One participant, however, exhibited a positive correlation, whereas two participants exhibited a negative correlation. This indicates that asynchrony measures decreased as the density of syncopation increased for one participant, and asynchrony increased as density of syncopation increased for the other two participants. It may be concluded that those participants who attempted to follow the rhythmic structure better synchronized with a higher density of syncopated rhythms, whereas, for the participant who attempted at following the beat, playing a higher density of syncopation rhythms compromised synchronicity. This suggests that synchronization is affected by the degree to which participants tend to follow the beat or the rhythmic structure.

The participants' asynchrony showed a significant positive correlation to DK's density of syncopation in two participants. This indicates that the participants became less synchronized when DK's density of syncopation increased. It may be concluded that for those participants who mainly attempted to follow the rhythmic structure had more difficulty in maintaining an internal representation of the beat while playing at higher density of syncopation levels, resulting in more asynchrony. This suggests that the density of syncopation levels played by DK can impact the participants' synchronization for those attempting to follow the rhythmic structure.

The study results also indicated that most participants increased their gait velocity and stride length from pre-baseline to post-baseline measurements. The participant's gait velocity and stride length, however, decreased when moderate-high density of syncopation was administered during IAMT sessions. While the effectiveness of the overall IAMT sessions (both baseline and treatment conditions combined) suggests the possibility of an overall IAMT effect

for participant's mean gait velocity and stride length, this change may not be significant. The study results indicate that gait velocity and stride length demonstrated larger improvement from pre-baseline to post-baseline measurements than from post-baseline to post-treatment. This suggests that these measures could be additionally enhanced when a low-moderate density of syncopation is administered compared to when a moderate-high density of syncopation is administered during IAMT sessions. The study results also indicated that most participants decreased gait variability measures from post-baseline to post-treatment measurements and the overall IAMT sessions (both baseline and treatment conditions combined). These results suggest that moderate-high density of syncopation administered during IAMT sessions positively impacted gait variability measures. On the other hand, low-moderate density of syncopation administered during IAMT sessions positively impacted gait velocity and stride length. Overall, IAMT sessions has demonstrated to have a positive impact on all gait measures analyzed in this study.

The results of the BAT perceptual task in the current study is consistent with the results found in the literature, allowing for the designation of the participants as either good beat perceivers or a poor beat perceivers. According to mean BAT test results, one participant can be placed in the good beat perceiver group, whereas, the other three can be placed in the poor beat perceiver group. These results are consistent with the aforementioned music measures results in that the good beat perceiver participant reported music training, demonstrated the lowest asynchrony mean scores, and tapped at a slower metrical level. Furthermore, this participant demonstrated an increase in BAT perception performance throughout conditions, whereas, the other three participants demonstrated score fluctuations, above and below the median scores of 64%. This suggests that IAMT sessions can potentially improve beat perception abilities for

participants with previous music training. The study results also demonstrate a negative association between BAT perception and tapping variability in the production test scores, indicating that individuals with better performance on the beat perception task had lower variability on the production task. BAT asynchrony scores, on the other hand, did not correlate to perception task scores or tapping variability.

4.4. Contributions to the Literature

The results of the current study are unique, making it difficult to compare these results with other results in the literature. Currently, there is no information in the literature about the specific benefits and limitations of acquisition of rhythmic complexity levels and its impact on motor skills. The literature also demonstrates a dearth of published research findings from studies that examined individual IAMT, where participants actively play and improvise music, without combining the approach with other interventions such as relaxation or music and movement (Kogutek et al., 2016). The results of the present study provide important information regarding the utilization of IAMT in targeting physical improvements in neurological rehabilitation. Entrainment is one of the most important underlying mechanisms for the successful application of IAMT. Understanding how entrainment is best achieved can, therefore, inform how to best facilitate the musical experience to attain clinical aims. In the present study, different rhythmic complexity structures were introduced during IAMT sessions in order to explore the musical responses from individuals with PD. The utilization of two contrasting conditions in the current study allowed for the manipulation and interpretation of the participants' abilities to acquire different rhythmic complexity levels played by the therapist. Playing a drum-set is a multimodal art; combining sound, motion, effort, visual, and

proprioceptive properties. Using both hands and both feet is clearly demanding both in terms of exertion and motor control.

MIDI provides the possibility to measure the participants' music responses such as, acquisition of rhythmic complexity, amount of notes, striking force, and synchronicity levels. These are very important domains in the treatment of PD in MT in order to identify music behavior. Research studies about the specific parameters for musical interventions in MT can provide the field with important evidence concerning the use of improvisation. When data exists for several participants representing the same diagnostic populations, commonalities in their musical behavior across the sample can provide valuable hints for interpretation. The use of MIDI in IAMT approach can provide daily measures and analysis of data using statistical analyses alongside visual analysis. This method of quantifying changes in a therapist's and patient's use of music over time can be used to evaluate treatment effectiveness and assess patient progress. For example, information on striking force and note count could be used to monitor a treatment session intended to engage the participant in using the side of the body most impacted by PD symptoms. Ultimately, this represents progress toward the design of more rigorous protocols, which then can establish the generalized efficacy of the intervention across sites as well as of different treatment intensities, leading to new evidence-based intervention model in MT.

4.5. Limitations

While the current study provides the first data on the efficacy of rhythmic acquisition on gait performance among individuals with PD, the current study clearly has some limitations. Due to a small sample size, the study may not have obtained enough data to accurately detect treatment effects. Similarly, follow-up data was obtained from only two participants, which

significantly limited any implication that could be made about the long-term effect on gait performance. The homogeneous nature of the sample, however, may have increased the generalizability of results.

An additional limitation of the study is the validity of the Humdrum Toolkit. Although this measuring tool has been demonstrated to be effective in detecting syncopation moments, it cannot distinguishes between hemiola rhythms such as 3 against 2 (Huron & Ommen, 2006). Syncopation in triplets, therefore, was probably not counted as such, or mistakenly counted during the processing of the data. This may have somewhat influenced the final results since hemiola was utilized by DK in order to alter the rhythmic structure in a less predictable way when participants became accustomed to the rhythmic structure, or in order to maintain the participants' attention. Similarly, a large asynchrony score could have been mistakenly counted by the Humdrum Toolkit as a syncopation moment. Nonetheless, this error in the detection of syncopation moments was uniformly distributed among participants. The error may have, however, influenced scores differently across participants when considering the participants' personal interpretation of playing the drum-set.

Another limitation was the MIDI trigger position of the drum-set pedals. The number of notes played by participants with lower extremities needed a minimum of velocity threshold in order to be captured by MIDI. This suggests that attempts made by the participants under a certain velocity threshold were not captured by the MIDI trigger, thus considerably reducing the note count in some instances. Considering that asynchrony was significantly correlated with note count, it may be important to find a way of lowering the velocity threshold in future research as this may have an impact on asynchrony scores and on other music measures. Variability in LF asynchrony in three participants might be explained by the low note count scores which could

have been directly associated with MIDI trigger threshold. Future protocols should, therefore, consider the angle or ankle movement motion involved in pedal pressing, as well as acquiring pedal triggers with an adjustable velocity threshold.

The BAT was selected because it is a concise measure of beat perception and production ability, uses ecologically valid music, is easily implemented, and is practical to administer. Beat perception has been suggested to be affected by pitch, melody, harmony, and timbre perception (Fujii & Schlaug, 2013). Pitch perception deficits can influence rhythm perception in music, but pitch perception was not tested here in this study. Future studies may, therefore, benefit from using more in-depth and comprehensive assessments of beat perception and production, such as the Battery for the Assessment of Auditory Sensorimotor and Timing Abilities (Dalla Bella et al., 2017) or the Harvard Beat Assessment Test (Fujii & Schlaug, 2013).

4.6. Ideas for Future Research

Although the utilization of two contrasting conditions in the current research allowed for the manipulation and interpretation of the participants' abilities to acquire different rhythmic complexity levels played by the therapist, this produced a problem. From the patients' informal descriptions of their experience with the sessions, it appears that even though the intervention was highly enjoyable and a highlight of their rehabilitation process, the intervention could have enhanced participants' motivation if there was a gradual increase of rhythmic complexity levels throughout the intervention, allowing participants to experience more success. In future research, with the knowledge acquired in this research, an incremental increase in rhythmic complexity level, from easier to more complex, played by the therapist would be optimal instead of two contrasting conditions. A gradual increase in rhythmic complexity level over the length of the intervention may also have a greater treatment effect on gait performance.

There is a strong tradition of teamwork in the origins of the practice and training of Nordoff and Robbins (1977), which is the foundation of IAMT. The approach originated historically in the collaboration of a composer-pianist (therapist) and a special educator (co-therapist) combining their individual areas of expertise. The advantage of having a co-therapist in a broadly supplemental role is that it allows the primary therapist to concentrate more closely on the musical interaction with the patient. The co-therapist works alongside the therapist to support the therapeutic process by interacting and encouraging the patient to play instruments and/or vocalize. For future research, a co-therapist could assist in IAMT sessions by providing musical directions to participants through interactive examples, such as providing possible rhythm patterns to play on the drum-set or demonstration on how to properly hold the drum sticks for maximum control. By sitting alongside participants, a co-therapist could demonstrate different patterns by level of difficulty. For example, the co-therapist could show participants how to march to the beat with LE, and later on, could show how to include UE in parallel movement. Likewise, the co-therapist could provide examples of how to follow the rhythmic structure from simpler UE unilateral patterns, to more complex bilateral alternating patterns. Thus, including a co-therapist could potentially enhance participants' enjoyment and increase motivation throughout the intervention. Furthermore, after the MIDI data was analyzed, the amount of notes played by different extremities revealed relatively fewer pedal strokes of the LF and RF than with UE. This finding provides critical implications for future protocol development regarding the distribution and incorporation of all limbs. The co-therapist could further assist by, at times, providing directions to use mainly LE, or to increase the use of relatively weak extremities according to therapeutic aims.

The gait performance outcome measures may have not fully captured motor skill improvements as expected. For example, the effect could have been attenuated from the time between the last IAMT session and the corresponding gait test, usually after two to four days. Throughout the sessions, two participants mentioned LF improvements, but only in relation to their ability to synchronize within the musical context. Therefore, in order to further understand the direct treatment effect, outcome measures used in the literature related to motor improvement should be used immediately before, after, or during the intervention. Electromyography (EMG), for example, has been used to provide information regarding muscle activity during music performance (Fjellman-Wiklund, Grip, Andersson, Karlsson, & Sundelin, 2004). The EMG is a biosignal that measures the underlying electrical activity of muscle fibers using surface recording electrodes. This electrical activity is rich in information about the underlying impulses of activation of the innervating motor neuron and easily applied (Farina et al., 2014). Individual finger motion, for example, has been recognized from a single channel of EMG recording on the back of the forearm (Jensenius & Lyons, 2017). EMG has also been suitable for investigating drummers' conscious and unconscious movements such as the way the arms control the drumsticks in terms of muscle laxity and strain (Fujisawa & Miura, 2010). The electrical signals measured by EMG can also be transmitted to a digital signal processing algorithm that can output messages in synchrony with MIDI events, as a continuous data stream (Donnarumma, 2017). In future research, EMG could be utilized to measure muscle activity of limbs during IAMT sessions in order to directly correlate motor outcome and MIDI measures.

Another measuring tool gaining attention in the literature is a motion capture tracking system. The main idea of this method is that significant changes in the trajectory of a gesture can be indicated by significant changes in the acceleration of a body part (Sigal, Balan, & Black,

2010). The program reads the motion capture data and transforms it into either MIDI parameters or parameters controlling signal processing (Bevilacqua, Ridenour, & Cuccia, 2002). The mapped data can thus control MIDI synthesizers and sound processors, digital audio, and digital video all within the same software system (Dobrian & Bevilacqua, 2003). Motion capture has been utilized in studies related to the movement of the a drumstick as influenced by the grip of drummers (Dahl & Altenmuller, 2008) and infant engagement in rhythmic behavior when exposed to music (Zentner & Eerola, 2010). Motion capture is one of the most effective methods for digitizing human motion (Moeslund & Granum, 2001). Therefore, in future research, motion capture could also be utilized to measure the trajectory and acceleration of limbs during IAMT sessions while directly correlating motion capture data and MIDI measures.

Moreover, motor skill improvements of UE were not tested in the current study. Two participants described improvements in hand dexterity throughout the sessions. Changes in hand function and fine motor skill improvements have been identified in the literature by employing measurements such as, the Grip and Pinch Strength Test, the Box and Block Test of Manual Dexterity, the Jebsen-Taylor Hand Function Test, the 9-Hole Pegboard Test, the Action Research Arm Test, and the Arm Paresis Score. In future research, these tests could supplement gait tests by identifying UE motor skill improvements acquired during IAMT sessions.

Finally, several follow-up sessions should be incorporated in such a study to more accurately assess maintenance of changes in outcome measures over time. Since only two participants in the present study attended follow-up sessions, further incentives should be offered in future sessions to decrease attrition rate during follow-up sessions. Finally, depending on recruitment methods and opportunities, future studies should include a sample of healthy participants, with no comorbidity, in order to identify commonalities and differences in music

behaviors during IAMT sessions.

4.7. Implications for Practice

The findings of the current study indicate IAMT sessions can be implemented as an effective strategy to increase physical mobility among individuals with PD. MT has historically aligned itself with non-musical theoretical traditions developed in the areas of psychology, psychotherapy, and medicine (Horden, 2017). The need to understand and validate therapeutic processes and outcomes within the parameters of non-musical disciplines has been essential for the development of professional identity (Abrams, 2010). The need, however, to achieve desired clinical outcomes has led to the oversight of the importance of music itself, its rhythmic construction, content, and even aesthetic value. After all, it is music that holds the essential core of what defines MT (Lee, 2016). Connecting the musical process and clinical outcomes can highlight the relationship between music and therapy.

For music therapists, there is a great need to improve knowledge regarding the use of IAMT interventions. This information from this study could be helpful in developing clinical knowledge for therapists utilizing this approach. Specifically, therapists could potentially identify the outcomes of clinical improvisations in and of itself, that is, how patients play with musical structures and how the capacities that are gained in musical play help patients attaining therapeutic aims (i.e., connecting the musical process and clinical outcomes). Computational improvisation analysis is a relatively new approach in music therapy (Erkkilä, Ala-Ruona, & Lartillot, 2014). Computational analysis via MIDI provides the possibility to measure rhythmic structures, note count, striking force, and synchronization while correlating them to clinical outcomes measures. Research studies about the specific parameters for musical interventions in

MT can then provide the field with important evidence concerning the use of IAMT (De Backer, 2016).

MT is rapidly moving into new areas where the use and understanding of, and need for, computer technology is becoming an efficient way to analyze music during IAMT sessions. The main benefits of computational tools are precision, effectiveness and objectivity, particularly when individuals have unique ways of expressing her or himself musically. When data exists for several patients representing the same diagnostic populations, commonalities in their musical behavior across the sample can provide valuable hints for interpretation. For example, utilizing a MIDI-based approach, Luck et al. (2006) found that severe intellectual disability correlates with a staccato style of musical expression. This finding could probably be associated with a lower developmental age, where cognitive competencies such as the idea of phrasing, the creation of a melody line, or the general ability to deal with notes sequentially (all of which lead to legato rather than staccato style) are underdeveloped. If a therapist had some knowledge regarding the relationship between different diagnoses and musical features, he or she could interpret these various diagnoses more meaningfully. Such models in rehabilitation sciences would allow changes in patient's functional capacity over time (i.e., during an extended therapy process) to be examined. The therapist could offer their opinion as to the accuracy of the various diagnoses within the intervention (Luck et al., 2006). It would be a step towards much needed evidence-based models of IAMT. Furthermore, explicit knowledge concerning relationships between musical features and diagnostic populations would allow therapists to generate realistic expectations regarding their patients' progress. This is essential in both the therapist's initial assessment of a patient, as well as throughout the therapy process. Therefore, it is crucial to

develop an evaluation tool that therapists can use in their daily practice and that can serve as a framework for a shared system of evaluating progress in MT.

4.8. Conclusions

Research is needed on the effectiveness of active MT treatments in addressing physical improvements in PD. Given the limitations associated with pharmacotherapy, surgical, and rehabilitation treatments among this population, the current study sought to determine the effectiveness of acquisition of rhythmic complexity levels and its impact on motor skills during IAMT sessions. Results of the study indicated partial evidence for the ability of individuals with PD to acquire different rhythmic complexity levels through IAMT. Partial evidence was also found to suggest the overall effectiveness of IAMT sessions in increasing participant's gait performance. The participants' gait performance had greater improvements after baseline (low-moderate density of syncopation) for gait velocity and stride length measures than after treatment (moderate-high density of syncopation) conditions. For gait variability measures, participants' gait performance had greater improvements after treatment (moderate-high density of syncopation) than after baseline conditions. The findings of this study are that using MIDI in IAMT approach can provide daily measures and analysis of data using statistical analyses alongside visual analysis leading to new evidence-based interventions modeled in MT. Further research is needed to identify commonalities in music behavior in individuals with PD and healthy subjects aimed to improve physical rehabilitation.

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Appendix A

Test Instructions

Beat Alignment Test

- *Instructions 1* (beat perception)

This experiment explores your perception of the beat in music.

The beat is your sense of a regular pulse in music. It's what you might clap or tap your foot to.

You will hear several music clips. You will be then asked to decide if "beeps" played with the music sound ON or OFF the beat.

Listen to the following music clips. Decide whether the beeps are ON or OFF the beat.
Please DO NOT tap or move along with the music.
Press the space bar to begin the practice trials.

- *Instructions 2* (beat production)

During this test, you will tap to the beat while hearing music.
Listen to each music clip. As soon as you feel the beat, use the spacebar on your keyboard to tap regularly in time with the beat until the clip ends.

A series of asterisks (*) will appear when you tap so you can tell your taps are being registered.

There will be a three second countdown before each trial so you know when each clip will begin.

Press SPACEBAR to begin the practice trial.

Appendix B

Humdrum Script

Syncopation:

1. Locate folder:
   cd <name of folder>

2. Convert XML file into a KRN file:
   xml2hum <file name.xml> > <new file name.krn>

3. Set the timebase register:
   timebase –t 16 <file name.krn> > <new file name.krn>

4. Set the metpos register:
   metpos –t 16 <new file name.krn> > <new file name.krn>

5. Run syncopation:
   synco <file name.krn> > <file name.syn>

Appendix C

P1 note count scores by extremity across conditions

	Total NC	NC UE	NC LF	NC RF
Baseline 1	2151	717	203	1231
Baseline 2	4048	2395	302	1351
Baseline 3	3949	2695	137	1117
Baseline 4	6373	3031	1258	2084
Treatment 1	6520	4231	638	1651
Treatment 2	6601	4225	984	1392
Treatment 3	6232	4105	756	1371
Treatment 4	6381	4081	942	1358
Treatment 5	6817	4050	1088	1679
Treatment 6	7344	5031	998	1315
Treatment 7	6188	4371	476	1341
Treatment 8	6960	4333	1325	1302
Treatment 9	7381	4386	1217	1778
Treatment 10	7812	4497	1223	2092
Treatment 11	6050	3872	616	1562
Treatment 12	7793	5577	800	1416
Treatment 13	6792	4517	897	1378
Treatment 14	7106	4576	1058	1472
Treatment 15	6685	4309	843	1533
Treatment 16	5848	3984	543	132
Average Baseline	4130	2209	475	1445
Average Treatment	6781	4384	900	1497
Totals Average	6251	3949	815	1487

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix D

P2 note count scores by extremity across conditions

	Total NC	NC UE	NC LF	NC RF
Baseline 1	3571	3045	49	477
Baseline 2	6809	5981	51	777
Baseline 3	7623	6938	24	661
Baseline 4	9504	7424	587	1493
Baseline 5	6419	6194	85	140
Treatment 1	13089	10456	395	2238
Treatment 2	10285	9830	104	351
Treatment 3	9335	9082	19	234
Treatment 4	11179	9511	160	1508
Treatment 5	12493	11490	276	727
Treatment 6	10558	9327	39	1192
Treatment 7	10890	9929	214	747
Treatment 8	13756	10979	154	2623
Treatment 9	13488	10476	224	2788
Treatment 10	13181	11701	6	1474
Treatment 11	12136	10316	13	1807
Treatment 12	15320	12928	4	2388
Average Baseline	6785	5916	159	709
Average Treatment	12142	1050	134	1506
Total Average	10566	9153	141	1272

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix E

P3 note count scores by extremity across conditions

	Total NC	NC UE	NC LF	NC RF
Baseline 1	7055	6204	86	765
Baseline 2	9966	8867	20	1079
Baseline 3	6961	6374	315	272
Baseline 4	8264	6134	895	1235
Baseline 5	7897	5217	1117	1563
Baseline 6	6445	4519	1109	817
Treatment 1	9449	7745	556	1148
Treatment 2	6564	5207	379	978
Treatment 3	8813	7443	283	1087
Treatment 4	10545	9779	32	734
Treatment 5	6759	5588	270	901
Treatment 6	10418	8132	664	1622
Treatment 7	6675	4849	60	1766
Treatment 8	8177	7101	85	991
Treatment 9	11592	10367	18	1207
Treatment 10	7128	6218	292	618
Treatment 11	7351	6159	3	1189
Treatment 12	7406	5405	588	1413
Treatment 13	9903	7876	754	1273
Treatment 14	6500	4510	224	1766
Treatment 15	8295	6923	218	1154
Treatment 16	8899	6945	650	1304
Average Baseline	7764	6219	590	955
Average Treatment	8404	6890	317	1196
Total Average	8230	6707	391	1131

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix F

P4 note count scores by extremity across conditions

	Total NC	NC UE	NC LF	NC RF
Baseline 1	3108	3090	3	15
Baseline 2	5989	5904	21	64
Baseline 3	5959	5249	8	702
Baseline 4	8332	7211	568	553
Baseline 5	7500	7070	58	372
Baseline 6	8176	7268	403	505
Baseline 7	11635	8039	3418	178
Baseline 8	9932	8309	1148	475
Treatment 1	8986	7335	1475	176
Treatment 2	12273	9304	2939	30
Treatment 3	10403	9773	495	135
Treatment 4	11441	9325	1763	353
Treatment 5	10370	10208	24	138
Treatment 6	13011	10480	2243	288
Treatment 7	10112	8916	443	753
Treatment 8	12299	8811	2876	612
Treatment 9	10961	9585	889	487
Treatment 10	12734	8324	3947	463
Treatment 11	13460	8955	4093	412
Treatment 12	9862	9486	0	376
Treatment 13	10430	9569	343	518
Treatment 14	9270	8792	112	366
Treatment 15	9186	8331	194	661
Treatment 16	10065	9161	160	744
Average Baseline	7578	6517	703	358
Average Treatment	10928	9147	1374	407
Total Average	9812	8270	1150	390

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity.

Appendix G

P1 mean velocity scores by extremity across conditions

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	45.09 (24.95)	43.4 (15.35)	102.92 (25.69)	36.51 (14.69)
Baseline 2	42.7 (15.97)	46.78 (15.18)	35 (18.51)	37.05 (14.33)
Baseline 3	36.49 (13.88)	40.28 (13.09)	35.12 (14.5)	27.3 (11.08)
Baseline 4	47.87 (24.67)	44.19 (14.66)	86.99 (13.01)	29.6 (13.04)
Treatment 1	37.4 (15.34)	39.58 (15.71)	28.92 (11.71)	35.08 (14.11)
Treatment 2	41.39 (15.01)	43.22 (16.01)	32.14 (11.66)	42.38 (11.06)
Treatment 3	39.23 (16.65)	41.06 (18.08)	24.81 (7.04)	41.69 (11.05)
Treatment 4	42.45 (15.47)	47.21 (16.02)	29.91 (10.02)	36.86 (8.72)
Treatment 5	47.37 (22.43)	47.53 (17.61)	64.49 (34.58)	35.86 (14.11)
Treatment 6	39.72 (17.04)	39.79 (18.8)	31.28 (12.09)	45.88 (8.25)
Treatment 7	42.73 (14.59)	43.94 (15.39)	27.03 (12.33)	44.35 (7.82)
Treatment 8	45.2 (19.13)	38.38 (15.68)	69.07 (18.4)	43.6 (7.48)
Treatment 9	47.45 (18.47)	44.02 (15.51)	59.08 (23.38)	47.97 (18.09)
Treatment 10	43.99 (19.75)	38.14 (14.79)	65.07 (25.43)	44.24 (16.57)
Treatment 11	39.54 (14.89)	38.54 (14.16)	30.84 (13.96)	44.4 (15.17)
Treatment 12	36.75 (15.5)	35.2 (16.21)	32.01 (11.54)	45.5 (10.64)
Treatment 13	37.49 (15.22)	35.68 (14.89)	27.04 (9.25)	50.23 (10.75)
Treatment 14	44.32 (18.45)	43.75 (17.89)	28.77 (10.8)	57.28 (14.91)
Treatment 15	42.28 (16.61)	41.32 (15.91)	41.53 (23.14)	45.4 (13.63)
Treatment 16	46.51 (19.22)	47.08 (21.14)	30.61 (16.32)	51.31 (7.19)
Average Baseline	43.04 (19.87)	43.66 (14.57)	65.01 (17.93)	32.62 (13.29)
Average Treatment	42.11 (17.11)	41.55 (16.49)	38.91 (15.73)	44.5 (11.85)
Total Average	42.3 (17.66)	41.98 (16.1)	44.13 (16.17)	42.12 (12.13)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix H

P2 mean velocity scores by extremity across conditions

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	32.15 (15.03)	32.01 (15.17)	27.36 (8.9)	33.55 (14.51)
Baseline 2	32.2 (13.67)	32.6 (13.83)	29.03 (9.88)	29.29 (12.21)
Baseline 3	37.92 (17.09)	38.69 (17.39)	23.83 (5.75)	30.41 (11.08)
Baseline 4	44.78 (25.82)	49.94 (26.25)	26.81 (9.74)	26.21 (11.08)
Baseline 5	52.59 (25.45)	53.24 (25.55)	30.65 (13.58)	37.43 (12.53)
Treatment 1	34.71 (17.82)	37.15 (18.55)	23.13 (6.96)	25.35 (10.16)
Treatment 2	41.28 (20.78)	41.8 (20.92)	27.85 (9.96)	30.74 (13.95)
Treatment 3	39.06 (19.3)	39.09 (19.38)	27.89 (8.51)	38.79 (16.31)
Treatment 4	34.37 (17.9)	35.88 (18.33)	27.42 (9.32)	25.63 (12.34)
Treatment 5	37.05 (17.41)	37.77 (17.67)	25.9 (8.63)	29.9 (11.82)
Treatment 6	34.45 (15.71)	35.21 (16.09)	22.38 (6.11)	28.9 (11.04)
Treatment 7	31.54 (14.72)	32.55 (14.68)	24.4 (7.68)	20.19 (11.07)
Treatment 8	34.56 (15.52)	36.08 (16.22)	27.25 (10.18)	28.65 (10.4)
Treatment 9	31.94 (15.79)	34.44 (16.29)	23.57 (6.45)	23.19 (10.01)
Treatment 10	33.89 (14.96)	35 (14.91)	25.33 (6.53)	25.1 (12.29)
Treatment 11	38.01 (20.85)	40.97 (20.84)	23.69 (8)	21.21 (10.29)
Treatment 12	38.5 (19)	41.92(118.28)	21 (4.24)	19.97 (9.94)
Average Baseline	39.93 (19.41)	41.3 (19.64)	27.54 (9.57)	31.38 (12.28)
Average Treatment	35.78 (17.48)	37.32 (17.68)	24.98 (7.71)	26.47 (11.64)
Total Average	37.00 (18.05)	38.49 (18.26)	25.73 (8.26)	27.91 (11.83)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix I

P3 mean velocity scores by extremity across conditions

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	17.95 (12.06)	15.90 (10.24)	27.53 (9.43)	33.58 (13.93)
Baseline 2	23.34 (15.24)	24.30 (15.52)	26.45 (7.47)	15.40 (9.67)
Baseline 3	16.08 (9.65)	14.92 (8.53)	31.2 (12.49)	23.50 (11.2)
Baseline 4	27.72 (19.38)	26.69 (20.29)	33.91 (11.25)	31.12 (15.39)
Baseline 5	47.74 (21.97)	40.63 (23.87)	40.06 (14.28)	42.97 (17.16)
Baseline 6	47.01 (21.06)	40.76 (19.16)	47.87 (28.58)	37.16 (15.23)
Treatment 1	31.02 (15.62)	30.21 (15.64)	32.38 (12.55)	35.85(15.94)
Treatment 2	35.16 (16.91)	35.93 (17.6)	32.48 (11.12)	32.05 (14.37)
Treatment 3	38.01 (16.99)	37.13 (17.31)	35.74 (13.56)	44.57 (13.79)
Treatment 4	30.28 (14.85)	30.41 (14.99)	24.15 (7.02)	28.89 (13.01)
Treatment 5	35.25 (16.94)	35.31 (17.47)	31.14 (10.76)	36.04 (14.81)
Treatment 6	30.28 (15.6)	30.82 (16.22)	30.00 (11.66)	27.67 (13.42)
Treatment 7	36.51 (14.94)	36.85 (15.86)	26.93 (8.11)	35.91 (12.13)
Treatment 8	29.58 (14.82)	29.43 (15.08)	27.68 (9.76)	30.82 (13.16)
Treatment 9	28.22 (14.18)	28.76 (14.22)	30.38 (6.8)	23.58 (12.97)
Treatment 10	36.54 (17.69)	37.81 (17.98)	30.53 (11.31)	26.61 (12.84)
Treatment 11	30.97 (16.54)	29.6 (16.42)	38.00 (20.07)	38.08 (15.29)
Treatment 12	35.35 (19.89)	32.67 (18.83)	32.81 (11.55)	46.62 (22.47)
Treatment 13	28.96 (15.08)	29.05 (15.62)	26.98 (9.63)	29.60 (14.23)
Treatment 14	40.92 (18.66)	40.55 (18.33)	31.41 (10.68)	43.07 (19.83)
Treatment 15	32.86 (15.36)	32.34 (15.07)	26.32 (8.91)	37.25 (17.05)
Treatment 16	35.59 (15.93)	35.68 (16.36)	28.71 (9.58)	38.53 (15.13)
Average Baseline	29.97 (16.56)	27.20 (16.27)	34.50 (13.92)	30.62 (13.76)
Average Treatment	33.47 (16.25)	33.28 (16.44)	30.35 (10.82)	34.70 (15.03)
Total Average	32.52 (16.33)	31.63 (16.39)	31.48 (11.66)	33.59 (14.68)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix J

P4 mean velocity scores by extremity across conditions

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	31.44 (9.17)	31.52 (9.1)	19.66 (2.51)	15.50 (9.15)
Baseline 2	35.81 (14.27)	35.92 (14.27)	19.52 (3.64)	31.12 (12.87)
Baseline 3	29.88 (11.74)	31.66 (10.94)	22.87 (7.51)	16.63 (8.59)
Baseline 4	36.42 (10.99)	38.11 (9.84)	30.20 (12.03)	20.69 (9.16)
Baseline 5	34.74 (13.11)	35.69 (12.76)	22.68 (5.4)	18.59 (8.05)
Baseline 6	30.75 (12)	31.58 (12)	28.92 (7.34)	20.21 (9.63)
Baseline 7	40.85 (13.51)	42.01 (11.91)	39.47 (15.63)	14.95 (8.23)
Baseline 8	35.10 (10.26)	36.47 (8.94)	32.93 (12.08)	16.46 (7.68)
Treatment 1	36.45 (9.87)	37.05 (8.92)	35.33 (12.48)	21.00 (9.61)
Treatment 2	26.85 (12.38)	24.28 (12.05)	35.07 (9.48)	16.33 (7.94)
Treatment 3	34.91 (8.72)	35.10 (8.54)	34.83 (8.48)	21.71 (11.88)
Treatment 4	34.87 (10.5)	35.80 (9.86)	33.11 (11.1)	19.04 (9.98)
Treatment 5	32.46 (7.55)	32.73 (7.24)	18.91 (1.74)	15.06 (8.08)
Treatment 6	31.94 (8.86)	31.70 (8.42)	34.18 (9.79)	23.48 (10.42)
Treatment 7	30.02 (9.8)	30.57 (9.16)	34.55 (11.16)	20.79 (11.09)
Treatment 8	35.63 (12.98)	33.13 (10.25)	46.15 (14.5)	22.29 (9.79)
Treatment 9	30.70 (9.65)	31.35 (9.38)	29.40 (9.34)	20.24 (9.09)
Treatment 10	32.84 (11.47)	32.48 (11.27)	35.53 (10.49)	16.47 (8.16)
Treatment 11	37.85 (12.27)	35.79 (10.02)	44.14 (13.6)	20.10 (9.99)
Treatment 12	29.52 (10.61)	30.09 (10.31)		15.01 (6.98)
Treatment 13	32.40 (10.75)	33.14 (10.51)	29.75 (8.13)	20.40 (9.18)
Treatment 14	34.14 (10.61)	34.86 (10.21)	27.72 (8.08)	18.80 (8.21)
Treatment 15	31.01 (10.91)	32.44 (10.19)	21.76 (4.68)	15.07 (6.29)
Treatment 16	28.82 (10.12)	30.12 (9.48)	21.14 (4.59)	14.45 (5.82)
Average Baseline	34.37 (11.88)	35.37 (11.22)	27.03 (8.27)	19.27 (9.17)
Average Treatment	32.53 (10.44)	32.54 (9.74)	32.10 (9.18)	18.77 (8.91)
Total Average	33.14 (10.92)	33.48 (10.23)	30.34 (8.86)	18.93 (8.99)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix K

P1 mean asynchrony scores by extremity across conditions in msec

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	-2.9 (39.9)	-0.37 (38.8)	1.2 (31.2)	-5.1 (41.8)
Baseline 2	-7.8 (34.7)	-10.9 (33.1)	-6.8 (36.5)	-2.2 (36.7)
Baseline 3	-2.7 (34.2)	-4.5 (33.6)	-5.1 (34.7)	2.7 (35.2)
Baseline 4	-4.9 (34.2)	-1.7 (32.8)	-14.9 (32.6)	-4 (36.5)
Treatment 1	-10.8 (37.5)	-14 (36.3)	-2.8 (38.3)	-5.3 (39.1)
Treatment 2	-8.5 (37.5)	-11.2 (36.5)	-7.1 (37.9)	-1.6 (39.1)
Treatment 3	-10.8 (37.8)	-13.5 (36.8)	-5.3 (40.3)	-5.3 (38.9)
Treatment 4	-13.6 (35.9)	-16.1 (34.7)	-4.3 (39.7)	-11.9 (35.6)
Treatment 5	-18.7 (33.6)	-19.5 (32.8)	-18.1 (36.6)	-16.7 (34)
Treatment 6	-17.3 (34.6)	-18.4 (33.4)	-16.4 (39.3)	-14.4 (35.7)
Treatment 7	-22 (34.2)	-22.6 (33.1)	-15.6 (41.9)	-21.4 (35.7)
Treatment 8	-19 (36.2)	-16.2 (34.9)	-23.6 (38.9)	-30.1 (38.3)
Treatment 9	-19.5 (32.80)	-19.6 (32.7)	-20.9 (35.6)	-18.8 (31.6)
Treatment 10	-15.5 (35.6)	-15.8 (34.5)	-19.6 (40.2)	-12.9 (35.4)
Treatment 11	-13.1 (33.4)	-15.6 (32.3)	-14.3 (34.1)	-6.7 (35)
Treatment 12	-13.7 (35.1)	-14.9 (34.6)	-7.5 (38.1)	-12.6 (34.8)
Treatment 13	-14 (34.7)	-16.5 (34.2)	-8.4 (36.4)	-10.1 (34.4)
Treatment 14	-16.6 (33.8)	-17.9 (32.7)	-16.9 (36.2)	-13.5 (35.2)
Treatment 15	-18.5 (33.6)	-18.3 (31.7)	-16.5 (37.5)	-19.9 (36.1)
Treatment 16	-19.8 (34.7)	-16.6 (34.2)	-40.1 (37.7)	-26 (34.3)
Average Baseline	-4.6 (35.8)	-4.3 (34.6)	-6.4 (33.7)	-2.1 (37.6)
Average Treatment	-15.7 (35.1)	-16.7 (34.1)	-14.9 (38)	-14.2 (35.8)
Total Average	-13.5 (35.2)	-14.2 (34.2)	-13.2 (37.2)	-11.8 (36.2)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix L

P2 mean asynchrony scores by extremity across conditions in msec

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	-11.7 (34.8)	-12.5 (34.1)	0.18 (30.2)	-8.8 (37.8)
Baseline 2	-8.3 (35.4)	-9.3 (34.4)	6.1 (40.4)	6.1 (40.7)
Baseline 3	-9.5 (35.7)	-8.7 (35.7)	-11.8 (35.1)	-16.8 (34.8)
Baseline 4	-11.4 (33)	-11.8 (32.3)	-5.1 (40.2)	-9.4 (39.4)
Baseline 5	-14.9 (34)	-15 (34.2)	-24.3 (30.4)	-9.4 (27.4)
Treatment 1	-0.7 (40.7)	-3.1 (40)	8.1 (37.9)	9.1 (42.9)
Treatment 2	-10.4 (37.3)	-11.5 (36.7)	8.6 (42.7)	4.9 (41)
Treatment 3	-16.4 (35.7)	-17.3 (35.4)	14.7 (31.9)	5.4 (35.4)
Treatment 4	-6.8 (37.5)	-8.9 (36.5)	-3.5 (48.4)	11.3 (40)
Treatment 5	-8.1 (36.9)	-8.8 (36.4)	-1.7 (40.4)	0.16 (42.9)
Treatment 6	-8.5 (36.7)	-8.9 (36.3)	-3.6 (34.8)	-5.8 (40.2)
Treatment 7	-11.2 (38.7)	-12 (38.6)	0.5 (36.4)	-4.8 (39.8)
Treatment 8	2.1 (38.7)	-0.03 (37.8)	-1.4 (41.1)	10 (40.6)
Treatment 9	-5.1 (38.7)	-8.6 (36.7)	10.8 (37)	6.3 (44.4)
Treatment 10	-5.1 (38.5)	-6.7 (37.9)		7.2 (40.7)
Treatment 11	-5.9 (38.9)	-8.8 (37.4)	30.8 (24.1)	12 (43)
Treatment 12	-0.6 (35.9)	-2.7 (34.5)	39.5 (20.8)	13.3 (41.5)
Average Baseline	-11.2 (34.6)	-11.5 (34.1)	-7 (35.3)	-7.7 (36)
Average Treatment	-6.4 (37.9)	-8.1 (37)	12.7 (33)	5.8 (41)
Total Average	-7.8 (36.9)	-9.1 (36.2)	6.9 (33.6)	1.8 (39.6)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix M

P3 mean asynchrony scores by extremity across conditions in msec

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	8.5 (38.9)	8.1 (38.8)	8.7 (35.6)	11.2 (38.8)
Baseline 2	20.7 (39.5)	20.6 (39.5)	41.2 (38.9)	21.6 (37.4)
Baseline 3	8.2 (39.1)	7.9 (39.3)	16.6 (37.7)	7 (36.2)
Baseline 4	1.5 (40.1)	0.44 (40.5)	4 (40.1)	5 (38.6)
Baseline 5	-1 (39.2)	-2.1 (40.2)	2.3 (38.9)	-0.01 (35.3)
Baseline 6	-0.7 (41)	-2.7 (41.4)	3.3 (42.6)	5.6 (35)
Treatment 1	3.3 (41.2)	2.4 (41.5)	0.8 (42.9)	9.9 (33.4)
Treatment 2	-3 (41.8)	-3.5 (41.9)	-6.8 (35.8)	0.8 (38.1)
Treatment 3	0.3 (43)	0.7 (43.5)	-10.8 (39.9)	0.01 (36.3)
Treatment 4	6.8 (43.3)	7.3 (43.3)	-28.2 (1.6)	0.2 (37)
Treatment 5	-1.7 (42.2)	-2.9 (42.1)	-0.07 (50)	3.8 (36.3)
Treatment 6	8.1 (43.6)	9.2 (44.3)	5.3 (38.7)	2.7 (36.5)
Treatment 7	-2 (40.5)	-2.3 (40.6)	-10.8 (34.9)	-1 (35.8)
Treatment 8	-2.3 (42.1)	-3.1 (42.1)	7.6 (43.3)	4.5 (36.4)
Treatment 9	11.1 (44.1)	11.2 (44)	-25.1 (37.2)	11.3 (40)
Treatment 10	6.5 (42.6)	7 (43)	-6.7 (47.4)	5.8 (32.8)
Treatment 11	2.6 (36.2)	2 (44.1)		4.8 (35.1)
Treatment 12	-4.6 (40.9)	-6.8 (41)	-9.2 (37.4)	2.5 (36.1)
Treatment 13	3.8 (42.7)	3.4 (43.8)	4.2 (40.8)	5.7 (32.6)
Treatment 14	-8.3 (42.7)	-12.8 (42.5)	-11.3 (36.9)	-0.44 (37.8)
Treatment 15	-1.9 (42.7)	-2.2 (42.8)	-4.9 (38.2)	0.2 (37.5)
Treatment 16	-3 (40.7)	-3.9 (41.4)	-4.5 (36.5)	0.47 (35.2)
Average Baseline	6.2 (39.6)	5.4 (39.9)	12.7 (39)	8.4 (36.9)
Average Treatment	1 (41.9)	0.36 (42.6)	-6.3 (35.1)	3.2 (36.1)
Total Average	2.4 (41.3)	1.7 (41.9)	-1.1 (36.1)	4.6 (36.3)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix N

P4 mean asynchrony scores by extremity across conditions in msec

	Mean (SD)	Mean (SD) UE	Mean (SD) LF	Mean (SD) RF
Baseline 1	0.08 (39)	0.15 (38.9)		
Baseline 2	6.8 (40.8)	6.8 (40.9)	1.4 (14.6)	13.6 (31.3)
Baseline 3	-2.2 (40.1)	-2.5 (40.2)		1.8 (38.8)
Baseline 4	2.9 (40.9)	2.1 (41.2)	13 (37.8)	4.9 (36.2)
Baseline 5	2.1 (41.4)	1.5 (41.3)	28.7 (46)	10.8 (40.8)
Baseline 6	5.7 (42)	5.2 (42.2)	5.9 (38.4)	13.5 (40)
Baseline 7	1.1 (40.3)	-3.1 (40.3)	12.2 (37.8)	5.1 (45.9)
Baseline 8	1.7 (41.3)	-0.71 (41.2)	15.1 (38.4)	13.9 (41.3)
Treatment 1	10.1 (41.7)	9 (41.7)	16.8 (42)	8.2 (33)
Treatment 2	8.8 (42.2)	7.2 (42.4)	14.4 (41.2)	16.2 (30.9)
Treatment 3	2.7 (42.4)	1.8 (42.3)	18.1 (41.4)	10.6 (42)
Treatment 4	9.7 (41.8)	8.4 (42.2)	17.2 (39.7)	11.1 (35.2)
Treatment 5	0.23 (41.6)	0.23 (41.6)	24.3 (24.9)	-9 (37.4)
Treatment 6	14.9 (42.1)	13.9 (42.2)	20.3 (40.9)	14.4 (48.2)
Treatment 7	9.2 (40.7)	8.49 (40.7)	20.7 (37.8)	12.4 (41.3)
Treatment 8	17.5 (40.6)	17.1 (40.8)	19.1 (40.2)	15 (39.3)
Treatment 9	13.3 (40.3)	12.4 (40.3)	21.7 (39.7)	16.2 (41.8)
Treatment 10	18.6 (40)	18.3 (39.7)	19.6 (40.9)	14.8 (39.1)
Treatment 11	13.8 (40.2)	14.1 (40.5)	14.1 (39.4)	3.6 (39.6)
Treatment 12	5.3 (41.4)	4.9 (41.4)		19.8 (39.1)
Treatment 13	10.2 (39.9)	9.1 (39.7)	29.2 (40.4)	25.2 (38.3)
Treatment 14	6.5 (40.8)	6.6 (40.9)	4.8 (36.1)	3.1 (36.6)
Treatment 15	12.3 (40.3)	12.1 (39.9)	20 (53.3)	15.6 (46.9)
Treatment 16	7.7 (39.2)	7.7 (36)	-5 (41.7)	11.2 (41)
Average Baseline	2.3 (40.7)	1.2 (40.8)	12.7 (35.5)	9.1 (39.2)
Average Treatment	10.1 (40.9)	9.5 (40.8)	16 (37.5)	11.8 (39.4)
Total Average	7.5 (40.9)	6.7 (40.8)	15.1 (36.9)	11 (39.3)

Note. LF, left foot; NC, note count; RF, right foot; UE, upper extremity

Appendix O

Ethics Documentation

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Jeffrey Holmes
Department & Institution: Health Sciences\Occupational Therapy,Western University

Review Type: Delegated
HSREB File Number: 108090
Study Title: Efficacy of rhythmic acquisition on gait performance among individuals with Parkinson's disease
Sponsor:

HSREB Initial Approval Date: July 21, 2016
HSREB Expiry Date: July 21, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Received 30Jun16	
Other	Table 1 Figure 2 (Received 23May16)	
Advertisement	Recruitment Poster (Received 23May16)	
Letter of Information & Consent		2016/06/30
Advertisement	Ad (Received30Jun16)	
Instruments	MoCA Test (Received 39Jun16)	
Other	Tips for Personal Safety Home Visit (Received 18Jul16)	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

[redacted]
Ethics Officer, on behalf of Dr [redacted] HSREB Chair

Ethics Officer: Erika Basile ___ Nicole Kaniki ___ Grace Kelly ___ Katelyn Harris___ Vikki Tra___ Karen Gopaul ___

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6G 1G9 t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/ethics

VITA

Name:	Demian L. Kogutek
Place of birth:	Buenos Aires, Argentina
Year of birth:	1978
Post-secondary Education and Degrees:	Bachelor of Honors of Music Therapy University of Windsor, Windsor, Ontario, Canada 2005 - 2009
	Master of Music Therapy Wilfrid Laurier University, Waterloo, Ontario, Canada 2010 - 2011
	PhD Rehabilitation Sciences University of Western Ontario, London, Ontario, Canada 2013 - 2018
Related Work Experience:	Teaching Assistant University of Western Ontario, London, Ontario, Canada 2013 - 2017
	Music Therapist St Joseph's Health Care London, London, Ontario, Canada 2013 - 2015

Publications:

Kogutek, D., Holmes, J., Grahn, J. A., Lutz, S., & Ready, E. (2016). Active music therapy in the treatment of physical improvement in rehabilitation. *Adv Mind Body Med*.

Kogutek, D. (2014). Tango improvisation in music therapy. *Canadian Journal of Music Therapy, 20(2)*, 166-180.

Conference Presentations:

Kogutek, D. (2018) Efficacy of Rhythmic Acquisition on Gait Parameters Among Individuals with Parkinson's Disease. Presented Ontario Music Therapy Association. February 24th, 2018.

Kogutek, D. (2017) Efficacy of Rhythmic Acquisition on Gait Parameters Among Individuals with Parkinson's Disease. Presented Symposium on Timing and Rhythm at McMaster University. April 8th, 2017.

Kogutek, D. (2017) Efficacy of Rhythmic Acquisition on Gait Parameters Among Individuals with Parkinson's Disease. Presented at 3M Thesis Competition. Western University. March 28th, 2017.

Kogutek, D., Holmes, J., Grahn, JA., Lutz, S., Ready, E. (2016). *Active Music Therapy and Physical Improvements from Rehabilitation for Neurological Conditions*. Presented at the Online Conference for Music Therapy, February 6th, 2016.

Kogutek, D. (2015). *Major Research Paper: "Tango Improvisation in Music Therapy"*. Presented at Perley Rideau Veteran's Health Centre, Ottawa. Music Therapy Association of Ontario Annual Conference and AGM Conference, Ottawa, Ontario, January 31st, 2015.