THESIS

THE EFFECT OF PATTERNED SENSORY ENHANCEMENT ON SIT-TO-STAND MOVEMENTS IN PEOPLE WITH PARKINSON'S DISEASE

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ABSTRACT

THE EFFECT OF PATTERNED SENSORY ENHANCEMENT ON SIT-TO-STAND MOVEMENTS IN PEOPLE WITH PARKINSON'S DISEASE

Parkinson's disease (PD) is considered an age-related neurologic disorder that causes motor and non-motor disabilities. Patients with PD present different motor characteristics including bradykinesia, reducing muscular strength, weaker motor and postural control, abnormal range of motion and joint torque, and greater variability during movement. These features cause difficulties in patients' activities of daily living and also bring higher fall risks when they do transferred movements, such as sit-to-stand (STS). The purpose of this study was to consider if Patterned Sensory Enhancement (PSE), a neurologic music therapy (NMT) technique might impact sit-to-stand movement with people with PD. Data were collected on fifteen participants who completed sit-to-stand exercises in baseline, PSE music, and no music conditions. Each sit-to-stand movement was divided into three phases: standing, balance, and sitting. Movements were analyzed for duration/time of movements, sum of movement acceleration (standard deviations) of x, y, and z, pitch of movements, and rotation rate (in z). Significant differences were found in sum of acceleration of x, y, and z in all three phases, with means that participants showed less postural control under PSE music condition. Another significant difference was found in fluctuations of the rotation rate (in z) in the sitting phase, with means indicating participants presented less postural control under PSE music condition compared to no music condition. No other significant differences were found. These results are contrary to prior findings and more research is needed to determine the influence of PSE on STS movements.

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CHAPTER 1. INTRODUCTION

Purpose of the Study

The purpose of this study was to apply Patterned Sensory Enhancement (PSE), a neurologic music therapy (NMT) technique, to sit-to-stand movements with people with Parkinson's disease. The study examined if musical cueing (force, timing and spatial cueing) could change movement speed and postural control during sit-to-stand movement.

Problem and Need

Parkinson's disease (PD) is one of the age-related neurologic diseases. Compared with other neurologic disorders, PD is the second general disease after Alzheimer's disease and it makes up a large population in the aging society (Cano-de-la-Cuerda, Pérez-de-Heredia, Miangolarra-Page, Munoz-Hellín, & Fernández-de-las-Penas, 2010; Hammond, Bergman, & Brown, 2007). Patients with this progressive disorder present difficulties in numerous areas, including motor and non-motor skills (Jankovic, 2008). Those features not only influence patients' physical functions and performances but also impact their daily lives (Dibble, Addison, & Papa, 2009; Nieuwboer et al., 2007).

There is no single identified cause of PD. Researchers have indicated there are several aspects may lead to PD pathological performances, including genetics, cellular and environmental elements. Those aspects may occur independently, but may also influence each other (Obeso et al., 2010). Persons with PD have degeneration of substantia nigra pars compacta (SNc) and other parts of the central nervous system, leading to abnormal motor performance (Georgiev, Lange, Seer, Kipp, & Jahanshani, 2016; Hammond et al., 2007). Akinesia, bradykinesia, tremor, rigidity and postural instability are main motor characters in PD (Jankovic,

2008) and they relate to the impairments of the basal nuclei and decreasing of dopamine concentration (Clark, Baker, & Taylor, 2012; Rodriguez-Oroz et al., 2009). When patients with PD go through the progression of the disease, losing motor functions can cause a lower quality of life, decrease independence and increase fall risk.

Sit-to-stand is an important functional movement in daily life and also an indicative action for independent living (Inkster & Eng, 2004). This movement requires the ability to change body position form a stable position to a less support and unbalance position (Dall & Kerr, 2010). During this complicated movement process, lower limb strength, mobility and balance are key factors that affect sit-to-stand quality (Lord, Murray, Chapman, Munro, & Tiedemann, 2002); however, patients with PD often exhibit decreased strength, mobility, and motor and postural control. Finding evidence-based treatments to support sit-to-stand movements may increase safety and independence in patients with PD.

Researchers have indicated that physical exercises can improve patients' motor and postural control ability when they are in mild to moderate stages of PD. According to a systematic review article, many types of exercises have been used with persons with PD for balance training including body weight support treadmill training, lower extremity strengthening and progressive tango training (Dibble et al., 2009). Moreover, different devices such as audio-biofeedback system, tri-axial accelerometers (Doheny et al., 2013; Mirelman et al., 2011), and sensory strategies including auditory, visual and somatosensory cueing training (Nieuwboer et al., 2007) were shown to improve balance and mobility training. External auditory cueing has been shown to be an effective medium in active gait training with PD (Keus, Bloem, Hendriks, Bredero-Cohen, & Munneke, 2007; Nieuwboer et al., 2007). Furthermore, music therapy interventions have been widely applied in physical rehabilitation with different populations demonstrating positive outcomes in gait, volitional movement, and sit to stand movements (Thaut, 2013). However, there are no studies on the impact of PSE on efficient sit-to-stand movements in patients with PD.

Rationale

The sit to stand movement is completed numerous times throughout the day. According to Dall & Kerr (2010) healthy adults performed sit-to-stand movement around 60 times per day. In other words, people may do this movement around 3 times per hour (Dall & Kerr, 2010). Although typical adults complete the sit to stand movement frequently, a high percentage of patients with PD described they have difficulty to finish this task due to their physical limitations (Inkster & Eng, 2004; Inkster, Eng, Maclntyre, & Stoessl, 2003; Mak, Levin, Mizrahi, & Hui-Chan, 2003).

According to the Parkinson's Foundation, there are more than 10 million people diagnosed with PD. Since PD is a large population around the world, health care providers have developed various interventions to work with this population. There are several studies focused on the use of music therapy for motor rehabilitation with people with PD (Kadivar, Corcos, Foto, & Hondzinski, 2011; Thaut et al., 1996). For example, Rhythmic Auditory Stimulation (RAS) is one NMT technique that researchers have shown to be successful using in gait training with persons with PD (Kadivar et al., 2011; Thaut et al., 1996). The research conducted by Thaut et al. (1996) indicated participants with PD showed improvements in cadence, gait velocity and stride length after 3-week home-based RAS training. Moreover, Kadivar et al (2011) pointed out that applying RAS in multidirectional gait training with people with PD might enhance participants' functional gait and balance performance over 8 weeks. Those results showed that auditory-motor interaction in RAS brings positive impacts in gait rehabilitation with PD.

Patterned Sensory Enhancement (PSE) is another NMT technique commonly used to support movement rehabilitation of physical movement exercises (Thaut & Hoemberg, 2014). This technique has been researched for sit to stand in persons with cerebral palsy (CP). PSE was applied in two previous loaded sit-to-stand studies in children with CP (Peng, Lu, Wang, Chen, Liao, Lin, & Tang, 2011; Wang, Peng, Chen, Lu, Liao, Tang, & Shieh, 2013). The music therapist designed different recorded musical patterns to match different physical movements during sit-to-stand trainings. The results indicated that the individualized music brought immediate improvements in the physical activity (Peng et al., 2011), which were maintained three months after a home-based six-week training (Wang et el., 2013). These findings support that PSE is a feasible intervention in sit-to-stand training. However, there is no research on the use of PSE for sit-to-stand training in persons with PD.

The purpose of this study is to investigate the effects of Patterned Sensory Enhancement on sit-to-stand movements with people with Parkinson's disease.

Hypotheses

1. Patterned Sensory Enhancement intervention in sit-to-stand exercise with PD will change movement speed.
2. Patterned Sensory Enhancement intervention in sit-to-stand exercise with PD will change postural control during movement process.

CHAPTER 2. LITERATURE REVIEW

Introduction to Parkinson's Disease

Parkinson's Disease (PD) is considered an age-related neurologic disorder (Georgiev et al., 2016; Hammond et al., 2007; Rodriguez-Oroz et al., 2009) which causes motor and non-motor symptoms (Rodriguez-Oroz et al., 2009). As an age-related disease, PD is the second common neurological disease (Cano-de-la-Cuerda et al., 2010; Hammond et al., 2007) and affects millions of people in the world, especially people who are over 50 years old (Dibble et al. 2009; Duncan, Leddy & Earhart, 2011; Ford, Malone, Nyikos, Yelisetty, & Bickel, 2010).

James Parkinson’s "An essay on the shaking palsy" in 1817 was the first document detailing the clinical presentation of PD (Jankovic, 2008; Parkinson, 2002). The disease was named Parkinson's Disease by Jean-Martin Charcot in the 19th century (Jankovic, 2008; Kempster, Hurwitz, & Lees, 2007). Even though researchers have been working to understand PD over the past two hundred years, there is no definitive cause of PD (Obeso et al., 2010). Researchers pointed out that genetic factors, cellular aspects, and environmental elements may be key factors of PD and those factors may interact (Obeso et al., 2010; Perier et al., 2007; Sulzer, 2007).

In the 20th century, neuroscientists discovered that clinical motor syndromes in PD related to the loss of cells in the substantia nigra, which is a part of basal nuclei. This loss results in a decrease in dopamine concentration, a neurotransmitter that innervates with motor control, emotion behaviors, motivation, reward system and working memory function (Chinta & Anderson, 2005; Jankovic, 2008; Rodriguez-Oroz et al., 2009; Young, Shreve, Quinn, Craig, & Bronte-Stewart, 2016). The degeneration in basal nuclei causes four main abnormal physical features, bradykinesia, tremor, rigidity and postural instability (Hammond et al., 2007; Jankovic, 2008; Young et al., 2016). Besides those motor impairments, patients with PD also present non-motor issues including sensory disabilities, sleeping problem, degeneration of cognitive functions and emotional issues (Jankovic, 2008; Obeso et al., 2010; Rodriguez-Oroz et al., 2009; Schapira, 2009). Because of those physical and cognitive disabilities, some patients with PD have a lower quality of life and more psychological difficulties (de Bruin et al., 2010). Persons with PD may demonstrate less independence and less confidence in their everyday life (Nieuwboer et al., 2007). Anxiety is also frequently observed with this population (Pasman, Murnaghan, Bloem, & Carpenter, 2011). All of these symptoms not only impact the patient's life, as treatments needed incur huge expenditures in the healthcare system (Dibble et al. 2009; Nieuwboer et al., 2007; Grimgergen, Munneke, & Bloem, 2004). Fortunately, different professions are working to develop effective treatment interventions for persons with PD (Wade et al., 2003). Common treatments include surgical procedures and pharmaceuticals to improve neurotransmission process (Obeso et al., 2010). For example, deep brain stimulation and levodopa are common treatments in clinical settings (Hammond et al., 2007). Furthermore, different rehabilitative disciplines develop numerous types of interventions to treat and train in different goal areas (Wade et al., 2003).

Neuropathology of Parkinson's Disease

Even though there is no clear cause of PD, abnormal function of basal nuclei is the main pathological issue and causes disconnection between cortical and subcortical networks (Petzinger et al., 2010). Basal nuclei, also known as the basal ganglia, are a group of subcortical nuclei, including the putamen and caudate (collectively called the striatum), the nucleus accumbens, the globus pallidu interna (GPi) and globus pallidus externa (GPe), the subthalamic nucleus (STN), and the substantia nigra pars comparcta (SNc) and substantia nigra pars reticulata (SNr) (Nolte, 2002). These structures are associated with voluntary movement controlling, motor learning, executive process and memory functions (Calabresi, Picconi, Tozzi, Ghiglieri, & Di Filippo, 2014; Monchi, Petrides, Strafella, Worsley, & Doyon, 2005). The planned behavior information transfers to basal nuclei from the cerebral cortex, and then delivers to thalamus and back to the cortex via direct and indirect loops to present corresponding outcomes (Calabresi et al., 2014; Nolte, 2002). Different pieces of basal nuclei process particular types of information; for example, the planned motor activity information will deliver to putamen, and project to different structures through both direct and indirect pathways and then back to the cerebral cortex (Nolte, 2002). The two pathways transfer input information by both excitatory and inhibitory neurotransmitters to regulate output information so people may present appropriate outcomes (Azekawa, 2011; Nolte, 2002). Additionally, dopamine (DA) is an important neurotransmitter, which is produced by dopaminergic neurons in the substantia nigra pars compacta (SNc) to maintain the function of cortical-basal nuclei circuits (Chinta & Anderson, 2005; Hammond et al., 2007). However, losing cells in SNc decreases production of dopamine (Dibble et al. 2009; Rodriguez-Oroz et al., 2009), and therefore patients with PD show unusual basal nuclei functions and display abnormal outcomes, especially motor and cognitive domains (Chinta & Anderson, 2005; Georgiev et al., 2016; Hammond et al., 2007; Rodriguez-Oroz et al., 2009).

Physical performance of Parkinson's Disease

Due to the loss of dopaminergic cells in the SNc, there are several physical characters that usually presented by patients with PD, such as bradykinesia, rigidity, tremor (Jankovic, 2008; Rodriguez-Oroz et al., 2009), postural instability (Jankovic, 2008; Mirelman et al., 2011) and freezing of gait (Young et al., 2016). Bradykinesia, which is the indication of basal nuclei degeneration and the most identify motor feature of PD (Jankovic, 2008). Patients with bradykinesia show slowness when they execute volunteer movements (Jankovic, 2008;

Rodriguez-Oroz et al., 2009), and keep decreasing the amplitude of their movements (Rodriguez-Oroz et al., 2009). Except reducing the speed of movements, lacking of spontaneous movements, mask face, swallowing difficulty, monotonic and hypophonic dysarthria are common symptoms that related to bradykinesia (Jankovic, 2008).

Rigidity is the other physical feature presented by patients with PD and this feature may happen on both proximal and distal parts of a body (Jankovic, 2008). Patients with rigidity present higher muscle tone than healthy people and causes difficulty on both voluntary and passive movements (Jankovic, 2008; Rodriguez-Oroz et al., 2009). Since having more resistance on extended movements and less expansion on passive movements, patients with PD present smaller range of motion of their functional movements (Jankovic, 2008; Rodriguez-Oroz et al., 2009).

Tremor is a common sign of PD and displays in the early stage of the disease. Patients with PD may exhibit both postural tremor and action tremor (Helmich, Toni, Deuschl, & Bloem, 2013; Raethjen et al., 2005). Resting tremor occurs with 75% of PD population and it is easily seen on unilateral distal limb, lips, jaw and chin and less observed on neck, head and voice (Jankovic, 2008). Action tremor classify as postural, kinetic and isometric tremor depends on different causes (Helmich et al., 2013). For example, postural tremor displays when patients maintain a same posture, especially extension horizontal position (Jankovic, 2008). These symptoms occur during voluntary muscle contractions and may cause disability on dexterous movements (Raethjen et al., 2005).

Furthermore, postural instability and freezing of gait are other physical symptoms observed of PD. Freezing of gait, which people describe as 'glued to the floor' is a common feature of PD (Lindaman & Abiru, 2013; Young et al., 2016) and around 50% of patient with advanced PD show this symptom (Young et al., 2016). Postural instability usually occurs in the late stages of PD (Jankovic, 2008; Mirelman et al., 2011). People with postural instability issue may have a higher risk to fall and be injury (Jankovic, 2008; Pasman et al., 2011). Postural instability is not just related to pathological functions, but is also related to sensory and psychological factors. Researchers indicated that sensory disabilities and anxiety could influence postural control in patients with PD (Jankovic, 2008; Pasman et al., 2011).

Sit-to-stand and Parkinson's Disease

Sit-to-stand (STS) is a critical functional and complex movement in daily life (de Souza, de Biagi Curtarelli, Mukherjee & Dionisio, 2011; Lomaglio & Eng, 2005). According to Dall and Kerr (2010), healthy adults performed STS movement around 60 times per day. Therefore, STS is a frequent motor task for human and also a symbolic movement of independent living (Inkster & Eng, 2004). Rising up from a chair is a continuous action that shifts a body position from a stable, static condition to a small support mass (de Souza et al., 2011; Mak et al., 2003), this process may cause higher falling risk (Dall & Kerr, 2010; Doheny et al., 2013).

There are many physical factors associates with STS, including muscle strength (Cano-de-la-Cuerda et al., 2010), force control and generation in lower limbs (Duncan et al., 2011; Inkster & Eng, 2004), knee and hip extension and flexion (Inkster et al., 2003; Lomaglio & Eng, 2005; Lord et al., 2002), muscle contraction and coordination (Mak et al., 2003). In addition, STS performance also related to non-motor factors such as sensory input, proprioception function and psychological status (Lord et al., 2002).

Due to many motor and non-motor requirements, STS is a challenging task for people with PD. Researchers indicated that 81% of 101 participants with PD reported they had difficulty to rising up from a chair (Brod, Mendelsonhn & Roberts, 1998; Inkster & Eng, 2004; Inkster et al., 2003). Other studies indicated that each year, 68% of people with PD fall and 50% of them fall frequently (Allen et al., 2010; Wood, Bilclough, Bowron, & Walker, 2002). Researchers used wearable sensors to measure whole-body movements with healthy people and people with PD during walking and sit-to-stand periods. Results from this study showed people without medication presented lower mobility than people with medication and healthy people (Memar et al., 2018). Compared to healthy people, patient with PD present smaller knee and hip flexion, smaller ankle dorsiflexion torque (Lord et al., 2002; Mak et al., 2003), smaller hip and lower limbs strength (Inkster et al., 2003) and weaker force generation ability (Inkster & Eng, 2004) during STS process. Moreover, sensory impairments, fear of fall, anxiety (Lord et al., 2002), and less motor learning ability (Nieuwboer, Rochester, Müncks, & Swinnen, 2009) may also impact STS performance.

Various programs have been applied in STS and balance training in order to improve patients' motor functions and movement performance. Besides traditional rehabilitative treatments, researchers investigated that exercise program for PD may improve STS performance, freezing gate, and muscle strength and decrease falling risk (Allen et al., 2010). Other research has proved intensity exercise may cause active-dependent neuroplasticity with PD (Fisher et al., 2008). The positive outcomes showed the programmatic and supervised exercises might provide safe and efficient training conditions for patients with PD. In addition, these studies also provided novel and nonpharmacological interventions (Allen et al., 2010; Fisher et al., 2008).

Besides new treatment programs, different assessment tools and training devices are also provided in STS movement. Five Times Sit to Stand (FTSTS) is a simple, quick and effective tool for patients with PD to measure gross fall risk (Duncan et al., 2011). Accelerometers are valid devices to measure postural status and timing data in single and repeated STS movements.

Since the fall risk strong correlate with motor control abilities and movement timing, combining accelerometers in FTSTS test provided accurate and comprehensive qualitative measurement outcomes (Doheny et al., 2013). Otherwise, numerous sensory instruments and strategies were applied with PD in clinical and home-based settings, and showed positive impacts in STS and balance tasks. These devices provided extra auditory feedback and visual cueing, assisted patients to carry out and modify their movements (Azarpaikan, Torbati, & Sohrabi, 2014; Esculier, Vaudrin, Bériault, Gagnon, & Tremblay, 2012; Mirelman et al., 2011; Zijlstra, Mancini, Lindemann, Chiari, & Zijlstra, 2012).

Neurologic Music Therapy

Neurologic Music Therapy (NMT) is one music therapy approaches, and it is based on neuroscience, evidence-based research and practice (Thaut & Hoemberg, 2014). NMT began in 1999 (Darrow, 2008); however, the roots of a neuroscience approach started much earlier. Modern music therapy developed rapidly after world war two, different approaches and academy theories were announced and applied in clinical settings with various populations (Wheeler, 2015). Since the early 1990's, neuroscientists and music therapists use modern medical science and technologies to explore the relationship between music and a human brain. Using brain-imaging techniques helps people to understand how a human brain processes music and also how music changes a human brain. This change provides perspective to explain how music and music therapy impacts different populations (Grahn & Watson, 2013; Limb, 2006; Thaut & Hoemberg, 2014).

NMT is comprised of 20 systematic therapeutic techniques used to address nonmusical goals in numerous populations (Thaut & Hoemberg, 2014). Techniques address in different areas of need including gross and fine motor rehabilitation, speech and language rehabilitation, attention training, executive function training, memory care and so on (Thaut & Hoemberg, 2014). Using these techniques in clinical settings, music therapists follow the transformational design model (TDM). The TDM is an integral therapeutic procedure, including music therapy assessment, goals and objectives setting, functional non-musical exercise, functional musical exercise, reassessment and transfer learning into daily life six steps (Thaut & Hoemberg, 2014). This process ensures the music therapy interventions are designed based on client's clinical needs and can be generalized back in to daily life.

As an evidence-based profession, music therapists used the therapeutic techniques in their practices and also examined outcomes by scientific research to support and modify their interventions. According to those research, there are two significant theories relate to musical behaviors and neuron activities, "Shared network" and "Neuroplasticity."

Shared Network

Through brain imaging, researchers observed activities and changes in brains when human process different music elements. According to previous studies, researchers indicated that different music components are not just processed through the cochlear nerve, auditory subcortical and cortical structures, but also in particular brain regions which also associate with non-musical behaviors and pathological functions (Bengtsson et al., 2009; Limb, 2006; Popescu, Otsuka & Ioannides, 2004). This overlap between music and nonmusical networks in the brain has been called overlapping (Patel, 2012) or shared networks. These shared networks allow for music interaction to affect non-musical behaviors, as the same area in human's brain. For example, premotor cortex, supplementary motor area, cerebellum and basal nuclei are all associated with motor functions, they also relate to auditory rhythm perception (Bengtsson et al., 2009; Grahn & Brett, 2009; Popescu et al., 2004) and that is way researchers used rhythmic cueing as an auditory stimulus in movement rehabilitative studies to enhance patients' motor planning and performance (Kadivar et al., 2011; Kwak, 2007; Lindaman & Abiru, 2013; Thaut, 2013; Thaut et al., 1996). Researchers also used music interventions in speech and language rehabilitation because the overlapping of the language and music regions. Broca's area and Wernicke's are the two prominent areas of the brain that associate with in speech and language functions, are also involved in music processing and production (Azekawa, 2011; Limb, 2006). Those examples supported that musical activities have many connections with non-musical functions, wherefore applying music, as a stimulus in music therapy to work on non-musical areas would be a feasible intervention.

Neuroplasticity

Neuroplasticity is an important factor in NMT. Neuroplasticity is a phenomenon where neuron cells create or modify connections in neuronal networks through learning, development, and experience. The connections may happen between two individual neurons, and also occur between different regions of the brain (Stegemöller, 2014). Neuroplasticity processes make the neuron connections stronger to enhance the change of behaviors; neuroplasticity also repairs the damaged circuitry or forms new connections that might increase the restoring or replacing of the lost functions (Petzinger et al., 2013; Stegemöller, 2014). After birth, most neurons do not regenerate; however, neurons can keep creating new connections or pruning connections (Nolte, 2002; Stegemöller, 2014). Before an individual’s early 20s, their human brain has a higher amount of neuroplasticity to create effective networks and prune superfluous connections. After the age of 20s, the human brain has become maturely and developed integral networks (Gogtay et al., 2014; Stegemöller, 2014). Even though the brain shows different neuroplasticity actives in particular development stages, the brain keeps changing for a lifetime. Therefore, music therapy may enhance neuroplasticity activities through musical activities to address patients' needs when working with patients from different age groups (Stegemöller, 2014).

Researchers indicated music stimulation might facilitate cortical changes (Baker & Roth, 2004; Zatorre, Chen & Penhune, 2007). The musical stimulation actives brain regions (Patel, 2012) and neuroplasticity. Therefore, in order to promote neuroplasticity, the music therapist will design different interventions, using music or music elements to stimulate and improve clients' non-musical functions (Baker & Roth, 2004). Working with individuals with neurological disorders, there are two perspectives to design interventions: building the compensatory abilities based on the remaining function, or retrain the impaired parts to regain the function as much as possible (Baker & Roth, 2004). Music therapists use both two modes to provide interventions according to clients' needs and physiological functions. For example, a music therapist wrote a song about wheelchair using, and used this song to remind a client safety instruction when she used her wheelchair (Baker & Lee, 1997; Baker & Roth, 2004). In this case, the song was a compensatory cue for the client to substitute her impaired memory function. An example for the latter perspectives, music therapists used a keyboard in fine motor training with clients with subacute stroke and got positive results after sessions. Different playing tasks were provided to train specific finger movements; furthermore, music also provided auditory feedback to facilitate movements (Chong, Han & Kim, 2016). In this case, music therapists designed the training program based on the impairment with the intention of improving functions.

Auditory Entrainment and Motor System

Entrainment is a phenomenon that energy transfers between two moving bodies and causes the two objects present a same synchronize moving frequency. This physical phenomenon first announced in 1666 by Christian Huygens and later discovered in many physical and biological systems (Moens & Leman2015; Thaut, 2013; Thaut, McIntosh & Hoemberg, 2015). Entrainment also occurs between human auditory and motor systems. An auditory system detects and organizes auditory signals to rhythmic patterns speedily and the patterns may impact motor performance immediately (Schaefer & Overy, 2015; Thaut, 2013). In 1967 and 1976, two studies showed rhythmic music and sound information associated with muscle activation through reticulospinal tracks, which are the connections between auditory and motor systems (Thaut, 2013). The findings drove people to discuss auditory-motor interaction and apply this idea in physical rehabilitation.

Later in the 1990's, music therapists and neuroscientists conducted numerous researches based on auditory motor synchronization concept to explore applying music and rhythmic auditory stimulation for motor activities with health people and people with neurological disorders. Positive outcomes were found from gait trainings with patients with stroke and PD. Auditory entrainment affected and benefited patients' gait performance, including stride length, velocity, cadence and more stable mobility (Thaut, 2013; Thaut et al., 1996). According to those results, researchers discovered even people with neurological disorders, auditory entrainment still occur in the injured brains (Thaut, 2013).

Moreover, auditory stimulations provide motor prepared cues and modify motor planning and execution (Thaut, 2013). Thaut, Miller, and Schauer conducted an upper extremity entrainment experiment and found that individuals entrained physical movements to the metronome beat and kept with the rhythmic patterns even tempo of the metronome changed at a rate below conscious perception, for the reason that rhythm plays a substantial role to integrate input auditory information and facilitate movement outcomes (Thaut, 2013; Thaut et al., 2015). Rhythmic patterns are arranged by a period of time and the time interval entrains the movement interval. Because of the period entrainment phenomenon, the brain adjusts the motor planning to alter the movement execution (Thaut, 2013). Therefore, auditory entrainment is widely used in therapeutic settings (Schaefer & Overy, 2015) and many NMT techniques were developed and applied based on this foundational theory (Thaut, 2013).

Rhythmic Auditory Stimulation

According to the shared network, neuroplasticity, and auditory entrainment concepts; there are several NMT techniques that can be applied for physical rehabilitation with persons with neurologic disorder or disease. Rhythmic auditory stimulation (RAS) is a gait training protocol that has been research with different populations, including persons with cerebral palsy (CP), traumatic brain injuries (TBI), stroke, and PD (Kadivar et al., 2011; Kwak, 2007; Lindaman & Abiru, 2013; Thaut, 2013; Thaut et al., 1996). RAS involves rhythmic patterns as an external auditory cueing to facilitate gait movements. The metronome is a common device that is applied in RAS training to keep the steady auditory structure (Thaut & Hoemberg, 2014).

Previous studies showed that RAS bring positive impacts in gait training with PD (Hove & Keller, 2015). Thaut and colleagues (1996) found that persons with PD receiving RAS in a 3-week home-based gait training program showed improved gait velocity, stride length, and cadence more than the participants in the self-paced group (Thaut et al., 1996). Similar results found in the other RAS study where participants with PD showed improvements in velocity, stride length, and cadence after RAS training, even they were or were no on medication (Lindaman & Abiru, 2013; McIntosh, Brown, Rice & Thaut, 1997). Kadivar et al. (2011) investigated if RAS would benefit the functional gait performance of patients with PD. Researchers used several standard assessment tools for gait evaluations before and after RAS multidirectional step interventions, which involved three different stepping directions. Three different sounds were applied as three cues for forward, side and back step movements. The researchers combined two or three movement directions as training tasks for the RAS group and they found that participants who received RAS training improved their functional gait performance and balance ability, and that those improvements were kept for at least 8 weeks (Kadivar et al., 2011).

Studies and clinical application showed the value of RAS in gait rehabilitation; moreover, this technique also became a foundation of other new NMT techniques, which applied with voluntary movement rehabilitation (Lamb, 2012). Results from previous studies indicated that rhythm could improve movements in people with PD. The external auditory cueing stimulates the auditory cortex, and also actives other areas that associate with motor performance (Kadivar et al., 2011; Lindaman & Abiru, 2013; McIntosh, Brown, Rice & Thaut, 1997). Because of the auditory entrainment, people with PD had better movement outcomes under the musical environment. The auditory cueing helps people to initiate their movements, modify motor planning and keep the same movement pattern. Therefore, structured rhythmic stimulate might be a critical element to apply in this sit-to-stand study to help participants facilitating the movement process.

Patterned Sensory Enhancement

Patterned sensory enhancement (PSE) is an NMT technique, which is applied to volitional (Lamb, 2012) and complex movements rehabilitation that relate to daily functional activities (Peng et al., 2011; Thaut, 2005; Thaut & Hoemberg, 2014). Various music elements are applied in PSE to lead temporal, force and spatial cues and enhance movements that are not rhythmic (Lamb, 2012; Peng et al., 2011; Thaut & Hoemberg, 2014; Wang et al., 2013). Since rhythmic stimulation is an important factor in RAS, it plays the same role in PSE to provide steady movement prompts, facilitate movement or modify movement duration (Thaut & Hoemberg, 2014). Besides rhythm, more musical components are also involved in PSE to improve patients' motor performances. Meter, pattern, duration, pitch, melody, harmony, dynamic, structure, and form are used to compose customized therapeutic music to facilitate particular movements (Peng et al., 2011; Thaut & Hoemberg, 2014; Wang et al., 2013). For example, in a shoulder flexion exercise, ascending and descending arpeggios provide a spatial cue hand lifting movement and also address shoulders' range of motion; tension chords offer a force cue which leads patients to keep a specific position to increase muscle strength; a designed music form bring a timing cue that patients may follow the musical structure and facilitate the movement easily (Thaut, 2005; Thaut & Hoemberg, 2014; Wang et al., 2013).

Peng and colleagues (2011) conducted a study to investigate the impact of using PSE in loaded sit-to-stand (LSTS) exercise with children with spastic diplegia (SD). Twenty-three participants wore 50% maximal load weighted vests to repeat sit-to-stand movements with and without music. The researchers tracked 46 infrared retroreflective markers for movement data collection during three STS movement phases (Peng et al., 2011). The first movement phase was the beginning of the whole movement to seat-off; the second phase was from seat-off to standing position; the last part was stand-to-sit process (Peng et al., 2011). During the three movement phases, the pre-recorded PSE music patterns and verbal directions were applied in three parts of LSTS. The therapeutic music involved different rhythmic, melodies and intensity cueing that matched different movement patterns and those musical cueing facilitate and enhance participants' movement performances (Peng et al., 2011). Participants repeated the STS movements eight times continuously, the PSE music was provided for the first 5 times. The results showed that PSE was an effective technique for LSTS exercises with children with SD.

Participants showed higher total and knee extensor strength, smoother and faster movements with PSE music, and the positive impacts maintain at least three cycles even in the no music condition (Peng et al., 2011). The therapeutic music provided a structure that participants may follow it and used the same strategy to facilitate movements; timing, spatial and force cues also enhance better movement quality (Peng et al., 2011).

Researchers in another study used the similar intervention to apply PSE in a home-based LSTS training for children with cerebral palsy (Wang et al., 2013). Twenty-six participants were randomized to a PSE group or no-music group to execute the LSTS training for six weeks (Wang et al., 2013). All participants completed the LSTS training at home and were supervised by their caregivers three times a week. For participants in the PSE group, an individualized therapeutic music was selected from music database after the assessment session. The music database included various music templates that composed by a music therapist with different tempi and patterns. The pre-recorded individualized music was selected to match individual's STS movements, based on the their speeds and movement durations (Wang et al., 2013). Three LSTS trainings in different loaded conditions and repetitions provided data of exercise time and repetition numbers (Wang et al., 2013). Researchers reassess participants' performance every two weeks and modify training tool, including the loaded weight of vests and therapeutic music (Wang et al., 2013). Standard assessment tools were applied to measure participants' gross motor functions. Results indicated that there were no significant differences between the PSE and non-music group. However, the participants who had the PSE intervention presented larger gross motor improvements and keep those abilities for at least three months (Wang et al., 2013). Although these studies have some positive findings, there is no study use PSE on STS training with PD.

Patterned sensory enhancement brings positive impacts in the motor rehabilitation field, but also increase patients' motivation and participation (Clark et al., 2012; O'Konski, Bane, Hettinga, & Krull, 2010). O'Konski and colleagues (2010) conducted a research study to compare the effect of using PSE and big band background music in an exercise program with long-term care residents (O'Konski et al., 2010;). There were no significant difference between two types of music and participants reported both types of music enhanced motor performance and bring positive experience. However, PSE music still showed benefits in this study. The researchers indicated that under the musical environment, participants presented higher enjoyment and imitated the movements easily. PSE music also provided a musical structure that participants may follow and repeat the movements without verbal repetition counting (O'Konski et al., 2010). The other study showed PSE not only brings positive experiences for participants but also creates interprofessional collaboration opportunities (Clark et al., 2012).

Those studies showed PSE might bring different benefits in different therapeutic settings. This NMT technique not just improves clients' movement performances, but also increase their participation and enjoyment in the trainings. The results from the two sit-to-stand studies indicated that PSE is an efficient technique on sit-to-stand training with children with CP. Different music components were applied to facilitate different movement patterns and the immediately outcome may keep for a period of time. Therefore, pre-recorded, designed music and PSE technique might be a beneficial intervention on sit-to-stand training for people with PD.

Since auditory stimulation has been proved as an efficient element in rehabilitative programs for people with PD, and PSE is also a successful technique on sit-to-stand training, it would be valuable to explore if would be an effective intervention on sit-to-stand training with people with PD.

Therefore, the purpose of this study is to investigate the effects of Patterned Sensory Enhancement on sit-to-stand movements with people with Parkinson's Disease. There are the two research questions:

1. Will patterned sensory enhancement intervention in sit-to-stand exercise with PD change participants' movement speed?
2. Will patterned sensory enhancement intervention in sit-to-stand exercise with PD change participants' postural control during movement process?

CHAPTER 3. METHOD

Participants

The participants with Parkinson's disease who volunteered to join this study were recruited from the Parkinson's Music Therapy Movement Group at Colorado State University and individuals recruited from Rehabilitative Rhythms Music Therapy. All participants met the following inclusion requirements: (1) able to finish sit-to-stand and stand-to-sit movements independently without use of assistive device (2) able to follow verbal directions (3) without hearing impairment (4) without surgery in the past six months (5) without other neurological disorders or cognitive disorders (i.e., depression or dementia). Participants' level of Parkinson's (using the Hohen and Yahr scale) were assessed by the primary researcher. Their medication statuses were also recorded before the music therapy intervention. Written consent was obtained from all participants.

Study Design

This study was within participants design study, all participants completed three tasks included baseline condition, PSE condition, and no music condition. The baseline condition was always offered first in order to establish the participant's tempo. The independent variable was using PSE technique for the STS movement. The dependent variables were movement speed and postural control ability in three conditions.

Materials

A Yamaha NP-31 midi keyboard and the GarageBand software 10.2.0 on MacBook Pro by Apple (mid-2012) were used to compose and record PSE music. A stopwatch was used to record time of individual movement phase, those periods of time were used to analyze the meter, which was utilized in the PSE music.

An iPod touch by Apple and the Sensor Data application were used to measure movement velocity and postural control during STS exercises. Four movement factors were captured from the iPod: time of movements, sum of movement acceleration, pitch of movements, and rotation rate (in z). Time of movement was the movement period from seat-off to standing, balance period, and standing to sitting back three phases. Sum of movement acceleration was the standard deviation of acceleration from x (forward and back), y (up and down), and z (left and right) axis movements. Also, the pitch factor indicated the rotation angle of the iPod around the z axis (left and right) in rising and falling movements; it also represented the angular changes of the body during standing and sitting phases. Rotation rate (in z) measured body left and right axial rotation rate in three movement phases (Zampieri et al., 2010). After data collection, the data were analyzed using Spike Program, SPSS, and Excel.

Procedure

All participants completed the conditions individually. For the STS preparation, each participant sat upright in a chair with two feet on the ground, and arms folded in front of the chest (Duncan et al., 2011; Doheny et al., 2013; Peng et al., 2011; Wang et al., 2013). To complete the whole movement cycle, participants had to rise up from a chair, stand fully straight and sit back down in the chair. An iPod was velcroed facing out to a belt that will be positioned over the participant's right greater trochanter. The iPod was set to record three-dimensional body acceleration data. A speaker was set three meters in front of the chair to play the PSE music at the 75dBA intensity that measured from the participant's location (Karageorghis, Jones & Stuart, 2008; Peng et al., 2011).

There were three STS tasks involved in this study. Before every task, the researcher explained the instruction verbally and demonstrated the movements. The first task was the baseline task. Participants completed four repetitions of the STS cycle at their own self-selected pace. During this phase a stopwatch and tap metronome were used to measure the average period of time of one STS movement and the body position data; participants were asked to finish the cycle as fast as possible under a safe conditions. This task was completed two total times, for a total of 8 sit to stand movements, with a 20-second break between each trial. After the first task, participants had a five-minute break to rest before the next task.

The second STS (music) task was two cycles of the four repetitions STS with the pre-recorded PSE music. The tempo of PSE music was matched to the average movement period tempo that the participant displayed in the baseline condition. Participants were instructed to stand to the music, involving a metronome beat and chords signifying the sit to stand movement will be played. Before the participants performed this task, the researcher demonstrated completing the movements to music. Participants were asked to perform two cycles of four-repetition STS movements with 20-second breaks between the cycles. A five-minute break also provided between tasks two and three.

Task three (no-music) was the same task as task one; participants completed two cycles of four-repetition STS without music, with 20-second breaks between the cycles.

Patterned Sensory Enhancement Music

The pre-recorded music was used in musical condition to facilitate STS movements (Peng et al., 2011; Wang et al., 2013). The tempo of music was arranged based on the average of the standing speed that measured from the first task. The period of time was divided into four equal parts, as four beats in music and the music was composed in 4/4 meter. Different music elements were used in musical patterns to facilitate different movement phases (Peng et al., 2011; Thaut & Hoemberg, 2014). The whole movement task was divided into three parts; initiation of lifting off the seat, moving to a fully standing position, and moving from standing position back to sitting position.

Strong ascending major chords were used to enhance the first movement phase for two beats. Harmony was an effective element to create force cue that might help participants to generate muscle force and start this movement (Thaut & Hoemberg, 2014). The second phase, short running ascending scale for two beats provided a spatial cue, which might lead the participants to reach fully standing position. The music patterns for the first and second movement phases used the same chord but increasing the loudness to enhance participants reaches the straight position (Peng et al., 2011; Thaut & Hoemberg, 2014). For the last movement phase, minor descending triplet arpeggio and unsolved chords were used for the first two beats and a dominant seventh chord and a solved chord were used for the last two beats to finish this pattern. The descending arpeggio provided a temporal cue to enhance muscle control; the chord progression applied tension in the harmony to generate muscle force till the end of the movement (Peng et al., 2011; Thaut & Hoemberg, 2014). Steady metronome beats were involved in the music to provided steady auditory stimulates and enhance the auditory entrainment (Thaut, 2013; Thaut et al., 2015). Moreover, a chord progression I-I-IV-V was used in preparation part to remind the participants the beginning of the movement task.

Figure 1. An example of patterned sensory enhancement music, which includes preparation (first measure), standing up (second measure) and sitting down (last measure) three parts.

Statistical Analysis

Spike, SPSS, and Excel were utilized for data analysis. All movement factors were collected from the Sensor Data application and represented as waveforms in Spike Program. The waveforms presented all changes during the whole movement process, including start, stop, and also direction changes. In the Spike program, waveforms presented changes (up and down) when the device detected movement acceleration changes during data collection. Three movement phases (standing, balance, and sitting) were selected manually, based on movement start and end points shown in the waveforms. The standing and sitting phases were selected when the waveforms indicated a change in acceleration, indicating the beginning and end of the phase. The period of time between standing and sitting movements that presented less or no waveform changes was selected as the balance phase. After regions of the waveforms were selected, the Spike program computed the standard deviation of the waveform for that movement period. The numbers utilized in final data analysis were the averages across the eight sit-to-stand in each condition. In all conditions, lower numbers indicated more postural control. SPSS and Excel were used to run statistic tests. Repeated measure analysis of variance (Repeated-Measures ANOVA) and dependent *t*-tests with Bonferroni correction were used to determine if there were significant differences between the three conditions.

CHAPTER 4. RESULTS

Sixteen participants were recruited in this study and completed the intervention. However, one participant did not complete the task, so the final sample size was 15 participants (Figure 2). The 15 participants who were included in the final analysis (8 females, 7 males) were between 49 to 79 years old (*M*=68.2, *SD*=7.47). Their Hoehn and Yahr Scale were between 2 to 4. The participants' characteristics are listed in Table 1.

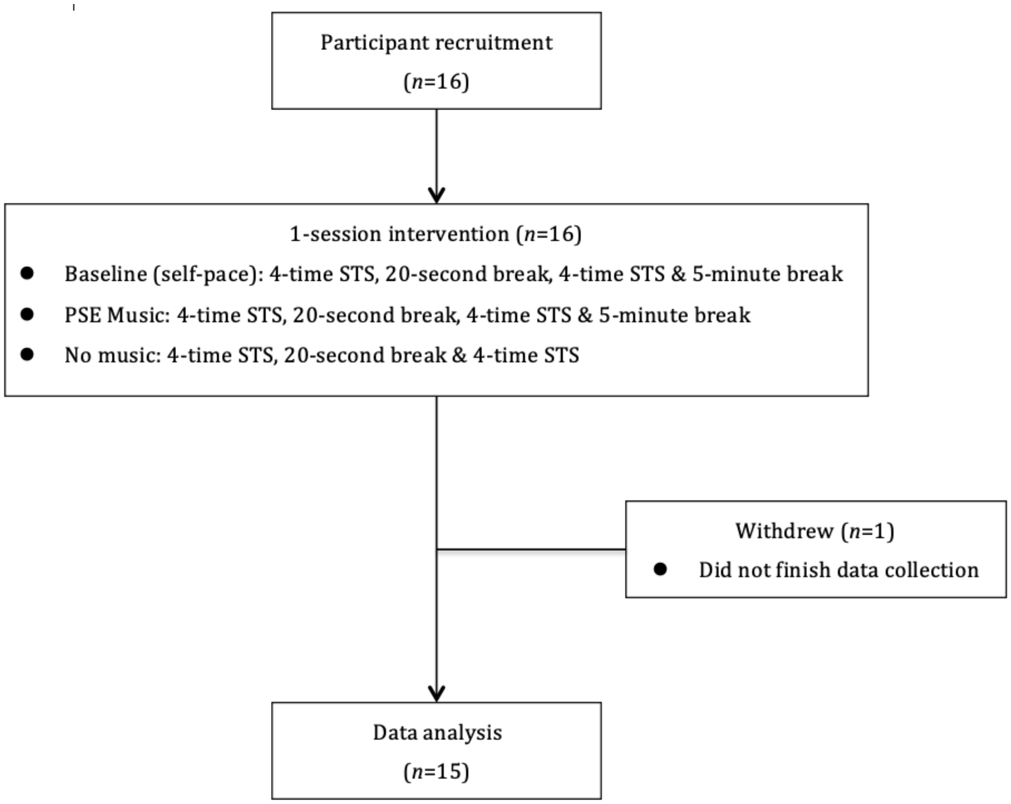

Figure 2. Participant flow chart.

Table 1

Participant's Characteristics

Participant	Age	Gender	Level of PD
01	78	F	3
02	79	M	4
03	65	F	3
04	63	F	2
05	70	M	2
06	70	M	3
07	71	M	2
08	70	F	3
09	69	M	2
10	63	M	2
11	49	F	2
12	71	M	2
13	74	F	2
14	71	F	2
15	60	F	3

Note. Level of PD calculated using the Hoehn and Yahr Scale

SPSS and Excel were used to analyze the sit-to-stand data sets which included average of timing, sum of movement acceleration (standard deviations) in x, y and z, pitch of movements (the changes of angular around z axis) and rotation rate (in z) factors. Repeated-Measures ANOVAs were used to compare those factors in baseline, music, and no music conditions. Each condition included three movement phases: standing, balance, and sitting. However, pitch of movements and rotation rate (in z) were only calculated for rising and sitting movements. Post-hoc analyses were completed using dependent *t*-tests with a Bonferroni correction.

Average of Time

A one-way repeated-measures ANOVA was calculated comparing the average standing, balance, and sitting phase time in three different conditions: baseline, music, and no music. Average of time data showed the periods of time that participants took to complete three movement phrases. Table 2 represents the results of the ANOVA. No significant effect was found for standing phase time ($F(2,28) = 1.735$, $p = 0.195$). There was no significant difference between baseline ($M = 0.632$, $SD = 0.243$), music ($M = 0.587$, $SD = 0.186$) and no music ($M = 0.627$, $SD = 0.24$). No significant effect was found for balance phase time ($F(2,28) = 0.301$, $p = 0.742$). There was no significant difference between baseline ($M = 0.412$, $SD = 0.263$), music ($M = 0.419$, $SD = 0.341$) and no music ($M = 0.393$, $SD = 0.295$). No significant effect was found for), or the sitting phase time ($F(2,28) = 2.623$, $p = 0.09$). There was no significant difference between baseline ($M = 0.639$, $SD = 0.261$), music ($M = 0.577$, $SD = 0.262$) and no music ($M = 0.631$, $SD = 0.32$).

Table 2

Average of Time One-Way Repeated-Measure ANOVA

Condition	Mean (*SD*)	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Standing phase		2	.009	1.735	.195	.110
Baseline	.632 (.243)					
Music	.587 (.186)					
No music	.627 (.24)					
Balance phase		2	.003	.301	.742	.021
Baseline	.412 (.263)					
Music	.419 (.341)					
No music	.393 (.295)					
Sitting phase		2	.017	2.623	.090	.158
Baseline	.640 (.261)					
Music	.577 (.262)					
No music	.631 (.320)					

Note. *$p < .05$.

Average of sum of movement acceleration (standard deviations) in x, y and z

A one-way repeated-measure ANOVA was calculated comparing the average standing, balance and sitting phase sum of movement acceleration (standard deviations) in x, y and z in three different conditions: baseline, music and no music. The average of sum of movement acceleration data presented the acceleration changes in all three axes (x, y, and z axes). Table 3 represents the results of the ANOVA. A significant effect was found for standing phase ($F(2,28) = 3.702$, $p = 0.037$); however, post-hoc analyses did not yield any significant comparisons when the Bonferroni correction was applied. A significant effect was found for balance phase ($F(2,28) = 5.185$, $p = 0.012$). A post-hoc was conducted using a dependent *t*-tests with Bonferroni correction (Table 4), which revealed a significant difference between baseline and music ($t(14) = -2.898$, $p = 0.012$), where the mean for music condition, participants presented less postural control compared to the baseline condition. There was no significant difference between baseline and no music, and again between music and no music. A significant effect was found for sitting phase ($F(2,28) = 9.718$, $p = 0.001$). A post-hoc was conducted using dependent *t*-tests with Bonferroni correction (Table 5), which revealed significant differences between baseline and music ($t(14) = -4.306$, $p = 0.001$), and also between music and no music ($t(14) = -2.857$, $p = 0.013$), where the group means indicated that participants had less postural control under music condition compared to both the baseline condition and the no music condition. There was no significant difference between baseline and no music.

Table 3

Average of Sum of Acceleration (standard deviations) of x, y, and z One-Way Repeated-Measure ANOVA

Condition	Mean (*SD*)	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Standing phase		2	.020	3.702	.037*	.209
Baseline	.260 (.081)					
Music	.332 (.181)					
No music	.285 (.141)					
Balance phase		2	.028	5.185	.012*	.270
Baseline	.193 (.129)					
Music	.279 (.203)					
No music	.227 (.211)					
Sitting phase		2	.047	9.718	.001*	.410
Baseline	.254 (.090)					
Music	.365 (.157)					
No music	.301 (.176)					

Note. $^*p < .05$.

Table 4

Average of Sum of Acceleration (standard deviations) of x, y, and z in Balance Phase Dependent t-Test

Condition		Paired Differences		*df*	*t*	*Sig.* (2-tailed)
		Mean (*SD*)	Std. Error Mean			
Pair 1	Baseline Music	-.086 (.114)	.030	14	-2.898	.012*
Pair 2	Baseline No Music	-.034 (.108)	.028	14	-1.238	.236
Pair 3	Music No Music	.051 (.087)	.022	14	2.283	.039

Note. **p* < .016, two-tailed.

Table 5

Average of Sum of Acceleration (standard deviations) of x, y, and z in Sitting Phase Dependent t-Test

Condition		Paired Differences		*df*	*t*	*Sig.* (2-tailed)
		Mean (*SD*)	Std. Error Mean			
Pair 1	Baseline Music	-.112 (.100)	.026	14	-4.306	.001*
Pair 2	Baseline No Music	-.047 (.106)	.027	14	-1.709	.109
Pair 3	Music No Music	.065 (.088)	.023	14	2.857	.013*

Note. **p* < .016, two-tailed.

Average of pitch of movements

A one-way repeated-measure ANOVA was calculated comparing the average standing and sitting phase pitch of movements in three different conditions: baseline, music and no music. Pitch of movement data represented the angular changes of participants' bodies around the z axis (left and right) when they did standing and sitting movements. Table 6 represents the results of the ANOVA. No significant effect was found for pitch in standing phase ($F(2,28) = 0.907$, $p = 0.415$). There was no significant difference between baseline ($M = 0.101$, $SD = 0.064$), music ($M = 0.099$, $SD = 0.052$) and no music ($M = 0.107$, $SD = 0.067$). No significant effect was found for sitting phase ($F(2,28) = 3.182$, $p = 0.057$). There was no significant difference between baseline ($M = 0.106$, $SD = 0.063$), music ($M = 0.096$, $SD = 0.055$) and no music ($M = 0.108$, $SD = 0.065$).

Table 6

Average of Pitch of Movements One-Way Repeated-Measure ANOVA

Condition	Mean (*SD*)	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Standing phase		2	.000	.907	.415	.061
Baseline	.101 (.064)					
Music	.099 (.052)					
No music	.107 (.067)					
Sitting phase		2	.000	3.182	.057	.185
Baseline	.106 (.063)					
Music	.098 (.055)					
No music	.108 (.065)					

Note. $*p < .05$.

Average of rotation rate (in z)

A one-way repeated-measure ANOVA was calculated comparing the average standing and sitting phase rotation rate (in z) in three different conditions: baseline, music and no music.

Rotation rate (in z) data represented the movement rotation rate around z axis (left and right) throughout the two movement phases. Table 7 represents the results of the ANOVA. No significant effect was found for standing phase ($F(2,28) = 3.096$, $p = 0.061$). There was no significant difference between baseline ($M = 0.201$, $SD = 0.088$), music ($M = 0.245$, $SD = 0.139$) and no music ($M = 0.221$, $SD = 0.118$). A significant effect was found for sitting phase ($F(2,28) = 4.453$, $p = 0.021$). A post-hoc was conducted using a dependent *t*-tests with Bonferroni correction (Table 8), which revealed a significant difference between music and no music ($t(14) = 3.191$, $p = 0.007$), where the mean for music condition, participants showed less postural control compared to the no music condition. There was no significant difference between baseline and music, and again between baseline and no music.

Table 7

Average of Rotation Rate (in z) One-Way Repeated-Measure ANOVA

Condition	Mean (*SD*)	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Standing phase		2	.007	3.096	.061	.181
Baseline	.201 (.088)					
Music	.245 (.139)					
No music	.221 (.118)					
Sitting phase		2	.005	4.453	.021*	.241
Baseline	.237 (.103)					
Music	.269 (.125)					
No music	.241 (.128)					

Note. *p < .05.

Table 8

Average of Rotation Rate (in z) in Sitting Phase Dependent t-Test

Condition		Paired Differences		*df*	*t*	*Sig.* (2-tailed)
		Mean (*SD*)	Std. Error Mean		-2.728	.016
Pair 1	Baseline Music	-.032 (.046)	.012	14	-2.728	.016
Pair 2	Baseline No Music	-.005 (.054)	.014	14	-.331	.746
Pair 3	Music No Music	.028 (.033)	.009	14	3.191	.007*

Note. $*p < .016$, two-tailed.

CHAPTER 5. DISCUSSION

The purpose of this study was to explore the impact of Patterned Sensory Enhancement (PSE) technique on sit-to-stand exercise with people with Parkinson's disease (PD). There were two main areas of focus in this study, including movement speed and postural control. All participants completed sit-to-stand tasks under three conditions, baseline (self-paced), PSE music, and no music. There was no significant difference in movement speed; however, the results indicated some significant differences in postural control between the three conditions.

Since the tempo of the PSE condition was set to each participant's self-paced tempo, there was no expected difference in movement speeds between baseline and music intervention. However, the results showed that participants maintained the same speed in the last condition (no music) despite already completing sixteen sit-to-stand repetitions, even though some participants stated that they were feeling more tired by the last set of exercises. This maintenance of movement speed may be attributed to auditory entrainment carrying over from the PSE condition. Researchers have indicated that external auditory stimulus initiates an auditory-movement interaction (Kadivar et al., 2011; Lindaman & Abiru, 2013; McIntosh, Brown, Rice, & Thaut, 1997) and the effects may have still been present in the last condition, no music. Therefore, participants may have been able to continue with the same pace despite feeling fatigue. Researchers may consider including a control group in future studies in order to determine if PSE has any impact on maintaining movement speed.

In postural control, there were several significant differences found between conditions, including average of sum of movement acceleration (standard deviations) in x, y, and z in all three phases (standing, balance, and sitting) and also average of rotation rate (in z) in sitting phase. Results indicated that participants showed less postural control in the music condition. These results were in contrast to previous PSE and sit-to-stand studies, where music was found to improve sit-to-stand movements in persons with Cerebral Palsy (Peng et al., 2011; Wang et al., 2013). Although these results do not support prior findings, this is the first known study with individuals with PD. Furthermore, there were some factors that may have contributed to the results including differences in music providing and arrangements, participants' experiences and expectations, and study design.

In this study, pre-recorded PSE music was applied for the PSE condition and the only difference between each participant was the tempo of the music. Recorded music may provide steady music stimulus and could be a cost-effective intervention for music therapy in different settings (Peng et al., 2011; Wang et al., 2013); however, live PSE music may be more adjustable and flexible to the client’s needs. Participants in this study were asked to follow the music and also verbal cuing during the music tasks, but some of them presented difficulties to follow the music and showed unstable movements or awkward postures. Since the pre-recorded music was playing during the whole PSE intervention and could not be adjusted, some participants appeared to have difficulty pacing with the music, moving ahead of or behind the beat in the music. Furthermore, participants who were behind the musical beat tried to move faster and catch up the rhythm, which may have impacted their movement patterns.

Comments from participants indicated that some found the music helpful, while others weren’t sure how to move with the music. Some participants reported they felt they moved faster and easier with music while others asked questions about how they should move to the music (despite the example provided by the researcher). For example, participants asked if they should move faster in the music condition, despite the music being set to their self-paced tempo.

Although participants were told to follow the music and the verbal cuing, some appeared to rush and exhibited unstable movements. This different movement pattern was especially preset during the first few sit-to-stand movements, or when they tried to slow down and match the cuing. Even though there was no significant difference in movement speed, participants may have otherwise negatively altered their movements in response to the music.

According to previous studies, sit-to-stand is a non-intrinsically rhythmic movement requiring lots of weight shifting, muscle and joint sequential/coordination movements (de Souza et al., 2011; Mak et al., 2003), to which the PSE technique can provide cues through the pattern (Thaut & Hoemberg, 2014). In the prior two PSE for sit-to-stand studies, the music therapist used various musical patterns to create musical cuing and promoted three movement phases, starting trunk movement to seat-off, seat-off to standing, and standing to sit down (Peng et al., 2011; Wang et al., 2013). The same overall idea was applied to the music in this study. However, there were some variations that might cause differing results including differences in movement phases, music element applications, length of intervention, and participants' music therapy experiences.

First of all, the definition of movement phases was different in this study. In the prior studies, researchers provide specific musical prompts for the first (initiation to seat-off) and second (seat-off to standing) movement phases (Peng et al., 2011; Wang et al., 2013), which combined as one movement phase in this study. In this study, four preparation chords were provided at the beginning of each four-time sit-to-stand cycle; however, there was no specific cuing to facilitate the initiation of each individual movement phase. Since Bradykinesia is one of the characters of Parkinson's disease and it causes difficulty to initiate movements (Jankovic, 2008), applying a clear, specific cuing at the beginning of each movement phase should be considered.

Besides movement phases, musical elements would be the other variation between these studies. Researches used diverse musical features in these PSE for sit-to-stand studies to offer timing, spatial, and force cuing (Peng et al., 2011; Wang et al., 2013). However, there is no study indicated an exact musical element/pattern would bring the most effective outcome in a specific movement. Therefore, comparing the influences between music arrangements in PSE would be needed in the future.

Another possible reason for the results in this study is the length of the intervention. The study protocol in this study was an immediate effect of music on sit-to-stand, which was similar to Peng's study (2011). However, there were several factors might cause the different outcomes. In the prior study, participants performed three sit-to-stand without music right after they finished five sit-to-stand with PSE music (Peng et al., 2011). In other words, there was no gap between the two conditions. In this study, a five-minute break was provided between the PSE condition and the last conditions (without music). Therefore, a length between the two conditions might be a factor that impacts the continuous effects of PSE. In addition, participants in this study had already completed sixteen sit-to-stand before they started eight more repetitions in the last condition, which was more than the prior study which provided five repetitions under PSE condition and three without music (Peng et al., 2011). Thus, the amount of movement repetition would be another consideration between the two studies.

Moreover, the other prior study provided a six-week procedure and also afforded re-assess sessions, the participants were more familiar with the whole PSE exercise, and the researchers also had opportunities to modify the music they applied in the study (Wang et al., 2013). Compared with previous research, all participants in this one-time intervention study completed the whole protocol within 30 minutes and had no prior experience with the PSE cueing. Out of the fifteen participants, just 4 of them had music therapy experiences before (one was in a Parkinson's movement group and 3 were in a Parkinson's singing group). Therefore, experience with music therapy and PSE cueing maybe a factor that influenced the results. Without music therapy experience, the participants may have been uncomfortable or unsure about how to move with the music. Although more research is needed, there is a possibility that PSE, unlike RAS, requires some learning in order to optimize movement.

Limitations and Future Directions

In this study, small sample size is a limitation. Only 15 participants completed data collection in this study, and results may be difference with a larger sample size. Furthermore, there were large differences in the participants' characteristic including Parkinson's level (per the Hoehn and Yahr Scale) and experience with music therapy. Although this was a within-participant study, the various characteristics that included may have impacted the results.

Sit-to-stand is a functional daily movement (Inkster & Eng, 2004; Lomaglio & Eng, 2005) and it contains several sequenced patterns. Since the pre-recorded music was only adjusted in tempo for this study, providing live PSE music would allow for more flexibility in the intervention to best support and facilitate each movement based on participants' own movement patterns. Live PSE music is modifiable with tempo, and also could support extra auditory stimulants to provide spatial and force cuing that were lacked in this study. Therefore, live PSE music may be considered in future studies to determine if live music would impact sit-to-stand movements.

There were also some difficulties with analyzing the sit-to-stand movement on the iPod due to the placement of the iPod and lack of video recording. Because of various PD levels and physical functions, participants had different movement performances and the results presented different waveforms in the analysis program. However, some irregular waveforms were difficult to explain without image data. These waveforms may have been due to the placement of the iPod on the hip, as opposed to another location such as the upper leg or back. More research on placement of the iPod for optimal data collection is needed. Videotaping would augment data collection, as the video of the participant’s movement process may provide insight as to the data differences observed.

Finally, qualitative data are recommended to take in future studies. Since both motor and non-motor factors impact sit-to-stand movement on people with PD (Lord et al., 2002), qualitative reports from participants during the whole protocol will be valuable witch could provide researchers with important information including physiological and psychological status.

Conclusions

Based on the results from this study, even though PSE technique did not improve postural control in sit-to-stand exercise with people with Parkinson's disease, some valuable information were learned through the whole study. Participants maintained similar movement speed in three phases under three conditions. However, different study design factors and music applications in this study may have led to less movement control under the music condition than the prior studies. Since various musical elements may impact the application of the PSE intervention, more research on music used in PSE would be crucial in the future.

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APPENDIX A. HOEHN & YAHR SCAHLE (HOEHN & YAHR 1967)

Stage 0: No signs of disease

Stage 1: Symptoms are very mild; unilateral involvement only

Stage 1.5: Unilateral and axial involvement

Stage 2: Bilateral involvement without impairment of balance

Stage 2.5: Mild bilateral disease with recovery on pull test

Stage 3: Mild to moderate bilateral disease; some postural instability; physically independent

Stage 4: Severe disability; still able to walk or stand unassisted

Stage 5: Wheelchair bound or bedridden unless aided