THESIS

THE EFFECT OF GROUP VOCAL AND SINGING EXERCISES FOR VOCAL AND

SPEECH DEFICITS IN INDIVIDUALS WITH PARKINSON'S DISEASE:

A PILOT STUDY

Submitted by

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ABSTRACT

THE EFFECT OF GROUP VOCAL AND SINGING EXERCISES FOR VOCAL AND

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Although the majority of individuals with Parkinson's disease (PD) develop

characteristics of hypokinetic dysarthria during the course of the disease, there is no

known treatment that provides consistent efficacy. The purpose of this study was to

investigate the effect of the Music Therapy Treatment Protocol for Hypokinetic

Dysarthria (MTPHD), which utilized two neurologic music therapy (NMT) techniques

for treating voice and speech characteristics developed due to hypokinetic dysarthria.

Five participants with PD exhibiting characteristics of hypokinetic dysarthria participated

in six weekly group music therapy sessions. Three speech assessments were

administered as pretest and posttest to assess participants' improvement in variables that

measured vocal function, voice quality, articulatory control, and connected speech

intelligibility through acoustic and perceptual analyses. A paired samples t-test exhibited

significant differences at posttest in the number of inter-word pauses, total inter-word

pause time, and speaking fundamental frequency. No other significant differences were

observed. Suggestions for future research are discussed.

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Chapter One

Introduction

Purpose of the Study

The purpose of the study was to investigate the effectiveness of the Music

Therapy Protocol for Hypokinetic Dysarthria (MTPHD) that was designed using two

Neurologic Music Therapy (NMT) techniques to treat individuals with voice and speech

deficits such as monotone pitch, breathy and hoarse voice quality, imprecise articulation,

and decreased speech intelligibility due to Parkinson's disease (PD). The study aimed to

examine whether or not MTPHD improved vocal/phonatory function, voice quality,

articulatory control, and connected speech intelligibility by comparing the baseline data

and post-treatment data of the participants.

Need/Problem

Parkinson's disease (PD) is the second most common neurodegenerative disease

after Alzheimer's disease (de Lau & Breteler, 2006). Over 1.5 million people in the

United States are affected with the disease and approximately 60,000 new cases are

diagnosed every year (Parkinson's Disease Foundation, 2010).   The incidence of the

disease is noticeably higher in the people over sixty years of age, although about 4% of

these cases are diagnosed before age fifty (de Lau & Breteler, 2006; National Parkinson

Foundation, 2010). Due to the degenerative and progressive nature of the disease, PD

afflicts both individuals and societies on economic and social levels. The estimated cost

for the treatment, social security payment, and loss of income due to the inability to work

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is estimated at almost 25 billion dollars per year in the United States (Parkinson's Disease Foundation, 2010).

Parkinson's disease exhibits a variety of symptoms highlighted with a lack of motor function control such as resting tremor (involuntary shaking at rest), bradykinesia (slowness of movement), rigidity (stiffness), and postural instability (Duffy, 2005; National Parkinson Foundation, 2010). In addition, more than 80% of the PD population develops some degree of speech and voice deficit during the course of disease (Pinto, Ozsancak, Tripoliti, Thobois, Limousine-Dowsey, & Auzou, 2004; Schultz & Grant, 2000; Trail, Fox, Ramig, Sapir, Howard, & Lai, 2005). Such conditions are collectively called hypokinetic dysarthria, a specific type of dysarthria seen in individuals with PD. Common characteristics include reduced loudness, monotone pitch, reduced stress, breathy and hoarse voice quality, imprecise articulation, and varied rate of speech (Duffy, 2005). Hypokinetic dysarthria can be developed at any stage of the disease and worsen as the disease progresses over time (Stewart et al., 1995; Holmes, Oates, Phyland, & Hughes, 2000). As a result, the symptoms of hypokinetic dysarthria affect individuals' communication with their caregivers, friends, and family members, thereby negatively impacting their well-being (Miller, Noble, Jones, & Burn, 2006).

The existing treatment type for communication issues in PD includes pharmacological treatment, surgical treatment, and speech therapy treatment (National Parkinson Foundation, 2010). However, no treatment option has demonstrated consistent efficacy. Thus, exploring alternative treatment options is strongly suggested (Pinto et al., 2004; Shultz & Grant, 2000; Trail et al., 2005).

Background and Rationale

Over 80% of individuals with PD exhibit the voice and speech characteristics of hypokinetic dysarthria, which affects their communication ability (Trail et al., 2005). Yet, there is no single reliable treatment option available to manage symptoms. Music therapy has been documented as an effective intervention in treating a variety of speech and language deficits including aphasias, apraxia, fluency disorder, delayed development of speech and language skills (Cohen, 1992; Cohen and Masse,1993; Davis, Gfeller, Thaut, 2008; Haneishi, 2001, 2006; Tamplin, 2008b; Thaut, 2005). Among them, the studies on investigating music therapy as a treatment for dysarthria have not demonstrated the generalizability of the results due to confounds such as the types of speech deficits and neurological impairment in participants, small size samples, and irregular treatment schedules among participants.

Referring to the aforementioned studies, Tamplin (2008b) conducted a pilot study to examine the effectiveness of a music therapy protocol using several neurologic music therapy (NMT) techniques for improving dysarthric speech characteristics in individuals with neurological impairment. The results suggested statistically significant improvement in speech intelligibility scores and the rate of speech.   However, the study did not include the participants with voice and speech deficits due to PD, and did not demonstrate the generalizability of the outcomes to individuals with hypokinetic dysarthria due to PD. Thus, further study with more systematic and controlled design are recommended to examine the effectiveness of music therapy to specifically treat voice and speech deficits due to PD.

Hypotheses

The following directional hypotheses are proposed to investigate the effectiveness of a music therapy protocol in improving voice and speech production quality of individuals with PD:

1. Music Therapy Protocol for Hypokinetic Dysarthria will improve vocal function of the participants measured through the duration of sustained vowel phonations and the first (f1) and second (f2) formants during sustained vowel phonation task as compared to their baseline levels.

2. Music Therapy Protocol for Hypokinetic Dysarthria will improve vocal quality of the participants measured through jitter, shimmer, and Harmonics-to-Noise Ratio during sustained vowel phonation task as compared to their baseline levels.

3. Music Therapy Protocol for Hypokinetic Dysarthria will improve articulatory control of the participants measured through the rate of sequenced syllable repetitions during diadochokinesis test as compared to the baseline levels.

4. Music Therapy Protocol for Hypokinetic Dysarthria will improve speech intelligibility of the participants measured through the percentage of discernible words, the speaking fundamental frequency (sF0), the standard deviation of the speaking fundamental frequency (sF0Sd), the number of inter-word pauses, the mean duration of the inter-word pauses, the total inter-word pause time, and the pause ratio during passage reading task as compared to the baseline levels.

Chapter Two

Literature Review

Parkinson's Disease: Overview

As the elderly population has increased in recent years, it is assumed we will see a growing number of individuals with neurodegenerative disease, such as Parkinson's disease (PD) (Meara & Koller, 2000). The prevalence of PD is around 1% among individuals over 60 years old in industrialized countries (Nussbaum & Ellis, 2003). As a consequence of its progressive and neurodegenerative nature, the disease continues to raise significant economical and societal challenges not only at the individual level but also the national level.

Parkinson's disease (PD) was first described in *An essay on the shaking palsy* by a British physician James Parkinson in 1817 (Parkinson, 1817). In his essay, Parkinson described six cases of then-called "paralysis agitans", including his speculation regarding the neurological involvement of the observed symptoms. The observed symptoms included tremor, reduced muscle control, stoop postures, and shuffled gait patterns (Parkinson, 1817). Although Parkinson did not clearly define the characteristics of voice and speech problems, he illustrated observed symptoms including reduced speech intelligibility, varied speech rate, and imprecise articulation in his essay (Parkinson, 1817). After his essay, subsequent literature has restated the clinical descriptions of paralysis agitans, which were then refined by Jean-Martin Charcot and his colleagues in the late nineteenth century (Elmer, 2005). Charcot renamed the disease in Parkinson's honor (Lees, 2007).

The most pronounced symptom of PD is a lack of motor movement control. However, the condition may also affect an individual's communication abilities. It is estimated that more than 80% of the PD population exhibits voice and speech deficits at any stage of the disease (Trail et al., 2005). The common characteristics of voice and speech impairments in PD include reduced volume of speech, monotone pitch, reduced stress in speech pattern, breathy and hoarse voice quality, imprecise articulation, and varied rate of speech (Darley, Aronson, & Brown, 1975; Duffy, 2005). These are collectively called hypokinetic dysarthria. These symptoms worsen over time as PD progresses and negatively influence the person's communication ability (Stewart et al., 1995; Holmes et al., 2000; Pinto et al., 2004), resulting in frustration, decreased self-esteem, and withdrawal from conversations (Miller, Noble, Jones, & Burn, 2006).

Neuropathophysiology of Parkinson's Disease

The ultimate cause of Parkinson's disease is yet unknown. Both environmental triggers and genetic predispositions have been thought to play important roles for the development of the disease (Bartels & Leenders, 2009). The lack of motor movement control in PD is largely due to dopamine depletion in the area of the brain called the substantia nigra in the basal ganglia. The basal ganglia are a part of the subcortical structures in the brain that consists of a group of nuclei including the putamen and caudate nucleus (collectively called striatum), the globus pallidus interna (GPi) and globus pallidus externa (GPe), the substantia nigra pars comparcta (SNc) and substantia nigra pars reticulata (SNr), and the subthalamic nucleus (STN) (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Nolte, 2008).

The basal ganglia form complex parallel loops involving motor related areas of the cerebral cortices and thalamus to balance the excitatory and inhibitory neural activities for controlling motor movements. Those are called the direct pathway and indirect pathway (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Nolte, 2008). The direct pathway is the excitatory loop projecting from the pre-motor/motor cortical areas through striatum, globus pallidus interna, thalamus, and returning to the cortex. The inhibitory signal from the striatum to globus pallidus interna will lead to disinhibition input to the thalamus, thereby facilitating cortical activity for initiating motor movements. Whereas, the indirect pathway is the inhibitory loop projecting from the pre-motor/motor cortical areas through striatum, globus pallidus externa, subthalamic nucleus, globus pallidus interna, thalamus, and returning to the cortex. The inhibitory projection from the striatum to the globus pallidus externa will result in a disinhibitory projection to the subthalamic nucleus. This disinhibition then facilitates excitation to the substantia nigra pars reticulata and the globus pallidus interna, which produce inhibitory inputs to the thalamus for less cortical facilitation to suppress unwanted movements (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Nolte, 2008).

The neurotransmitter dopamine plays a pivotal role in balancing between these parallel loops. Dopamine is released from the substantia nigra pars comparcta through nigrostriatal fibers, and is thought to exert influence over the direct pathway via D1 receptors, and the indirect pathway via D2 receptors. Thus, dopamine depletion in the substantia nigra leads to abnormal inhibitory neural activity in both pathways to cause less motor cortical activities, thereby resulting in hypokinetic motor deficits (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Nolte, 2008).

Moreover, the association of subcortical structures such as the basal ganglia and cerebellum to motor speech disorders has been reported (Darley, Aronson, & Brown, 1975; Murdoch & Whelan, 2009). This indicates that speech motor control appears to share the same neuropathological origin with limb motor movement control. Nevertheless, underdevelopment of the neuropathophysiology of hypokinetic dysarthria has posed consistent challenges in developing an ultimate treatment to improve voice and speech deficits by hypokinetic dysarthria.

Speech Treatment for Hypokinetic Dysarthria

There is currently no treatment to either cure the disease or stop the progression of hypokinetic dysarthria. The standard care for PD is pharmacological treatment, and the most common pharmacological treatment option is a prescribed medication such as levodopa (or L-dopa). L-dopa is a dopamine agonist that modifies enzymes in the brain to produce dopamine, thereby facilitating normal functioning of the brain for controlling movements (Parkinson's Disease Foundation, 2010). Although the effectiveness of L-dopa to reduce tremor and muscle rigidity has been supported (National Parkinson Foundation, 2010), its effect has not been shown consistently to improve on the characteristics of hypokinetic dysarthria (Pinto et al., 2004; Schulz & Grant, 2000; Trail et al., 2005). Moreover, pharmacological treatments often produce side effects such as dyskinesia (i.e. abnormal voluntary movement) or wearing-off effect, which is the diminished effect of the medication as a result of taking it for a long time (National Parkinson's Foundation, 2010). Therefore, the surgical option is also available for those who have exhausted the pharmacological treatments or who suffer from significant motor

fluctuations resulting in wearing-off effects and dyskinesia (National Parkinson's Foundation, 2010).

There are two types of surgery that target the symptoms of hypokinetic dysarthria. One type of surgical treatment is lesion surgery for decreasing motor symptoms such as tremor and rigidity. Types of lesion surgeries are pallidatomy (lesions to the globus pallidus of the basal ganglia), thalamatomy (lesion to thalamus), and subthalamatomy (lesion to the subthalamic nuclei of the basal ganglia) (National Parkinson Foundation, 2010). Another type of surgical treatment is called Deep Brain Stimulation (DBS). DBS is the use of a surgically implanted battery-operated medical device called a neurostimulator to deliver electrical stimulation to targeted areas in the brain that control movement, blocking the abnormal nerve signals that cause tremor and other PD-related symptoms (National Parkinson's Foundation, 2010).

Although these surgical options have demonstrated successful results in some gross motor deficits, they appear to be less effective or even detrimental in treating the symptoms of hypokinetic dysarthria (D'Alatri et al., 2008; Murdock & Whelan, 2009; Pinto et al., 2004; Schulz & Grant, 2000; Trail et al., 2005). D'Alatri et al. (2008) found that perceptual analysis data on speech intelligibility exhibited more significant improvement in the subthalamic nucleus deep brain stimulation (STN DBS) condition than the medication condition. On the other hand, instrumental acoustic analysis displayed a limited effect of STN DBS on some of the measured voice parameters. Along with the comparison with prior similar study results, the authors concluded the overall effect of the subthalamic nucleus stimulation was more significant on limb motor deficits than on overall speech motor deficits due to hypokinetic dysarthria. Hence, both

pharmacological and surgical treatment options have not consistently demonstrated effectiveness for improving speech and voice deficits of hypokinetic dysarthria.

Speech therapy treatment has also been introduced as another treatment option (Pinto et al., 2004; Trail et al., 2005; Shultz & Grant, 2000). Among them, the Lee Silverman Voice Treatment (LSVT), a speech therapy technique developed by a group of scientists and clinicians led by Ramig has demonstrated considerable success in increasing vocal loudness (i.e. volume) due to hypokinetic dysarthria, and is supported by several study results (Deane, Whurr, Playford, Ben-Shlomo, & Clarke, 2009; Ramig, 1998; Ramig, et al., 2001; Sapir, Ramig, & Fox, 2008). LSVT is a one-month intensive speech therapy protocol to mainly focus on improving the loudness of the speech by instructing the clients to "Think Loud and Shout" (LSVT, 2010).

However, LSVT draws criticism. De Swart, Willemse, Maassen, & Horstink (2003) argued that the method of LSVT, "Think Loud and Shout" might allow for increasing laryngeal muscle tone and vocal pitch, resulting in a high-pitched strained sound. In addition, a Cochrane review conducted by Deane et al. (2009) pointed out a lack of statistical comparisons between the changes made by LSVT and by other treatment type, thereby resulting in weaker validity. Moreover, although a substantial number of studies reported the efficacy of LSVT, many participants overlapped in multiple LSVT studies, which led to weaker external validity (Academy of Neurologic Communication Disorders and Sciences, 2001). Adams and Dykstra (2009) also stated that nonlaryngeal processes including oral articulation, velopharyngeal control, respiratory function, and postural control might play more important roles in producing less speech intelligibility in hypokinetic dysarthria. Thus, the primary focus of LSVT on

the improvement of the vocal loudness may not be applicable to most individuals with hypokinetic dysarthria (Adams & Dykstra, 2009). In short, no single treatment option has been yet established with consistent efficacy in treating voice and speech deficits due to hypokinetic dysarthria, thereby encouraging the exploration of alternative treatment options.

Music Therapy for Speech Rehabilitation

Current literature has documented the use of music therapy for speech rehabilitation (Davis, Gfeller, Thaut, 2008; Thaut, 2005). In addition, several studies have examined the effectiveness of voice and singing instructions for treating voice and speech problems due to neurological diseases (Baker, Wigram & Gold, 2005; Cohen, 1992; Cohen & Masse, 1993; Haneishi, 2001, 2006; Tamplin, 2008b). Cohen (1992) studied the effectiveness of group singing instruction as a treatment for improving speech intelligibility of individuals with traumatic brain injury (TBI) and cerebral vascular accident (CVA). The results revealed that 67% of the treatment participants exhibited improvement in speaking fundamental frequency variability, rate of speech, and verbal intelligibility, as no control subjects exhibited consistent improvement. Furthermore, Cohen & Masse (1993) compared the effectiveness of two treatment types (i.e. rhythmic instruction and singing instruction) on the rate of speech and verbal intelligibility of individuals with neurological impairments. The singing instruction group showed the most significant improvement for verbal intelligibility. Although other speech parameters did not show any significant improvement, both the singing and rhythmic instructions exhibited a positive trend in each speech parameter as the non-treatment control group

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only maintained baseline data (Cohen & Masse, 1993). Cohen's studies laid the systematic foundation of the use of vocal and singing exercises for improving speech intelligibility of individuals with neurological impairments. However, further study was suggested due to the lack of specificity in the process of participant selection by differentiating between their diagnoses, as well as limited sample size.

Haneishi (2001) developed the Music Therapy Voice Protocol (MTVP), based on the session format from the vocal instruction program by Cohen (1995) to treat speech symptoms due to PD. The study exhibited a significant increase in speech intelligibility and intensity range upon receiving music therapy treatment. Further study by Haneishi (2006) randomly assigned twenty participants into two groups (MTVP treatment group and control group) to examine the effectiveness of MTVP on speech intelligibility, voice quality, vocal intensity range, intonation as well as psychological measures. Speech intelligibility, vocal intensity range, intonation, and positive affect were significantly improved in the MTVP treatment group compare to non-treatment control group. However, the time frame for data collection and session schedules varied among participants due to their physical condition and schedule conflicts, thereby weakened the validity of the data. The author also mentioned that some MTVP techniques were speech therapy techniques, implying a confound between the effect of musical training and that of speech therapy techniques on the target measures.

Prior studies (Cohen, 1992; Cohen & Masse, 1993; Haneishi, 2001, 2006) limited the validity of the study results due to lack of controlling diagnoses among participants, unbalanced treatment-control group size, inconsistent study schedule, and lack of support with neuroscience-based evidence. In addition to controlling confounds, further

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investigation is encouraged to take different angles in determining the effectiveness of the

therapeutic use of music as speech rehabilitation with neurophysiological evidence

(Thaut, 2005).

Neural Representation of Music Processing

The advancement of brain imaging techniques over the past couple of decades has

allowed researchers to inquire as to the neural mechanisms of music processing through

direct observation of neural activities in the brain. Past literature has introduced evidence

that music processing is widely distributed within the brain systems (Thaut, 2005). For

instance, brain imaging studies have displayed the tendency of left hemispheric

lateralization for language perception and production, whereas the tendency of right

hemispheric and also bihemispheric lateralization has been observed in music perception

and production (Brown, Martinez, & Parsons, 2006; Özdemir, Norton, & Schlaug, 2006;

Thaut, 2005). Brown, Martinez, & Parsons (2006) investigated the brain activation

patterns of sentence and melody generation tasks by using positron emission tomography

(PET). The results exhibited overlapped activations for both tasks in the identical or

adjacent areas of the brain, including Broca's Area (Brodmann area (BA) 44/45), primary

motor cortex (BA6), anterior insula, primary and secondary auditory cortices (BA 41/42),

supplementary motor area, temporal pole (BA 38), Wernicke's Area (BA 22) as well as

subcortical areas such as the basal ganglia, ventral thalamus, and posterior cerebellum.

The results implied that activations in the shared areas of the brain through both language

processing and music processing indicate the possibility of music functioning as a driving

force for neural rewiring to overcome damaged language function. Likewise, the act of

singing and speech share the functions of respiratory, phonatory, and articulatory organs (Sundberg, 1990). Thus, it is also important to investigate neural activity patterns of singing and speech to discover the similarities and differences between them.

The functional MRI (fMRI) study by Özdemir, Norton, & Schlaug (2006) displayed activations in the overlapping areas of the brain upon singing and speech tasks in both hemispheres of the brain. The areas include the inferior precentral and postcentral gyri, superior temporal gyri, and superior temporal sulci in both hemispheres. Moreover, the singing condition activated additional areas such as Heschl's gyrus (i.e. transverse temporal gyrus), anterior part of superior temporal gyrus (BA 22) and temporopolar area (BA 38), inferior frontal gyrus in the right hemisphere. These additional activation areas becoming active during singing task may provide a clue as to why singing skills do not become impaired, despite damage to the language production skills. Due to the shared neural mechanisms between singing and speech and the extended neural network for singing, singing might positively contribute toward enhancing neuroplasticity to regain motor speech functions (Özdemir, Norton, & Schlaug, 2006; Tamplin, 2008a, 2008b; Thaut, 2005). Further research questions have been explored regarding the influence of music processing on motor performance entrainment.

Auditory Rhythmic Entrainment on Motor Performance

One of the groundbreaking studies to explain the influence of musical processing in the brain indicated that motor performance could be entrained very precisely and quickly to external auditory rhythmic stimuli (Thaut, Miller, & Schauer, 1998). Thaut, Miller, and Schauer (1998) found that during finger tapping tasks, motor synchronization

occurred very rapidly and precisely with a few correction movements upon small magnitude change in frequency, even the change was below the conscious awareness level. These imply that auditory rhythms quickly built temporal templates for the motor system to entrain motor movements (Thaut, Miller, & Schauer, 1998; Thaut, 2005).

In addition, recent brain imaging studies have certainly advanced our knowledge in neurobiology of motor synchronization, neuroscience approach to investigate temporal processing in the brain (Molinari, Leggio, De Martin, Cerasa, & Thaut, 2003; Thaut, 2003). Molinari et al. (2003) used Magnetoencephalography (MEG) to examine neural activity changes upon motor synchronization to an external auditory rhythmic stimulus. Activated areas were widely distributed at the cortical and subcortical levels. The cortical areas include primary sensorimotor and cingulate areas, bilateral opercular premotor areas, bilateral opecular parietal areas, ventral prefrontal cortex, and the subcortical areas include anterior insula, putamen, and thalamus. Activation was also observed in the areas of cerebellum such as the vermal regions and anterior hemispheres. This implies a wide distribution of neural networks for rhythmic processing in the brain, rather an isolated single neural network that serves for rhythmic processing. Furthermore, a MRI study by Thaut, Demartin, and Sanes (2008) revealed that different brain activation patterns were observed while musician participants performed finger tapping tasks to two different rhythmic patterns. The finger tapping tasks to both an isorhythmic pattern (i.e. "on the beat") and a polyrhymic pattern called "hemiola" (2:3 or 3:2) activated the areas of the brain including contralateral primary motor cortex (M1), supplemental motor cortex (S1), and primary motor area, temporal operculum, and basal ganglia, and ipsilateral cerebellum. However, polyrhythmic production, which was more complex rhythmic

pattern, resulted in reduced activation in ipsilateral basal ganglia as well as greater activation in contralateral M1/S1, thalamus, putamen, and parietal operculum, and ipsilateral cerebellum. The results posed that while basal ganglia may play a role in temporal processing for basic timing and rhythmic sequence perception, celebellum may be involved in computing complex temporal patterns. Thus, neocortical, subcortical, and celebellar structures appeared to consciously play different roles in rhythm perception.

Interestingly, past research has indicated that auditory rhythmic stimuli could positively influence motor entrainment in individuals with basal ganglia or cerebellar damage. McIntosh, Brown, Rice, and Thaut (1997) studied whether gait velocity, cadence, stride length, and symmetry of individuals with Parkinson's Disease would be improved upon gait training using rhythmic auditory stimulation (RAS). Significant improvements were found in gait velocity, stride length, and cadence in individuals with PD who were off of dopaminergic medication. This suggested that external auditory cues appeared to be effective in facilitating gait coordination despite the impairment of basal ganglia due to Parkinson's disease. Similarly, Morinari et al. (2005) found cerebellar activation in individuals with cerebellar damage upon performing finger tapping tasks to external auditory stimuli (Molinari et al., 2005). Results suggested that the ability of conscious detection in rhythmic variations in individuals may be impaired by cerebellar damage, but the ability of rhythmic entrainment to the rhythmic stimuli may still be intact.

Hence, motor entrainment to external rhythmic auditory stimuli could be pertinent to motor rehabilitation. Another research question that requires study is whether or not motor entrainment occurs in speech motor areas.

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Auditory Rhythmic Entrainment on Speech Motor Control

Findings regarding motor synchronization in aforementioned studies have been applied to investigate whether or not speech motor movement could also be entrained by external auditory rhythmic stimuli. LaGasse (2009) studied whether an external auditory stimulus facilitates speech motor entrainment in children and adults while repeating the bilabial syllable /pa/ with or without an external auditory stimulus. The kinematic data was recorded by video-based 4-dimensional motion capture technology to measure movements of the upper lip, lower lip, and jaw. The results of the Spetiotemporal Index and synchronization error calculated based on the recorded kinematic data exhibited that an external auditory stimulus appeared to positively influence speech motor synchronization, despite child's underdevelopment of motor coordination as compared to adults. Results also suggested that children participants had greater speech motor stability with the external auditory stimulus at the faster tempo. This supports the use of external auditory cues as a strategy to facilitate speech motor synchronization in speech rehabilitation.

The clinical use of external auditory cues in speech rehabilitation has been studied in the past (Pilon, McIntosh, and Thaut, 1998, Thaut, K. McIntosh, G. McIntosh, and Hoemberg, 2001). Pilon, McIntosh, and Thaut (1998) examined the effectiveness of the use of external auditory cues to improve abnormal rates of speech observed in three individuals with acquired spastic-ataxic dysarthria due to traumatic brain injury (TBI). Results indicated that metronomic cueing produced the most significant improvement in the rate of speech of the participants with mild to severe dysarthria. Thaut, K. McIntosh,

G. McIntosh, and Hoemberg (2001) studied how the application of rhythmic cuing may help improve speech intelligibility in people with hypokinetic dysarthria due to PD. Although the effect of the rhythmic cueing varied among subgroups of the participants by severity of hypokinetic dysarthria (mild, moderate, severe), the results showed significant improvement in speech intelligibility of all participants. The above studies suggested the effectiveness of external auditory rhythmic stimulus for motor synchronization despite the damage to basal ganglia and cerebellum. Thus, motor entrainment could not only benefit to treat individuals with gross motor deficits but also speech motor deficits such as hypokinetic dysarthria. The above studies suggested the effectiveness of the therapeutic use of rhythmic entrainment based on neuroscientific evidence to both limb and speech motor rehabilitation.

Neurologic Music Therapy for Speech Rehabilitation

Prior research supported by neuroscientific findings (Lim, 2010; Pilon, McIntosh, & Thaut, 1998; Tamplin, 2008b; Thaut, 2005; Thaut, McIntosh, McIntosh, & Hoemberg, 2001) investigated the effectiveness of music therapy for speech treatment. With a reductionist approach of breaking down music into the elements of music, neurologic music therapy (NMT) has further advanced the potential of music therapy to efficiently and effectively work toward non-musical functional goals based on scientific and clinical research evidence (Thaut, 2005). Tamplin (2008b) conducted a pilot study to examine the effectiveness of music therapy protocol using neurologic music therapy techniques in improving speech intelligibility and speech naturalness of individuals with acquired dysarthria due to traumatic brain injury or stroke. Statistically significant improvements

in speech intelligibility and speech naturalness were observed. This suggests that music therapy protocol using vocal and singing exercises based on the principles of neurologic music therapy may be effective. However, this study only included individuals who acquired dysarthria due to traumatic brain injury or a cerebral vascular accident. Thus, further study should target the improvement of dysarthric speech due to Parkinson's disease by developing a music therapy protocol using these neurologic music therapy techniques.

There are three neurologic music therapy techniques used in the study by Tamplin (2008b); 1) Oral Motor and Respiratory Exercises (OMREX), 2) Vocal Intonation Therapy (VIT), and 3) Therapeutic Singing (TS). According to Thaut (2005), Oral Motor and Respiratory Exercises (OMREX) is a technique that uses musical materials to improve articulatory control, respiratory strength, and function of the speech apparatus. For instance, Haas, Distenfeld, and Axen (1986) hypothesized that musical rhythm might function as a pacemaker for respiratory patterns, which employ repeated rhythmic patterns. The investigator asked twenty music student participants to tap their fingers to the metronome sound or the beat of the musical stimuli influences respiratory pattern. The result indicated a positive effect of external auditory rhythmic stimuli on the participants' respiratory pattern control. Respiratory entrainment also implied the interaction between external auditory rhythmic stimuli and the central pattern generator (CPG). Therefore, this technique appeared to effectively target weakened breath control due to muscle rigidity caused by PD.

Vocal Intonation Therapy (VIT) is meant for training voice control, including inflection, pitch, breath control, timbre, loudness, phonation, resonance and intonation.

Sabol, Lee, and Stemple (1995) examined whether 4-week long Vocal Function

Exercises (VFE) positively enabled the trained singer participants to achieve vocal

efficiency through their phonation tasks. The result demonstrated significant

improvement in airflow rate, phonation volume and maximum phonation times,

suggesting increased efficiency in glottal function. Likewise, Sundberg (1990) explained

that the loudness of voice is controlled by the change in air pressure below the vocal

folds, called the subglottal air pressure. The higher the subglottal pressure, the louder the

sound. Furthermore, higher pitches require higher subglottal pressure. As a result,

singing requires fine control of subglottal pressure. Although speech does not employ

subglottal pressure for controlling loudness and pitch as singing does, fine control of

subglottal pressure would yield improved inflection in the speaking voice. Moreover,

Sataloff (2005) explained that formants are an important factor in determining the quality

of a voice. Formants are a series of harmonics of the fundamental frequency to

characterize vocal resonance. In particular, trained singers develop a specific type of

formant called singer's formant, a clustering of formant frequencies that enhances their

voices to be more discernible against loud background volume (e.g. orchestra).

Barrichelo, Heuer, Dean, and Sataloff (2001) investigated whether or not trained singers

extended their singer's formant into speech. The result indicated that trained singer

participants exhibited significantly higher intensity in both spoken and sung vowels

compared to untrained speaking controls. The finding suggests that singing training

affects the speaking vocal resonance. Thus, use of this technique may help reduce

hoarseness and breathiness in voice quality, the lack of prosody due to monotone pitch,

and increase the volume (loudness) of speech.

Therapeutic Singing (TS) is the use of singing exercises to facilitate better initiation, development, and articulation in speech as well as improve respiratory apparatus functions. DiBenedetto, Cavazzon, Mondolo, Rugiu, Peratoner, and Biasutti (2009) stated that group choral singing provided a significant effect in improving respiratory control in speech tasks performed by individuals with PD. Thus, vocal and singing exercises that utilize the aforementioned techniques will be a beneficial treatment for individuals who exhibit the characteristics of hypokinetic dysarthria due to PD.

In addition to the above techniques, additional effects of the therapeutic use of music that are supported by several studies (Clair & Memmot, 2009; Di Benedetto et al., 2009; Thaut; 2005; Tonkinson, 1994) should be taken into consideration for optimizing the effectiveness of music therapy treatment. Tonkinson (1994) suggested that group singing may provide the Lombard effect – the tendency to increase one's own volume of speech/singing due to the masking effect by the surrounded voices, which leads to providing less auditory feedback. Thus, group singing may encourage participants to sing in a louder volume, which requires them to use more breath support and respiratory muscle control. Moreover, a group singing exercise instead of individual singing exercise may better facilitate clients' motivation (Di Benedetto et al., 2009). Similarly, a number of studies suggested the use of clients' preferred music to encourage their participation and increase their engagement in the treatment (Clair & Memmot, 2009; Thaut, 2005).

In conclusion, although a considerable amount of literature introduced the high prevalence of speech and voice deficits among individuals with PD, there is no single treatment option developed with consistent efficacy and evidence-based strategies (Deane

et al., 2009; Pinto et al., 2004; Schultz & Grant, 2000; Trail et al., 2005). Recent

advancement of scientific research in exploring the relationship between neural

mechanisms and music perception and production seems to suggest that music could be

an effective alternative treatment option for individuals with PD who exhibit voice and

speech deficits. However, there has not been any empirical research conducted to

examine the effectiveness of music therapy treatment based on these postulations. Thus,

research is needed to investigate whether or not group music therapy treatment is

effective to improve voice and speech deficits in individuals with PD.

Chapter Three

Methods

Participants

Participants were recruited from a local Parkinson's Disease Support Group and their exercise group held at the Center for Biomedical Research located in the Center for the Arts at Colorado State University, Fort Collins, CO. The study was approved by the Institutional Review Board of Colorado State University. Seven individuals (3 females, 4 males) originally volunteered for their participation in this study. However, only five participants completed the entire study, as two (1 female, 1 male) withdrew due to the development of health conditions during the treatment phase of the study.

The inclusion and exclusion criteria were a current diagnosis of Parkinson's disease (PD), the severity of the disease determined by the Hoehn & Yahr scale (Hoehn & Yahr, 1967) from 1 to 3 according to the participants' self reports, their age over 55, and the onset of PD after age 55 (i.e. non early-onset PD), and neither co-morbidity with other neurological impairments nor cognitive deficits, and use English as their native language. The mean age (standard deviation) of the participants was 70.8 (10.305) years. The mean years of post PD diagnosis was 8.2 (5.263). Their mean of Hoehn and Yahr scale rating was 2.6 (0.224). All the participants exhibited one or more characteristics of hypokinetic dysarthria including reduced volume of speech, monotone pitch, reduced stress in speech pattern, breathy and hoarse voice quality, imprecise articulation, and varied rate of speech. Inform consent was obtained before participation in the pretest.

Measurement Instruments

Three speech tasks were given as pretest and posttest to assess on the following criteria: (a) vocal function and voice quality (sustained vowel phonation task), (b) articulatory control ability (diadochokinesis test), and (c) connected speech intelligibility (Rainbow Passage Reading). The audio samples of each participant were recorded by phonetic analysis software called Praat (Boersma & Weenink, 2010) installed in Mcintosh MacBook Pro by Apple (2009) through the Snowball USB condenser microphone manufactured by Blue Microphones (2009). The microphone was placed 8 inches in distance from the participant's mouth to assure accurate and reliable audio recording at both pretest and posttest.

1. Sustained Vowel Phonation Task
Vocal/(Phonatory) Function Assessment

Voiced phonation production involves effective and efficient vocal fold vibration (The National Center for Voice and Speech, 2009). A number of observations has been made in individuals with PD regarding the insufficient glottal closure caused by abnormal vocal fold vibration that may result in poor voice quality, difficulty of voice projection, and vocal fatigue (Baken & Orlikoff, 2000, Trail et al., 2005). The measurement of the duration of sustained vowel phonation could be an indicator to explain the ability of glottal function in individuals with PD (Baken & Orlikoff, 2000, Canter, 1963). The data of the sustained vowel phonation tasks were also used to analyze the variances of the first formant ($f1$) and second formant ($f2$). Formants are a series of variable resonances of the human vocal tract and numbered from the lowest in frequency (Nair, 1999; The National Center for Voice and Speech, 2009). The first two formants, the first formant ($f1$) and

second formant (*f*2) account for distinguishing the vowels. The vowel /a/ is one of the open/back vowels, which have the combination of the higher *f*1 and lower *f*2 (Kent & Ball 2000; Sataloff, 2005). Sustaining a vowel phonation for the longest duration not only involves efficient vocal fold vibrations and respiratory function, but also vocal tract function steadiness. Therefore, the variance of the *f*1 and *f*2 could indicate the degree of vocal function stability from an acoustic perspective.

Voice Quality Assessment

Slight deviation in the voice sound could be observed as normal variance relating to physiological mechanisms for voice production. However, increased perturbation level in voice frequency and amplitude could be abnormal or even pathological (Brockmann, Drinnan, Storck & Carding, 2009; Forrest & Weismer, 2009). There are several indicators to describe the abnormality of voice quality.

Jitter and shimmer have been considered variable indicators as the perturbation level in the voice sound for acoustic analyses (Adams & Dykstra, 2009). Jitter displays cycle-to-cycle variation in frequency (i.e. time) and shimmer describes cycle-to-cycle variation in amplitude (Kent & Ball, 2000; Adams & Dykstra, 2009). The abnormal increment of jitter and shimmer contribute to the perceptual effect, which is called as "harshness" (Laver, Hiller, & Beck, 1992). Praat analysis defines the jitter above 1.040 % and shimmer above 3.810 % as thresholds of pathology (Boersma & Weenink, 2010).

Harmonics-to-Noise Ratio (HNR) is another acoustic index of voice quality that refers to the proportion of noise to the vocal sound measured. The greater the noise in the voice, the lower the HNR (Forrest & Weismer, 2009; Yumoto & Gould, 1982). Praat

analysis defines the HNR of 20 dB or below as threshold of pathology (Boersma & Weenink, 2010).

2. Diadochokinesis Test for Articulatory Control Assessment

The diadochokinesis test has been widely used as a standard speech assessment for articulatory movements in neurological evaluation. The test used three monosyllables /pa/, /ta/, /ka/ as a sequence and the participants were asked to repeat the sequence for five seconds, requiring the participants to select or alternate place for syllabic productions with similarly-voiced stops (R. Kent, J. Kent, & Rosenbek, 1987). Since the test only involved the repetitions of monosyllables, it enabled assessment of speech motor control ability without the influence of language production (Padovani, Gielow, & Behlau, 2009). Therefore, the rate of the diadochokinesis test would be a valuable indicator for the participants' speech motor control ability.

3. Rainbow Passage Reading Task for Connected Speech Intelligibility Assessment

The Rainbow Passage is a standard piece of text that contains every vowel and consonant sound in the English Language (Deane, Whurr, Playford, Ben-Shlomo, & Clarke, 2009), so it has been widely used for connected speech intelligibility assessment. It is a public domain text that can be located on page 127 in the *Voice and Articulation Drillbook Second Edition* by Fairbanks (1960). The first paragraph of the Rainbow Passage was used for the pretest and the second paragraph for the posttest. Each participant was asked to read the full paragraph at each test. However, the third and fourth sentences of each paragraph were used for data analyses. The number of words in

the third and fourth sentences of the first paragraph is 35 words and that of the second paragraph is 34 words.

The recorded Rainbow Passage reading audio samples of each participant was used to measure connected speech intelligibility by counting the words that were discernible. In addition, the speaking fundamental frequency (sF0) and the standard deviation of speaking fundamental frequency (sF0Sd) were measured. The mean sF0 is associated with one's habitual pitch. While speaking, habitual pitch should vary to create prosody, that is, a melodic contour of speech with various patterns of stress and intonation. Although sF0 is not the only attribute to determine speech prosody, past literature has indicated that individuals with PD tended to demonstrate reduced sF0 variations that might lead to monotone speech (Canter, 1963; Skodda, Rinsche, & Schlegel, 2009). The measurement of the sF0Sd could indicate the overall variance in one's speech prosody (Kent & Ball, 2000).

In addition, speech pauses, precisely, the number of inter-word pauses (i.e. pauses between words), the duration of each inter-word pauses, and the pause ratio were measured. The measurement of speech pauses is meant to investigate the rate of speech that might be related to one's speech prosody. Abnormal numbers and durations of speech pauses affect the rate of speech (Duffy, 2005, Skodda & Schlegel, 2008). A pause between the end of the third sentence and the beginning of the fourth sentence was excluded from the analysis. An inter-word pause was determined by spectrogram analysis as presented fewer than 200 milliseconds (R. Kent, J. Kent, & Rosembek, 1987; Van Nuffele, Botd, Vanderwegen, de Heyning, & Wuyts, 2010). The pause ratio was

calculated as the total pause time as a percentage of the total reading time for the third and fourth sentences.

In summary, these three speech tasks would provide pertinent information to examine the effectiveness of the music therapy protocol for hypokinetic dysarthria (MTPHD) on voice and speech characteristics seen in individuals with PD.

Acoustic Analyses

The recorded audio samples were transformed into spectrograms and waveforms displayed in Praat for acoustic analyses. A spectrogram is a graphical representation of a sound in both time and frequency. The X axis represents time, and the y axis represents frequency. The color (or intensity) of the lines represents amplitude. Each horizontal band (i.e. cluster of lines) in the graphic display represents a different harmonic in the sound spectrum (The National Center for Voice and Speech, 2010). Waveform displays a shape of a sound at a given time. The author and a board-certified music therapist performed acoustic analyses on spectrogram and waveform displays by visually detecting the duration of the sustained vowel phonation, the mean of the first ($f1$) and second ($f2$) formants, jitter, shimmer, and the Harmonic-to-Noise ratio (HNR) of the voiced sound from the sustained vowel phonation audio samples, the number of syllable repetitions from the diadochokinesis test audio samples, and the number of inter-word pauses, the duration of each inter-word pause, the speaking fundamental frequency (sF0) and the standard deviation of the speaking fundamental frequency (sF0Sd) from the Rainbow Passage reading audio samples.

Perceptual Analysis

For measuring connected speech intelligibility, a board-certified music therapist and a trained graduate music therapy research assistant who are native speakers of English performed perceptual analyses by dictating the words that were discernible through listening to the recorded Rainbow Passage reading audio samples of each participant.

Procedures

Recruitment flyers were distributed along with a brief announcement to the participants of the PD exercise group held at the Center for Biomedical Research in Music (CBRM). Participants responded to the researcher to indicate their interest in participating in the study after the announcement and the researcher scheduled an appointment with each participant for the pretest. A number was assigned to each participant prior to the pretest to assure anonymity of the participants. The pretest and posttest occurred at CBRM. Prior to the pretest, each participant provided an informed consent to agree to join the study. A pre-study questionnaire form was distributed to each participant to obtain information regarding their preferred songs and genres of music and the history and current status of their musical experiences. The pre-study questionnaire results were used to choose their preferred songs and songs from their preferred genres or their age group for singing exercises. A brief interview to obtain the participants' basic information such as age, the time of PD onset, medications was also given prior to the pretest. Then, each participant was administered three speech tasks for a pretest measurement. Within a week after each participant completed the pretest, a 50-minute

weekly group music therapy session was provided to the participants for six weeks (i.e. six sessions) by using the Music Therapy Protocol for Hypokinetic Dysarthria (MTPHD) in a classroom next to CBRM. Within a week after the last treatment session, each participant took the posttest. During all treatment sessions, a speech language pathologist was present to support the sessions by providing emphasized articulation cues, visual cues for dynamic change and breathing timing.

Design

The research design of the study is a pilot study of a music therapy protocol with one group pretest posttest design. The independent variable was music therapy treatment using the Music Therapy Protocol for Hypokinetic Dysarthria (MTPHD). The dependent variables include the following measures obtained from three speech tasks: (a) sustained vowel phonation task measured the duration of the sustained vowel phonation and the mean of the first (f1) and second (f2) formants for vocal function, and the percentages of jitter and shimmer, and the Harmonic-to-Noise Ratio (HNR) for voice quality, (b) the diadochokinesis test measured the number of sequenced syllable repetitions for articulatory control, and (c) Rainbow Passage reading task measured the percentage of discernible words, the number of inter-word pauses, and the mean of inter-word pause time, pause ratio, speaking fundamental frequency, and standard deviation of speaking fundamental frequency for connected speech intelligibility.

Music Therapy Protocol for Hypokinetic Dysarthria (MTPHD)

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Music Therapy Protocol for Hypokinetic Dysarthria (MTPHD) is designed by the author for individuals who exhibit the characteristics of hypokinetic dysarthria due to Parkinson's disease (PD). MTPHD is based on two Neurologic Music Therapy techniques: Vocal Intonation Therapy (VIT) and Therapeutic Singing (TS). MTPHD was provided in the form of a group therapy treatment and involved six weekly sessions over six weeks. Each session lasted around 50 minutes, consisting of a 5-minute opening/relaxation exercise, a 15-minute vocal warm-up, two 10-minute singing exercises, and a 5-minute closing/relaxation exercise, with a 5-minute water break in the middle of the session. The author facilitated each exercise using keyboard accompaniments and verbal instructions along with PowerPoint slides for visual cues. The sessions were conducted while participants were seated in chairs.

Opening/Relaxation Exercises (5 minutes)

At the introduction, the purpose of the session, the role of the music therapist, and goals and objectives targeted by Therapeutic Music Exercises (TMEs) using the aforementioned two NMT techniques were explained. Then, the author led a relaxation exercise for general muscular relaxation, including neck stretches, shoulder rotations, and orofacial muscle stretches to help decrease muscle tension in the face and upper body to prepare for the session.

Vocal Warm-up (15 minutes)

VIT was used to lead a series of vocal warm-up exercises aimed at expanding respiratory control, improving phonatory controls, as well as improving vocal prosody by

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expanding pitch range. For instance, a gliding exercise was used to stretch the vocal folds by gliding from a higher pitch to a lower pitch, ascending a half step each time.

Singing Exercises for Articulation Clarity (10 minutes)

TS was used to exercise articulatory control on certain sounds of speech (i.e. consonants/vowels/syllables) within a context of singing. Target sounds were, but not limited to, nasal, fricatives, and affricatives, with which individuals with hypokinetic dysarthria tend to struggle (Duffy, 2005). In each session, two songs based on the participants' preferences that contain the target speech sounds were chosen for the exercises.

Water Break (5 minutes)

A small cup of water was distributed by the author to each participant for preventing dry mouth and soar throat due to the exercises and resting of the voice/speech apparatus.

Singing Exercises for Breath Support (10 minutes)

TS was used to exercise respiratory control within a context of singing. In each session, two songs were selected based on participant' preferences that encourage strategic breathing patterns due to long and connected phrasing patterns.

Closing/Relaxation Exercises (5 minutes)

The session ended with a relaxation exercise to facilitate muscle relaxation with neck stretches, shoulder/arm extensions, and deep breathing. The author also reflected on the key points of all exercises, acknowledged the participants' effort, reminded them of the time and date for the next session, and provided a brief period for questions from the participants.

Chapter Four

Results

Data analysis was performed using the SPSS 19 for Macintosh (SPSS, 2010). An

alpha level of 0.05 served as the threshold for two-tailed significance that was used for

statistical testing. A paired samples t-test was used to test each hypothesis to determine

whether or not there was a significant difference between pretest to posttest data among

all participants in the dependent variables, including the duration of the sustained vowel

phonation, the mean of first and second formants, the rate of syllable repetitions, the

number of inter-word pauses, the mean duration of inter-word pauses, the total inter-word

pause time, and the percentage of discernible words during the tasks. The mean of each

datum that was analyzed by two raters were used for the statistical testing. Reliability of

the data analyses between two raters was calculated by using a correlation coefficient

test. The calculation resulted in a mean agreement of $r = .93$, indicating a high degree of

agreement.

Vocal Function Assessment

Table 1 provides a summary of a paired samples t-test that compared pretest and

posttest data for the dependent variables measuring vocal functions through the sustained

vowel phonation task. The mean duration of sustained vowel phonation increased from

13.193 (2.612) seconds at the pretest to 18.498 (4.063) seconds at the posttest. Results

showed that there were no significant differences.   Figure 1 summarizes the duration of

sustained vowel phonations by participant. At posttest, Participant 2 exhibited an

increase in the duration of sustained vowel phonation for 13.062 seconds, participant 3

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for 3.941 seconds, and participant 5 for 10.765 seconds. Conversely, Participants 1 and 4

showed a decrease for 1.119 seconds and for 0.126 seconds, respectively.

Table 1. Results of a Paired Samples t-Test Measuring Vocal Functions

Dependent Variables	Pretest		Posttest		$t(4)$	p
	Mean	*sd*	Mean	*sd*		(2-tailed)
The Duration of Sustained Vowel Phonation (s)	13.193	2.612	18.498	4.064	-1.869	.136
Mean *f*1 (Hz)	660.320	146.500	700.375	63.823	-.826	.455
Mean *f*2 (Hz)	1198.844	104.906	1243.005	178.522	-1.169	.307

Figure 1. Changes in the Duration of Sustained Vowel Phonations by Participant
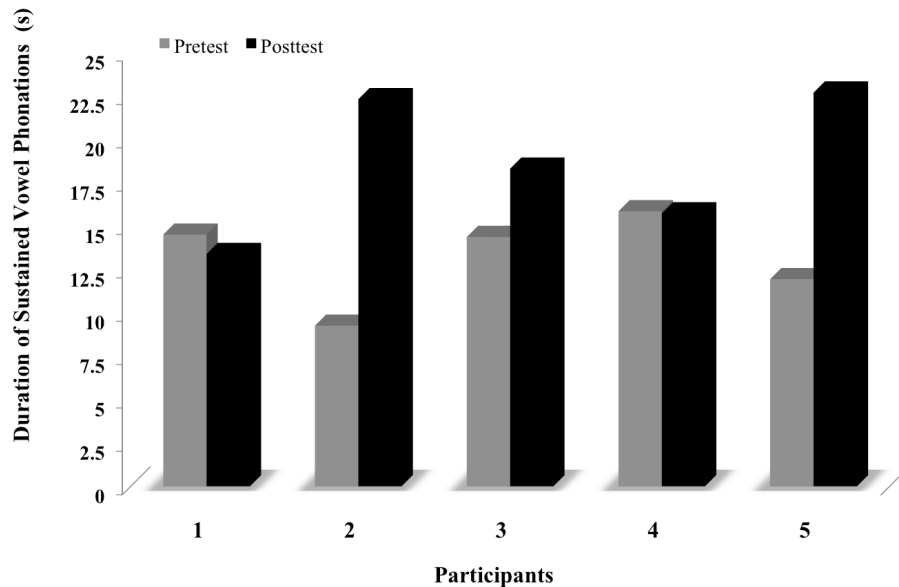
Results of a paired samples t-test for both the first and second formants exhibited

no significant changes. Although the mean of the first formant (*f*1) and second formant

(*f*2) increased from pretest to posttest, the changes among individuals yielded mixed

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results. As Figures 2 and 3 displays, Participants 1, 2, and 3 exhibited an increase in f1

and f2, whereas Participant 4 demonstrated an increase in f1 and a decrease in f2, and

Participant 5 demonstrated a decrease in f1 and an increase in f2.

Figure 2. Changes in the First Formant (f1) by Participant
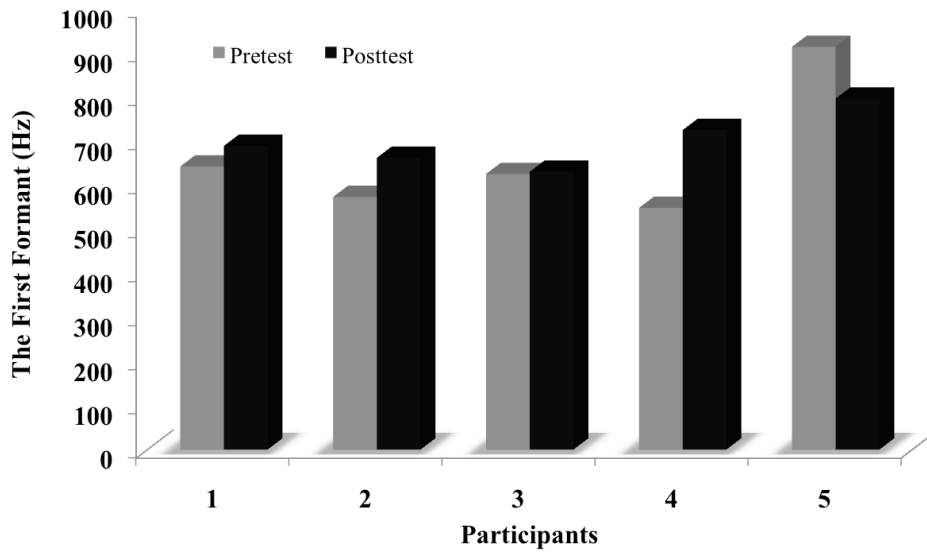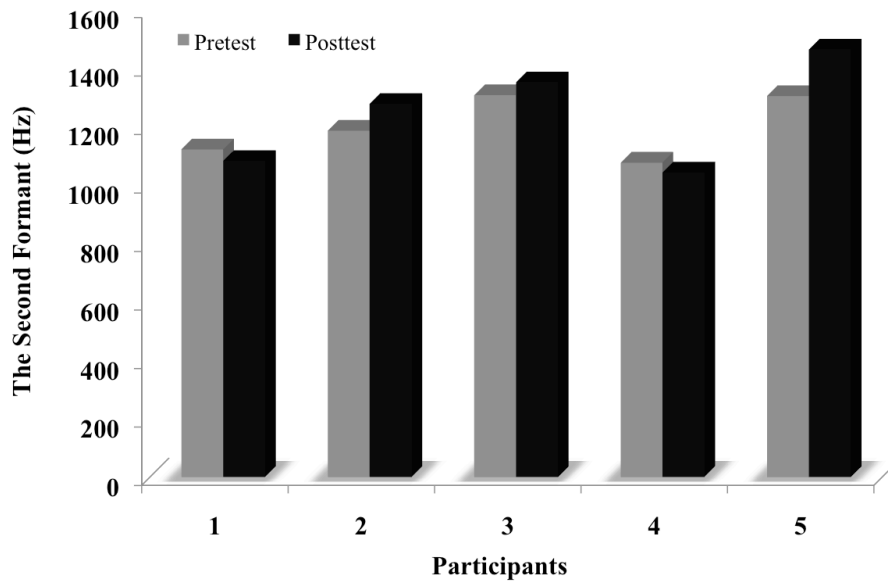

Figure 3. Changes in the Second Formant (f2) by Participant

Voice Quality Assessment

Results of a paired samples t-test comparing the pretest and posttest data for voice quality variables including jitter, shimmer, and the Harmonics to Noise Ratio (HNR) are presented in Table 2, and showed no significant difference. The mean percentage of shimmer exhibited poorer performance at posttest as compared to pretest, and the Harmonics-to-Noise Ratio (HNR) did not exhibit evident change. However, the mean percentage of jitter exhibited a reduction from .877 (1.335) at pretest and .742 (.637) at posttest. Figures 4 and 5 showed that at posttest, Participant 1 increased (i.e. had worsened) jitter by 1.569 % and shimmer by 9.486 %. Participant 3 also showed slight increment of jitter by .036 % and shimmer by 1.884 %. In contrast, Participant 4 demonstrated decreased (i.e. had improved) jitter by 2.434 % and shimmer by 2.931 % at posttest. However, Participant 2 decreased jitter but increased shimmer, and Participant 5 increased jitter but decreased shimmer at posttest. The Harmonics-to-Noise Ratio (HNR) also exhibits mixed trend as Participant 1, 2 and 5 decreased (i.e. had worsened) at posttest while Participant 3 and 4 increased (i.e. had improved) at posttest (Figure 6).

Table 2. Results of Paired Samples t-Test Measuring Voice Quality

Dependent Variables	Pretest		Posttest		$t(4)$	p
	Mean	*sd*	Mean	*sd*		(2-tailed)
Jitter (%)	.877	1.335	.742	.637	.208	.846
Shimmer (%)	6.711	3.326	8.463	3.447	-.835	.451
Harmonics-to-Noise Ratio (dB)	14.958	3.640	14.844	3.799	.082	.939

Figure 4. Changes in Jitter By Participant
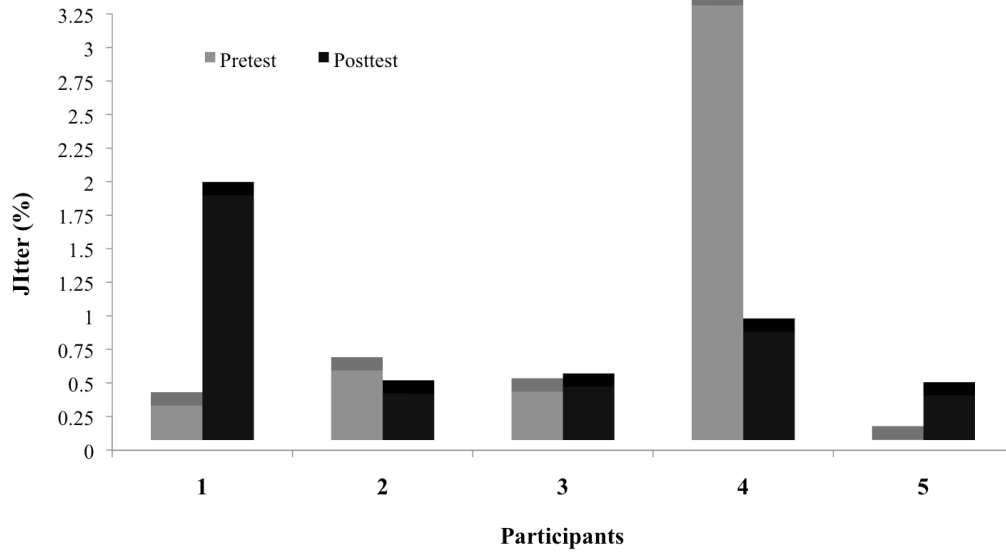
Figure 5. Changes in Shimmer by Participant
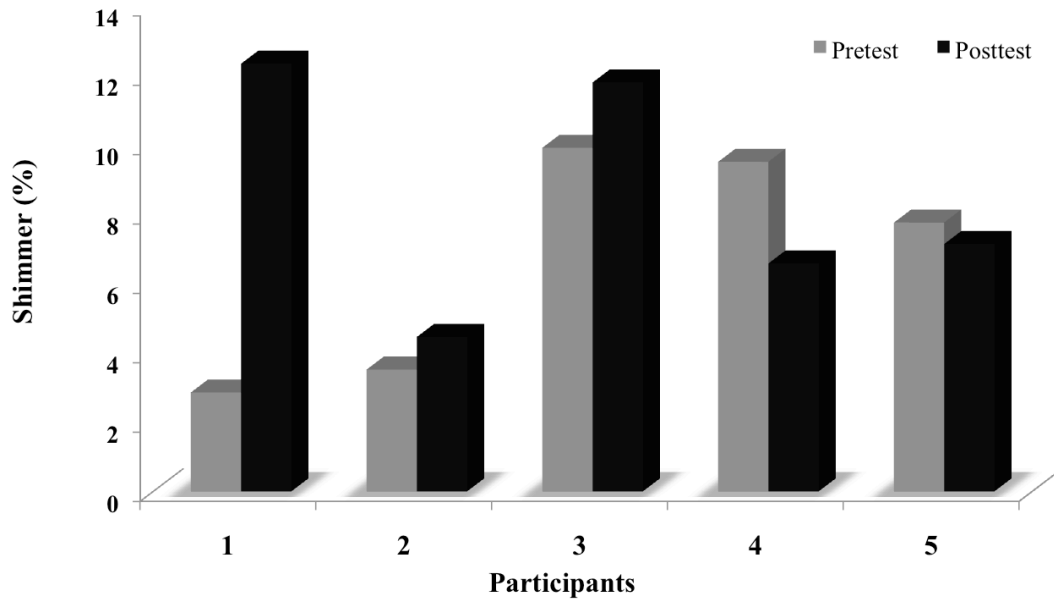
Figure 6. Changes in Harmonics-to-Noise Ratio by Participant
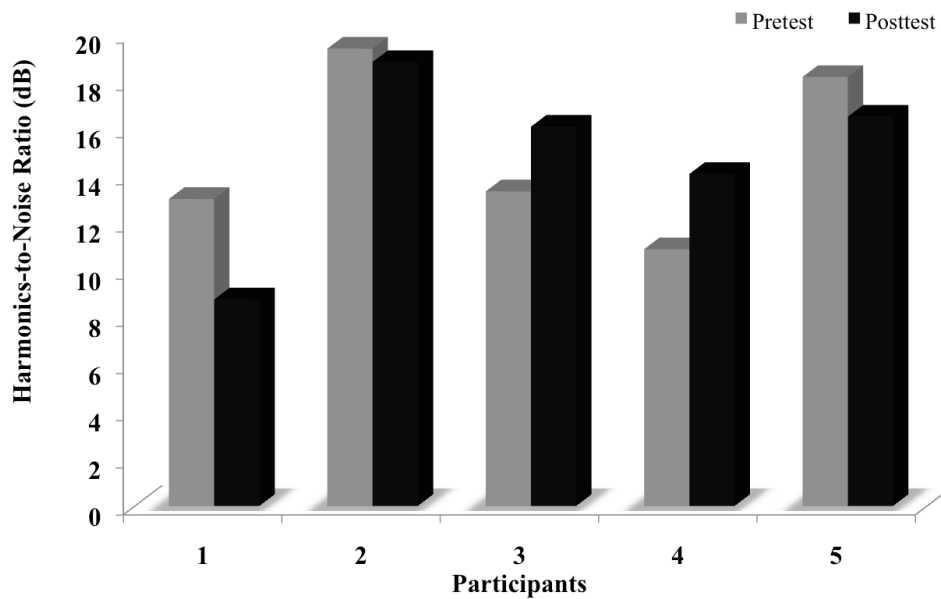
Articulatory Control Assessment

Table 3 shows the result of the paired samples t-test for the diadochokinesis test comparing posttest to pretest. No significant difference was found. Table 4 displays the individual results of the diadochokinesis test between pretest and posttest.

Table 3. Results of Paired Samples t-Test for Diadochokinesis Test

Dependent Variables	Pretest		Posttest		$t(4)$	p (2-tailed)
	Mean	*sd*	Mean	*sd*		
Diadokinesis Rate (count)	4.00	1.541	4.35	1.764	-.555	.608

Table 4. Results of Diadochokinesis Tests by Participant

Participant	Pretest (frequency)	Posttest (frequency)
1	4	5.75
2	3	5
3	6.5	6
4	4	3
5	2.5	2

Connected Speech Intelligibility Assessment

Table 5 summarizes the results of the paired samples t-test comparing the pretest and posttest that measured connected speech intelligibility through the Rainbow Passage reading task. Most of the variables exhibited no significant differences. However, there was nearly a significant difference for the number of inter-word pauses ($t(4) = 2.739$, $p = .052$) and a significant difference was apparent for the total inter-word pause time ($t(4) = 3.313$, $p = .03$) and speaking fundamental frequency ($t(4) = -3.035$, $p = .039$)

Table 6 displays the differences among participants in the percentage of discernible words and speech pauses between pretest and posttest. Participants 1, 2, 4, and 5 exhibited reduced (i.e. improved) numbers of inter-word pauses, mean duration of inter-word pauses, total inter-word pause times, and pause ratios. Participant 3 reduced the number of inter-word pauses by half, but slightly increased the mean inter-word pause time. The percentage of discernible words during Rainbow Passage reading for participants 1, 2, 4 and 5 exhibited perfect speech intelligibility at pretest. Participants 4 and 5 retained perfect speech intelligibility at posttest. However, participants 1 and 2 showed a slight decrease of speech intelligibility at posttest. Participant 3 improved from 88.5 % at pretest to 98.5 % at posttest. The speaking fundamental frequency (sF0) of

each participant increased from pretest to posttest (Figure7). The standard deviation of

the speaking fundamental frequency (sF0Sd) of participants 1, 3, 4, and 5 exhibited an

increase at posttest, whereas participant 2 showed a reduction in sF0Sd at posttest (Figure

8).

Table 5. Results of Paired Samples t-Test Measuring Connected Speech Intelligibility

Dependent Variables	Pretest		Posttest		$t(4)$	p
	Mean	*sd*	Mean	*sd*		(2-tailed)
Discernible Words (%)	97.700	5.143	98.200	1.956	-.198	.853
Number of Inter-Word Pauses (count)	2.800	1.483	1.300	.9747	2.739	.052*
Mean Inter-word Pause Time (ms)	.474	.049	.342	.236	1.114	.328
Total Inter-Word Pause Time (ms)	1.268	.539	.618	.601	3.313	.030*
Pause Ratio (%)	9.703	3.519	5.532	5.475	2.033	.112
Speaking Mean F0 (Hz)	150.879	34.269	164.879	29.460	-3.035	.039*
Speaking F0Sd (Hz)	35.279	17.835	38.194	21.547	-1.685	.167

Table 6. Results of Variables Measuring Connected Speech Intelligibility by Participant

Part.	Discernible Words (%)		Number of inter-word pauses (frequency)		Mean Inter-Word Pause Time (s)		Total Inter-word Pause Time (s)		Pause Ratio (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	100	100	3	2	0.478	0.481	1.434	0.964	9.747	9.132
2	100	95.5	3	0	0.473	0	1.420	0	11.805	0
3	88.5	98.5	5	2.5	0.393	0.584	1.964	1.48	14.106	13.233
4	100	100	1	1	0.524	0.208	0.524	0.208	4.962	2.200
5	100	100	2	1	0.5	0.438	1	0.438	7.897	3.093

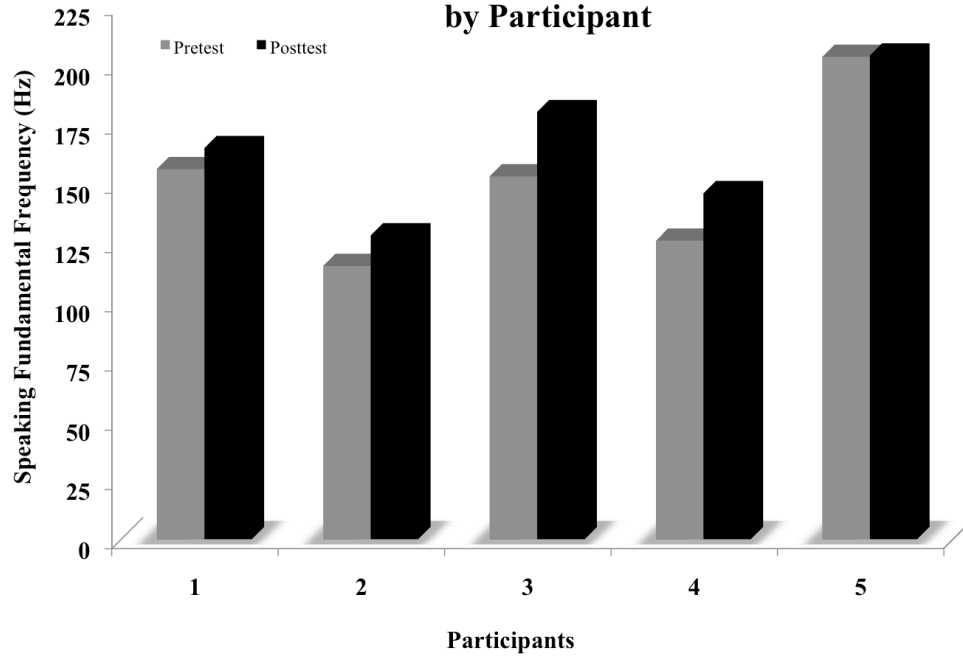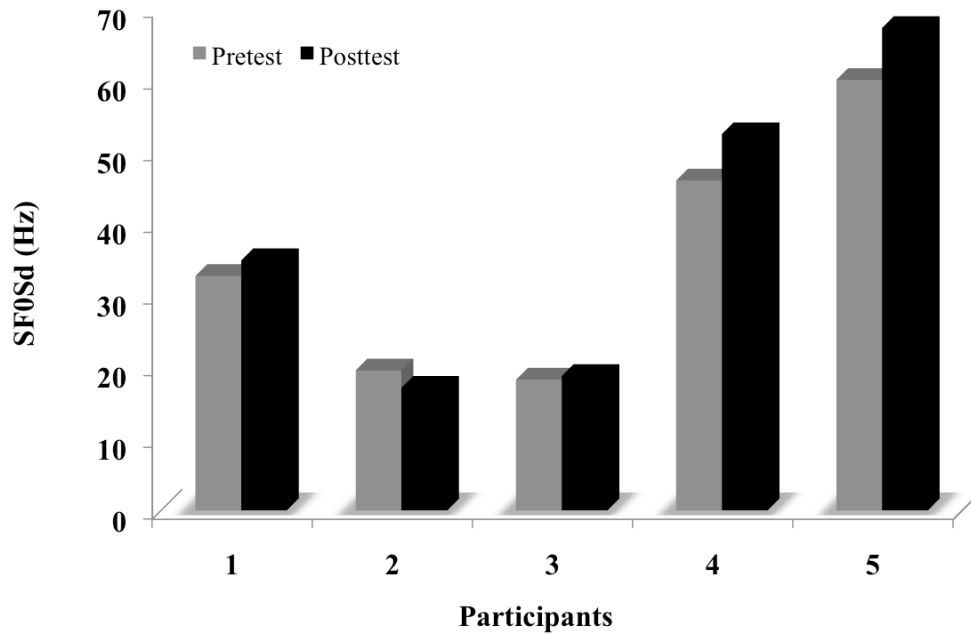Figure 7. Changes in Speaking Fundamental Frequency (sF0) by Participant

Figure 8. Changes in the Standard Deviation of the Speaking Fundamental Frequency (sF0Sd) by Participant

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Chapter Five

Discussion

The purpose of this study was to investigate the effect of the Music Therapy

Protocol for Hypokinetic Dysarthria (MTPHD), which was based on two Neurologic

Music Therapy (NMT) techniques to treat individuals with voice and speech deficits due

to Parkinson's Disease (PD). Although no statistically significant changes were observed

in most of the dependent variables at posttest, there were evident positive changes among

participants in some of the measured variables.

One of the notable improvements was that two out of five participants increased

their duration of sustained vowel phonations by nearly double at posttest. The posttest

result of Participant 2 (male) was 22.326 seconds and that of Participant 5 (female) was

22.709 seconds. The normative data of the maximum vowel phonation for males are

within $25 - 35$ seconds and for females are within $15 - 25$ seconds (Mathieson, 2001).

According to these, Participant 2 was approaching the normal phonation time, and

Participant 5 achieved the normal phonation time, which may indicate improved (i.e.

more efficient) vocal fold vibrations for a vowel phonation.

On the other hand, the mean of the first formant ($f1$) and second formant ($f2$) did

not exhibit significant changes. Changing the formant frequencies directly relates to the

change of the shape of the vocal tract through moving articulators such as the mandible,

tongue, lips, larynx, and the sidewalls of pharynx (Sataloff, 2005). In particular, the $f1$ is

influenced by the opening of the mandible (i.e. jaw) and the $f2$ is influenced to tongue

shape (Nair, 1999; Sataloff, 2005). Participant 5 showed a decrease in $f1$ and Participants

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1 and 4 showed a decrease in $f2$. Although these observations may represent a negligible change, they may explain the participants' experiencing vocal fatigue by widening the jaw and the tongue in remaining position to sustain their vowel phonations during the task.

Jitter, shimmer, and the Harmonics-to-Noise Ratio (HNR) also exhibited mixed results among the participants. For instance, Participant 1 exhibited increased jitter at posttest by surpassing the threshold of pathology (i.e. above 1.040 %), whereas Participant 4 demonstrated decreased jitter (0.808 %) at posttest, below the threshold of pathology. One possible reason to explain these mixed results is that the recording quality during data collection might be affected by the lack of noise control in the room that was used for assessments. For example, Brockmann, Drinnan, Storck, & Carding (2009) suggested ways to increase the sensitivity in measuring jitter and shimmer is by standardizing the voice sound pressure level (SPL) level at 80dB at 10 cm distance, using the vowel /a/ and taking the mean of at least three phonations.

In addition, more frequent treatment sessions might be necessary for improvement in these vocal attributes. The Lee Silverman Voice Treatment (LSVT), a speech therapy protocol to treat speech or voice disorders due to Parkinson's Disease, shows consistent effectiveness compared to pharmacological or surgical treatment options. LSVT is an intensive speech therapy treatment that requires a series of sixteen hourly sessions over a month involving exercises with many repetitions (LSVT, 2010). For this study, more frequent music therapy treatment sessions in the same six-week period, or a longer treatment phase might be factors to consider when attempting to achieve carryover.

Results did not exhibit apparent improvement in the diadochokinesis rate that measured the rate of sequenced syllable repetitions. Both increment and decrement of the rate of sequenced syllable repetitions were within the range of one or two syllables. The possible reason of these results could be explained by the choices of songs for the articulation clarity exercises during the treatment sessions. Each exercise was meant to target various speech sounds— not only the syllables /pa/, /ta/, /ka/, or syllables starting with /p/, /t/, or /k/, but also nasal sounds, fricatives and affricates. To achieve generalization of the skills learned through music therapy treatment, particularly regarding articulation control, it might be necessary to choose appropriate songs more strictly or even compose original songs with these specific syllables.

All participants exhibited high achievement in connected speech intelligibility, measured by the percentage of discernible words at pretest, and retained over 90 % at posttest. However, participants 1 and 2 showed a decrease in the percentage of discernible words at posttest, although the difference was made by only one to three words. This might be due to the ceiling effect, as the participants achieved a high level of connected speech intelligibility, including at pretest. Thus, the results of the assessment did not express a valid measurement of the abilities of the participants who had a high level of connected speech intelligibility. In contrast, evident improvements were observed in variables measuring speech pauses among all participants. In particular, Participant 2 did not have any inter-word pauses at posttest, indicating a steadier rate of speech. Participant 3 also reduced the number of inter-word pauses by half, but slightly increased the mean inter-word pause time due to the increased duration of each or some pauses, but a decreased number of inter-word pauses. Together, these results indicate that

all participants had a generally decreased varied rate of speech. However, these results did not appear to show any correlation between the degree of speech intelligibility and rate of speech. Although past research has suggested the speech rate to be one of the variables to indicate the speech intelligibility, the correlation between rate and intelligibility may not have emerged due to unknown factors (Duffy, 1995; Van Nuffele, Botd, Vanderwegen, de Heyning, & Wuyts, 2010).

As the significant difference observed from the result of the paired samples t-test, the increment of sF0 might suggest that the participants had increased amplitude in contour (i.e. prosody) while reading the passage at posttest. The normative data of the speaking fundamental frequency for adult males is around 128 hertz, and for adult females it is around 225 hertz (Mathieson, 2001). All male participants (Participant 2, 3, and 4) exhibited their sF0 over the normative data. Female participants (Participant 1 and 5) did not demonstrate their sF0 at the normative level, though an increase in sF0 was observed. However, careful application of the normative data of the sF0 is suggested as one's habitual pitch varies from person to person as well as speech to speech (Baken & Orlikoff, 2000). Similarly, the standard deviation of the speaking fundamental frequency (sF0Sd) explains the degree of variability in speech prosody. Although it was a negligible improvement, the increment of sF0Sd in four out of five participants might indicate the change in speech prosody, as extant literature has suggested the association between sF0 variability and prosody (Baken & Orlikoff, 2000, Kent & Ball, 2000). In summary, the music therapy treatment has appeared to positively influence particular aspects of connected speech intelligibility: varied rate of speech and speech prosody.

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To further explain possible reasons for the overall results, there were limitations in addition to those previously mentioned. First, since this study was a pilot study, the experimental group consisted of a small number of participants with no control group, which drastically reduced the statistical power of the results. In addition, the participants were recruited from a convenience sample pool, so no randomization was done. Similarly, there was a lack of medication control due to ethical considerations, thereby not minimizing one of the confounds. Some results might be influenced by the types of PD medications or (medication) ON/OFF states. Moreover, ratings of the Hoehn and Yahr scale were used to determine the severity of PD based on the participants' self-reports due to the lack of access to participants' medical demographic data. In addition, the post PD diagnosis time of each recruited participant widely ranged from one year to fifteen years due to the limitation of the prospective participants in the community. It is reported that speech deficits due to Parkinson's disease can appear at any stage of the disease, and worsens the symptoms as the disease progresses (Pinto et al., 2004; Stewart, Winfield, Hunt et al., 1995). Anecdotally, there are obvious similarities between motor and speech impairments in individuals with PD due to hypokinesia. According to the study by Cantiniaux et al. (2009), individuals with PD have demonstrated similar spatiotemporal tendencies between their gait and speech patterns. The variance in the severity of PD among the participants might also be related to their patterns of voice and speech deficits, thereby influencing mixed results of the study. As a part of the screening process, more detailed information regarding the severity of the assessment results of Unified Parkinson's Disease Rating Scale (UPDRS) (The Movement Disorder Society, 2011) along with a dysarthria assessment tool such as Frenchay Dysarthria Assessment

(FDA) (Enderby, 1980) and Assessment of Intelligibility in Dysarthric Speakers (AIDS) (Yorkston & Beukelman, 1981) should be obtained. In addition, future correlation research relating to the severity of motor impairment and speech impairment in individuals with PD when choosing a research design would be beneficial.

Aside from research design concerns, a testing effect may be confounding the results. Each speech task was very simple and easy to be remembered, so even after six weeks from the pretest, participants might perform better at the posttest because the tests were essentially the same. Longer period of the treatment phase may minimize this effect. Lastly, maturation should also be taken into consideration, as Parkinson's disease is a progressive, neurodegenerative disease. Likewise, aging factors should also be considered, as the elderly are prone to changes in physiological, cognitive, and psychological features (Kent & Ball, 2000; Meara & Koller, 2000). The symptoms of hypokinetic dysarthria can also be seen as a matter of aging (Meara & Koller, 2000). Although maturation might influence the results of the study, preserving their posttest results close to baseline levels despite no significant improvement might be an indication of no progression of the target vocal and speech deficits due to the music therapy treatment. In short, the effect of group weekly music therapy did not exhibit statistical significance in most of the dependent variables. However, the number of inter-word pauses, total inter-word pauses, and differences in the mean speaking fundamental frequency (sF0) showed significant change. This provides avenues for further study to investigate possible correlations between the variables regarding overall connected speech intelligibility.

In conclusion, this pilot study served as a trial run with a small number of participants to confirm the plausibility of the study design. For instance, the results of acoustic analyses of voice and speech characteristics by using an objective instrument allowed the researcher to discuss voice and speech characteristics with objective, quantitative results in clinical speech pathology terms (e.g. Boersma & Weenink, 2010; Brockmann, Drinnan, Storck & Carding, 2009; Forrest & Weismer, 2009). This may also lead music therapy research, in collaboration with allied therapy disciplines, to optimize treatment outcomes. Neurologic music therapy consists of a series of standardized music therapy techniques based on a considerable amount of neuroscience evidence (Thaut, 2005). Therefore, clinical research studies using neurologic music therapy techniques for vocal and speech goals may prompt researchers to replicate these studies, which may further establish the validity of a music therapy treatment. This pilot study provided insights as to how to design similar future studies. Although results of the study did not exhibit significant results, it did support the use of vocal and singing exercises in a group setting, which may improve some aspects of voice and speech deficits seen in individuals with PD.

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Appendix A

Hoehn & Yahr Scale (Hoehn & Yahr, 1967)

Stage 0: no signs of disease

Stage 1: symptoms are very mild and appear only on one side of the body

Stage 1.5: symptoms appear only on one side of the body but with axial involvement

Stage 2: symptoms appear on both sides without impairment of balance

Stage 2.5: symptoms appear on both sides and still mild, with recovery on pull test

Stage 3: symptoms are mild to moderate, some postural instability occurs, but patients are physically independent

Stage 4: symptoms are severe, the patient is severely debilitated and needs some assistance, but can still walk or stand unassisted

Stage 5: symptoms are very severe, the patient is typically wheelchair-bound or confined to a bed, unless aided

Appendix B

The First and Second Paragraph of the Rainbow Passage (Fairbanks, 1960)

(In bold = the third and fourth sentences that were used for data analyses)

<u>First Paragraph</u>

When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. **These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end.** People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

<u>Second Paragraph</u>

Throughout the centuries people have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation. **To the Hebrews it was a token that there would be no more universal floods. The Greeks used to imagine that it was a sign from the gods to foretell war or heavy rain.** The Norsemen considered the rainbow as a bridge over which the gods passed from earth to their home in the sky. Others have tried to explain the phenomenon physically. Aristotle thought that the rainbow was caused by reflection of the sun's rays by the rain.

Appendix C

Pre-Study Questionnaire

The Effect of Vocal and Singing Exercises for Individuals with Parkinson's Disease

This questionnaire is to collect information regarding your preference of songs and your musical experiences. We will gather all participants' information and select appropriate songs to optimize the benefit of the group music therapy treatment in the study.

1. Have you participated in a singing group/choir in the past?   Yes   No

    Explain _____

2. Circle your preferred genres of music (up to 2):

    Western/Country   Movie/Musical   Religious   Folk

    Jazz   Classical   Other (please specify) _____

3. List up your favorite songs (up to 3 songs)

    _____

    _____

    _____

4. List up your favorite singer's names (up to 3 singers)

    _____

    _____

    _____

5. Circle the one (s) below to explain your musical experiences
    Listen to music   Enjoy singing with family and friends
    Have sung in a choir   Currently sing in a choir
   Studied voice at post-secondary institutions

Appendix D

The Song Examples being Used in

Music Therapy Protocol for Hypokinetic Dysarthria

Articulation Clarity Exercise	Breath Support Exercise
Bye Bye Love	America The Beautiful
Don't Fence Me In	Back In The Saddle Again
Five Foot Two	Blueberry Hill
Hey Good Lookin'	Edelweiss
High Hopes	Home On The Range
I'm Looking Over A Four-Leaf Clover	How Much Are The Doggies In The Window
Java Jive	Love Me Tender
Side By Side	Red River Valley
Singin' In The rain	Side By Side
Take Me Out To The Ball Game	Springtime In The Rockies
Walk The Line	The Water is Wide
Your Grand Old Flag	Your Cheatin' Heart

APPENDIX E

Sample Slides of Exercises in the Music Therapy Protocol for Hypokinetic Dysarthria

Vocal Warm-Up
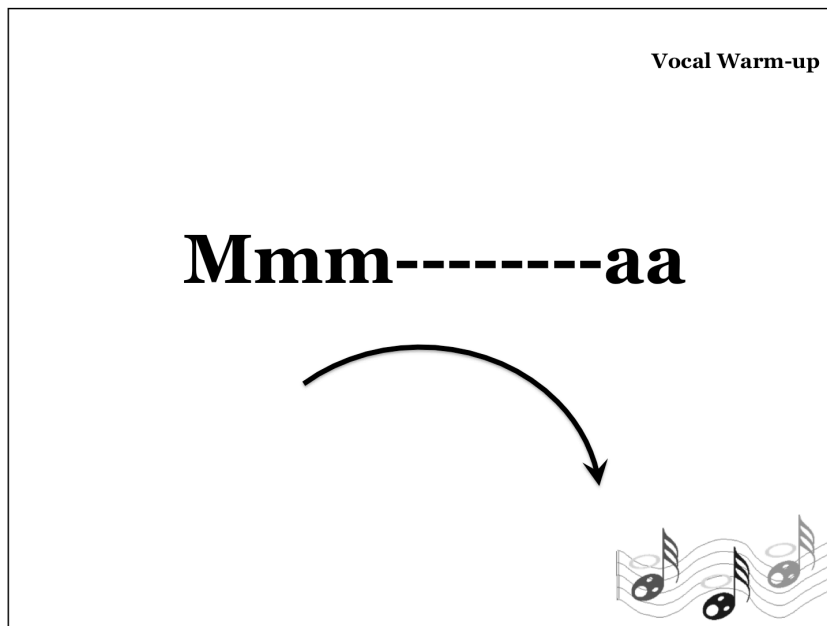
Singing Exercise for Articulation Clarity

K-K-K-Katy

K-K-K-Katy, **b**eau**t**iful **K**aty
You're the o**n**ly **g-g-g-g**irl
Tha**t** I a**d**ore
Whe**n** the **m-m-m-m**oo**n shines**
O**v**er the cow**shed**
I'll **b**e wai**t**ing a**t**
The **k-k-k-k**i**t**che**n d**oor

Singing Exercise for Breath Support

The Water Is Wide

The water is wide ⟶ ' (breathe)
I cannot get o'er ⟶ ' (breathe)
And neither have I ⟶ ' (breathe)
Wings to fly ⟶ ' (breathe)
Give me a boat ⟶ ' (breathe)
That can carry two ⟶ ' (breathe)
And both shall row ⟶ ' (breathe)
My love and I ⟶