Intergenerational Choir Participation: Examining the Effects on Voice, Speech, and Quality of Life of Two Individuals with Parkinson's Disease

By

Julia Benson
B.A. Northeastern University, 2017

Submitted to the graduate degree program in Speech-Language Pathology and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Co-Chair: Panying Rong, PhD.

Co-Chair: Jane Wegner, PhD.

William Matney, PhD.

Lindsey Heidrick, SLPD

Date Defended: 1 May 2020

The thesis committee for Julia Benson certifies that this is the approved version of the following thesis:

Intergenerational Choir Participation: Examining the Effects on Voice, Speech, and Quality of Life of Two Individuals with Parkinson's Disease

Co-Chair: Jane Wegner, PhD.

Co-Chair: Panying Rong, PhD.

Date Approved: 1 May 2020

Abstract

This research examines the concept of intergenerational choral singing as a behavioral intervention for speech and voice in Parkinson's Disease (PD). Prior research examining music therapy and group singing protocols has focused exclusively on groups composed of individuals with PD, which are not always accessible depending on location. Therefore, this research asks if participation in a group of mixed age and ability lends itself to physiologic (articulatory, phonatory, respiratory) and perceived quality of life benefits. To address this, two individuals with early-stage idiopathic PD were recruited to participate in an intergenerational choir (IC) conducted by music therapy and education students at the University of Kansas. At three dates, acoustic data regarding frequency, intensity, voice onset time, triangular vowel space area, diadochokinetic rate, maximum phonation duration, and pause number and mean duration were gathered during the completion of structured speech tasks. Perceived quality of life data was obtained through self-perception questionnaires. Results showed inconclusive evidence that once weekly participation in an intergenerational choir for one hour influenced quality of life or physiologic mechanisms in the participants recruited for this study. Slight articulatory improvements were noted, which may be a result of choral singing or a separate confounding variable. Further research in this area is warranted with adjustments to intervention protocol, data collection methods or tasks, or sample size.

Acknowledgements

The past two years have been a wild ride, to say the least, and it is with a joyful heart that I acknowledge the many individuals who have, in ways large and small, contributed to this project. First off, to my committee; I must thank Drs. Panying Rong, William Matney, and Lindsey Heidrick for their guidance towards this thesis's completion. They each offered a wholly unique perspective that I have attempted to integrate as best I can in these results. It has been a real pleasure to obtain an interdisciplinary perspective through this project, and I hope to continue investigating where Music Therapy and Speech-Language Pathology intersect in my future career. This thesis would also not have been possible without the generosity and flexibility of Dr. Melissa Grady, also of the Music department at the University of Kansas, to whom I owe an immense amount of gratitude for allowing the use of her choir and class for my research. Gratitude is owed to my two participants as well, who were an absolute joy to get to know, and I am blessed to have had their enthusiastic participation. I hope that they keep singing! And finally, on a personal note, I wish to thank the ladies of Vocal Standard for providing a space for me to heal through singing over the past two years, and specifically to director Rob Mance for igniting my interest in choral singing from a research perspective. *I loved being here with you.*

TABLE OF CONTENTS

INTRODUCTION

Parkinson's Disease (PD) is a neurological condition caused by a deficiency in dopamine production – the neurotransmitter that aids muscle control. PD is often characterized by resting tremor, stiffness, slowness, balance problems, and changes in natural gait. These symptoms are typically combatted successfully with medication. Some additional symptoms of PD related to speech-language pathology include difficulty chewing and swallowing, difficulty controlling saliva, and hypokinetic dysarthria. The latter of these three symptoms affects close to 90% of individuals with PD (Moya-Galé & Levy, 2019) and is categorized by monopitch, monoloudness, reduced loudness, rapid speech rate, inappropriate silences, rapidly repeated phonemes, and palilalia (Duffy, 2005).

One of the leading treatment programs for individuals with hypokinetic dysarthric speech is Lee Silverman Voice Treatment (LSVT). This treatment is used worldwide and involves training patients to "think loud;" by doing this, the patient exerts more force on the vocal folds to overcome vocal fold weakness through high intensity exercises and home practice. The patient therefore simultaneously improves respiration, voice volume, and articulation. Typically, biofeedback is provided during sessions in the form of a decibel meter. Researchers have published on LSVT's efficacy in improving sentence intelligibility (Cannito et al., 2012), vowel articulation (Sapir et al., 2007), and voice (Spielman et al., 2007). According to the World Health Organization (WHO)'s International Classification of Functioning, Disability, and Health, (ICF), LSVT targets body functions and structures, thereby ignoring activity limitations, participation restrictions, and environmental factors. The ICF framework's purpose is to classify disability as a holistic state of being; it is not only characterized by physiological impairments and needs, but also has a significant effect on socialization and activities in which an individual participates.

While LSVT does enable individuals with PD to participate more actively in their social lives, the therapy itself does not target these needs. An ideal therapy will target all components of disability.

By focusing on one factor of the ICF framework, LSVT ignores a crucial element of patient progress and satisfaction – their ability to participate in everyday life activities. Ignoring the framework components of "activities" and "participation" may make LSVT less motivating for patients. To address this, Haneishi (2001) developed a Music Therapy Voice Protocol (MTVP), using singing as naturally motivating activity for his research participants. From his small sample size of four women with idiopathic PD, Haneishi noted significant increases in speech intelligibility as rated by caregivers, as well as significant increases in vocal intensity after 12 to 14 sessions at an hour each over the course of several weeks. The sessions were individualized and adhered to a specific structure developed by Haneishi himself. MTVP was later applied to group therapy with similar statistically significant findings in conversational speech intensity (Yinger & Lapointe, 2012). Around the same time, Di Benedetto and colleagues found that choral singing could be an effective means of improving functional residual capacity, maximum inspiratory pressure, maximum duration of sustained vowel phonation, prosody, and fatigue while reading a passage. Likewise, studies using qualitative methods have found choral singing to be a satisfying social experience for many people with PD (Buetow et al., 2014; Fogg-Rogers et al., 2016; Reagon et al., 2016; Stegemöller, Hurt et al., 2017). While there has been a wealth of research looking into how training the voice can be used to lessen the decline seen in some individuals with PD, all the studies conducted so far have involved either individual singing instruction or creating a chorus composed solely of individuals with PD. Conventional treatment approaches for PD are typically in a one-on-one setting, and research has shown that group approaches have the potential to be as beneficial as individualized attention (Searl et al., 2011). Results from research on the effects of choral singing on vocal and psychosocial parameters in the general population has been promising, while also leaving room for further investigation (Clark & Harding, 2012). Some unique potential benefits of community singing for individuals with PD could be comparable voice and speech changes as with individual singing therapy, and psychosocial benefits of belonging to a community consisting of a variety of individuals – with and without PD. Thus, the question begs to be asked – what would happen if choral singing was an immersive activity? By immersing individuals with PD in a community singing environment, with a wide variety of individuals of all ages and abilities, can there be significant effects on voice, speech, and quality of life? This study sets out to answer the following questions:

1. What are the effects of intergenerational choir participation on individuals with PD's articulatory, vocal, and respiratory mechanisms?
2. What are the effects of intergenerational choir participation on perceived quality of life, in accordance with the activities and participations components of the WHO's ICF framework?

LITERATURE REVIEW

Introduction to Parkinson's Disease

Parkinson's disease (PD) is a neurological condition caused by a deficiency in dopamine production – the neurotransmitter that aids muscle control. This dopamine deficiency is correlated with Lewy pathology – that is, the presence of abnormal clumps of protein throughout the nervous system. Lewy bodies and their locations within the nervous system can be a strong indicator of the stage of disease (Braak et al., 2003), which typically begins with Lewy pathology in the peripheral nervous system and olfactory system, and progresses medially through the spinal cord and brain stem. In the final stages, Lewy pathology spreads to cortical areas.

Idiopathic PD is characterized by resting tremor, stiffness, slowness, balance problems, and changes in natural gait. These symptoms are typically combatted successfully with medication. Some additional symptoms of PD are difficulty chewing and swallowing, difficulty controlling saliva, and hypokinetic dysarthria. The latter of these three symptoms affects close to 90% of individuals with PD (Moya-Galé & Levy, 2019) and is categorized by monopitch, monoloudness, reduced loudness, rapid speech rate, inappropriate silences, rapidly repeated phonemes, and palilalia – the involuntary repetition of words, syllables, or phrases, often towards the end of a speaker's utterance (Duffy, 2005).

Risk factors for PD are both environmental and genetic. In the United States, genetic risk factors (family history outstanding) include sex, ethnicity, and age. Sex is a risk factor, with the male-to-female ratio of PD diagnosis being 3:2. Additionally, the prevalence of PD is highest in those of Hispanic origin, followed by those of non-Hispanic white ethnicity, Asian ethnicity, and finally by black ethnicity. Finally, the risk for a PD diagnosis increases exponentially with age, peaking at 80 years old (Noyce et al., 2012). With the growth of life expectancy in coming years, the incidence of PD is projected to increase by more than 50% worldwide by 2030 (Dorsey et al., 2007). Some of the most likely environmental factors to increase the risk of PD include pesticide exposure, head injury, and rural living, whereas factors noted to decrease the risk of PD include coffee consumption and NSAID use (Noyce et al., 2012; Ritz et al., 2014).

The onset of PD may begin years before motor symptoms are present and a diagnosis is made (Kalia & Lang, 2015). Non-motor symptoms that are likely to develop before a diagnosis are constipation, sleep disorder (specifically rapid eye movement sleep behavior disorder – RBD

– and excessive daytime sleepiness – EDS), hyposmia (reduction in sense of smell), and depression. However, motor symptoms are often the most noticeable, and the presence of bradykinesia (slowness of movement), rigidity, or tremor often prompts diagnosis. Motor symptoms are not homogenous among individuals with PD, often occurring at different rates and in different manners. Because of these differences, ongoing attempts are being made to categorize PD (Marras & Lang, 2013). Marras and Lang reviewed nine data-driven studies attempting to categorize subtypes of PD. The conclusion of which indicates the most promising results from Liu and colleagues (2011). In their classification, Liu et.al. contribute to the idea that the PD can be classified into the four subcategories of non-tremor dominant (NTD), rapid disease progression (RDP), young onset (YO), and tremor dominant (TD). They contributed to this base by clustering data points related to age/age of onset, disease duration, Unified Parkinson's Disease Rating Scale (UPDRS) scores, cognitive capabilities, fatigue, apathy, sleep, and other physical symptoms not frequently associated with PD such as constipation. The non-tremor dominant group featured in this study demonstrated greater postural instability and gait changes when compared to other subgroups; this was reflected in UPDRS scores – specifically in the Postural Instability/Gate Disturbance (PIGD) section. This group was also categorized by more significant depression, rapid disease progression, and more significant cognitive decline, particularly in the area of executive function. Individuals in the rapid disease progression group were relatively rare. However, they were characterized by generalized rapid changes as a result of PD. It was also noted that the L-dopa dosage of this group was lower than that of other groups. Those in the young onset group were characterized by younger disease onset, slow rate of progression, mild motor symptoms, no cognitive impairment, and lower depression ratings. The fourth classification, tremor dominant, consisted of individuals who exhibited slow rate of disease progression, moderate motor symptoms, and no statistically significant cognitive symptoms or indications of depression. The clustering yielded results similar to previous attempts at categorization using more linear comparison methods (Lewis, 2005), though it should be made clear that this research base is very much in its early stages, and it is not current standard practice to use subcategories to classify PD.

Voice Changes in PD

The literature frequently separates voice-related symptoms from motor symptoms in individuals with PD, yet research indicates acoustic evidence of vocal pathology in early stages of the disease (Holmes et al., 2000), characterized primarily by decreased intensity, monopitch, and monoloudness. Vocal tremor is an additional symptom often present only in the later stages of PD. Research has attempted to identify acoustic biomarkers of the disease in both pre-diagnostic and early post-diagnostic stages (Harel et al., 2004; J. Rusz et al., 2011; Jan Rusz et al., 2013). Harel and colleagues (2004) noted that a decrease in fundamental frequency variability is apparent at the time of diagnosis and may be present before motor symptoms are noted. This finding is significant; results imply that hypokinetic dysarthria is one of the first noticeable symptoms of PD. However, caution is necessary regarding interpretation, as there could be multiple reasons behind a decrease in fundamental frequency variability (monotone).

Harel and colleagues also noticed that individuals with PD have greater pause durations when completing speaking tasks. This finding suggests two potential underlying issues – respiratory deficits or difficulties with initiating phonation – both of which coincide with PD pathology. Interestingly enough, a study by Harris and colleagues (2016) finds that, while speech prosody is negatively affected in individuals with PD, their singing prosody is unimpaired compared to healthy age-matched peers. A February 2020 summary of current evidence related to vocal changes in PD (Ma et al., 2020) presents several insights connecting the voice, PD diagnosis, and monitoring. The primary auditory features of vocal dysfunction in PD are changes in perceptual quality reflected in reduced harmonic-to-noise ratio and increases in jitter (frequency perturbation) and shimmer (loudness perturbation), changes in volume (hypophonia, monoloudness), and changes in pitch (monopitch). Direct visualization of the vocal folds through laryngoscopy or videostroboscopy reveals physiologic findings that explain the acoustic changes. For example, there is frequently incomplete closure of the vocal folds, lending itself to decreased loudness and greater breathy quality. Furthermore, vocal fold vibratory patterns of individuals with PD are often irregular and asymmetric, with a longer open phase (when vocal folds are apart) than closed (vocal folds together). The asymmetric vibration is attributed to rigidity (bradykinesia) seen throughout the body in individuals with PD.

As is the case with neurodegenerative diseases, these symptoms are not apparent through all stages of the disease, in correlation with previously discussed Lewy pathology. According to Braak's model (2003), throughout the six hypothesized stages of Lewy pathology in relation to PD, vocal changes occur in the second and third stages. During stage two, Lewy bodies are found throughout the brainstem, which leads to a reduction in prosodic variability. In early-stage PD patients it is far more likely to perceive prosodic impairments than articulatory and phonatory impairments (Rusz et al., 2011). Lewy pathology reaches the basal ganglia, specifically the substantia nigra, in stage three. At this point, dopamine production is affected, which leads to greater phonatory, articulatory, and respiratory deficits due to its effects on motor movement.

Current Treatment Approaches

Treatment approaches for PD include pharmaceutic, surgical, and behavioral therapies. All approaches target alleviating symptom, as there is no available evidence for a treatment that prevents or delays disease progression (Fox et al., 2018). Motor symptoms are often treated pharmaceutically, a popular drug being levodopa-carbidopa. Levodopa itself converts into dopamine directly, and carbidopa is used tangentially to limit adverse side-effects of levodopa as it makes its way through the bloodstream to the brain. Additional pharmaceutical options include dopamine agonists, MAO-B Inhibitors, and anticholinergic drugs (Green, 1999). Dopamine agonists work by stimulating dopamine receptors in the brain, thus simulating the effect of dopamine. They have been shown to have fewer adverse side-effects than levodopa-carbidopa but are also not as potent. MAO-B inhibitors work by inhibiting the enzymes in the brain that break down dopamine. By inhibiting these specific enzymes, more dopamine is available in the brain, and thus motor symptoms of PD are reduced. Anticholinergic drugs, unlike the three previous drug types, do not influence dopamine whatsoever. Rather, they work by suppressing the activity of acetylcholine – a neurotransmitter that regulates movement. They are typically prescribed for the management of tremor only. Combination of these drugs is possible, as each patient is different and requires tailored intervention. However, two drugs that are frequently combined with levodopa-carbidopa are amantadine and COMT inhibitors. Amantadine works to reduce dyskinesias that often result from levodopa-carbidopa, whereas COMT inhibitors work to prolong its effects.

Deep brain stimulation (DBS) is a surgical treatment option that targets motor symptoms by placing electrodes in the subthalamic nucleus or globus pallidus – the parts of the brain that play the most significant roles in dopamine production and metabolism. The electrodes are stimulated by a pacemaker-like transmitter that is implanted near the collarbone. The transmitter is connected to the electrodes by a wire that runs under the skin. The part of the brain that is stimulated is dependent on the individual undergoing the procedure, and research is ongoing to help refine that choice. Currently, targeting the subthalamic nucleus appears to provide more medication relief, whereas the globus pallidus may reduce the risk of adverse effects on language and cognition (Fox et al., 2018; Odekerken et al., 2013).

Behavioral treatment is often used in conjunction with the former two therapy approaches. Individuals with PD can benefit from speech therapy, physical therapy, and occupational therapy (Gage & Storey, 2004). Beginning with speech therapy, the method with the strongest evidence base thus far is the Lee Silverman Voice Treatment program, which consists of four sessions of intensive vocal therapy per week for four weeks, for a total of 16 sessions. The sole focus of LSVT is loudness, and typically the only feedback that individuals certified in LSVT can give to their patients is "think loud." Of the existing research, LSVT has been shown to have positive effects on vocal sound pressure level, loudness and intonation (Ramig & Fox, 2007; Ramig et al., 2001; Ramig et al., 1995, 1996). In addition to perceptual changes, physiological evidence of increased laryngeal strength and respiratory capacity has been documented in LSVT (Baumgartner et al., 2001; Huber et al., 2003; S. Sapir et al., 2002). Additional benefits have been seen in the swallow function of PD patients (Sharkawi, 2002). Additional speech therapy methods may include the use of feedback devices, including altered auditory feedback (AAF), in which an individual is fed the sound of their own voice through a portable microphone/headphone set. The voice is altered in one of three ways – masking the voice completely, delaying the feedback, or adjusting the pitch of the voice. AAF has little supporting evidence. However, studies have shown that individuals with PD enjoy using the devices for their portability and ease of use. Additionally, participants have perceptually rated themselves as being more intelligible with the use of the devices (Atkinson-Clement et al., 2015). An additional feedback device relies on the Lombard Effect (Quedas et al., 2007; Stathopoulos et al., 2014), in which noise is relayed to the device-user's ear, thus prompting greater speaking effort reflexively. The evidence supporting the beneficial use of these devices is limited.

Returning to LSVT, following the statistic and clinical success of LSVT-Loud, LSVT-BIG was developed as a novel physical therapy approach. It uses many of the same concepts as LSVT, the difference being that patients are instructed to "think BIG" instead of "think LOUD" when completing a series of physical exercises involving gross motor movements. LSVT-BIG has been compared to other efficacious PT approaches such as Nordic walking, with comparatively greater gains in UPDRS scores made from LSVT-BIG (Ebersbach et al., 2010). Results were similar given a shorter, less-intensive protocol (Ebersbach et al., 2015).

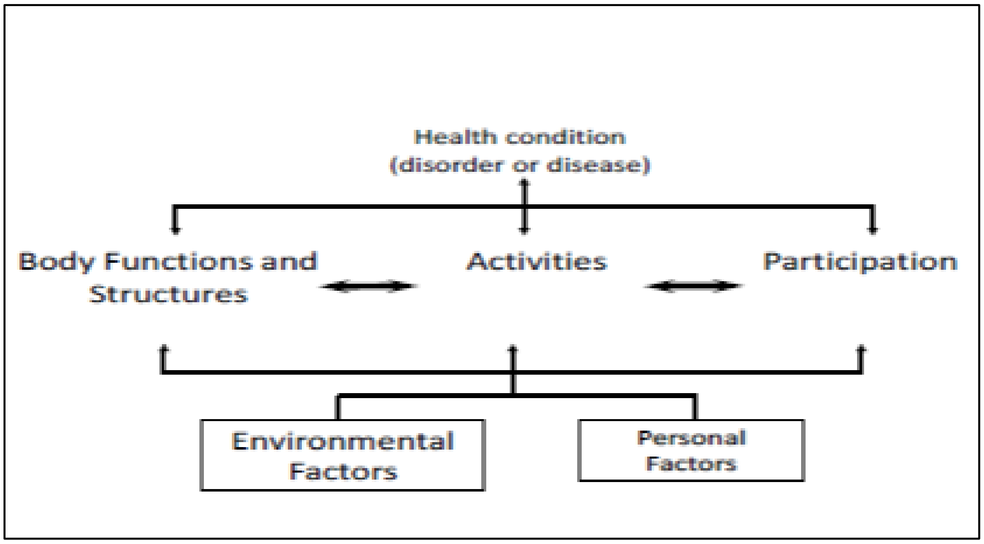
In addition to pharmacologic and behavioral treatment approaches in the realm of physical therapy and speech therapy, several complementary treatment options have been researched and considered viable in combination with treatments of strongly established efficacy. These complimentary treatments include recreational exercises (e.g tai chi, qi gong, yoga, dance), massage/acupuncture, herbal medicine, and of interest to this research, music therapy (Dong et al., 2016; García-Casares et al., 2018; Ghaffari & Kluger, 2014). A review conducted by Ghaffari and Kluger (2014) notes that of the aforementioned complementary treatments, studies have shown that tai chi, yoga, massage therapy, and music therapy have potentially lead to improved motor symptoms and health-related quality of life (HRQoL). García-Casares and colleagues (2018) deepened our understanding of the potential benefits of music therapy in patients with PD with their review of 27 relevant studies. Most of the studies focused on motor symptom relief, with seven of them examining vocal, respiratory, swallow, and dysarthria parameters. Of the eight studies that considered quality of life as a dependent variable, only two failed to show improvement, though no negative effects were demonstrated. The conclusion of their review noted that musical therapy could be considered concomitant with conventional PD treatments, though further study is needed to identify the most beneficial music therapy protocol.

International Classification of Functioning, Disability, and Health

When working with individuals with disabilities, the World Health Organization (WHO) recommends the use of the International Classification of Functioning, Disability, and Health (ICF) as a framework for how a disability affects an individual in more ways than what can be measured physically (World Health Organization, 2001). It was developed using four principles: universality, parity, neutrality, and environmental influence. Universality is the applicability to all people regardless of disability. It considers that all people may experience disability to some degree at some point in their lives. Parity implies that there is no distinction between "mental" and "physical" disability, and that impact cannot be defined solely by a diagnosis. Neutrality implies that all concepts are defined in balanced language, highlighting both positive and negative aspects of functioning and disability. The final principle of environmental influence highlights the importance of the environment (including both social and physical factors) in influencing an individual's ability to function with a disability.

Using these underlying principles, the WHO developed three domains in which disability may manifest: body functions and structures, activities, and participation. These three domains are affected by an individual's health condition, environmental factors, and personal factors. Figure 1 presents this framework and how these domains and factors interact. It is important to note that while personal factors are included in the framework, they are not classified farther within the ICF. Additionally, the ICF framework presents the notion that disability is a continuum, in that all people can experience it to varying degrees throughout life.

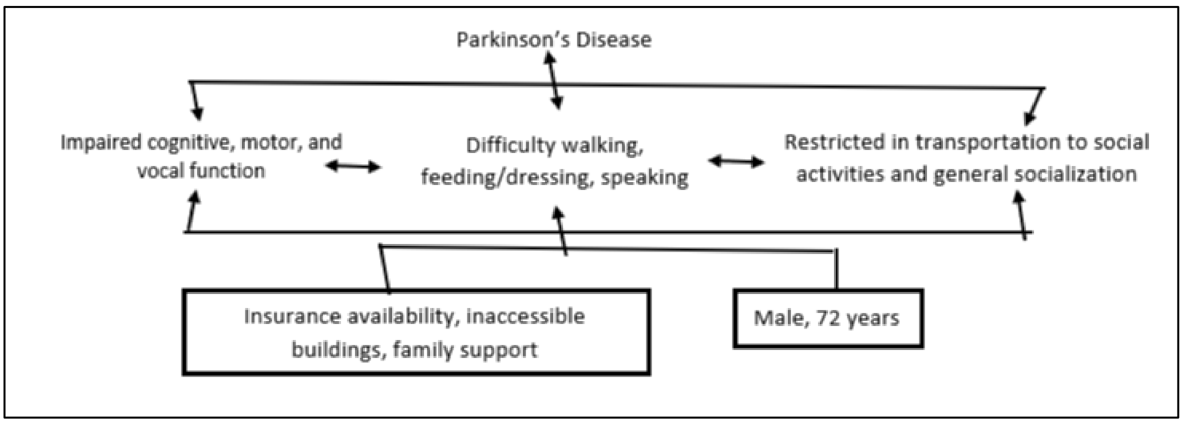
Figure 1
WHO's International Classification of Functioning, Disability, and Health



Body functions include how the systems throughout the whole-body work: mental, sensory, voice/speech, cardiovascular, respiratory, digestive, endocrine, neuromusculoskeletal, skin, and reproductive. Body structure includes the physical form of systems throughout the body – much like body functions are comprehensive, so too are the structures related to their function. When something is awry with either a body structure or function, it is considered an impairment. Activities and participation include learning, general tasks and demands, communication, mobility, self-care, domestic life, interpersonal relationships, and community/social/civic life. It considers the execution of a task or action (activity), and the involvement of an individual in a life situation (participation). When an individual does not participate in an activity due to disability, it is considered an activity limitation or participation restriction. Environmental factors include products/technology, human-made changes to the natural environment, support and relationships, attitudes/stigma, services, systems, and policies that impact how an individual receives care.

Using the ICF framework, health care providers and service workers can classify a disability by how it affects the individual holistically. Providers can also choose treatment methods that will benefit their patients in all four domains of the framework. In the case of PD, the framework can be used as outlined in Figure 2.

Figure 2
WHO's ICF As Applied to Parkinson's Disease



With this framework in mind, one can see how treatment options for PD are considered. Pharmaceutic and surgical options across all realms of disability largely target body functions, which may by proxy remove activity limitations or participation restrictions. Conventional treatment programs such as LSVT are focused on "loudness," which is a direct target of body function as well. LSVT does consider participation in that a portion of the program is dedicated to functional phrases that an individual is likely to use. However, the program itself is not inherently social, as sessions are typically one-on-one with a certified therapist, four times per week with additional at-home practice. Study cohorts comprised of individuals who have undergone LSVT appear to have yielded mixed psychosocial results (Spurgeon et al., 2015). Some individuals state that the at-home practice exercises are a source of embarrassment or anxiety, and thus they maintain social isolation. Group options of LSVT have been considered (Searl et al., 2011) to address this sense of isolation. The results of these investigative studies are promising, as they reveal comparative results to those of traditional LSVT.

Relationship between Singing and PD

A preliminary review of relevant literature yields 17 articles published between 2000 and 2018 connecting singing and outcome measures in individuals with PD and other neurologic conditions. Further examination of the articles reveals three distinct categories to consider: the effects of singing on perceived quality of life, the effects of individual singing activities on various acoustic speech and voice measures, and the effects of choral singing activities on similar acoustic speech and voice measures. It is helpful to first approach the existing research chronologically, thus highlighting how different researchers have influenced each other in this new area of behavioral treatment research.

Initial research in 2000 indicated improved overall quality of life and reduced Unified Parkinson’s Disease Rating Scale (UPDRS) scores following participation in active music therapy (Pacchetti et al., 2000). Pachetti and colleagues used both instruments and voice to achieve improved outcomes. The improvements were comparable to a group of individuals who received solely physical therapy. Nearly simultaneously, Eric Haneishi (2001) developed a Music Therapy Voice Protocol (MTVP), using singing as naturally motivating activity for his research participants. From his small sample size of four women with idiopathic PD, Haneishi noted significant increases in speech intelligibility as rated by caregivers, as well as significant increases in vocal intensity after 12 to 14 sessions at an hour each over the course of several weeks. The sessions were individualized and adhered to a specific structure developed by Haneishi himself. The structure included a short opening conversation, a physical warmup that involved both facial massage and lower abdominal breathing practice, vocal exercises, singing exercises specific to preferred tunes, maximum phonation time exercises, speech exercises consisting of words, phrases, and sentences, and finally a brief closing conversation. The vocal exercises consisted of:

1. Yawning while gliding from high to low on “mah” or “pah”
2. Singing “ee-ay-ah-oh-oo” without a break on a single, comfortable pitch
3. The same vowel sequence on ascending and descending pitches stepwise
4. Scales that included ascending to a perfect fifth, and then descending back to the starting pitch
5. Singing of the phrase “lah-beh-da-meh-nee-poh-too-lah-beh” on a single, comfortable pitch

MTVP was later applied to group therapy with similar statistically significant findings in conversational speech intensity, singing quality, and voice range (Elefant et al., 2012; Yinger & Lapointe, 2012). Both groups of researchers additionally raise the point that, given the degenerative nature of PD, maintenance of vocal quality may be significant.

Following these studies, which focused on the implementation of singing intervention on an individual basis, the research base appeared to shift its focus to group intervention. Twenty participants in a study conducted by Di Benedetto and colleagues (2009) received speech therapy 2 hours per week, in addition to choral singing with each other 2 hours per week. Researchers concluded that choral singing could be an effective means of improving functional residual capacity, maximum inspiratory pressure, maximum duration of sustained vowel phonation, and prosody and fatigue while reading a passage in those with PD. However, no attention was paid to measures of acoustic vocal intensity – a hallmark of hypokinetic dysarthria. Shih and colleagues

(2012) conducted a similar study addressing this gap in literature, where they concluded that 12 weeks of once-weekly 90-minute sessions of choral singing was not sufficient to significantly improve the loudness of its 15 participants. They mention that the lack of home practice and low intensity (both of which are important factors in LSVT) may have contributed to their negative findings. However, these findings are contradicted by more recent results by Stegemoller and colleagues (2017). They conducted a choral singing study that examined changes in intensity, maximum phonation duration, phonatory range, and maximal/minimal inspiratory pressure as a result of participating in two separate singing groups; one group, consisting of 18 participants, was "low intensity", and the other group was "high intensity" and included nine participants. While results indicated no significant difference between a high intensity and low intensity group across all outcome measures, they did find overall significant improvements from baseline to post-intervention of phonation time, and maximum inspiratory/expiratory pressures – regardless of treatment intensity. Stegemoller noted that there was no significant improvement in vocal intensity; however, she indicated high baseline outcomes for this measure, which would naturally lead to a ceiling effect. She also stated that the individuals she recruited for this study largely had no complaints regarding their vocal loudness, indicating a lack of perceived impairment. An additional study by Stegemoller and Hibbing (2017) examined how singing in groups may impact swallow function in individuals with PD. Interestingly, the results concluded that there may be a positive effect on the maintenance of laryngeal elevation on liquids of all consistencies post-intervention.

Choral singing has additionally been shown to improve triangular vowel space area (tVSA) following 11 weeks of participation (Higgins & Richardson, 2018). Vowel space area is a metric that has been shown to decrease in individuals with PD. It is calculated by plotting the lowest two formants (F1 on the x-axis, F2 on the y-axis) produced by the vowels /a/, /i/, and /u/, and then calculating the triangular area created by those three points. A smaller vowel space area is indicative of reduced contrasts among the vowels contributing to decreased intelligibility. Vowel space area and similar metrics such as formant centralization ratio and articulatory-acoustic vowel space (AAVS) have been widely used as objective measures of articulatory deficits in individuals with dysarthria (J. Rusz et al., 2011; Shimon Sapir et al., 2010; Whitfield & Goberman, 2014). tVSA is currently the most widely used vowel space metric; however, research is ongoing regarding which vowel space metric is most effective in distinguishing dysarthric speech from healthy controls.

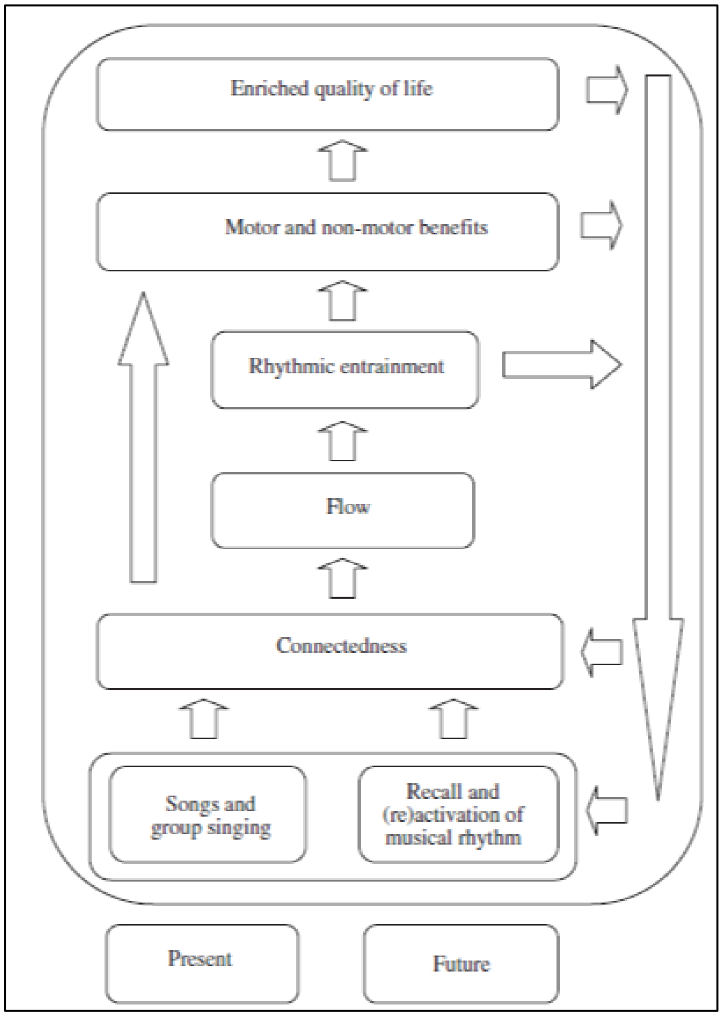
Building on research completed by Haneshi (2001), Di Benedetto (2009), Elefant (2012), and Yinger (2012), Azekawa and Lagasse (2018) sought to conduct a feasibility study using Vocal Intonation Therapy (VIT) and Therapeutic Singing (TS) in groups. Both techniques fall under the umbrella of Neurologic Music Therapy (NMT), where music therapy techniques are implemented with neurologic rehabilitation principles in mind (Thaut, 2005). VIT operates on the principle that when singing, parameters shared by voice and speech production are most easily visible. VIT exercises include singing through pitch scales to improve range, and moderating dynamics (i.e. soft to loud, loud to soft) to reduce monoloudness. TS primarily refers to unspecific use of singing activities to facilitate speech and language development and increase respiratory function. The key with this technique is that it intentionally integrates several speech techniques and mechanisms, with the product being musical production. Thus, the production of music is a reward for adequate use of speech and voice subsystems. Returning to Azekawa and Lagasse (2018), their research not only investigated whether participants would willingly consent to music-therapy based intervention, but also preliminarily investigated the effects of group VIT and TS on vocal function, vocal quality, articulatory control, and speech intelligibility. Interestingly, their study is the only study in the reviewed literature that collected data on diadochokinetic rate (DDK), which has been shown to be significantly reduced in a comparison of individuals with PD and age-matched neurologically healthy controls (J. Rusz et al., 2011). Azekawa and Lagasse’s protocol indicated maintenance or improvement of maximum phonation time, harmonic-to-noise ratio, and diadochokinetic rate, with a relatively small effect size.

Psychosocial benefits of singing

While several of the aforementioned studies included outcome measures related to quality of life as a result of music therapy and singing (Elefant et al., 2012; Pacchetti et al., 2000; Shih et al., 2012; Stegemöller et al., 2017), quality of life continues to be a less explored intervention outcome, likely due to its subjective nature. Individual studies investigating psychosocial benefits of singing intervention appear promising across several physical, mental, and developmental disabilities, but these studies have significant methodological limitations, including small sample sizes, and lack of therapist and participant blinding. As with most small-scale studies, generalization from research subjects to the population they represent presents a challenge, but this does not discard potentially significant findings with specific individuals. Despite methodological limitations, it is necessary to conduct small-scale studies to identify potential directions of future large-scale research projects. Thus, there is room for further investigation. Comparatively recent research (Buetow et al., 2014; Fogg-Rogers et al., 2016; Reagon et al., 2016; Stegemöller, Hurt et al., 2017; Wan et al., 2010) has centered exclusively on obtaining evidence of psychosocial effects of singing and music therapy intervention in individuals with PD. Buetow and colleagues (2014) outlined a conceptual model of how quality of life may improve as a result of group singing. Their model is presented in Figure 3.

Figure 3

Buetow's conceptual model (2014) of group singing's effect on quality of life



This model relies on the two primary, albeit abstract, concepts of "connectedness" and "flow", which occur both during the act of singing with others and during recall of singing with others. Connectedness refers to the individual's ability to use singing as a mechanism to not only connect with themselves and exert control over their environment, but also to connect with others. This connectedness presumably leads to a state of being the developers label as "flow," in which an individual becomes immersed in the music and the sensation of creating music. This feeling of immersion is pleasurable and lends itself to the hypothesis that motor and cognitive skills may improve, which in turn leads to greater perception of improved quality of life.

A 2016 study completed by Fogg-Rogers and colleagues concluded that choral singing therapy was found to be enjoyable by both individuals with PD and individuals who had experienced a stroke (Fogg-Rogers et al., 2016). In this case chorus participations were able to attend rehearsals with the support of their significant others, who reported maintenance of their partners' communication abilities. Stegemoller and colleagues (2017) deepened research in this area by comparing high-dosage (once per week) and low-dosage (twice per week) singing groups. Results indicated no significant differences between groups, though participants in both groups reportedly experienced significant improvements in overall quality of life following the study. The fact that participants who met once weekly to engage in singing with others experienced improved quality of life is promising and suggests that intensity is not a significant factor in these gains. Meeting once per week is a reasonable commitment to make and yields gains for those willing to partake.

Implications for current study

The present study intends to further research on the link between group singing and PD. Previous research was initiated to address psychosocial outcomes not necessarily addressed in LSVT, and to provide a more accessible treatment option for individuals who for one reason or another, cannot access the full program. The researcher plans to contribute to this body of research by introducing a novel component to previously done choral singing studies; that is, singing with a wide variety of individuals of different ages and abilities. The surrounding individuals within an intergenerational choir contribute to the Lombard effect – the tendency to be louder in the presence of background noise. Additionally, they may serve as peer models, which is a popular and effective therapeutic intervention, primarily in the domain of social communication (Coleman & Stedman, 1974; Robertson & Weismer, 1997). While no studies could be found examining the effects of peer models on populations with neurodegenerative diseases such as PD, it is tangentially considered here and could be an avenue for future research. Methodologically, this study is an objectivist case study, and thus the participants mentioned are a small part of a heterogenous community with PD, with the researcher's primary role being that of observer and data collector. However, due to the depth of the outcome measures, results from this study may contribute to new directions of symptomatic, holistic treatment for individuals with PD.

METHODS

Setting

Study participation occurred at the Douglas County Senior Resource Center once per week for one hour during the fall 2019 semester at the University of Kansas (KU). Participation included singing with the intergenerational choir conducted by Melissa Grady in the music therapy department. Data collection occurred in the Speech Science and Disorders Lab at KU at three separate times – before participation in the choir, 1-2 weeks post-participation, and again 2-3 months post-participation.

Participants

Three participants were recruited for participation in this study from the Lawrence Parkinson's Support Group. Participants responded to a recruitment flyer and contacted the researcher directly through email or by phone. Inclusion criteria were:

1. A diagnosis of idiopathic Parkinson's Disease (PD)
2. Experience of vocal changes since the disease onset
3. Normal cognition as assessed by the Mini Mental State Examination (MMSE) (M = 24; Folstein, Folstein, & McHugh, 1975).

4. Exclusionary criteria included:
5. No comorbidity with other neurologic impairments
6. No voice treatment within 6 months prior to study participation. Treatments for other aspects of speech and language were acceptable.

One participant was unable to attend rehearsals and did not return for follow-up data collection. The remaining participants' demographic data, in addition to initial sentence intelligibility measures as calculated by two unfamiliar judges using the Sentence Intelligibility Test (SIT)(Yorkston et al., 1996), is outlined in table 1.

Table 1
Participants and Demographic Data

Participant	**1**	**2**
Age	82	76
Sex	Female	Male
Time Since PD Onset	~ 2 years	~2 years
Sentence Intelligibility %	90.9%	94.5%
Speaking Rate	210.9 words per minute	252.9 words per minute

Notably, each participant reported having been diagnosed with PD roughly two years prior to their initial meeting. Both participants were taking levodopa-carbidopa to manage their motor symptoms at the time of the study, and Participant 1 had participated in voice therapy for loudness about a year before the initial meeting. Between the second and third meetings, she had returned to therapy, with no self-perception of improvements as a result. However, she also acknowledged that she had not been diligent in completing at-home exercises, which are a key component of voice therapy targeting vocal changes related to PD. Participant 2 had relatively few complaints regarding his symptoms, and indicated that he was delaying behavioral treatments in favor of continued rigorous exercise in the form of hiking.

Instructional or Intervention Materials

The two research participants were provided informed consent sheets to sign, as well as a full schedule of intergenerational choir rehearsals. The clinician was present at each choir rehearsal to take notes and provide support to participants as needed. Other members of the choir included students in the music therapy and music education departments at the University of Kansas, and senior citizens from the Douglas County community. Music therapy and music education students from the University of Kansas conducted the choir. There were between 20 and 25 total choir members at each rehearsal. Each choir member was provided a rehearsal binder with the lyrics to each song selection.

The music was selected by the students who were conducting the choir, with each student selecting and teaching two songs of their choice. Songs were chosen depending on a mixture of personal preference and the dynamics of a choir consisting of a mix of age groups. The choir's repertoire is included in Appendix A. It appears as if the songs can be divided into five categories: songs related to the state of Kansas (e.g. Home on the Range, Over the Rainbow), well-known classics (e.g. L-O-V-E, Let it Be, My Girl), children's songs (e.g. Don Gato, A Ram Sam Sam), 80s-90s pop (e.g. Wannabe, Dancing Queen), and more traditional folk-esque songs (e.g. Hey Ho, Nobody Home, Swing, Low Sweet Chariot). Sheet music for the selected songs was not provided; rather, the songs were taught by ear with IC members following along with a sheet of written lyrics. For some of the more rhythmically complex songs, such as Tiny Dancer, symbols (such as a stop sign) were used above the lyrics to indicate pauses. Some lines of lyric sheets were also indented further to indicate more rests in a measure before initiating the lyrical phrase.

In addition to binders with sheets of annotated lyrics, during the latter half of choir rehearsals, musical instruments were introduced with which choir members accompanied certain songs. The instruments included kazoos and percussive instruments such as shakers, triangles, and handbells. Percussion instruments were used by willing choir members during songs for which there was not already a musical accompaniment – i.e. most of the children's songs. The choir members were generally instructed to use the percussive instruments on each quarter beat of these songs. Kazoos were used during Sweet Caroline to replace the musical trumpet interludes that occur after the titular phrase in the chorus. Other instruments used were the students' own guitars or a shared keyboard/piano, meant to accompany some of the more contemporary songs (e.g., "Tiny Dancer," "Let it Be.") One senior choir member accompanied the IC's rendition of "Over the Rainbow" on piano during their final public performance.

The students facilitating the choir met once weekly as a class to discuss their plans for the next choir rehearsal, with guidance from music department faculty. Each choir rehearsal was one hour, once per week, for nine weeks. The first eight rehearsals were conducted in the basement of the Douglas County Senior Resource Center, with rugs hung and placed throughout the room to reduce acoustic reverberation. After the nine rehearsals, a performance was scheduled in The University of Kansas's Swarthout Music Hall.

Each choir rehearsal began with choir participants arranged in a circle, and music students dispersed to promote engagement through proximity. A brief non-singing warm-up functioned as a way for the choir members to get to know each other. This was usually a "name game," during which members took turns calling out their names, while the rest of the chorus greeted them in succession. The bulk of rehearsals consisted of near-constant singing through the chosen repertoire, with each music therapy or education student getting an opportunity to conduct the chorus through the song of their choice. The order of the songs was not set and was rather decided by the randomized position of each student within the circular seating arrangement. The songs were taught primarily by the student modeling in an “echoing” fashion, meaning that the leading student would sing a phrase and the participants would repeat the phrase. More challenging or lesser known songs were taught in segments, whereas simpler or more well-known songs were sung through together, and spot-corrected after being sung through. Later in the semester, short music lessons were included to supplement direct song work. These lessons were often not related to a specific song but rather were intended to improve the musicality of the group as whole. One of these short music lessons included teaching of harmony and how to create harmonies independently using solfege (do-re-mi-fa-so-la-ti-do) coupled with hand signs. The hand signs used were the same ones found in the “Kodaly” method in music education spheres. Figure 4 is an illustration of these hand signs.

Figure 4
Kodaly Hand Signs Illustration

During the brief harmony instruction, participants were divided into three groups; one group was instructed to sustain the tonic “do”, while the other two groups traveled up the scale. The second group sustained the third note “mi,” while the remaining group continued up the scale until they sustained “so.” Choir participants were encouraged to independently add harmonies to the songs as they saw fit. Specific harmonies were taught for “Home on the Range,” per student preference. The song “Don Gato” included mild choreography and costuming, as established through group brainstorming and simultaneous input, with final instructions given by the student who selected the song. Costuming included cat ears supplied by members of the chorus. While most songs were sung in unison, some songs divided the chorus into groups of two at the most – e.g. “Wannabe” and “Hey, Ho, Nobody Home”, the latter of which was sung “in the round” (when the same melody is sung intermittently such that different groups’ melodies overlap to create harmonies).

Measurement Instruments

The Mini Mental State Exam (MMSE) (Folstein et al., 1975) was administered to assess cognition as a potential exclusionary criterion before participation. During data collection, a high-quality head-mounted microphone was used for recording to ensure equal distance from microphone regardless of head position. All acoustic recordings were parsed according to task and saved in .wav format, and analyzed through PRAAT (Boersma & Weenink, 2019). The Sentence Intelligibility Test (SIT) (Yorkston et al., 1996) was used at baseline to assess general severity of dysarthria of participants. Pitch glides, sustained phonation, reading of The Caterpillar Passage (Patel et al., 2013), and monologues in response to researcher-created prompts were used to obtain phonatory, articulatory, prosodic, and respiratory data. Phonatory data included the mean and range of both fundamental frequency (f0) and intensity. Articulatory data included Voice Onset Time (VOT), diadochokinetic rate (DDK), and triangular Vowel Space Area (tVSA). Prosodic information was gathered from f0 variability, and respiratory information was gathered from maximum phonation duration and pause length and number. In addition to speech substrate-related data, the WHOQOL-BREF (World Health Organization. Division of Mental Health, 1996) and Voice Handicap Index (VHI) (Jacobson et al., 1997) were administered as self-reported surveys of quality of life. These assessed any activity limitations and participation restrictions in line with the WHO ICF Framework. Outcome measures, the intended research question they address, corresponding tasks, and the evidence behind gathering data on each outcome measure is outlined in Table 2.

Table 2
Outcome Measures, Associated Tasks, and Corresponding Evidence Base

Outcome Measure	Research Question Addressed/ Speech Subsystem	Task(s)	Evidence Base
Perceived quality of life	#2/ Quality of Life	WHOQOL-BREF	Stegemoller, Hurt, et.al (2017)
Perceived vocal quality	#2/ Quality of Life	Voice Handicap Index (VHI)	Elefant et. al (2012); Searl et. Al (2011)
F0 (mean, range, variation)	#1/ Phonatory	Reading of "Caterpillar Passage", monologue, sustained and glided "ah"	Kent et. Al (1999, 2003); Metter et. Al (1986); Harel et. Al (2004); Holmes et. Al (2000); Rusz et. Al (2011)
Intensity (maximum, mean)	#1/ Phonatory	Reading of "Caterpillar Passage", monologue, sustained and glided "ah"	Kent et. Al (1999, 2003); Holmes et. Al (2000); Metter et. Al (1986); Rusz et. Al (2011)
VOT	#1/ Articulatory	Reading of "Caterpillar Passage", monologue, DDK	Auzoo et. al (2000); Kent et. Al (1999); Harel et. Al (2004); Rusz et. Al (2011)
tVSA	#1/ Articulatory	Reading of "Caterpillar Passage", Monologue	Whitfield et. Al (2014); Rusz et. Al (2013); Skodda et. Al (2012)
Maximum Phonation Duration	#1/ Respiratory, Phonatory	Sustained "ah"	Kent et. Al (2003); Metter et. Al (1986); Holmes (2000);
Pause length & number	#1/ Respiratory	Reading of "Caterpillar passage"	Metter et. Al (1986); Kent et. Al (1999); Harel et. Al (2004); Rusz et. Al (2011)
Diadochokinetic rate	#1/ Articulatory	DDK task	Rusz et. Al (2011)

Procedures

A recruitment flyer was distributed to the Parkinson's Support Group email list with their executive board's permission. Participants contacted the researcher directly via email or phone, at which time the researcher asked questions targeting inclusionary/exclusionary criteria outlined in section 3.2. The researcher scheduled an initial meeting to assess cognition using the MMSE. Following cognitive assessment pending results above a score of 24, an informed consent document was given outlining the purposes of the research and expectations of the participants. The participant was given ample time to review the document and sign in a separate room from the researcher. Baseline data was taken after signing the informed consent document and before participation in the intergenerational choir (IC, henceforth). The participant(s) were given a schedule of rehearsals and encouraged to attend the intergenerational choir as expected on a weekly basis through the Fall 2019 semester. They were given reminders throughout the semester that their participation remained voluntary. The researcher attended each rehearsal weekly to note attendance and general choir progress. Data collection was planned at two separate points after baseline – T1 at 1-2 weeks post-participation, and T2 at 2-3 months post-participation. Data collection tasks are outlined in section 3.4. Each task was described and programmed into a PowerPoint presentation. Table 3 presents a description of each task in the order in which they were presented. The researcher read the instructions aloud for each task while the participant read them on the screen. The participant was given the opportunity to practice sustained "ah," glided "ah," and DDK once before proceeding for three trials of each. The other tasks did not have opportunities for practice.

Table 3
Description of each data collection task

Task	Description
Sentence Intelligibility Test (SIT)	A software presents a series of 11 randomized sentences of increasing length. The participant reads each sentence while being recorded, and the recordings are transcribed by at least two unfamiliar listeners after the initial recording. The software calculates overall sentence intelligibility and speaking rate.
Sustained "ah"	The participant holds an "ah" vowel for as loud and as long as they can, on a flat modal pitch.
Glided "ah"	The participant holds an "ah" vowel while gliding their pitch from low to high, pausing in the middle, and back down from high to low.
DDK	The participant repeats "puh-tuh-kuh" over a period of five seconds. DDK rate is calculated in syllables per second. If "puh-tuh-kuh" is difficult, the patient may say "buttercup" to the same effect.
Caterpillar Passage	The participant reads a short passage titled "The Caterpillar" aloud in their normal speaking voice.
Monologue	The participant is given three questions – about family, job, and favorite places – and selects one of them to respond to for 30 seconds to one minute.
Voice Handicap Index (VHI)	A questionnaire is administered to the participant that allows them to rate their perception of their voice on a series of Likert scales.
WHOQOL-BREF	A questionnaire is administered to the participant that allows them to rate their overall quality of life – unrelated to their voice – on a series of Likert scales. The WHOQOL-BREF calculates perceived quality of life across four domains; the sum of these scores was used as the raw score.

Data coding and analysis

Each participant's data was coded in an individual excel spreadsheet, broken up initially by task, then by outcome measure - for example, separate rows for vowel space area during the caterpillar passage and during the monologue tasks. After being parsed by task, the resulting .wav files were uploaded to PRAAT, which displayed visualized spectrographic, formant, frequency, and loudness information.

Data was analyzed sequentially by participant, due to the nature of frequency calculation in the PRAAT software. To clarify, minimum and maximum frequency were highly subject to the minimum and maximum viewable frequencies in PRAAT's settings. Since participants were of different sexes, their frequency ranges were vastly different. For this reason, the researcher set the minimum and maximum viewable frequency settings based on each participant's range during the glided "ah" tasks and continued to code data for subsequent tasks with the same settings. Participant 1's minimum frequency was set at 75 Hz, and her maximum at 450 Hz, while participant 2's minimum frequency was set at 50 Hz, and his maximum at 300 Hz. Using these parameters, frequency range, mean, and variability were calculated using the "voice report" function in PRAAT. An example voice report can be found in Appendix B.

For all tasks, maximum intensity was calculated. The initial plan was to calculate participant intensity ranges instead of maximum; however due to ambient background noise the minimum intensity was often calculated as negative dB values. For this reason, maximum intensity was deemed sufficient for the purposes of this case study. Mean intensity was included in the sustained and glided "ah" tasks. It was excluded from speaking tasks due to the ambient noise in pause time lowering the overall acoustic intensity.

The first step to calculating tVSA involved first isolating vowels /a/, /i/, and /u/. In the caterpillar passage, these vowels occurred in "parking l<u>o</u>t", "I d<u>o</u>", and "I knew it was for m<u>e</u>". When calculating tVSA during monologue tasks, close approximations to these vowels were isolated in context. Once these vowels were isolated, PRAAT output frequencies for formants one and two. These numbers were plotted on a coordinate plane, with the first formant frequency being plotted on the x-axis and the second formant frequency being plotted on the y-axis (i.e. F1, F2 = x, y). This is the reverse of conventional tVSA plotting, with F1 being plotted on the y-axis and F2 being plotted on the x-axis, but it does not change the resulting area calculation. The resulting shape between the three points (one per vowel) is a triangle, the area of which was calculated using an excel formula.

VOT was an additional parameter requiring specific, measured analysis to guarantee consistency. To do this, during the caterpillar passage, /b/ was calculated in "Boy was I scared", /d/ in "Do you like amusement parks?" and /g/ in "I gave the man my change." These points were selected because of the target sound in the onset position. A similar strategy was implemented during the analysis of monologic speaking tasks. Once the individual sounds were isolated, the researcher zoomed in on the target sounds to identify the initial aperiodic "burst" – as seen in the acoustic waveform, followed by a periodic complex wave to indicate voicing. The clinician used the PRAAT cursor to calculate the time between initial burst and the start of the periodic complex wave. To verify timing and placement, the clinician played the recording before and after the selected timeframe; before the timeframe should have been ambient noise, and after, voicing. VOT was calculated on voiced sounds because studies have shown significant differences in VOT on voiced sounds between individuals with PD and healthy age-matched controls (Pascal Auzou, Canan Ozsancak, Richa, 2000). In typical English speakers, voiced sounds result in a VOT between 10 and 25 milliseconds. An example of the acoustic waveform and spectrogram provided by PRAAT to calculate VOT is in Appendix C.

To calculate the number of pauses and mean duration, *only* the caterpillar passage task was used. This was to account for natural pauses that occur while thinking in spontaneous speech. By providing the text to be read, only respiratory inferences could be gained from this outcome measure. A "pause" was decided to be any lack of vocal output for half a second or greater, ignoring the pause that occurred while the researcher switched PowerPoint slides halfway through the reading.

DDK rate was calculated as an average syllables per second across all three recorded trials. Similar, for glided and sustained "ah" tasks, where three trials were necessary, intensity and frequency mean were calculated as an average across all three trials. Maximum intensity and maximum phonation duration were calculated as *maximums* across all three trials – that is, the maximum intensity or duration was not calculated across each trial, then averaged into "average maximum intensity".

Following data coding, data was analyzed and interpreted descriptively to identify patterns that may have occurred as a result of this intervention in combination with confounding variables in each of the two participants' daily lives.

RESULTS

This study sought to answer the following questions through both qualitative and quantitative data:

1. What are the effects of intergenerational choir participation on individuals with PD's articulatory, vocal, and respiratory mechanisms?
2. What are the effects of intergenerational choir participation on perceived quality of life, in accordance with the activities and participations components of the WHO's ICF framework?

Question 1 is answered by analyzing each of the participant's quantitative measures of fundamental frequency, intensity, voice onset time, triangular vowel space area, maximum phonation duration, and diadochokinetic rate. Question 2 is answered by the interpretation of scores on the Voice Handicap Index (VHI) and abbreviated World Health Organization's Quality of Life (WHOQOL-BREF), two self-report questionnaires. The following sections report participant results in each of the outcome measures These results will then be synthesized into implications for articulation, voice, and respiration in the discussion section that follows.

Fundamental frequency

Fundamental frequency (F0) outcome measures included the mean F0 (modal pitch), F0 range, and F0 variability (which correlates with prosody). Tasks during which F0 mean was calculated included the monologue, reading of the caterpillar passage, and sustained “ah”. Tasks during which F0 range was calculated included the monologue, reading of the caterpillar passage, and glided “ah.” F0 variability was calculated across all tasks – as a correlate to prosody during speech tasks and as a correlate to pitch stability during “ah” tasks. All results were obtained in Hz. Results are detailed in table 4.

Table 4
Frequency results across tasks for both participants, in Hz

Outcome Measure	**Task**	**Participant 1**			**Participant 2**	
		T0	T1	T2	T0	T2
F0 Mean	Sustained “ah”	187.94	179.22	180.9	113.43	155.93
	Caterpillar	150.59	159.45	155.92	115.51	127.02
	Monologue	166.22	14811	168.56	105.46	108.82
F0 Range	Glided “ah”	368.75	498.76	516.4	199.97	293.34
	Caterpillar	356.19	372.95	369.38	160.89	249.98
	Monologue	238.75	372.99	363.44	196.43	242.35
F0 Variability	Sustained “ah”	3.9	4.22	3.17	2.71	4.71
	Glided “ah”	70.81	127.37	141.91	45.38	87.04
	Caterpillar	42.45	49.86	25.08	26.99	49.89
	Monologue	53.21	50.9	59.75	29.85	41.49

Figures 5 and 6 provide further visualization of changes in mean F0 over time for Participant 1 and Participant 2. There appears to be a change at T1 for participant 1, only to approximate the baseline mean F0 at T2.

Figure 5

Participant 1's mean F0, in Hertz, for each task over time

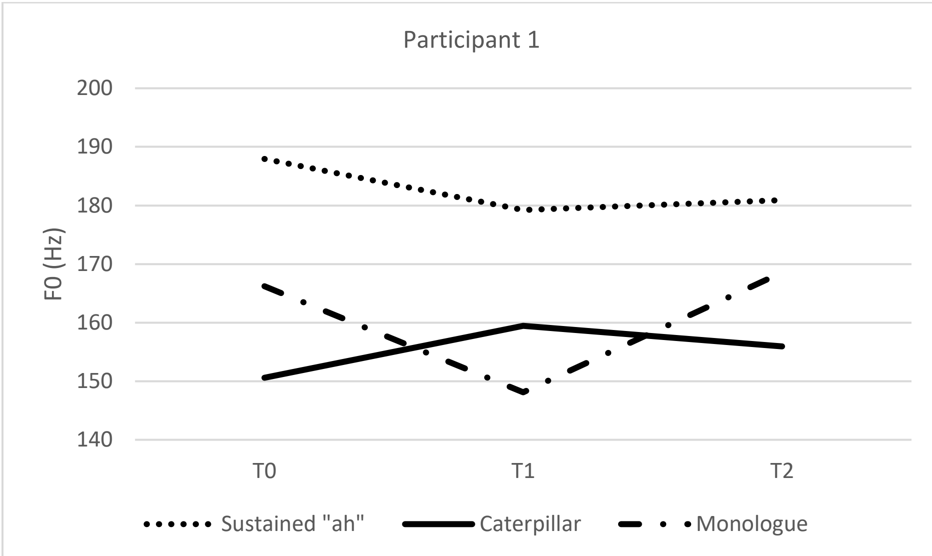
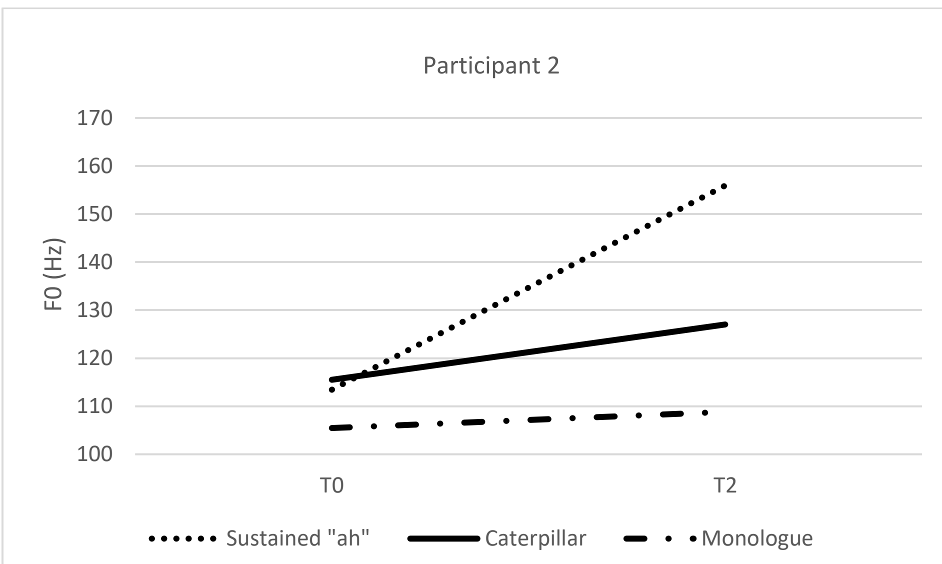


Figure 6

Participant2's mean F0, in Hertz, for each task over time



Figures 7 and 8 provide further visualization of changes in F0 range over time, which appears to have generally increased across time for all tasks and for both participants.

Figure 7

Participant 1's F0 Range, in Hertz, for each task over time

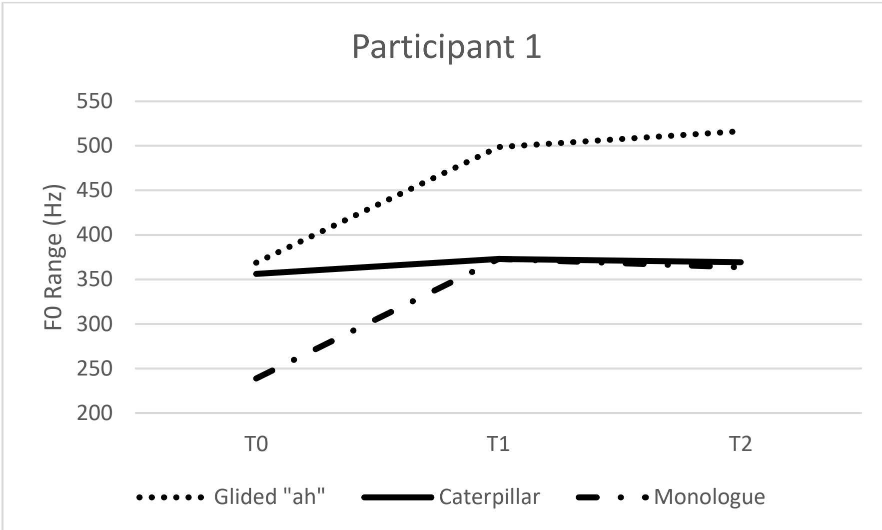
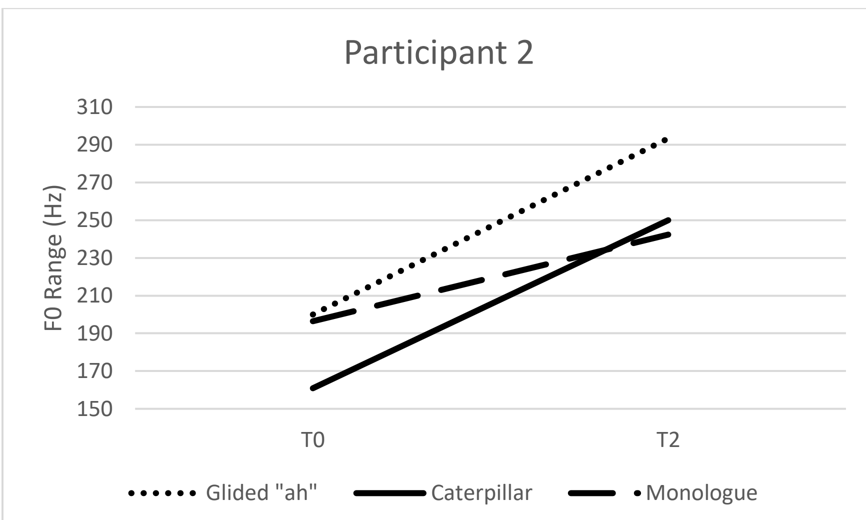


Figure 8

Participant 2's F0 Range, in Hertz, for each task over time



The final frequency outcome measure – variability – is visualized in figures 9 and 10. It appears to be more a correlate of task than time.

Figure 9

F0 Variability, in Hz, for Participant 1 across time and tasks

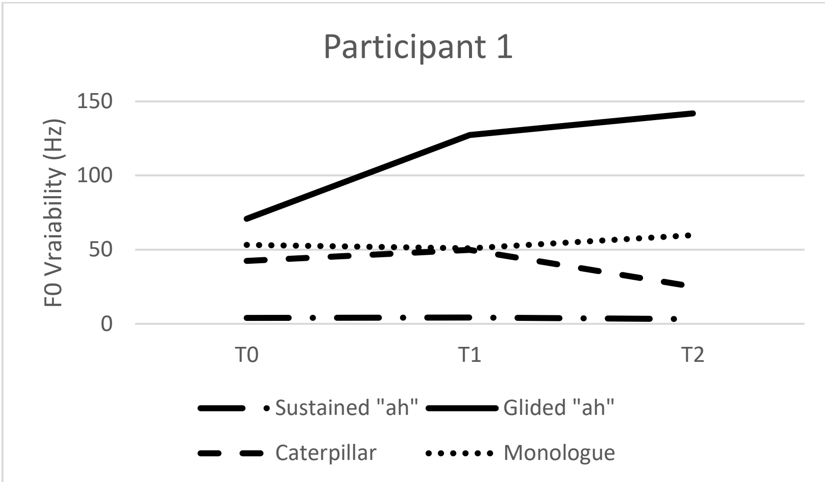
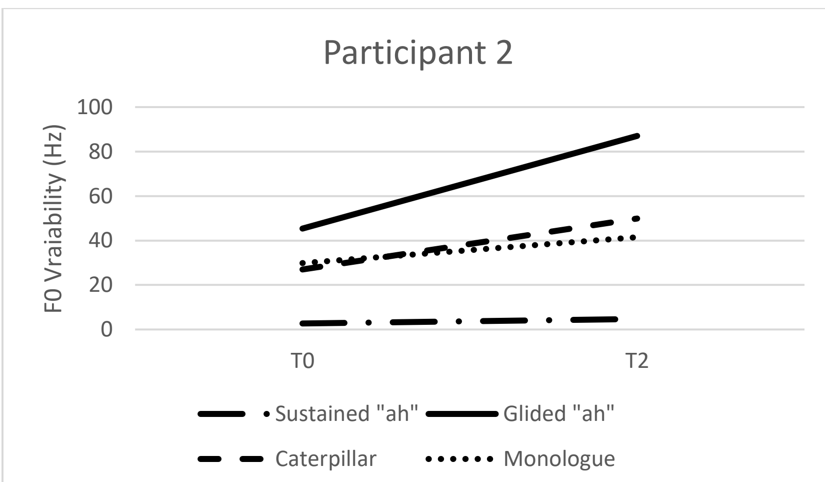


Figure 10

F0 Variability, in Hz, for Participant 2 across time and tasks



Intensity

Two measures of intensity were relevant to this case study: maximum and mean. The results of intensity are reported in table 5, with the unit being dB SPL. It is important to note that between T0 and T1, an alternate, more sensitive, amplification system was installed.

Table 5

Intensity results across tasks for both participants, in dB SPL

Outcome Measure	Task	Participant 1			Participant 2	
		T0	T1	T2	T0	T2
Intensity Max	Sustained “ah”	67.4	84.86	89.51	65.45	90.34
	Glided “ah”	64.75	84.56	89.81	65.69	90.2
	Caterpillar	57.47	78.94	88.9	64	89.09
	Monologue	53.31	66.84	84.77	64.52	86.45
Intensity Mean	Sustained “ah”	63.49	82.71	88.2	56.67	85.32
	Glided “ah”	56.98	74.66	85.34	74.53	90.2

Measures of intensity, as with measures of frequency, may correlate with effects on the vocal, and to some extent the respiratory, mechanisms. A visual representation of these outcomes is seen in figures 11 and 12, with the primary bars corresponding to the maximum intensity demonstrated by task and data collection time, and the individual dots representing the mean intensity at all three data collection points for the corresponding tasks (sustained and glided “ah”).

Figure 11

Participant 1’s maximum and mean intensity, in dB SPL, for each task and time

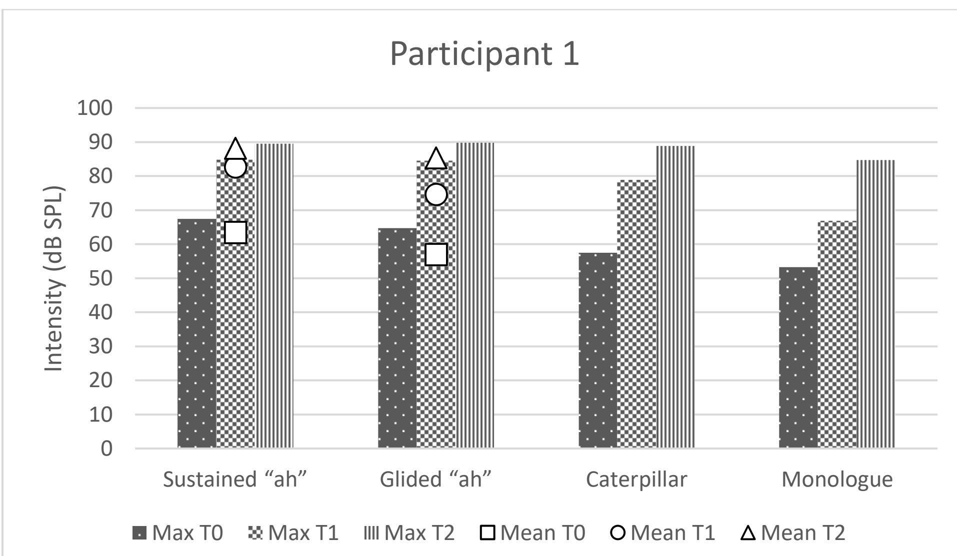
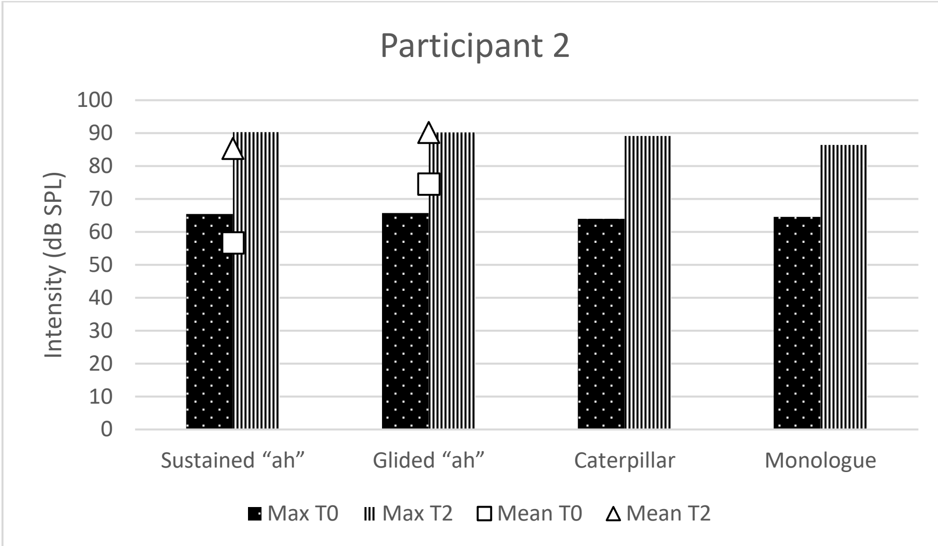


Figure 12

Participant 2's maximum and mean intensity, in dB SPL, for each task and time



Voice Onset Time

Voice onset time (VOT) is an articulatory measure, frequently used to discuss perception of voiced, voiceless, and aspirated vowels cross-linguistically. Participants' VOT was calculated for voiced stop consonants /b/, /d/, and /g/, in connected speech from both speech tasks - the Caterpillar passage task and the monologue task. Results on this outcome measure are presented in table 6, in milliseconds.

Table 6

VOT results across tasks for both participants, in milliseconds

Outcome Measure	**Task**	**Participant 1**			**Participant 2**	
		T0	T1	T2	T0	T2
/b/ VOT	Caterpillar	56	27	9	29	46
	Monologue	15	24	31	16	15
/d/ VOT	Caterpillar	79	62	43	16	14
	Monologue	14	16	61	20	30
/g// VOT	Caterpillar	51	58	19	55	27
	Monologue	48	41	39	68	32

Figures 13 and 14 present these results visually per participant.

Figure 13
Participant 1's VOT by task and target voiced stop across data collection points, in msec

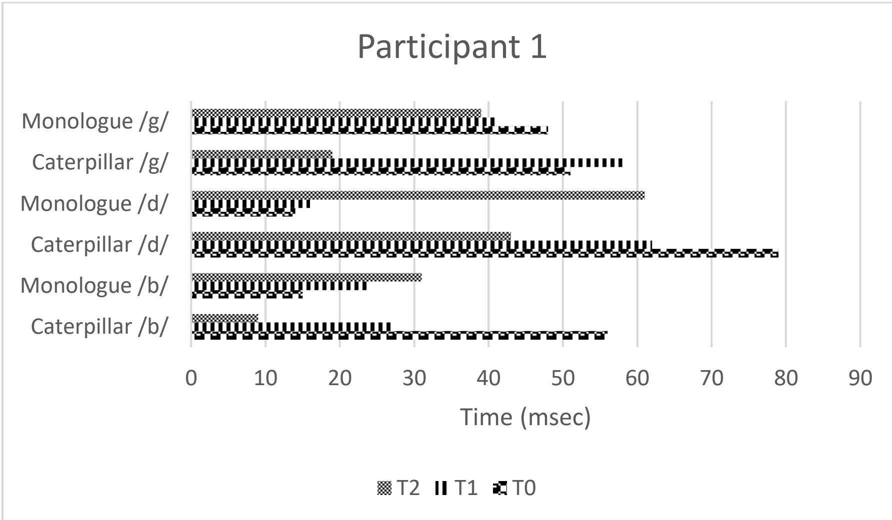
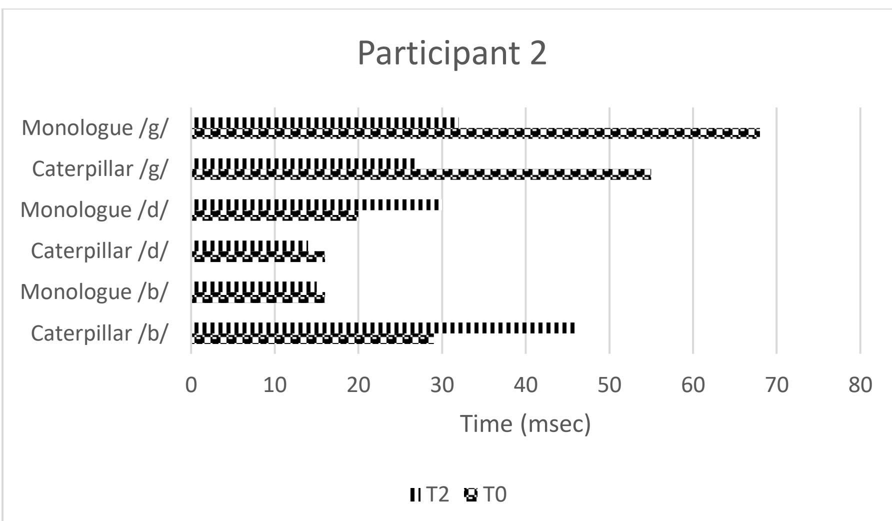


Figure 14
Participant 2's VOT by task and target voiced stop across data collection points, in msec



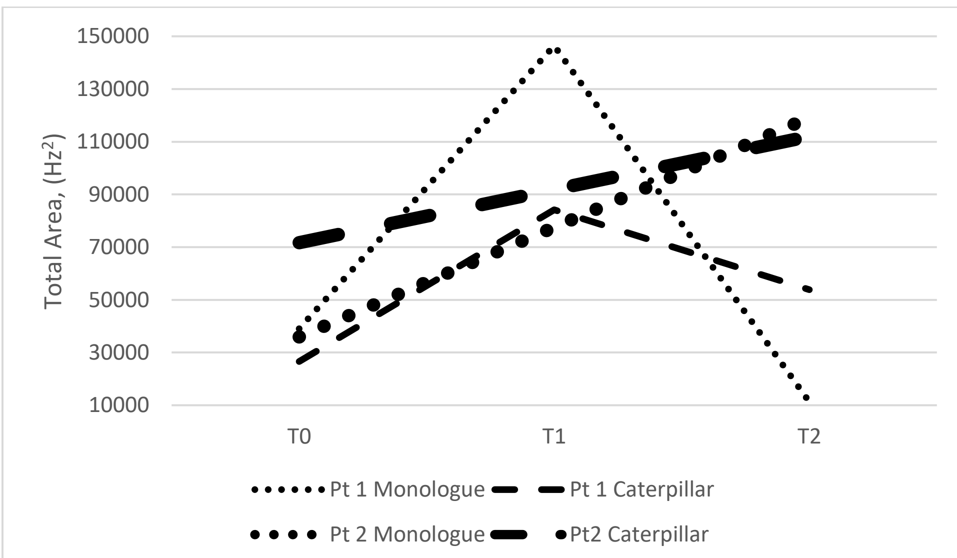
Triangular Vowel Space Area

Triangular Vowel Space Area (tVSA, as with VOT, is an articulatory measure focused on vowels. Research has shown that individuals with PD tend to centralize their vowels, leading to reduced tVSA. The graphs that visualize this outcome measure by plotting indvidiual vowel formant frequencies are included in Appendix D. From the plotted points, the area of the resulting triangle connecting each of the vowel points was calculated using the excel formula: tVSA= $((x_1*(y_2-y_3)+x_2*(y_3-y_1)+x_3*(y_1-y_2)))/2$. Total tVSA results are presented in table 7. The unit is technically Hz^2, given the individual plot points represent the first and second formants of vowels /a/, /i/, and /u/. Figure 15 illustrates changes in total area over time for both participants.

Table 7
tVSA results across tasks for both participants, in Hz^2

Outcome Measure	Task	Participant 1			Participant 2	
		T0	T1	T2	T0	T2
tVSA	Caterpillar	26591	84172	53887	71682	112004
	Monologue	39058	146428	11263	35913	119138

Figure 15
tVSA, in Hz^2, over time for both participants and speech tasks



For both participants' reading of the caterpillar passage, /a/ was gathered from the final syllable of "parking lot," /i/ from the final syllable of "I knew it was for me", and /u/ from the final syllable of "I do". The vowels varied considerably during their monologues given the lack of predictability. Table 8 charts the specific words taken from each participants' monologue to calculate tVSA.

Table 8
Vowels used to obtain tVSA during monologue speaking tasks

Vowel	**Participant 1**			**Participant 2**	
	T0	T1	T2	T0	T2
/a/	“daughter”	“daughter”	“long”	“Colorado”	“Rockies
/i/	“three”	“eat”	“be”	“peaks”	“peak”
/u/	“two”	“do”	“suits”	“beautiful”	“opportunity”

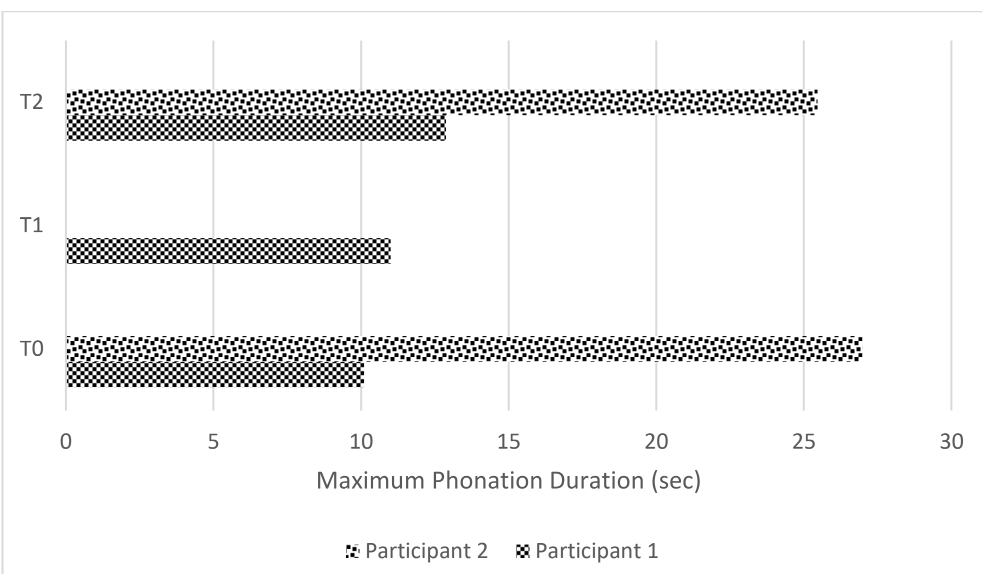
Maximum phonation duration

Maximum phonation duration was an outcome measure only during the sustained “ah” phonation task. It is primarily a measure from which one can interpret effects on the respiratory and phonatory systems. The results, in seconds, are in table 9, and a visualization of these results is charted in figure 16.

Table 9
Maximum phonation duration results for both participants, in seconds

Outcome Measure	**Participant 1**			**Participant 2**	
	T0	T1	T2	T0	T2
Maximum Phonation Duration	10.1	11	12.88	26.98	25.46

Figure 16
Maximum phonation duration over time by participant, in seconds



Pause duration and number

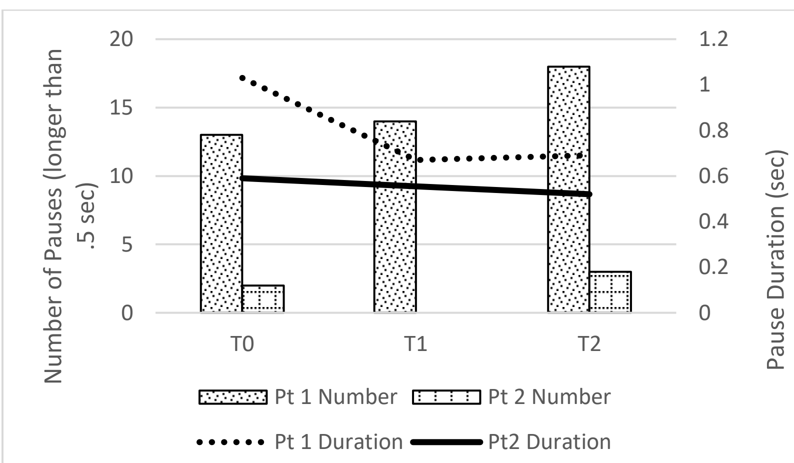
As mentioned in the section pertaining to data coding and analysis, a "pause" was defined as a .5 second gap in phonation as indicated by spectrographic and waveform representation. Number of pauses and mean pause duration is a measure intended to supplement interpretations of effects on respiratory mechanisms.

Table 10 presents results related to average pause length, in seconds, and number of pauses during the reading of the Caterpillar passage, while figure 17 provides a visual representation of the data.

Table 10
Total pauses and mean pause duration, in seconds, for both participants

Outcome Measure	**Participant 1**			**Participant 2**	
	T0	T1	T2	T0	T2
Pause #	13	14	18	2	3
Mean Pause Duration (s)	1.03	.67	.69	.59	.52

Figure 17
Pause # and mean duration, in seconds, during reading for both participants



Diadochokinetic rate

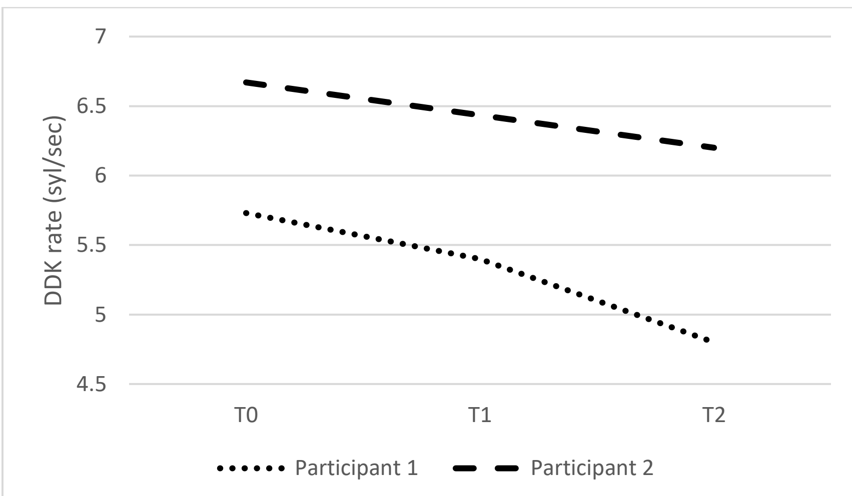
Diadochokinetic rate (DDK) was calculated in terms of syllables per second, over a period of five seconds. It is a frequently used outcome measure and task during assessments of dysarthria. It is related to articulatory effects of intervention in that it requires fast and coordinated movements of the articulators.

Results are displayed in table 11, with supplemental graphic visualization in figure 18. This was derived from its own dedicated task, as opposed to being an outcome measure embedded within speech tasks.

Table 11
DDK for both participants, in syllables per second

Outcome Measure	Participant 1			Participant 2	
	T0	T1	T2	T0	T2
DDK	5.73	5.4	4.8	6.67	6.2

Figure 18
Diadochokinetic rate for both participants over time, in syllables per second



Quality of Life

To assess quality of life and answer the second research question, both qualitative and quantitative measures were used. The two quantitative measures administered were the Voice Handicap Index (VHI) and World Health Organization Quality of Life Abbreviated Instrument (WHOQOL-BREF). Scores for these respective measures are displayed in table 12, with supplemental visualization in figures 19 and 20. For the VHI, higher scores generally indicate greater perceived handicap, and for the WHOQOL-BREF, higher scores generally indicate greater perceived quality of life.

Table 12
VHI and WHOQOL-BREF results for both participants

Outcome Measure	Participant 1			Participant 2	
	T0	T1	T2	T0	T2
VHI	74	75	59	6	11
WHOQOL-BREF	96	95	97	102	103

Figure 19
VHI scores for both participants over time

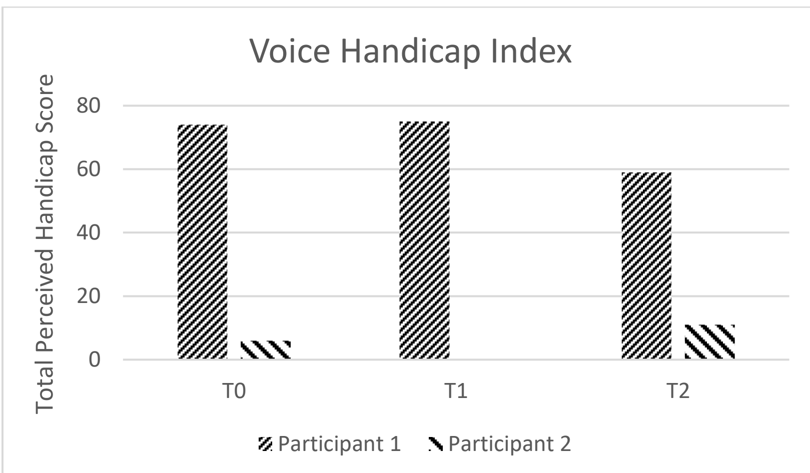
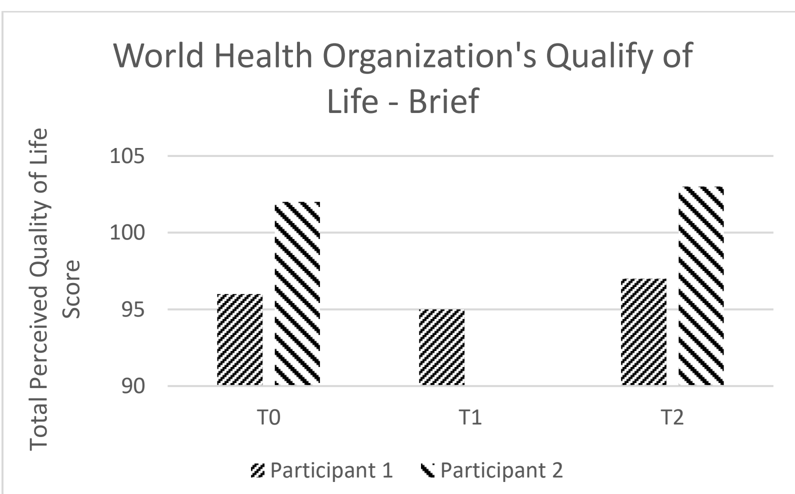


Figure 20
WHOQOL-BREF Scores for both participants over time



Qualitative measures were gathered from informal interviews before and after data collection sessions, as well as briefly during IC rehearsals. Qualitative data was typically centered on overall enjoyment of the activity, rather than perceived overall quality of life. Both participants stated to have had enjoyed singing in the choir. Participant 1 stated that she would have enjoyed it more had the songs been more to her taste. She indicated further interest in singing after participation in the IC, and noted to the researcher a recent development of a Parkinson's choir in the area that she was interested in. She also reported an increase in singing at home, though she would not continue with the IC. Participant 2 stated that he wanted to continue with the IC but was hindered due to other commitments, one of which was another local community choir.

DISCUSSION

The discussion that follows intends to use the obtained results to interpret effects of IC participation across four domains (respiratory effects, phonatory effects, articulatory effects, quality of life) for individuals with PD. It additionally will address methodological limitations and provide potential directions for future research, bearing in mind the established stages of phased behavioral intervention research.

Respiratory Effects

The main outcome measures from which respiratory data is derived include maximum phonation duration and mean pause duration and number. The rationale for examining respiratory effects of a choral singing intervention is that singing engages the intercostals consistently, requiring substantial breath support while phonating. By practicing this increased engagement, carryover effects may or may not be present in speech. Given the data, it appears as if Participant 1 experienced a gradual increase in her maximum phonation duration across all three visits; she also stated that she had been singing more often at home, beyond the scope of the IC. Her maximum phonation duration differed minimally from baseline to two months post-participation. This 2-second difference, supplemented by the maximum phonation duration data obtained from Participant 2, which remained relatively stable over time, makes it difficult to determine effects of choral singing on respiratory capacity and control. Furthermore, Participant 2 appears to have greater respiratory capacity than Participant 1 at baseline. Given the higher baseline and the categorization of PD as a neurodegenerative disease, it is less likely to see improvements over time. This is in line with results from other studies examining choral singing as an intervention (Di Benedetto et al., 2009; Stegemöller, Radig, et al., 2017). It is also important to note that speech production uses a small portion of respiratory capacity, and if effects from the intervention were present, they may not have been reflected from the speech tasks used during data collection. As for pause duration and number, the results reveal minimal change for Participant 2, who had few pauses longer than half a second throughout the reading at all data collection points. This is consistent with his maximum phonation duration, which was also high at baseline. With greater respiratory capacity, it is likely that he did not need to take as many pauses during speech. Participant 1, on the other hand, demonstrated an increase in pauses across the three data collection points, but with a decrease in mean pause duration from T1 (two weeks post-participation) onwards. This could be indicative of recognizing the need for more frequent, smaller "catch-breaths" when speaking to maintain naturalness. "Catch-breaths" are frequently used when singing, so some carryover of choral singing skills may be seen in this area. Overall effects on respiratory capacity and control from these two outcome measures imply maintenance of the system. No prominent decline or improvement is seen in this respiratory function as a result of participation in the IC.

Phonatory Effects

Phonation may be assessed through the outcome measures of maximum phonation duration, frequency, and intensity. As previously noted, minimal improvement or maintenance of maximum phonation duration was demonstrated. Analysis of frequency required parsing the data by task and by data collection point. From the data, the greatest effect on mean F0 appears to be related to task rather than time. Sustained “ah” for both participants was higher than their modal pitch from both monologue and caterpillar passage reading. This finding is unremarkable for several reasons. Without explicit instruction on increasing loudness while not increasing pitch it is likely that the two participants conflated the two parameters, due to the effort required to sustain phonation. There is a clear deviation (either higher or lower) at T1 for Participant 1 across all tasks, before easing back towards baseline measures for T2, which indicates some effect on fundamental frequency following participation, though minimal maintenance of said effect. For two out of the three tasks in which mean F0 was measured, it decreased for Participant 1 at T1; the only task in which it increased at T1 was for the Caterpillar passage reading. Reasons behind this is unknown and warrants further investigation on task type’s effects on mean F0. Meanwhile, it appears as if Participant 2’s overall fundamental frequency increased from baseline to two-months post-participation. Such an increase in F0 is in line with prior research on vocal changes in individuals with PD stating that men tend to show an increase in fundamental frequency over time (Harel et al., 2004), though it does not appear to be a result of choir participation.

Regarding F0 range, the general increase across both participants is promising and builds on previous research connecting singing interventions and vocal range in PD (Haneishi, 2001; Shih et al., 2012; Stegemöller, Radig, et al., 2017). The widest range, predictably, is seen during the glided “ah” task, when participants were asked to demonstrate their highest and lowest pitches. It is important to note that the extremes of an individual’s pitch range are typically not the pitches used in conversational speech, so range improvements related to this task may not be applicable to speech. It does, however, indicate an ability to access pitches that were not previously accessible, and thus points towards greater vocal fold flexibility and control. It is promising to see increases in phonatory range in speaking tasks, apart from the caterpillar task for Participant 1, which remained relatively stable over time. The range used during the Caterpillar passage may have been within normal limits at baseline. Therefore, the increase in monologue range to approximate the range used when reading a passage aloud may be indicative of low baseline being brought up to within normal limits. This greater phonatory range indicates less monotony during speech.

As with mean F0, the outcome measure of F0 variability appears to depend more on task than on time post-intervention. Measures of F0 variability are most stable during the sustained “ah” task with little demonstrated change across data collection points. Variability is greatest during glided “ah” tasks, due to the rapid change in pitch asked of the participants, and it is in between these two measures for both the monologue and Caterpillar passage reading. This reflects the natural pitch variability used when speaking. Measures of F0 variability during both caterpillar and monologue tasks are relatively concurrent with the control groups used in a study investigating this same measure in individuals with PD and healthy-age matched controls (Bowen et al., 2015). Thus, it is likely that due to a high baseline, no notable effects were seen in this area as a result of IC participation.

Another factor to consider regarding phonation is that of intensity – the key target outcome of the leading LSVT treatment approach. While these results do show an increase in intensity from baseline at both two weeks after intervention and two months after intervention, it is more likely a result of the change in amplification system between T0 and T1. Thus, any comparisons between T0 and T1 or T2 are not as valid had the system remained the same. The change in amplification led to more detailed recordings and greater analysis for several other acoustic parameters. With these limitations, one can observe an approximation of maximum intensity from T1 to T2 for Participant 1, in which her monologue and caterpillar passage intensities approximate the maximum intensities achieved during glided and sustained “ah” tasks. It is unlikely that these findings are a result of IC participation, because no participation occurred between these two times. Furthermore, Participant 1 had begun an LSVT refresher course between these two data points, which could likely have resulted in these findings. Overall, few conclusions can be drawn connecting choral singing with effects on vocal intensity, though there is promising data from these two participants that singing in a choir can lead to more vocal flexibility resulting in greater phonatory range and variability.

Articulatory Effects

Effects on articulation are interpreted from DDK rate, VOT and tVSA. DDK rate remained relatively stable for both participants, with a slight reduction in syllables per second over time. However, prior research has shown that DDK rate is a sensitive measure for tracking articulatory impairment in PD, which is expected to decline over time as the disease progresses (Rusz et al., 2011). Maintenance of DDK rate could be interpreted as a positive effect of participation.

VOT and tVSA are important outcomes to consider, because prior research has shown that greater VOT of voiced stops and smaller tVSA may be early biomarkers of PD (Harel et al., 2004; Pascal Auzou, Canan Ozsancak, Richa, 2000; Shimon Sapir et al., 2010; Whitfield &

Goberman, 2014). This is especially relevant given the two participants falling into the early stages of disease progression.

Visualizations of both participants' tVSA are found in Appendix D. Importantly, in both participants across monologue and caterpillar passage tasks, tVSA increased following intervention. It appears to have dramatically decreased at T2 for Participant 1's monologue. This may be attributed to greater unpredictability of vowels in monologic speech coupled with the researcher's acoustic analysis targeting slightly different vowels across monologues. Fortunately, some vowels were consistently found on the same words across monologues due to preferred topics, as with "daughter" for Participant 1 and "peak(s)" for Participant 2. However, the deviation seen in T2 for Participant 1 appears to be a direct result of the /a/ vowel (seen farthest right in the diagrams, representing high first formant, low second formant) being nasalized in "long." This is supported by previous research stating that nasalized vowels are typically more centralized than their oral counterparts (Arai, 2004). There were no other instances of an /a/ vowel in this monologue, so it is possible that with a lengthier speech sample, Participant 1's vowel space would have been altered with a more representative sample of her speech.

Another pattern to observe with Participant 1's tVSA is the generalized leftward shift of all vowels across both tasks. Given that F1 is plotted on the x-axis and is inversely correlated with tongue height (e.g. high vowels equate low F1 frequencies), this indicates that all vowels became higher – including naturally high vowels /i/ and /u/, and the naturally low vowel /a/. Thus, while /i/ and /u/ decentralized, /a/ moved closer to the center. This may be a result of nasalization as previously considered; however, this change persists in the Caterpillar passage reading, where all vowel targets are consistent. It is possible that the nasalization that occurred due to coarticulation in "long" at T2's monologue occurred unintentionally during T2's caterpillar speech. Given the motor movement required to lift the soft palate and produce oral speech sounds, it is reasonable to infer that the hypokinetic dysarthria which affects vocal fold closure may also affect the soft palate raising. This thus may contribute to hypernasality and the subsequent vowel shift. There is currently limited evidence supporting acoustic evidence of hypernasality in individuals with PD, though research points to an increase in perceptual hypernasality of this population (Novotný et al., 2016).

Regardless of from where this vowel shift originates, the resulting tVSA increased for both participants at different data collection points. This overall increase in tVSA is a promising indicator of increased intelligibility as a result of decentralization of vowels. Participation in choral singing may have contributed to this finding since singing occurs on vowels and sonorant consonants with pronounced articulation. However, it is unlikely that either participant actively thought about singing articulation when completing speech tasks, and there is limited evidence to support articulatory carryover from singing into speaking. Therefore, this may be a promising avenue for further research in PD intervention.

VOT, on the other hand, yields data from which it is difficult to draw a conclusion. This data was nonetheless important to obtain due to the implications it has for initiation of phonation. Since phonation is a motor act, initiation of phonation is expected to be more challenging for individuals with PD, similar to initiating gross motor movements. Given all the data points, the findings are concurrent with Auzou and colleagues (2000) in that 12 out of 18 data points fall outside the typical VOT range of voiced stops (10-25 msec) in English speakers for Participant 1. This occurs in seven out of 12 data points for Participant 2. Results from choir participation on this articulatory measure, however, are inconclusive and require further investigation and norming. This is not a concerning finding for these two participants given that VOT is not a direct correlate with intelligibility. This is further backed by Participant 1's SIT rating of 90.9% and Participant 2's SIT rating of 94.5%.

Effects on Quality of Life

Overall, both participants reported relatively high quality of life at baseline according to the WHOQOL-BREF. With this knowledge, there was a decreased likelihood of improving perceived quality of life as a result of intervention. The results reflect this reality. Notably, Participant 1 indicated greater levels of perceived vocal handicap than Participant 2 according to totaled VHI scores, despite comparable WHOQOL-BREF scores. Participant 1's VHI score decreased from "severe" (60-120) to "moderate" (31-60) with a score 59 at T2, while Participant 2 remained in the "mild" (0-30) range throughout. It is with caution that comparisons between participants are made, due to demographic differences. However, the similar dates of diagnosis promote curiosity regarding from where this difference in perceived vocal handicap originates. Both participants were highly motivated to achieve benefits from available treatments and to make the most of their diagnoses, which led them to be a part of this case study. Participant 2 frequently made statements referring to "getting ahead" of PD, whereas Participant 1 frequently commented on how PD was negatively affecting her daily life and speech. Participant 2 had not received any voice therapy throughout the period of this case study, which may be indicative of Participant 2's focus on his motor symptoms over voice symptoms. Participant 1, as has been stated, received voice therapy focused on loudness a year before participation, and an additional refresher course between T1 an T2. Thus, the greater perceived vocal handicap could be the result of a priming effect. Since she had received therapy for her voice, she may have developed greater awareness of vocal deficits.

Subjectively, it is difficult to conclude whether participating in an intergenerational choir leads to changes in perceived quality of life. Each choir experience is different and thus leads to different levels of enjoyment. Both participants indicated enjoyment from IC participation, though more information is necessary to understand which aspects of the IC were deemed enjoyable and which ones could benefit from adjustment in the future.

Limitations

When discussing limitations of this study, it is important to consider the role that phased research plays in the development of behavioral interventions. According to the National Institute of Health (NIH) there are at six stages to research regarding the development of a behavioral intervention (Onken et al., 2014). These consist of Stage 0 (basic research), Stage I (intervention generation/refinement), Stage II (Efficacy – research clinics), Stage III (Efficacy – community clinics), Stage IV (Effectiveness), and Stage V (Implementation and Dissemination). The stages are not unidirectional, and in fact skipping stages or retrograde movement is expected. Onken and colleagues merely advise caution when taking certain research pathways over others. Appendix E provides a graphic that they devised outlining possible research pathways through these stages, including the pathways for which they advise more caution than others.

Stage 0, basic research, entails much of what makes up a literature review. It consists of scientific knowledge that might propel the generation of a new intervention; for example, the knowledge that dopamine deficiency is present in individuals with PD resulted in the development of medications targeting dopamine production as an intervention. Basic research provides the science behind new interventions. Stage I may include modification of existing interventions, pilot testing of novel intervention, fidelity enhancement, and pilot testing of therapist or provider training. Typically, stage I research provides necessary materials and information to proceed to stage II or stage III. Stage II and Stage III are similar in that they both directly test the efficacy of an intervention, the main difference being that stage II research occurs in a research setting, while stage III research occurs in community settings. Typically, an intervention will not proceed from stage II to stage III without first being modified for community settings in stage I research. Stage IV research examines behavioral interventions in community settings (as does stage III), while maximizing external validity (how well an intervention can be generalized to the target population). Stage IV research contributes to an intervention's overall effectiveness, while the more internally valid stage II and III research contributes to an intervention's efficacy. Stage V examines how an evidence-based intervention can be implemented and adopted by providers in community settings. Stage V research has contributed to the widespread dissemination of LSVT, with all providers being trained on a strict, specific protocol.

Given these definitions, this case study, while attempting to maintain internal validity falls squarely into stage I research, as an objectivist case study with supplemental qualitative information. The primary limitations of this research are the lack of experimenter control and small sample size, both of which would need to be adjusted to be considered a higher stage of research. While all tasks were completed in a controlled environment to maintain internal validity as much as possible, the researcher had no part in conducting the IC itself; such was conducted by music therapy and music education students at the University of Kansas. With the lack of experimenter control comes several confounding variables, including but not limited to mood, illness, concurrent therapies, and travel. Some outcome measures may have improved or declined due to IC participation, but unless this variable can be isolated, it is impossible to derive correlation or causation. Given Participant 1's participation in an LSVT refresher, it is likely that improvement or maintenance of loudness from T1 to T2 was affected positively by the intervention. Participant 1's therapy in combination with Participant 2 being unable to attend a data collection session at T1 make it nearly impossible to infer maintenance effects of IC participation on physiologic measures.

Though lack of experimenter control is a limitation in the intervention delivery, it is important to note the differences that may also arise during data collection and interpretation. Although great care was taken to standardize data calculations, certain aspects of speech are "moving targets", and they require a level of nuance that cannot be achieved through standardization. For example, as mentioned in the section pertaining to data coding and analysis, tVSA was calculated during both monologue and reading speech tasks. This measure is far more reliable when calculated from a predictable reading passage in which all words (and expected vowels) are known. It is important to note that the researcher's choice of /i/ resulted in coding for the word "me". The /m/ before /i/ may have nasalized the vowel, thus centralizing the vowels and impacting the resulting formant frequencies. Since this was consistent across data collection points, it does not affect comparison across time for the Caterpillar reading passage, but it does provide some additional confounding variables to consider in isolation and when comparing across tasks. For example, the /i/ in Participant 1's caterpillar passage reading appears to have a greater first formant frequency than during her monologue. This effect, while present, is minimized when comparing /i/ across Participant 2's speech tasks.

VOT is another articulatory outcome measure that acts as a "moving target," and this is largely related to the effect that coarticulation has on acoustic properties of consonants and vowels. Coarticulation accounts for the nasalization of vowels next to a nasal consonant, as well as reduced VOT if a voiced consonant occurs between vowels – as is the case with /g/ in phrases such as “we go.” Even though /g/ occurs in the initial position of the word “go,” in connected speech it is typical that the final /i/ in “we” continues into “go” with no voicing breaks. Great care was taken to capture VOT for all vowels at the beginning of phrases to minimize this effect, though it was unavoidable in certain speech samples.

Though it is a positive indicator for the participants of this study, there are several outcome measures that were initially within normal limits of health age-matched controls, indicating little impairment to begin with. Given the nature of neurodegenerative disease and the relatively early stages both participants were in, this phenomenon created somewhat of a ceiling effect, in that improvements were less likely to occur regardless of intervention efficacy.

Another limitation of this research is that it is not possible to draw broad conclusions of a population based on the small sample size featured in this study. Any conclusions made are isolated to these two participants, and it is crucial to recognize that results from any intervention are highly subject to individual differences. Thus, further research in different stages is warranted to determine the efficacy and effectiveness of an intergenerational choral singing intervention.

Future directions

Fortunately, with numerous limitations and inconclusive evidence comes several directions for future research. Future research avenues may be concerned with intervention delivery, timing of data collection, or sample size, among other unmentioned possibilities. One possible direction would be to repeat this study, with slight modifications to the structure of the choir itself. The concept of an intergenerational choir is appealing in that it is low-commitment, easily accessible, and may still yield benefits comparable to more time-intensive or PD-specific choirs. These articulatory and phonatory benefits were, at most, hinted at from the two individuals featured in this study, and warrant more large-scale research as an additional research direction. Some changes to be made to the structure of the chorus would be to incorporate the previously researched Music Therapy Voice Protocol (MTVP) (Haneishi, 2001; Yinger & Lapointe, 2012). By incorporating MTVP in an IC, fewer variables are introduced in that the choir structure and intervention delivery remains the same. Thus, stronger connection between research studies can develop.

Another direction to consider would be that, while maintaining the concept of an intergenerational choir and increasing sample size, the scope of the obtained outcome measures could narrow. Broadly, research on acoustic measures of articulation and phonation as a result of singing intervention remains mixed. However, with greater sample sizes and greater statistical analysis on fewer variables – for example tVSA and F0 range – it may be possible to home in on a unique effect of singing intervention specifically.

One final adjustment to consider would be changing data collection timing and methods. This study emphasizes long-term change, which is presumably a result of repeated short-term changes, much like long-term exercise gradually builds up strength from short-term actions. However, it would be interesting to know what acoustic changes, if any, occur directly following choir participation, which would warrant a more intensive multi-baseline data collection schedule before and after rehearsals. Otherwise, improvements or detriments could be attributed to intervention, or any number of variables that occur on a given data collection day. Furthermore, data collection tasks may be altered, especially when considering the WHO ICF framework. Greater care could be taken to gather data on the activities in which an individual regularly participates, outside of a rigid self-report questionnaire. More descriptive data collection methods may yield a stronger answer to the second research question of this study. For articulatory measures, the use of different monologue prompts or the elimination of monologue tasks may control for coarticulation as a confounding variable. Caution is advised against this modification, however, as the elimination of monologue and conversational tasks eliminates the applicability to real-world speech. Behavioral speech and voice interventions are most impactful when they result in generalization. Phased research is important because it acknowledges that greater internal validity results in less generalizability, or less external validity. In order to determine generalizability, stage IV research is required.

Presently, this study as a stage I case study may remain at stage I with suggested modifications surrounding intervention structure, data collection, and outcome measures. A greater sample size would be beneficial to traverse towards Stage III research, once clearer parameters are established. Long-term, it may be beneficial to consider a comparative study observing outcomes between individuals who participate in an intergenerational choir and a PD-specific choir – as has been previously researched.

CONCLUSION

Participation in an intergenerational choir once per week under the structure of a case study appears to lend itself to inconclusive evidence about physiologic (articulatory, phonatory, respiratory) benefits, answering question #1 of our research proposal. The most promising outcomes from these two participants' data are the improvements seen in tVSA and F0 range, which were most consistent across all data collection points. A larger sample size and subsequent statistical analysis would be required to make a definitive conclusion from these outcomes. The improvements in tVSA align with results Higgins and Richardson derived from a similar case study comparing tVSA improvements from singing intervention with those found in LSVT and are possibly explained by bi-hemispheric cortical activation during singing (Higgins & Richardson, 2018). The improvements in phonatory range are less expected, given that prior research investigating singing and vocal range has led to mixed results (Haneishi, 2001; Shih et al., 2012; Stegemöller, Radig, et al., 2017). The results from this case study more closely align with Searl and colleagues' feasibility study investigating group delivery of LSVT, which found a resulting statistically significant improvements in phonatory range (Searl et al., 2011).

Results in response to research question #2 – whether singing in an IC has an impact on quality of life – are inconclusive, primarily due to a ceiling effect caused by the overall high perceived quality of life at baseline. More participants with a greater variety of perceived quality of life at baseline would have helped draw more definitive conclusions from this outcome measure.

While many of the outcome measures do not provide sufficient evidence of a positive treatment effect, it is important to note the implications that choral singing as a therapeutic activity may have for individuals with PD. One of the hallmark symptoms of PD, in addition to monopitch and monoloudness, is apathy. This apathy can lead to a lack of motivation to participate in traditional intensive voice therapies. Subsequently, lack of motivation may negatively impact patient outcomes. Choral singing as a community-based activity is a naturally motivating activity and it removes many of the barriers to intensive voice therapy. Should future research in this area yield promising outcomes, the therapy options for individuals with PD may be expanded, especially for those in later stages of PD who are exhibiting more apathy and cognitive decline. Long-term, additional research may also provide a basis for collaboration with choral conductors looking to address vocal pathology in a group of individuals with different abilities and levels of experience.

BIBLIOGRAPHY

Arai, T. (2004). Formant shift in nasalization of vowels. *The Journal of the Acoustical Society of America*, *115*(5), 2541–2541. https://doi.org/10.1121/1.4783589

Atkinson-Clement, C., Sadat, J., & Pinto, S. (2015). Behavioral treatments for speech in Parkinson's disease: Meta-analyses and review of the literature. *Neurodegenerative Disease Management*, *5*(3), 233–248. https://doi.org/10.2217/nmt.15.16

Azekawa, M., & Lagasse, A. B. (2018). Singing exercises for speech and vocal abilities in individuals with hypokinetic dysarthria: A feasibility study. *Music Therapy Perspectives*, *36*(1), 40–49. https://doi.org/10.1093/mtp/miw042

Baumgartner, C. A., Sapir, S., & Ramig, L. O. (2001). Voice quality changes following phonatory-respiratory effort treatment (LSVT®) versus respiratory effort treatment for individuals with Parkinson disease. *Journal of Voice*, *15*(1), 105–114. https://doi.org/10.1016/S0892-1997(01)00010-8

Boersma, P., & Weenink, D. (2019). *Praat: Doing phonetics by computer* (Version 6.1.08) [Computer software]. http://www.praat.org

Bowen, L. K., Hands, G. L., Pradhan, S., & Stepp, C. E. (2015). *Effects of Parkinson's Disease on Fundamental Frequency Variability in Running Speech*. 17.

Braak, H., Tredici, K. D., Rüb, U., de Vos, R. A. I., Jansen Steur, E. N. H., & Braak, E. (2003). Staging of brain pathology related to sporadic Parkinson's disease. *Neurobiology of Aging*, *24*(2), 197–211. https://doi.org/10.1016/S0197-4580(02)00065-9

Buetow, S. A., Talmage, A., McCann, C., Fogg, L., & Purdy, S. (2014). Conceptualizing how group singing may enhance quality of life with Parkinson's disease. *Disability and Rehabilitation*, *36*(5), 430–433. https://doi.org/10.3109/09638288.2013.793749

Cannito, M. P., Suiter, D. M., Beverly, D., Chorna, L., Wolf, T., & Pfeiffer, R. M. (2012). Sentence intelligibility before and after voice treatment in speakers with idiopathic Parkinson's disease. *Journal of Voice*, *26*(2), 214–219. https://doi.org/10.1016/j.jvoice.2011.08.014

Clark, I., & Harding, K. (2012). Psychosocial outcomes of active singing interventions for therapeutic purposes: A systematic review of the literature. *Nordic Journal of Music Therapy*, *21*(1), 80–98. https://doi.org/10.1080/08098131.2010.545136

Coleman, S. L., & Stedman, J. M. (1974). Use of a peer model in language training in an echolalic child. *Journal of Behavior Therapy and Experimental Psychiatry*, *5*(3), 275–279. https://doi.org/10.1016/0005-7916(74)90078-0

Di Benedetto, P., Cavazzon, M., Mondolo, F., Rugiu, G., Peratoner, A., & Biasutti, E. (2009). Voice and choral singing treatment: A new approach for speech and voice disorders in Parkinson's disease. *Eur J Phys Rehabil Med*, *45*, 13–19.

Dong, J., Cui, Y., Li, S., & Le, W. (2016). Current Pharmaceutical Treatments and Alternative Therapies of Parkinson's Disease. *Current Neuropharmacology*, *14*(4), 339–355. https://doi.org/10.2174/1570159X14666151120123025

Dorsey, E. R., Constantinescu, R., Thompson, J. P., Biglan, K. M., Holloway, R. G., Kieburtz, K., Marshall, F. J., Ravina, B. M., Schifitto, G., Siderowf, A., & Tanner, C. M. (2007). Projected number of people with CME Parkinson disease in the most. *Neurology*, *68*(5), 3.

Duffy, J. R. (2005). *Motor speech disorders: Substrates, differential diagnosis, and management*.

Ebersbach, G., Ebersbach, A., Edler, D., Kaufhold, O., Kusch, M., Kupsch, A., & Wissel, J. (2010). Comparing exercise in Parkinson's disease-the Berlin BIG Study. *Movement Disorders*, *25*(12), 1902–1908. https://doi.org/10.1002/mds.23212

Ebersbach, G., Grust, U., Ebersbach, A., Wegner, B., Gandor, F., & Kühn, A. A. (2015). Amplitude-oriented exercise in Parkinson's disease: A randomized study comparing LSVT-BIG and a short training protocol. *Journal of Neural Transmission*, *122*(2), 253–256. https://doi.org/10.1007/s00702-014-1245-8

Elefant, C., Baker, F. A., Lotan, M., Lagesen, S. K., & Skeie, G. O. (2012). The effect of group music therapy on mood, speech, and singing in individuals with Parkinson's disease—A feasibility study. *Journal of Music Therapy*, *49*(3), 278–302. https://doi.org/10.1093/jmt/49.3.278

Fogg-Rogers, L., Buetow, S., Talmage, A., McCann, C. M., Leão, S. H. S., Tippett, L., Leung, J., McPherson, K. M., & Purdy, S. C. (2016). Choral singing therapy following stroke or Parkinson's disease: An exploration of participants' experiences. *Disability and Rehabilitation*, *38*(10), 952–962. https://doi.org/10.3109/09638288.2015.1068875

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state." *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Fox, S. H., Katzenschlager, R., Lim, S.-Y., Barton, B., de Bie, R. M. A., Seppi, K., Coelho, M., Sampaio, C., & on behalf of the Movement Disorder Society Evidence-Based Medicine Committee. (2018). International Parkinson and movement disorder society evidence-based medicine review: Update on treatments for the motor symptoms of Parkinson's disease: Treatment of Motor Symptoms in PD. *Movement Disorders*, *33*(8), 1248–1266. https://doi.org/10.1002/mds.27372

Gage, H., & Storey, L. (2004). Rehabilitation for Parkinson's disease: A systematic review of available evidence. *Clinical Rehabilitation*, *18*(5), 463–482. https://doi.org/10.1191/0269215504cr764oa

García-Casares, N., Martín-Colom, J. E., & García-Arnés, J. A. (2018). Music Therapy in Parkinson's Disease. *Journal of the American Medical Directors Association*, *19*(12), 1054–1062. https://doi.org/10.1016/j.jamda.2018.09.025

Ghaffari, B. D., & Kluger, B. (2014). Mechanisms for Alternative Treatments in Parkinson's Disease: Acupuncture, Tai Chi, and Other Treatments. *Current Neurology and Neuroscience Reports*, *14*(6), 451. https://doi.org/10.1007/s11910-014-0451-y

Green, P. M. (1999). Recent medical and surgical treatments for Parkinson's disease. *Perspectives on Gerontology*, *4*(1), 9. https://doi.org/10.1044/gero4.1.9

Haneishi, E. (2001). Effects of a music therapy voice protocol on speech intelligibility, vocal acoustic measures, and mood of individuals with Parkinson's disease. *Journal of Music Therapy*, *38*(4), 273–290. https://doi.org/10.1093/jmt/38.4.273

Harel, B. T., Cannizzaro, M. S., Cohen, H., Reilly, N., & Snyder, P. J. (2004). Acoustic characteristics of Parkinsonian speech: A potential biomarker of early disease progression and treatment. *Journal of Neurolinguistics*, *17*(6), 439–453. https://doi.org/10.1016/j.jneuroling.2004.06.001

Harris, R., Leenders, K. L., & de Jong, B. M. (2016). Speech dysprosody but no music 'dysprosody' in Parkinson's disease. *Brain and Language*, *163*, 1–9. https://doi.org/10.1016/j.bandl.2016.08.008

Higgins, A. N., & Richardson, K. C. (2018). The effects of a choral singing intervention on speech characteristics in individuals with Parkinson's disease: An exploratory study.

Communication Disorders Quarterly, 152574011878304. https://doi.org/10.1177/1525740118783040

Huber, J., Stathopoulos, E. T., Ramig, L. O., & Lancaster, S. L. (2003). Respiratory function and variability in Individuals with Parkinson disease: Pre- and post-Lee Silverman Voice Treatment. *Journal of Medical Speech-Language Pathology*, *11*, 185–201.

J. Holmes, Jennifer M. Oates, Debbi, R. (2000). Voice characteristics in the progression of Parkinson's disease. *International Journal of Language & Communication Disorders*, *35*(3), 407–418. https://doi.org/10.1080/136828200410654

Jacobson, B. H., Johnson, A., Grywalski, C., Silbergleit, A., Jacobson, G., Benninger, M. S., & Newman, C. W. (1997). The Voice Handicap Index (VHI): Development and Validation. *American Journal of Speech-Language Pathology*, *6*(3), 66–70. https://doi.org/10.1044/1058-0360.0603.66

Kalia, L. V., & Lang, A. E. (2015). Parkinson's disease. *The Lancet*, *386*(9996), 896–912. https://doi.org/10.1016/S0140-6736(14)61393-3

Lewis, S. J. G. (2005). Heterogeneity of Parkinson's disease in the early clinical stages using a data driven approach. *Journal of Neurology, Neurosurgery & Psychiatry*, *76*(3), 343–348. https://doi.org/10.1136/jnnp.2003.033530

Liu, P., Feng, T., Wang, Y., Zhang, X., & Chen, B. (2011). Clinical heterogeneity in patients with early-stage Parkinson's disease: A cluster analysis. *Journal of Zhejiang University SCIENCE B*, *12*(9), 694–703. https://doi.org/10.1631/jzus.B1100069

Ma, A., Lau, K. K., & Thyagarajan, D. (2020). Voice changes in Parkinson's disease: What are they telling us? *Journal of Clinical Neuroscience*, *72*, 1–7. https://doi.org/10.1016/j.jocn.2019.12.029

Marras, C., & Lang, A. (2013). Parkinson's disease subtypes: Lost in translation? *Journal of Neurology, Neurosurgery & Psychiatry*, *84*(4), 409–415. https://doi.org/10.1136/jnnp-2012-303455

Moya-Galé, G., & Levy, E. S. (2019). Parkinson's disease-associated dysarthria: Prevalence, impact and management strategies. *Research and Reviews in Parkinsonism, Volume 9*, 9–16. https://doi.org/10.2147/JPRLS.S168090

Novotný, M., Rusz, J., Čmejla, R., Růžičková, H., Klempíř, J., & Růžička, E. (2016). Hypernasality associated with basal ganglia dysfunction: Evidence from Parkinson's disease and Huntington's disease. *PeerJ*. Publicly Available Content Database. https://doi.org/10.7717/peerj.2530

Noyce, A. J., Bestwick, J. P., Silveira-Moriyama, L., Hawkes, C. H., Giovannoni, G., Lees, A. J., & Schrag, A. (2012). Meta-analysis of early nonmotor features and risk factors for Parkinson disease. *Annals of Neurology*, *72*(6), 893–901. https://doi.org/10.1002/ana.23687

Odekerken, V. J., van Laar, T., Staal, M. J., Mosch, A., Hoffmann, C. F., Nijssen, P. C., Beute, G. N., van Vugt, J. P., Lenders, M. W., Contarino, M. F., Mink, M. S., Bour, L. J., van den Munckhof, P., Schmand, B. A., de Haan, R. J., Schuurman, P. R., & de Bie, R. M. (2013). Subthalamic nucleus versus globus pallidus bilateral deep brain stimulation for advanced Parkinson's disease (NSTAPS study): A randomised controlled trial. *The Lancet Neurology*, *12*(1), 37–44. https://doi.org/10.1016/S1474-4422(12)70264-8

Onken, L. S., Carroll, K. M., Shoham, V., Cuthbert, B. N., & Riddle, M. (2014). Reenvisioning clinical science: Unifying the discipline to improve the public health. *Clinical Psychological Science*, *2*(1), 22–34. https://doi.org/10.1177/2167702613497932

Pacchetti, C., Mancini, F., Aglieri, R., Fundarò, C., Martignoni, E., & Nappi, G. (2000). Active music therapy in Parkinson's disease: An integrative method for motor and emotional rehabilitation. *Psychosomatic Medicine*, *62*(3), 386–393. https://doi.org/10.1097/00006842-200005000-00012

Pascal Auzou, Canan Ozsancak, Richa. (2000). Voice onset time in aphasia, apraxia of speech and dysarthria: A review. *Clinical Linguistics & Phonetics*, *14*(2), 131–150. https://doi.org/10.1080/026992000298878

Patel, R., Connaghan, K., Franco, D., Edsall, E., Forgit, D., Olsen, L., Ramage, L., Tyler, E., & Russell, S. (2013). "The Caterpillar": A novel reading passage for assessment of motor speech disorders. *American Journal of Speech-Language Pathology*, *22*(1), 1–9. https://doi.org/10.1044/1058-0360(2012/11-0134)

Quedas, A., de Campos Duprat, A., & Gasparini, G. (2007). Lombard's effect's implication in intensity, fundamental frequency and stability on the voice of individuals with Parkinson's disease. *Brazilian Journal of Otorhinolaryngology*, *73*(5), 675–683. https://doi.org/10.1016/S1808-8694(15)30129-4

Ramig, L., & Fox, C. (2007). Voice treatment for individuals With Parkinson's disease. *Perspectives on Gerontology*, *12*(1), 2. https://doi.org/10.1044/gero12.1.2

Ramig, Lorraine O, Sapir, S., Fox, C., & Countryman, S. (2001). Changes in vocal loudness following intensive voice treatment (LSVT) in individuals with Parkinson's disease: A comparison with untreated patients and normal age-matched controls. *Movement Disorders*, *16*(1), 5.

Ramig, Lorraine Olson, Countryman, S., O'Brien, C., Hoehn, M., & Thompson, L. (1996). Intensive speech treatment for patients with Parkinson's disease. *Neurology*, *47*(6), 1496. https://doi.org/10.1212/WNL.47.6.1496

Ramig, Lorraine Olson, Countryman, S., Thompson, L. L., & Horii, Y. (1995). Comparison of two forms of intensive speech treatment for Parkinson disease. *Journal of Speech, Language, and Hearing Research*, *38*(6), 1232–1251. https://doi.org/10.1044/jshr.3806.1232

Reagon, C., Gale, N., Enright, S., Mann, M., & van Deursen, R. (2016). A mixed-method systematic review to investigate the effect of group singing on health related quality of life. *Complementary Therapies in Medicine*, *27*, 1–11. https://doi.org/10.1016/j.ctim.2016.03.017

Ritz, B., Lee, P.-C., Lassen, C. F., & Arah, O. A. (2014). Parkinson disease and smoking revisited: Ease of quitting is an early sign of the disease. *Neurology*, *83*(16), 1396–1402. https://doi.org/10.1212/WNL.0000000000000879

Robertson, S. B., & Weismer, S. E. (1997). The influence of peer models on the play scripts of children with specific language impairment. *Journal of Speech, Language & Hearing Research*, *40*(1), 49. aph.

Rusz, J., Cmejla, R., Ruzickova, H., & Ruzicka, E. (2011). Quantitative acoustic measurements for characterization of speech and voice disorders in early untreated Parkinson's disease. *The Journal of the Acoustical Society of America*, *129*(1), 350–367. https://doi.org/10.1121/1.3514381

Rusz, Jan, Cmejla, R., Tykalova, T., Ruzickova, H., Klempir, J., Majerova, V., Picmausova, J., Roth, J., & Ruzicka, E. (2013). Imprecise vowel articulation as a potential early marker of Parkinson's disease: Effect of speaking task. *The Journal of the Acoustical Society of America*, *134*(3), 2171–2181. https://doi.org/10.1121/1.4816541

Sapir, S., Ramig, L. O., Hoyt, P., Countryman, S., O'Brien, C., & Hoehn, M. (2002). Speech loudness and quality 12 months after intensive voice treatment (LSVT®) for Parkinson's disease: A comparison with an alternative speech treatment. *Folia Phoniatrica et Logopaedica*, *54*(6), 296–303. https://doi.org/10.1159/000066148

Sapir, Shimon, Ramig, L. O., Spielman, J. L., & Fox, C. (2010). Formant centralization ratio: A proposal for a new acoustic measure of dysarthric speech. *Journal of Speech, Language, and Hearing Research*, *53*(1), 114–125. https://doi.org/10.1044/1092-4388(2009/08-0184)

Sapir Shimon, Spielman Jennifer L., Ramig Lorraine O., Story Brad H., & Fox Cynthia. (2007). Effects of intensive voice treatment (the Lee Silverman Voice Treatment [LSVT]) on vowel articulation in dysarthric individuals with idiopathic Parkinson disease: Acoustic and perceptual findings. *Journal of Speech, Language, and Hearing Research*, *50*(4), 899–912. https://doi.org/10.1044/1092-4388(2007/064)

Searl, J., Wilson, K., Haring, K., Dietsch, A., Lyons, K., & Pahwa, R. (2011). Feasibility of group voice therapy for individuals with Parkinson's disease. *Journal of Communication Disorders*, *44*(6), 719–732. https://doi.org/10.1016/j.jcomdis.2011.05.001

Sharkawi, A. E. (2002). Swallowing and voice effects of Lee Silverman Voice Treatment (LSVT(R)): A pilot study. *Journal of Neurology, Neurosurgery & Psychiatry*, *72*(1), 31–36. https://doi.org/10.1136/jnnp.72.1.31

Shih, L. C., Piel, J., Warren, A., Kraics, L., Silver, A., Vanderhorst, V., Simon, D. K., & Tarsy, D. (2012). Singing in groups for Parkinson's disease (SING-PD): A pilot study of group singing therapy for PD-related voice/speech disorders. *Parkinsonism & Related Disorders*, *18*(5), 548–552. https://doi.org/10.1016/j.parkreldis.2012.02.009

Spielman Jennifer, Ramig Lorraine O., Mahler Leslie, Halpern Angela, & Gavin William J. (2007). Effects of an extended version of the Lee Silverman Voice Treatment on voice and speech in Parkinson's disease. *American Journal of Speech-Language Pathology*, *16*(2), 95–107. https://doi.org/10.1044/1058-0360(2007/014)

Spurgeon, L., Clarke, C. E., & Sackley, C. (2015). Subjective experiences of speech and language therapy in patients with Parkinson's disease: A pilot study. *Rehabilitation Research and Practice*, *2015*, 1–11. https://doi.org/10.1155/2015/839895

Stathopoulos, E. T., Huber, J. E., Richardson, K., Kamphaus, J., DeCicco, D., Darling, M., Fulcher, K., & Sussman, J. E. (2014). Increased vocal intensity due to the Lombard effect in speakers with Parkinson's disease: Simultaneous laryngeal and respiratory strategies. *Journal of Communication Disorders*, *48*, 1–17. https://doi.org/10.1016/j.jcomdis.2013.12.001

Stegemöller, E.L., Hibbing, P., Radig, H., & Wingate, J. (2017). Therapeutic singing as an early intervention for swallowing in persons with Parkinson's disease. *Complementary Therapies in Medicine*, *31*, 127–133. https://doi.org/10.1016/j.ctim.2017.03.002

Stegemöller, Elizabeth L, Hurt, T. R., O'Connor, M. C., Camp, R. D., Green, C. W., Pattee, J. C., & Williams, E. K. (2017). Experiences of persons with parkinson's disease engaged in group therapeutic singing. *Journal of Music Therapy*, *54*(4), 405–431. https://doi.org/10.1093/jmt/thx012

Stegemöller, Elizabeth L., Radig, H., Hibbing, P., Wingate, J., & Sapienza, C. (2017). Effects of singing on voice, respiratory control and quality of life in persons with Parkinson's disease. *Disability and Rehabilitation*, *39*(6), 594–600. https://doi.org/10.3109/09638288.2016.1152610

Thaut, M. (2005). Neurologic music therapy in speech and language rehabilitation. In *Rhythm, music, and the brain: Scientific foundations and clinical applications* (pp. 165–178). Routledge.

Wan, C. Y., Rüber, T., Hohmann, A., & Schlaug, G. (2010). The therapeutic effects of singing in neurological disorders. *Music Perception, 27*(4), 287–295. https://doi.org/10.1525/mp.2010.27.4.287

Whitfield, J. A., & Goberman, A. M. (2014). Articulatory–acoustic vowel space: Application to clear speech in individuals with Parkinson's disease. *Journal of Communication Disorders, 51*, 19–28. https://doi.org/10.1016/j.jcomdis.2014.06.005

World Health Organization (Ed.). (2001). *International classification of functioning, disability and health: ICF*. World Health Organization.

World Health Organization. Division of Mental Health. (1996). *WHOQOL-BREF : introduction, administration, scoring and generic version of the assessment: Field trial version, December 1996*. *WHOQOL-BREF*. WHO IRIS. https://apps.who.int/iris/handle/10665/63529

Yinger, O. S., & Lapointe, L. L. (2012). The effects of participation in a group music therapy voice protocol (G-MTVP) on the speech of individuals with Parkinson's disease. *Music Therapy Perspectives*, *30*(1), 25–31. https://doi.org/10.1093/mtp/30.1.25

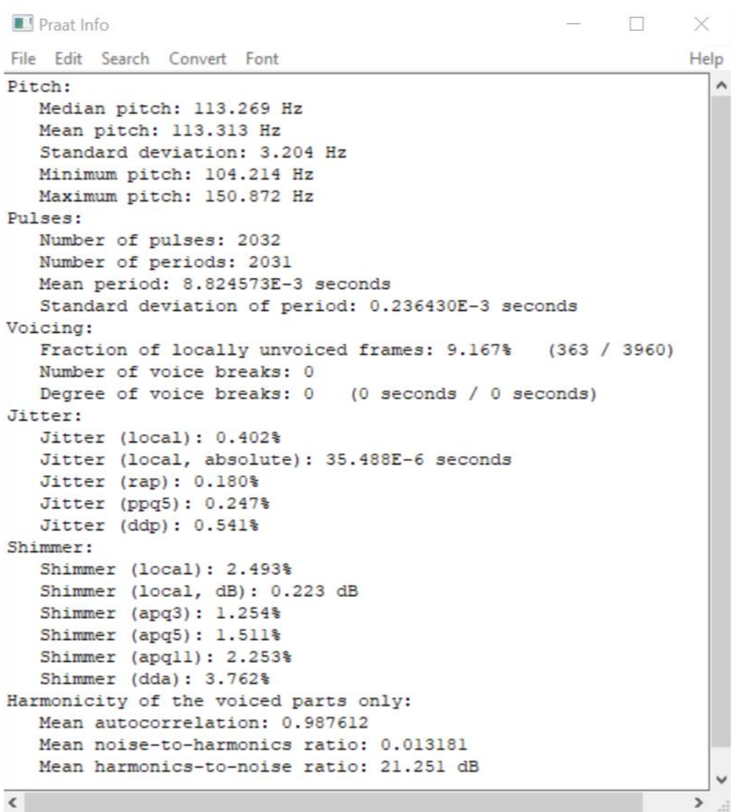
Yorkston, K., Beukelman, D., & Tice, R. (1996). *Sentence Intelligibility Test*. Tice Technologies.

APPENDICES

A. Chorus Repertoire

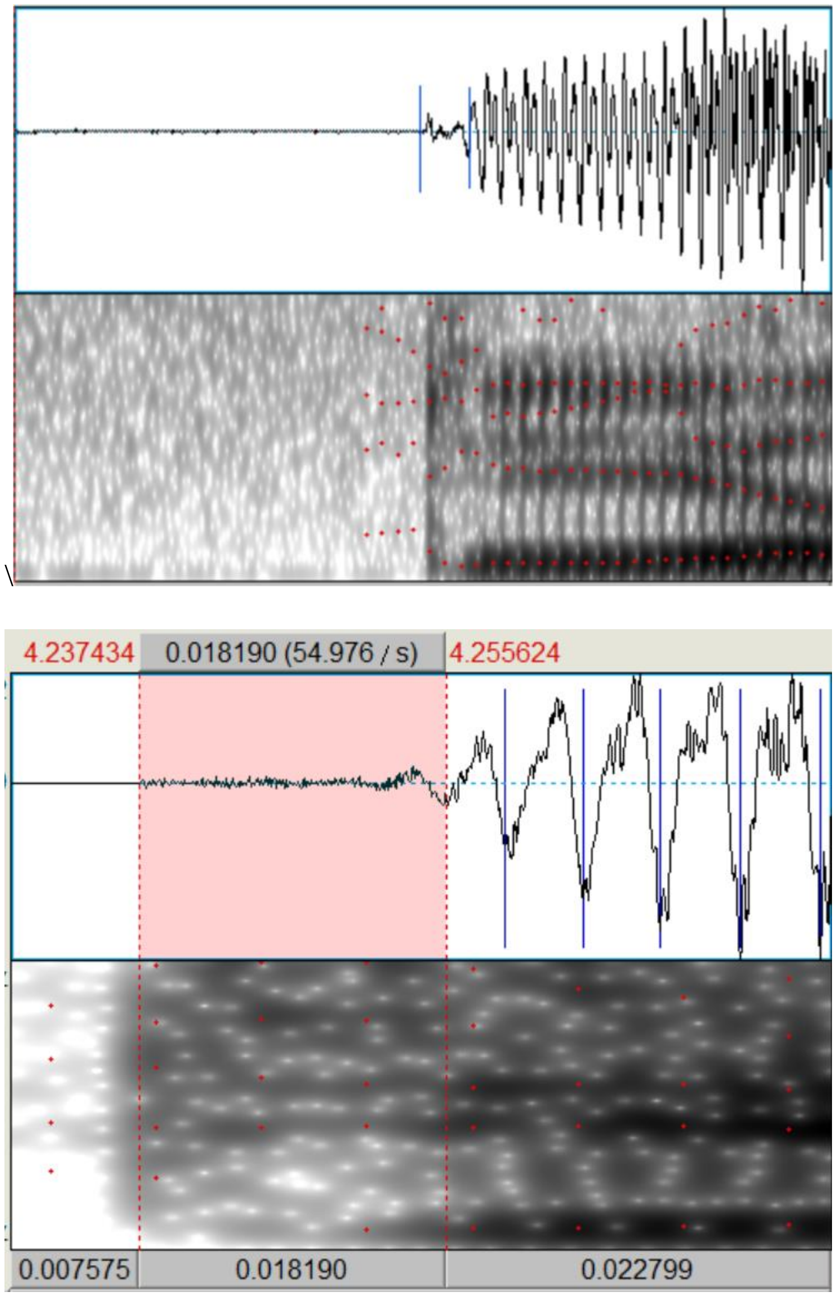
Song Title	Artist/Origin
Home on the Range	Kansas State Song
Do-Re-Mi	The Sound of Music
Can You Feel the Love Tonight?	Elton John
Tiny Dancer	Billy Joel
A Ram Sam Sam	Moroccan Children's Song
Bless the Broken Road	Rascal Flatts
L-O-V-E	Nat King Cole
Sweet Caroline	Neil Diamond
Hey, Ho Nobody Home	16th century carol
Don Gato	Children's song
Let it Be	The Beatles
Wannabe	Spice Girls
Country Roads	John Denver
Stand by Me	Ben E. King
16 Tons	Johnny Cash
Piano Man	Billy Joel
Over the Rainbow	The Wizard of Oz
My Girl	The Temptations
Dancing Queen	ABBA
Swing Low, Sweet Chariot	American Negro Spiritual
Bananas	Children's song

B. Sample Voice Report

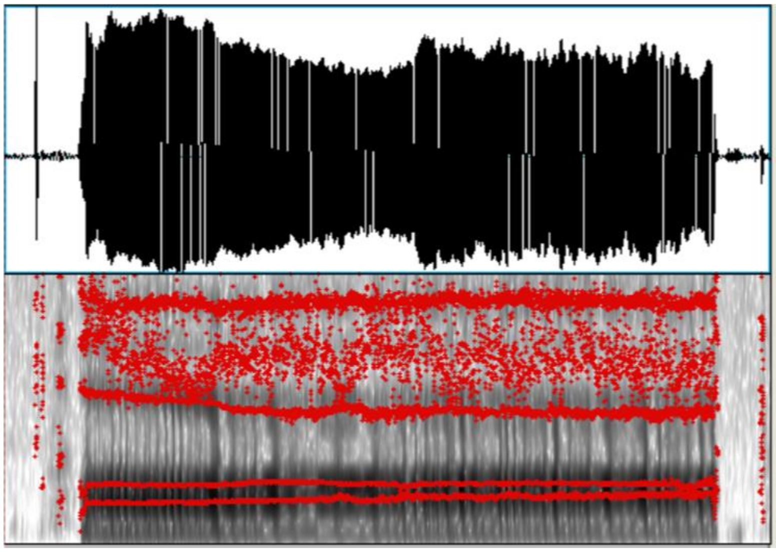



```
Pitch:
   Median pitch: 113.269 Hz
   Mean pitch: 113.313 Hz
   Standard deviation: 3.204 Hz
   Minimum pitch: 104.214 Hz
   Maximum pitch: 150.872 Hz
Pulses:
   Number of pulses: 2032
   Number of periods: 2031
   Mean period: 8.824573E-3 seconds
   Standard deviation of period: 0.236430E-3 seconds
Voicing:
   Fraction of locally unvoiced frames: 9.167%   (363 / 3960)
   Number of voice breaks: 0
   Degree of voice breaks: 0   (0 seconds / 0 seconds)
Jitter:
   Jitter (local): 0.402%
   Jitter (local, absolute): 35.488E-6 seconds
   Jitter (rap): 0.180%
   Jitter (ppq5): 0.247%
   Jitter (ddp): 0.541%
Shimmer:
   Shimmer (local): 2.493%
   Shimmer (local, dB): 0.223 dB
   Shimmer (apq3): 1.254%
   Shimmer (apq5): 1.511%
   Shimmer (apq11): 2.253%
   Shimmer (dda): 3.762%
Harmonicity of the voiced parts only:
   Mean autocorrelation: 0.987612
   Mean noise-to-harmonics ratio: 0.013181
   Mean harmonics-to-noise ratio: 21.251 dB
```

C. Sample Spectrograms

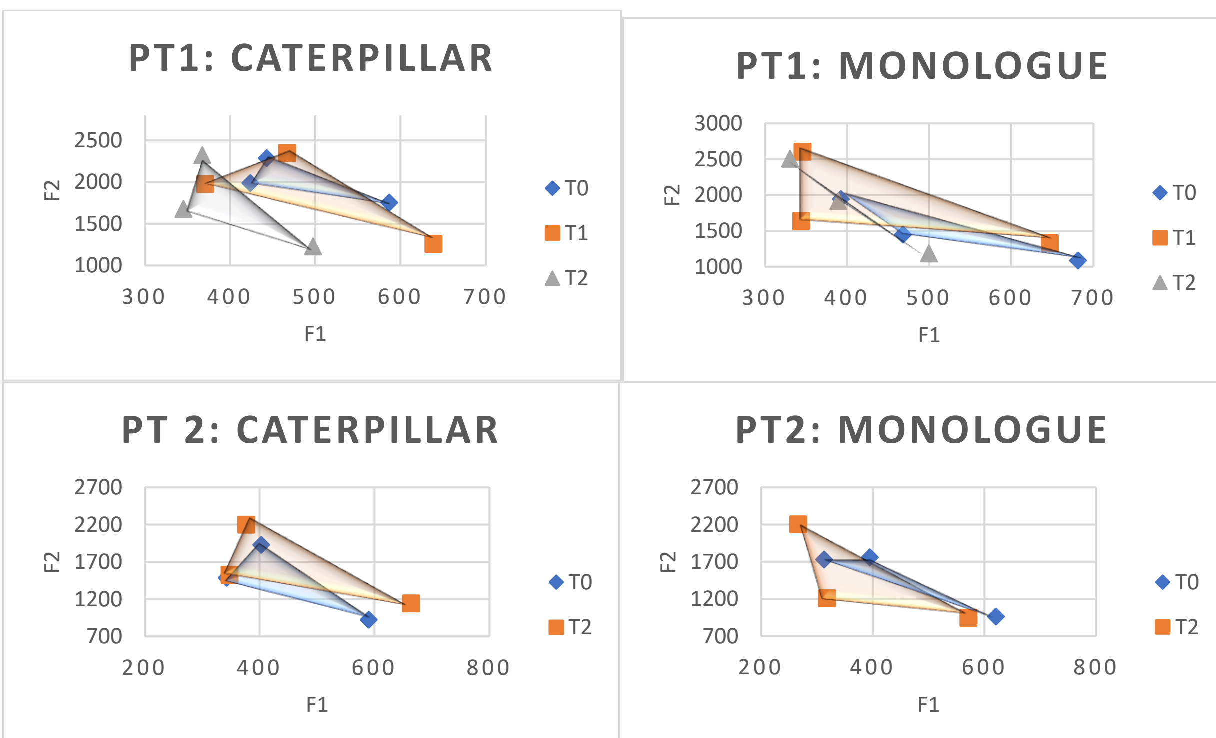


Spectrogram of the initial “do” of the Caterpillar Passage. Note the aperiodic burst of noise in the acoustic waveform (bounded by blue lines) followed by periodic voicing, from which VOT is derived. The second image zooms in to show a VOT of 18 milliseconds.

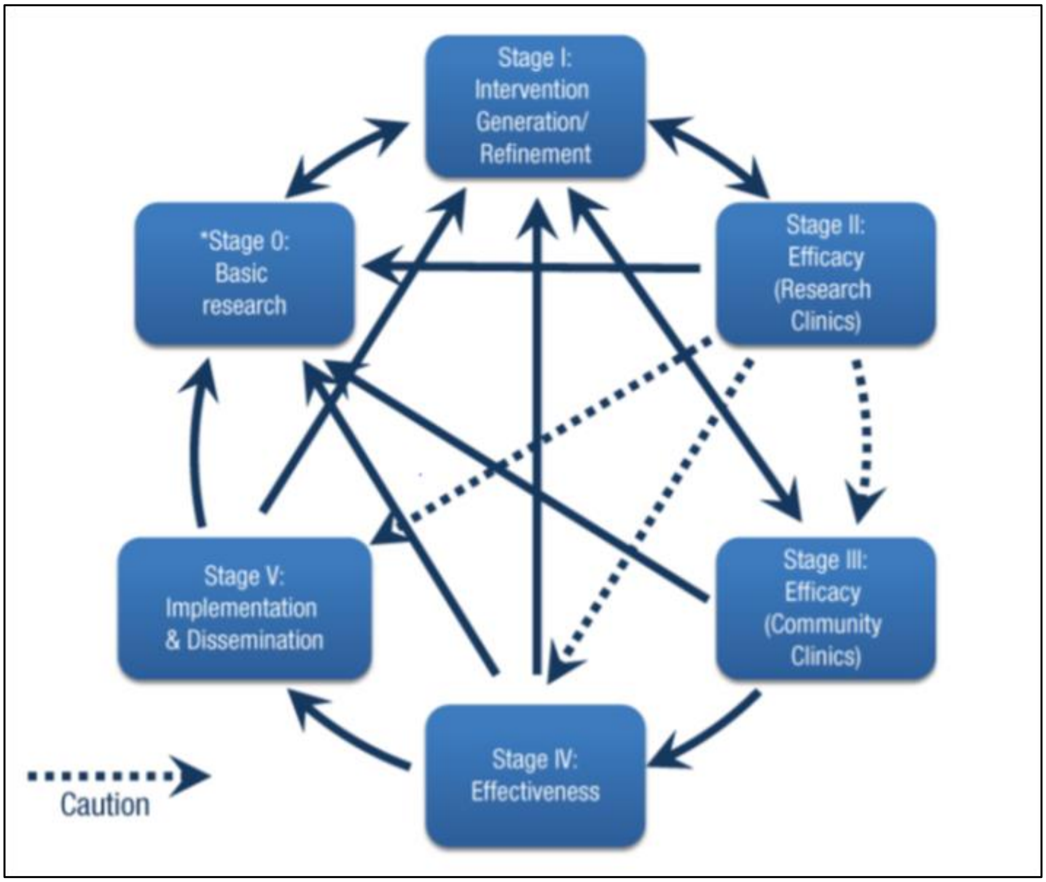


Spectrogram of sustained “ah”. Formants 1 and 2 (bottom two red lines) are clearly visible, and quite close to each other.

D. Triangular Vowel Space Graphs



E. NIH Staged Research Pathways



F. Caterpillar Passage

Do you like amusement parks? Well, I sure do. To amuse myself, I went twice last spring. My most MEMORABLE moment was riding on the Caterpillar, which is a gigantic rollercoaster high above the ground. When I saw how high the Caterpillar rose into the bright blue sky, I knew it was for me. After waiting in line for thirty minutes, I made it to the front where the man measured my height to see if I was tall enough. I gave the man my coins, asked for change, and jumped on the cart. Tick, tick, tick, the Caterpillar climbed slowly up the tracks. It went SO high I could see the parking lot. Boy was I SCARED! I thought to myself, “There’s no turning back now.” People were so scared they screamed as we swiftly zoomed fast, fast, and faster along the tracks. As quickly as it started, the Caterpillar came to a stop. Unfortunately, it was time to pack the car and drive home. That night I dreamt of the wild ride on the Caterpillar. Taking a trip to the amusement park and riding on the Caterpillar was my MOST memorable moment ever!