THE RELATIONSHIP BETWEEN MEASURES OF VOCAL FATIGUE METRICS AND PULMONARY FUNCTION TEST RESULTS

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ABSTRACT

THE RELATIONSHIP BETWEEN MEASURES OF VOCAL FATIGUE METRICS AND PULMONARY FUNCTION TEST RESULTS

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This research investigated the relationship between pulmonary function test metrics and vocal fatigue. Female participants underwent a two-day study, which included a screening, non-fatiguing and fatiguing tasks and pulmonary function testing. Subjective and objective measures indicating vocal fatigue were compared to pulmonary function measures. Subjective measures included participant's ratings of vocal fatigue on a 0-10 scale every 10 minutes throughout non-fatiguing and fatiguing tasks. Objective measures included variations of relative sound pressure level (SPL) and fundamental frequency (f_0) collected during both pre and post non-fatiguing and fatiguing tasks. Results indicated that the relationship between lung age and self-reported ratings of vocal fatigue were statistically significant ($p<0.05$). Variations in ΔSPL and f_0 that were collected during non-fatiguing and fatiguing tasks were both statistically significant ($p<0.001$) when compared to subjective ratings of vocal fatigue during the fatiguing task. Vocal tasks collected pre and post non-fatiguing and fatiguing tasks were not as sensitive to subjective ratings of vocal fatigue with ΔSPL compared to time ($p<0.05$) and f_0 compared to time ($p<0.05$). Data regarding pulmonary function and vocal fatigue call for continued study, as there are potential implications for use as a screening tool. Additionally, vocal measures collected during vocal fatiguing tasks are more indicative of vocal changes than pre and post non-fatiguing and fatiguing measures.

I would like to dedicate this thesis to my family who has supported me throughout all my endeavors at Michigan State University. I couldn’t have done it without you.

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KEY TO ABBREVIATIONS

BFI-10: Big Five Inventory-10

dB: Decibel

D1: Day 1

D2: Day 2

f_0: Fundamental Frequency

FEV1: Forced Expiratory Volume in the 1st second

FVC: Forced Vital capacity

Hz: Hertz

LME: Linear Mixed Effect

PEF: Peak Expiratory Flow

PFT: Pulmonary Function Test

REML: Restricted Maximum Likelihood

SPL: Sound Pressure Level

V-RQOL: Voice-Related Quality of Life Measure

VFI: Vocal Fatigue Index

VHI-10: Voice Handicap Index-10

ΔSPL: Change in Sound Pressure Level

CHAPTER 1: INTRODUCTION

There is a large sector, 25% or more of the working population in the United States, known as professional voice users who rely on voice use as an essential function of their job (National Center for Voice and Speech, 1993). These “occupational voice users” (e.g., teachers, counselors, telephone workers) that depend on vocal endurance and vocal quality are impacted by voice disorders, vocal limitations, and vocal fatigue, more frequently than the general population (Titze, 1997). The consequences implicated by voice problems, for example dysphonia (i.e. dysfunction in the ability to produce voice), are important and have a significant impact on job performance and quality of life (Verdolini & Ramig, 2001). Solomon (2008) discussed this “The obvious impact of dysphonia on lost wages and productivity has motivated researchers in many countries to study occupational voice” (p. 259).

Teachers are one group of professional voice users with an elevated incidence of voice problems (Roy et al., 2004), representing up to 76% of voice clinicians’ referrals (Morton & Watson, 1998). One study suggests that these issues cost an estimated two billion United States Dollars annually (Verdolini & Ramig, 2001). Smith, Kirchner, Taylor, Hoffman, and Lemke confirmed that within the teaching occupation females reported a higher rate of gender-related vocal symptoms (1998). This is a similar trend with other high voice use occupations where women make up the primary workforce. Women may be nearly twice as likely to report a history of voice problems (Roy, Merrill, Gray, & Smith, 2005), a finding that was consistent across the age span (Roy et al., 2004).

1.1 Vocal Fatigue Symptoms

A common complaint in populations with voice problems, such as teachers, is vocal fatigue. Vocal fatigue has been identified as a multifaceted voice problem; its limitations can come from several different functional problems in physiological and anatomical systems (i.e. the muscular system, the nervous system and the respiratory system). This is discussed in greater detail by Solomon (2008) and is referred to in several instances below. However, there is no universally accepted definition of vocal fatigue. Generally, vocal fatigue can be described as the worsening of one's voice with consistent use over an extended period of time, such as during the course of a day or over consecutive weeks. Parameters to measure the change in voice can include pitch, loudness, quality, etc. Verdolini, Rosen, Branski, Andrews, and the American Speech-Language-Hearing Association (2006) defined vocal fatigue as a feeling of local tiredness and weak voice after a period of voice use. In a comprehensive review of current vocal fatigue research, Welham and Maclagan (2003) stated "while a link between vocal fatigue and other laryngeal pathologies is plausible, it is unclear whether vocal fatigue primarily contributes to, results from, or exists independently of other voice conditions" (p. 22). Nevertheless, while the underlying pathophysiology of vocal fatigue is unclear, previous research has identified several symptoms that generally accompany it. Solomon (2008) identified these symptoms from the literature "(1) increased vocal effort and discomfort, (2) reduced pitch range and flexibility, (3) reduced vocal projection or power, (4) reduced control of voice quality, (5) an increase in symptoms across the speaking day, and (6) improvement after resting" (p. 254-255).

Supporting these symptoms and descriptions of vocal fatigue are different physiological and biomechanical mechanisms contributing to this multifaceted problem (Titze, 1984 & 1994). In one discussion of the physiological source, Titze (1999) highlights two possible types of vocal fatigue: laryngeal muscle fatigue and laryngeal tissue fatigue. Welham and Maclagan (2003) pointed out several different areas of research that have been conducted studying the symptoms of fatigue: neuromuscular fatigue, increased vocal fold viscosity, reduced blood circulation to the vocal folds, nonmuscular tissue strain, and respiratory muscle fatigue. Varying descriptions, a multitude of underlying factors and symptoms, and behavioral and individual differences have made it difficult to come to a consensus on vocal fatigue and its source. Research questions regarding fatigue have yet to be answered concretely by researchers indicating a need for continued exploration into this elaborate vocal problem. Additionally, Hunter, Tanner, and Smith (2011) identified several components mentioned above which may contribute specifically to women's higher level of vulnerability to voice disorders: anatomical differences in the laryngeal systems, the impact of the endocrine system (e.g., hormones), non-laryngeal differences (e.g., pulmonary), and gender dependent non-physiological and behavioral differences (e.g., stress reactions). These conclusions highlight a need to focus on the female population when researching voice problems.

1.2 Previous Studies of Vocal Fatigue

Several studies have been conducted in an effort to induce fatigue for the purpose of studying the changes in voice post vocally fatiguing tasks and the potential underlying mechanisms. Teachers are often required to speak for long periods of time with few breaks at an elevated voice level (e.g., high vocal load). Hunter and Titze (2009) suggested an experimental model called a vocal loading task where reading or speaking is maintained over a prolonged period of time and can be used to induce vocal fatigue. In absence of a direct measure for vocal fatigue, combinations of subjective and objective measures have been used in previous research to investigate fatigue, which include: acoustic measures, aerodynamic measures, and self-ratings by subjects who indicated fatigue. As Boucher and Ayad (2010) pointed out "One can no more assess the validity of subjective scales than that of acoustic signs of vocal fatigue without some estimate of the physiological condition of fatigue as it relates to structures of the voice system" (p. 324).

Solomon (2008) stated that individuals who experience vocal fatigue have an impression regarding its definition and how it feels. For example, Laukkanen and colleagues (2004) used a questionnaire about throat and voice symptoms, given to participants to help assess the impact of a vocal loading task. However, these impressions are, as previously stated, subjective; and, while they have clinical relevance for treatment, verification of the presence of vocal fatigue cannot be determined using only this measure. The complexity of evaluating fatigue requires multiple supports to accurately identify its existence. Therefore, in an attempt to quantify self-reports of vocal fatigue and other subjective measures, assessment of vocal fatigue has been investigated with the implication of acoustic and physiological measurements.

Laukkanen, Ilomäki, Leppänen, and Vilkman (2008) studied 79 female primary school teachers using a mixture of acoustic measures and self-reports of vocal fatigue. They analyzed the outcomes of female teachers prior to and following their typical workday and analyzed their speaking samples for fundamental frequency (f_0), sound pressure level (SPL), phonation type reflecting alpha ratio, and perturbation values (i.e. jitter and shimmer). The authors concluded that there was an increased value in the acoustic measures stated above evident after a working day; hence, the teacher's voices were more dysphonic. In another study of vocal fatigue, Vilkman, Lauri, Alku, Sala, and Sihvo (1999) also used acoustic measures as well as subglottal pressure and glottal flow waveform parameters. Again, consistent with other research findings, all acoustic measures increased after a period of vocal fatigue. The literature reflects that vocal fatigue results in acoustic changes but there is disagreement regarding what parameters should be used for assessment, as evidenced by the variety of measures mentioned in the studies above. However, besides these observable acoustic changes there may be a physiologic change in the vocal mechanisms that alter how people sound.

Other attempts to quantify the presence of vocal fatigue have implicated physiologic measures. Boucher, Ahmarani, and Ayad (2006) used intramuscular electromyograghy (EMG) spectral compression to observe whether laryngeal muscles fatigued as a result of prolonged vocal effort. Spectral compression was evidenced for all subjects proving that it is a reliable measure for a physiologic feature, muscle changes, and indicative of excessive vocalization. Boucher and Ayad (2010) conducted a three-part study, building on their research in 2006, in an attempt to define the physiologic features of vocal fatigue. In the study, electromyographic (EMG) observations demonstrated fatigue of laryngeal muscle fatigue after a vocal loading task with evidence for signs of tremor, which was indicative of increased vocal effort. However, after systematic vocal loading and confirmation of muscle fatigue there were no relationships with acoustic parameters. This poses the question whether the acoustic parameters currently being used to assess vocal fatigue are an accurate representation of laryngeal muscle responses. Putting all these measures together, researchers have still struggled to identify decisive information about this vocal problem. As stated by Hunter and Titze (2009), "Buekers (1998) found that vocal fatigue could not be conclusively identified using self-ratings of pain and fatigue, electroglottography (EGG), standard acoustic metrics (i.e., the Multi-Dimensional Voice Program), or pitch/loudness measures (monitored throughout the day on a subset of subjects)" (p. 3).

Presently, there is clear evidence that none of these measures alone are able to concretely identify vocal fatigue in an individual. While a person can indicate subjectively where they are feeling the effects of fatigue, this does not offer a standard measure among all individuals. Acoustic measures do show statistical correlation with subjective measures of fatigue, but varying acoustic parameters are used without agreement on the best one. Simultaneously, acoustic measures do not always correlate with physiologic measures that have been shown to identify fatigue. Research across the field of voice identifies a multitude of potential physiologic features that may be impacting vocal fatigue, with some causes having small amounts of evidential support and others being speculative. Solomon, Glaze, Arnold, and Mersbergen (2003) stated that there has been an increase in research to assist in "the development of methods and procedures that detect important changes in vocal function after vocally fatiguing tasks. These have included questionnaires, acoustic measures, laryngeal videostroboscopy, and aerodynamic measures" (p. 31-32).

To this end, a multifaceted problem like vocal fatigue requires exploration into several possible areas of human communication that it impacts. There is clear identification of a portion of the population that is most susceptible to fatigue and some of the evidenced symptoms. Additionally, defining and implementing the necessary measures and systems tied to fatigue has continued to improve. However, there is still a void regarding some of the physiologic and anatomical factors that could be contributing to vocal fatigue. This research could help to fill in some of the gaps in the current literature to give a more complete picture of the problem of vocal fatigue.

1.3 The Gap

Of all the plausible physiological systems that could contribute to vocal fatigue, little research has been done to investigate the significance of respiratory support, speech breathing and proper breath support and what its potential role may be. The general mechanism of the speech system can be thought of in three subsystems, though not independent: the lungs, the vocal folds and the vocal tract. The lungs act as the pump of the system and are needed to provide airflow to vibrate the vocal folds. This is necessary to produce energy for the system and fuel the voice. Airflow from the lungs comes up through the vocal folds causing a wave-like motion in the vocal folds producing vibration and thus voicing. Next, the vocal tract makeup of the tongue, palate, cheek and lips shape and filter the frequencies that create to make specific phonemes. These three components have to work together harmoniously to facilitate the coordination of the speech processes respiration, phonation, articulation and resonance. A more detailed description of voice production can be found elsewhere (Titze, 1994).

As explained above, the coordination of respiratory control and breath support in the lungs is key for subglottal air pressure and airflow necessary to phonate. Past researchers, (Welhman & Maclagan, 2003), have discussed the contribution of respiratory muscle fatigue in vocal fatigue. They commented, "Titze (1984 & 1994) suggests that respiratory muscle fatigue, resulting in reduced subglottal pressure capacity, may be a further contributing mechanism in the onset of vocal fatigue" (2003, p. 24). However, simultaneous functioning of the laryngeal and respiratory mechanisms is needed to produce adequate vocal intensity and the voice-voiceless contrast of consonants in the English Language. If there is poor breath support then laryngeal compensation is necessary; and, inadequate breath support initially will produce suboptimal vocal fold vibration causing fatigue to occur at a higher rate. Stathopoulos and Sapienza (1993) stated "Respiratory results indicate that tracheal pressure, percent rib cage contribution, lung volume, and rib cage volume initiations are higher, and lung and rib cage volume excursions are larger when higher vocal intensity levels are produced" (p. 64). While clinically discussed, limited studies have touched on the adequate breath support that supply the energy needed for good vocal fold vibration.

A general lack of breath support could be caused by lung function problems, such as disease or illness, or smaller than average lung size, which can be different among individuals, and may lead to vocal dysfunction. Iwarsson, Thomasson, and Sundberg (1998) studied the impacts of lung volumes relative to glottal voice source characteristics and definitively showed that respiration affects phonation. "We found higher subglottal pressure, greater flow amplitude, a lower closed quotient, greater glottal leakage, and greater relative estimated glottal area at high as compared to low LV (lung volume)" (Iwarsson et al., 1998, p. 430). Hunter and colleagues hypothesized something similar to this potential relationship within females, who are at greater risk for voice problems.

Hunter et al. (2011) stated "To maintain voicing with insufficient airflow, these women would have to compensate with increase laryngeal adduction, creating more contact force per unit area on the medical edges of the folds, which is ultimately a less healthy vocalization style" (p. 131). Further research has indicated that healthy lung function and capacity is associated with reduced vocal complaints. For example, Maxfield, Hunter, and Graetzer (2016) collected data from 122 teachers and showed that the Vocal Fatigue Index (VFI) (Nanjundeswaran, Jacobson, Gartner-Schmidt, & Verdolini Abbott, 2015) was a predictor to several spirometry measures in female teachers. While this study showed a moderate relationship between spirometry and vocal fatigue complaints, the later was only quantified by response to questions and not from actual changes (real or perceived) of vocal fatigue due to vocal loading.

1.4 Research Questions and Hypothesis

This study builds on the concept that breath support may affect vocal fatigue. Previous studies have implied a connection between lung function and breath support as well as breath support and vocal fatigue. Pulmonary function tests (PFTs) may give insights into a connection between lung volumes/function and vocal fatigue. Therefore, the research question for the study is as follows: To what degree (i.e., the magnitude of correlation) do PFT results relate to the extent of vocal fatigue from a fatiguing task?

In addressing this question, it was hypothesized that otherwise healthy individuals with lower PFT results indicating smaller lung volumes or lung utilization will have greater vocal fatigue (shown through measures of vocal effort and quality) compared to individuals with higher PFT results indicating average or larger than average lung volumes. Values from PFT results were compared against normative values of age, race, sex, and body size for each individual participant. To test the hypothesis and answer the question above, research participants took part in a vocal loading experiment. Within the experiment, the extent of vocal fatigue from the participants' voice samples during a vocal loading task were quantified via subject response and acoustic analysis and then compared to PFT results.

CHAPTER 2: METHODS

This study addressed the research question by having participants complete a vocal fatiguing task and a PFT. Objective and subjective measures related to vocal fatigue were used to compare against metrics of pulmonary function tests. Each measure introduced in the methods will be discussed in detail in the following chapter. To be eligible, participants underwent several screening and baseline measures, including a videoendoscopic exam. The Michigan State University Institutional Review Board approved study procedures outlined below. Written informed consent was obtained from each participant prior to beginning the study.

2.1 Research Participants

College-aged female participants were recruited for the study. This was due to the high propensity of vocal fatigue among women compared to men as reported in the literature, and by the results of Maxfield et al. (2016) where vocal fatigue complaints among female teachers significantly correlated to PFT metrics. There was no affect found among the male teachers in the study. The goal was to have 10 participants complete the study. This number was based on the previous results from studies done by Bottalico (2016) and Cutiva, Puglisi, Astolfi, and Carullo (2017) from which two different power analyses were calculated based on dB SPL of teacher's voices who were experiencing vocal fatigue. A balanced one-way analysis of variance power calculation showed that with 10 subjects a statistical power of 80% and a significance level of $p < 0.01$ was reached using both studies. The outcome used was the standard deviation f_0. Therefore, a total of ten college-aged females ranging from 18-40 years of age, participated in the entire study.

2.2 Inclusion and Exclusion Criteria

Only participants with no self-reported past vocal, speech, pulmonary or hearing problems that required intervention of a speech-language pathologist or other physician were accepted into the study. Vocally and athletically trained individuals, at the college level, and non-native English speakers were also excluded.

Study participants were required to meet inclusion and exclusion criteria from the Day 1 (D1) screening. Initially, participants were screened via a rigid oral endoscopic exam to ensure there are no apparent laryngeal abnormalities. Additionally, a recording of standard vocal tasks, breathing screening and hearing screening were conducted. If participants failed any of these three screenings they were excluded. Participants were asked about allergies and over the counter or prescribed medications, which may affect the respiratory system or airway. Common antihistamines for allergies can have a drying effect on the vocal folds or slightly adjust vocal fold quality, which was important to note. This included abnormalities such as a participant present with allergies, medications affecting vocal hydration, history of gastroesophageal reflux disease (GERD), benign lesions and upper respiratory tract infections. However, participants who answered "yes" to any of these questions were not excluded from the study. If after day one, any screening results excluded a participant from the study they were given appropriate compensation but not asked not to return for the remainder of the study. New participants were recruited and screened until a total of 10 participants successfully completed the study.

2.3 Procedure

The study was split into two days for each subject. Below is a short summary of each day. The goal of participation was to obtain PFT metrics that could be compared to subjective and objective measures of vocal fatigue. This included self-ratings of vocal fatigue, SPL and f_0 based on measures extracted from recordings as detailed below.

2.3.1 Day 1: Screening and Baseline Measures

On the initial day, participants completed a consent form, a baseline vocal recording, standard vocal health questionnaires, an endoscopic exam, a hearing screening and a breathing screening. After these screening and baseline procedures, participants engaged in a non-fatiguing task, where subjective fatigue ratings were gathered as well as pre and post vocal recordings, and a PFT.

After given appropriate information including risks and benefits of the study participants provided written consent to begin. An endoscopic exam was performed on all participants to verify vocal fold motility and lack of apparent laryngeal abnormalities. Participants completed a set of vocal and speech recordings as a baseline measure prior to the non-fatiguing task. They then began the non-fatiguing task for 30 minutes where the participant regularly rated their vocal fatigue level. During the non-fatiguing task, participants completed a breathing screening, hearing screening, and electronic vocal health surveys. These tasks were conducted within the non-fatiguing task since they only required a minimal amount of speaking by the participants, not enough to induce vocal fatigue, and decreased the overall run time of the study. The participants then completed a second set of vocal and speech recordings at the end of the non-fatiguing task. A PFT was then conducted with the use of a spirometer to complete the participation of D1.

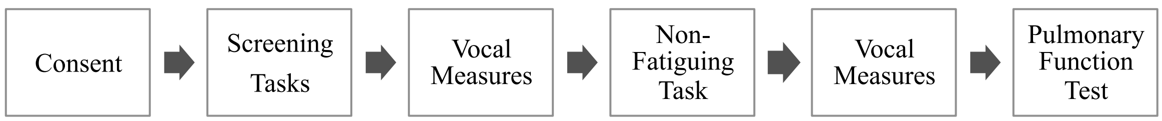

Figure 1. Diagram of Flow: Day 1, showing the tasks participants shared in.

2.3.2 Day 2: Vocal Loading Measures

On Day 2 (D2) of the study, participants again completed a PFT as well as the same set of vocal and speech recordings as done in D1. Next the participants read aloud in a vocal loading task for the same duration of time as the non-fatiguing task (30-mintues) and regularly rated their vocal fatigue level throughout. After the fatiguing task, participants again performed the same short vocal recordings as before followed by a PFT.

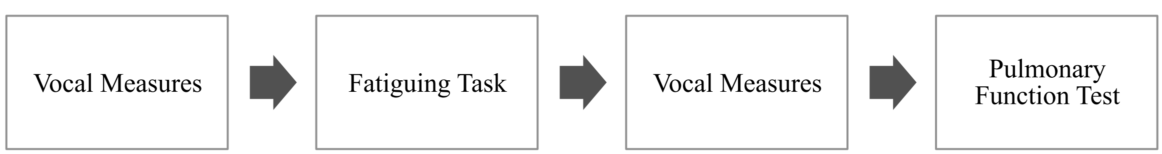

Figure 2. Diagram of Flow: Day 2, showing the tasks participants engaged in.

CHAPTER 3: MEASURES

To reiterate, the research question being investigated was the relationship between PFT results and measures of vocal fatigue. In order to understand this possible connection, objective measures from vocal recordings and subjective measures were quantified for comparison with spirometry metrics. The objective measures pulled from vocal recordings were collected pre and post non-fatiguing and fatiguing tasks and included f_0 and variations of SPL. Subjective measures were collected during non-fatiguing and fatiguing tasks and were participant's response to the statement: "My vocal fatigue level is…." (on a 0 to 10 scale). Thus, the independent variable within this research study was the variation of pulmonary function results (lung volumes and capacities) and the dependent variable being studied was the measure of change that was observed in subjective and objective tasks that represent fatigue.

3.1 Screening Tasks

While not specifically part of the research question, the participants filled out electronic vocal health related questionnaires. The survey responses were collected via Qualtrics Survey Software and included: the Voice Handicap Index-10 (VHI-10), the Voice-Related Quality of Life Measure (V-RQOL), the VFI and the Big Five Inventory - 10 (BFI-10) (see Appendices). Additionally, participants underwent a endoscopic screening exam, a breathing screening and a hearing screening.

A rigid oral endoscopy was used to identify any anatomical or laryngeal anomalies that could potentially affect the study participants. A rigid endoscope was coupled with a digital camera and stroboscopic light source to view the larynx and vocal folds. All equipment was disinfected and sterilized with 2.4 percent Gluteraldahyde prior to each use. A licensed and clinically certified speech-language pathologist supervised the experimenter performing the examination.

A general respiratory assessment was given to determine different types of breathing that participants might exhibit and whether their participation was appropriate for the study. The breathing types assessed included: (1) diaphragmatic (an inhale pushes the abdomen outwards); (2) thoracic (during inhale the chest expands anteriorly to accommodate the air that fills the lungs); (3) clavicular (during inhale the clavicle goes up to accommodate the air that has been sucked into the upper part of the lungs); (4) paradoxical (the chest compresses on the inhale rather than expands and vice versa). Participants who exhibited clavicular or paradoxical breathing patterns were excluded from the study because of the abnormality of these breathing types. The type of respiration cycle in the absence of speech, which can be oral-oral, nasal-nasal, and oral-nasal, were marked. Coordination of respiration and voice was the final component of the breathing screening which was marked adequate or inadequate based on the participants performance. Lack of coordination also excluded participants from the study.

A brief hearing screening was completed to ensure that participants' hearing was adequate for inclusion in the study. A bilateral hearing screening was conduced at 25 dB at frequencies of 125 Hz, 250 Hz, 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz and 8,000 Hz. If participants failed to respond to tones at any of these frequencies they were excluded from the study.

3.2 Independent Variables

A PFT was conducted with the use of an electronic *CareFusion* microlab spirometer and software program (SpiroUSB Model BZG, Micro Direct; Lewiston, ME) to assess, collect and record data about participant's lung function. This was done on the initial and second days of the study. To obtain accurate standardization results in post-test analysis participant's height, age, smoking history, gender, and race were recorded within the system prior to the test. Standards by Wang, Dockery, Wypij, Fay, and Ferris (1993) and Hankinson, Odencrantz, and Fedan (1999) were used to determine the range of percentage of normal for pulmonary function measures.

For the duration of the test, participants were seated in an upright position and asked to wear a nose clip. The experimenter provided a demonstration for participants and then asked them to perform a trial to confirm correct execution. Participants were provided the following instructions: "Please inhale as much and as deeply as you can as quickly as you can. Then, exhale as fast as you can pushing all the air out of your lungs. Do not pause between the inhalation and exhalation. Feel free to use the rest of your body to more as much air as possible." The *CareFusion* program required three attempts of results within 5% of each other to confirm accurate PFT results from the participant. If participants were unable to produce three attempts within 5% percent of each other after six trials, the next three closets attempts to the target were selected for analysis. The experimenter provided verbal motivation and coaching through encouraging phrases as necessary to elicit the best possible effort to produce accurate measurements of the PFT.

The measures collected included, but were not limited to, forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), peak expiratory flow (PEF) and predicted lung age. FVC, measured in liters, is the lung complete capacity that can be forcibly exhaled by someone after his or her deepest breath possible. FEV1, measured in liters, is the forced expiratory volume in 1st second of exhalation. PEF, measured in liters per second, is the maximum flow during expiration when produced with force. Predicted lung age, measured in years, is the based on a participant's lung function as measured during a pulmonary function test. An equation is used to calculate predicted lung age and often involves FEV1 compared to norms for the individual. These specific measures have been chosen for review based on results from Maxfield et al. (2016), which showed correlation between spirometery measures and participants' responses in the vocal fatigue index. Subjects were allowed to view spirometery results following their PFTs. They were not informed of the hypothesis of the study at any point during the experiment to avoid any potential bias of their self-rated responses.

3.3 Dependent Variables

Subjective Fatigue Rating: Participants' self-reported perception of their current vocal fatigue level was indicated via verbal response on a scale from zero to 10. They were instructed that a rating of zero indicated no sensation of vocal fatigue while a rating of 10 indicated the greatest level of vocal fatigue. The rating was elicited via the statement "My vocal fatigue level is…" throughout non-fatiguing and fatiguing tasks every 10 minutes during D1 and D2 of the study.

Objective Voice Metrics: Voice metrics were obtained from participants voice recordings taken before and after the non-fatiguing and fatiguing task as well as from the self-reported vocal fatigue ratings. Participants were asked to orally describe a picture

(Diapix) and to read aloud a standard passage (The Rainbow Passage, Appendix K). In the Diapix task, participants were given a picture scene and asked to describe its image to an unfamiliar listener for 40 seconds (Baker & Hazan, 2011). For the reading passage, participants were asked to read first paragraph of The Rainbow Passage. They were recorded with a head mounted microphone (Glottal Enterprises, M80) and a portable digital recorder (Roland). From these recordings, objective vocal measures were calculated, namely f_0 and SPL. A participant's vocal pitch is associated with the measure f_0, measured in hertz (Hz), and represents the number of vocal fold collisions per second (Hunter & Titze, 2010). SPL is a ratio of the sound pressure and a reference level, usually the human threshold of hearing, and is a physical reference for a participant's vocal intensity, which is measured in decibels (dB). An increase in SPL can imply an rise in vocal fold intensity or larger vocal fold stress (Hunter & Titze, 2010).

3.4 Non-Fatiguing and Fatiguing Tasks

A non-fatiguing task was completed during D1 and used as a control for participants to compare to their fatiguing task on D2. In both tasks, participants were asked to attend to the software program for the same 30-minute period of time. During the control vocal loading task, participants were asked to remain essentially silent, except to respond with one to two word answers, while completing a breathing screening and a hearing screening. Additionally, at four different time points (0 minutes, 10 minutes, 20 minutes and 30 minutes) in the non-fatiguing participants were asked to verbally respond to the subjective statement "My vocal fatigue level is…".

As an experimental task to compare to the non-fatiguing task, all participants completed a vocal loading test using the *lingWAVES* program (Version 3.0; Wevosys, 2014). Prior to the start of the program, participants were given instructions to ensure their comprehension of the task as well as reading material for the test. For this particular experiment Charlotte's Web by E.B. White (2012) was selected as the reading material because of its popularity in classic fiction, elementary reading level and opportunity to use increased prosody when reading the text. The experimental vocal loading task required subjects to complete the protocol listed in the following paragraph.

As stated, the *lingWAVES* system was used to conduct the vocal fatiguing task and collect data, specifically in vocal load test module setting. The system provided a very clear module for participants to follow in an attempt to induce vocal fatigue. During the 30-minute test dB SPL goals, vocal intensity measures, alternated between 66 dB and 72 dB, every five minutes, based on ISO 9921 standard of normal and raised speech level. This change in dB SPL throughout the task simulated typical speech patterns throughout the day, especially that of teachers. Individuals have to alter their vocal intensity in conjunction with social situations, distance between speakers and background noise that might occur within an environment. In a sound-treated booth, the participants were seated directly in from of a computer screen with the *lingWAVES* system and reading material on two separate monitors. The mouth-to-microphone distance relative to the sound level meter was placed 50 centimeters away the participants mouth. Throughout the vocal loading test, the program indicated to the participants with a large arrow if they fell below the desired dB SPL goal. Participants read the provided text given the following instructions: "Please read the provided material as if you were speaking to a classroom of students. Attempt to make your voice animated and engaging to your listeners while reading at the level dictated by the program. If you fall below the desired speaking level, a large blue arrow will appear on the screen indicating that you need to raise your voice. Please increase your speaking volume until the arrow disappears. Be aware that throughout the test the required volume level will alternate." Additionally, in exact comparison to the non-fatiguing task, at four different time points (0 minutes, 10 minutes, 20 minutes and 30 minutes) in the vocal loading task participants verbally responded to the subjective statement "My vocal fatigue level is…". So after one complete dB SPL goal cycle, which is five minutes at a normal speaking level (66 dB) and five minutes at a raised speaking level (72 dB), vocal fatigue ratings were assessed. This was done so the vocal load between each cycle was consistent. Self-reported vocal fatigue responses were also the primary fatigue indicator in analysis.

CHAPTER 4: RESULTS

Using the above protocol, descriptive and inferential statistical methods were performed. Specifically, measures from the PFTs and the prolonged speaking protocol (fatiguing test) and its counter (non-fatiguing test) were used in this analysis. Parametric but robust non-normal distributions (semiparametric) tests were used. To look directly at the hypothesis, inferential statistical analysis was conducted using Linear Mixed-Effects (LME) models. Outcome measures included self-reported ratings of vocal fatigue and acoustic measures of ΔSPL and f_0.

The results below were outlined in the following order. To begin, self-reported vocal fatigue ratings over time versus D1 and D2 were investigated. This provided verification that participants did perceive vocal fatigue in the fatiguing task. Self-reported vocal fatigue ratings were then compared to pulmonary function measures to explore a potential connection. Predicted lung age was found to have a statistically significant relationship with vocal fatigue. This was then researched further by comparing different predicted lung ages of participants to their reports of vocal fatigue over time. Next, acoustic measures were compared with other measures collected throughout the study. ΔSPL and f_0 in vocal tasks versus pulmonary function test measures were studied first. Then, ΔSPL and f_0 in D1 and in D2 versus time and self-reported vocal fatigue ratings were the second areas considered. Both of these measures showed statistically significant relationships within the non-fatiguing and fatiguing tasks. Finally, speech tasks completed pre and post non-fatiguing and fatiguing tasks were compared to ΔSPL and f_0.

In each results section below the model is described and more specifics of the factors used are provided.

It should be noted that Dr. Pasquale Bottalico provided his expert advice and assistance to gain a better understanding of the statistical analysis that should be conducted. For clarification of the hypothesis and to determine if an inverse relationship existed between vocal fatigue and pulmonary function, the following measures were included in statistical analysis:

- Subjective measures (self-reported ratings of vocal fatigue)
- Acoustic measures (ΔSPL and f_0)
- Pulmonary Function measures (FVC, FEV1, PEF and predicted lung age)
- Time of non-fatiguing or fatiguing task

4.1 Participants

In total 12 participants were run through the aforementioned protocol for the experiment. Two of those 12 participants were excluded in the final statistical analysis. One participant failed to pass a hearing screening conducted on Day 1 of the study. The other participant dropped a piece of equipment during the study thus affecting the recording and making data unusable. Of the 10 participants included in the final analysis age range was from 19-28 years with a mean age of 23.8 years. Participants responded to general questions regarding voice and specific questions to fulfill inclusion/exclusion (Appendix B).

4.2 Processing of Voice Recordings

From the vocal task recordings (Diapix, Rainbow and vocal fatigue response statement "My vocal fatigue level is…") time history estimates of f_0 and relative dB SPL were estimated every 125 msec using custom laboratory scripts in Matlab2016a. From the time history values, averages were calculated and used in statistical analysis. Additionally, a parameter termed ΔSPL was calculated as a within-participant centering (overall mean of a subject from all recordings subtracted by the individual task mean) in order to evaluate the variation in the participant's vocal behavior in the different conditions from the "mean" vocal behavior.

4.3 Statistical Method

Statistical analysis was conducted using R version 3.1.2 (RDevelopment, 2013). Linear Mixed-Effects (LME) models were fit by restricted maximum likelihood (REML). Random effects terms were chosen on the basis of variance explained in the model. These were selected on the basis of the Akaike information criterion (Akaike, 1998) (the model with the lowest value being preferred) and the results of likelihood ratio tests (a significant result indicating that the more complex of the two nested models in the comparison is preferred) and were conducted using lme4 and lmerTest packages. The *p* values for these tests were adjusted using the default single-step method (Hothorn, Bretz, & Westfall, 2008). The LME output included estimates of the fixed effects coefficients, the standard error associated with the estimate, the degrees of freedom, *df*, the test statistic, *t*, and the *p* value. The Satterthwaite method was used to approximate degrees of freedom and calculate *p* values.

4.4 Subjective Vocal Fatigue Ratings Over Time

The self-reported vocal fatigue ratings (My vocal fatigue level is…) change over the duration of the non-fatiguing and fatiguing tasks and are shown in Figure 3. Here the slope of the self-reported vocal fatigue rating (range 0 - 10) per minute was -0.06 in D1 and 0.16 in D2. This was calculated using a LME model with the response variable as subjective vocal fatigue (-) and as fixed factor the interactions between day and time. The random effect for this model was the participant. Other potential interactions were excluded after likelihood-ratio tests indicated that their inclusion did not improve the model fit ($p > 0.1$). The model results are presented in Table 1.

Table 1. A LME model fit by REML for the response variable self-reported vocal fatigue ratings (-) and as fixed factor the interactions of time and day.

Fixed factors	*Estimate*	*Std. Error*	*df*	*t*	*p*
(Intercept)	2.11	0.42	14	5.05	<0.001***
Time:Day 1	-0.06	0.01	70	-4.31	<0.001***
Time:Day 2	0.16	0.01	70	12.08	<0.001***

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

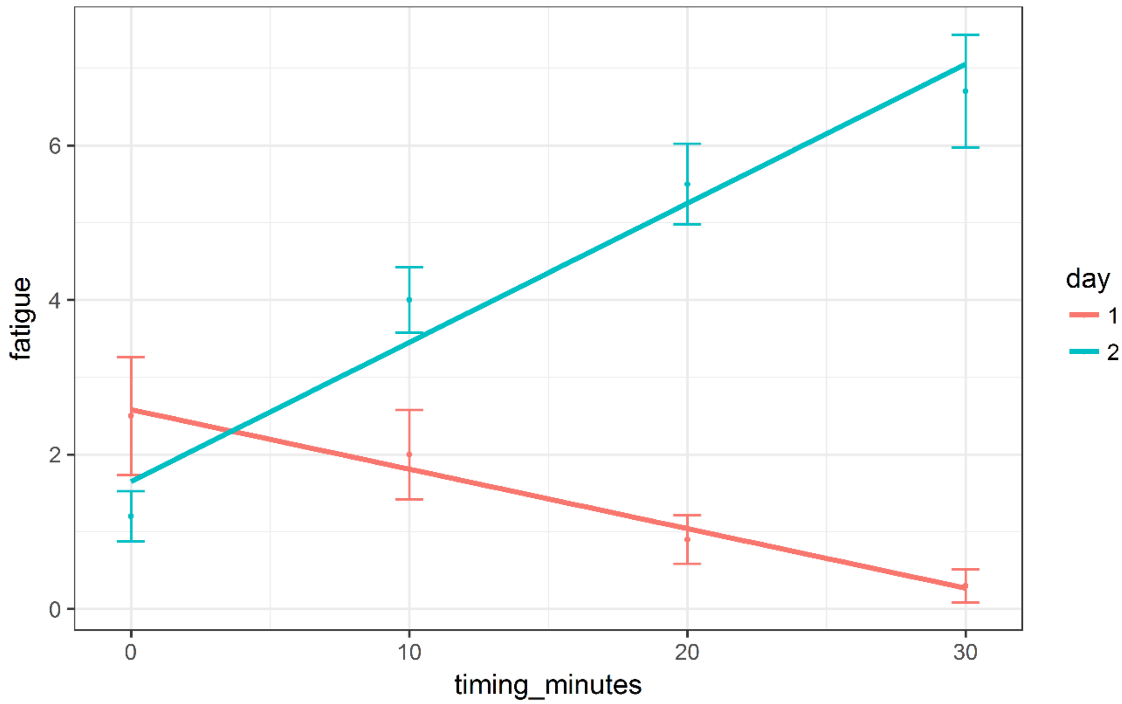

Figure 3. Self-reported vocal fatigue ratings over time in Day 1 and in Day 2.

4.5 Subjective Vocal Fatigue Ratings and Pulmonary Function Measures

The effects of pulmonary function on self-reported vocal fatigue ratings (My vocal fatigue level is…) during the fatiguing task on D2 are presented in Table 2. As would be expected, an association between self-reported vocal fatigue ratings and time was confirmed. But of the PFT metrics, only the relationship between estimated lung age and self-reported vocal fatigue ratings was statistically significant ($p < 0.05$). This was conducted with a LME model with the response variable as self-reported vocal fatigue ratings (-) and as fixed factors: (1) time, (2) FEV percentage, (3) FVC percentage, (3) PEF percentage, (4) Lung age and (5) age. The random effect for this model was the subject. To illustrate these effects, Figure 4 shows the average self-reported vocal fatigue ratings by lung age while Figure 5 displays the reported the slope of self-reported vocal fatigue ratings over the time by lung age.

Table 2. A LME model fit by REML for the response variable self-reported vocal fatigue ratings (-) and as fixed factors: (1) time, (2) FEV perc, (3) FVC perc, (3) PEF perc, (4) Lung age and (5) age.

Fixed factors	*Estimate*	*Std. Error*	*df*	*t*	*p*
(Intercept)	1.98	4.94	10	0.40	0.698
Time	0.18	0.01	30	12.84	<0.001***
FEV_perc	-0.11	0.09	10	-1.20	0.258
FVC_perc	0.15	0.07	10	2.09	0.063.
PEF_perc	0.02	0.04	10	0.45	0.660
Lung age	0.15	0.05	10	2.88	0.017 *
Age	-0.43	0.21	10	-2.01	0.072 .

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

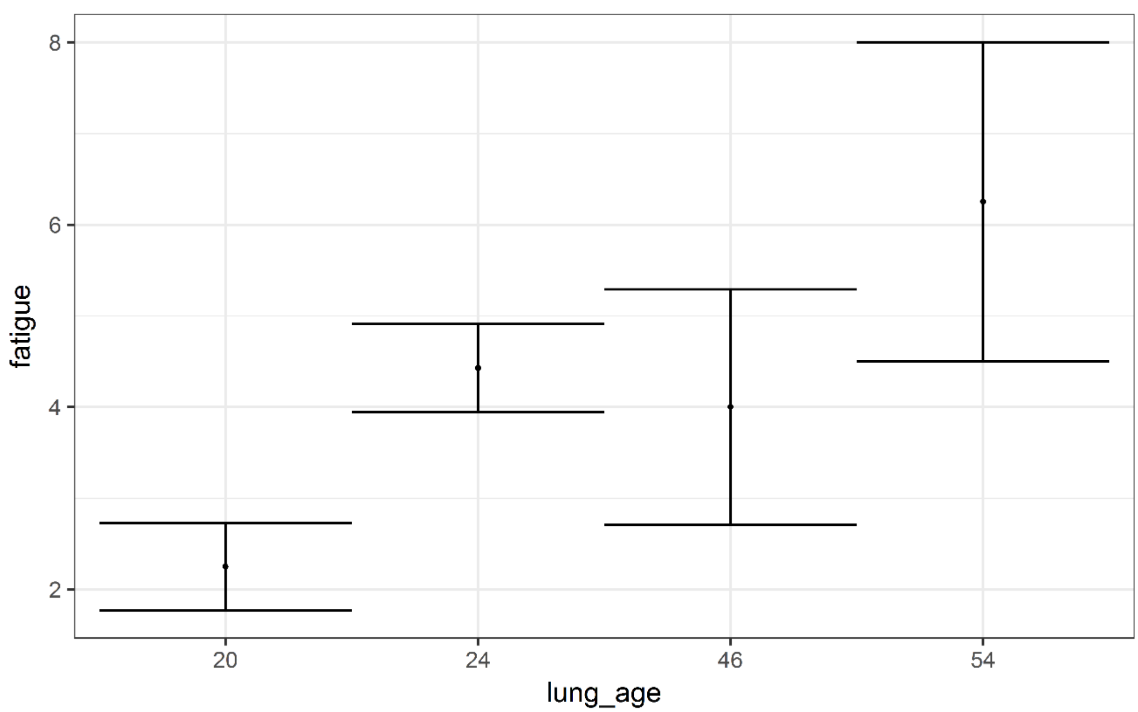

Figure 4. Self-reported vocal fatigue ratings by lung age.

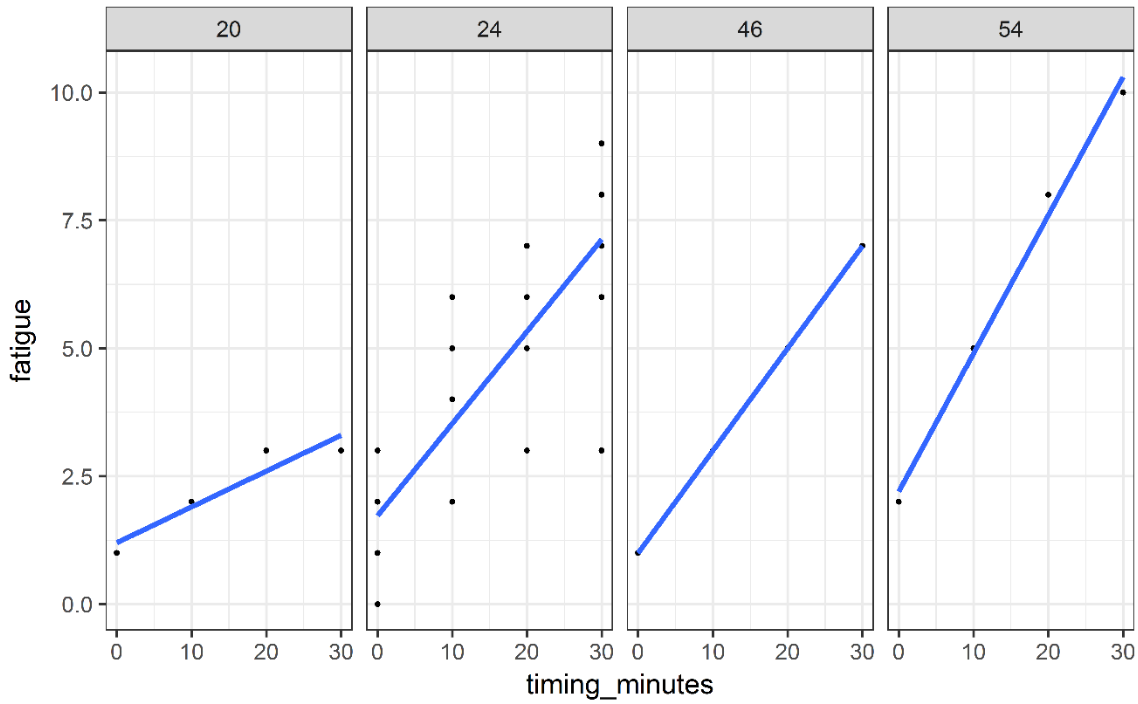

Figure 5. Self-reported vocal fatigue ratings by lung age over time.

4.6 ΔSPL and f_0 in Vocal Tasks and Pulmonary Function Test Measures

The effects of pulmonary function on variations in ΔSPL during vocal tasks (Diapix and Rainbow Passage) are presented in Table 3. An association between PFT metrics and time was confirmed however none of the other relationships between ΔSPL and PFT measures were significant. This was conducted with a LME model with the response variable as ΔSPL (dB) and as fixed factors: (1) time, (2) FEV percentage, (3) FVC percentage, (3) PEF percentage, (4) Lung age and (5) age. The random effect for this model was the subject.

The effects of pulmonary function on f_0 during vocal tasks are presented in Table 4. An association between PFT metrics and time was confirmed ($p < 0.001$) with relationships between PEF and lung age also showing significance ($p < 0.1$). This was conducted with a LME model with the response variable as variations in f_0 (Hz) and as fixed factors: (1) time, (2) FEV percentage, (3) FVC percentage, (3) PEF percentage, (4) Lung age and (5) age. The random effect for this model was the subject.

Table 3. A LME model fit by REML for the response variable ΔSPL (dB) and as fixed factors: (1) time, (2) FEV perc, (3) FVC perc, (3) PEF perc, (4) Lung age and (5) age.

Fixed factors	*Estimate*	*Std. Error*	*df*	*t*	*p*
(Intercept)	-2.18	4.54	40	-0.48	0.634
Time	0.15	0.02	40	6.12	<0.001***
FEV_perc	0.00	0.09	40	0.00	1.000
FVC_perc	0.00	0.07	40	0.00	1.000
PEF_perc	0.00	0.04	40	0.00	1.000
Lung age	0.00	0.05	40	0.00	1.000
Age	0.00	0.19	40	0.00	1.000

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

Table 4. A LME model fit by REML the response variable f_0 (Hz) and as fixed factors: (1) time, (2) FEV perc, (3) FVC perc, (3) PEF perc, (4) Lung age and (5) age.

Fixed factors	*Estimate*	*Std. Error*	*df*	*t*	*p*
(Intercept)	322.71	58.26	10	5.54	<0.001***
Time	0.74	0.20	30	3.74	<0.001***
FEV_perc	-0.59	1.14	10	-0.52	0.616
FVC_perc	-0.89	0.88	10	-1.02	0.333
PEF_perc	0.89	0.49	10	1.82	0.098.
Lung age	-1.15	0.61	10	-1.89	0.088.
Age	-1.05	2.43	10	-0.43	0.675

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

4.7 ΔSPL Over Time During Non-Fatiguing and Fatiguing Subjective Tasks

Over the course of the fatigue tasks, participants changed how they spoke (Figure 6). The linear model was ideal for variations in SPL over time completed during subjective vocal fatigue task (My vocal fatigue level is…) for D1. Alternatively, the quadratic model was ideal for variation in SPL over time completed in the same task for D2. This was computed with LME models with the response variable as ΔSPL (dB) and as fixed factor the time for D1 and D2 separately. The random effect for the model was the participant. Null, linear and quadratic models were compared for enhanced understanding of the relationship between ΔSPL and time. Between them the simplest was chosen after likelihood-ratio tests indicated that the inclusion of more complex ones did not improve the model fit ($p > 0.1$). Table 5 indicates the results from this model.

For D1 the variation in ΔSPL was not associated to self-reported vocal fatigue and a null model was preferred. In D2 the relationship between ΔSPL and vocal fatigue was quadratic. Figure 6 shows associations of both models. This was calculated with a LME model with the response variable as ΔSPL and as fixed factor self-reported vocal fatigue for D1 and D2 separately. The random effect for the model was the participant. Table 6 indicates the results from this model.

Table 5. A LME model fit by REML for the response variable ΔSPL (dB) and as fixed factor the time, for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	*(Intercept)*	-0.62	0.36	38	-1.71	0.096.
	Time	0.04	0.02	38	2.13	0.040*
2	*(Intercept)*	0.00	0.16	37	0.00	1
	Time	10.28	1.11	37	9.27	<0.001***
	Time²	-8.20	1.11	37	-7.40	<0.001***

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

Table 6. A LME model fit by REML for the response variable ΔSPL (dB) and as fixed factor self-reported vocal fatigue, for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	-	-	-	-	-	-
2	*(Intercept)*	0.00	0.23	37	0.00	1
	Vocal fatigue	8.89	1.43	37	6.23	<0.001***
	Vocal fatigue²	-7.99	1.43	37	-5.61	<0.001***

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

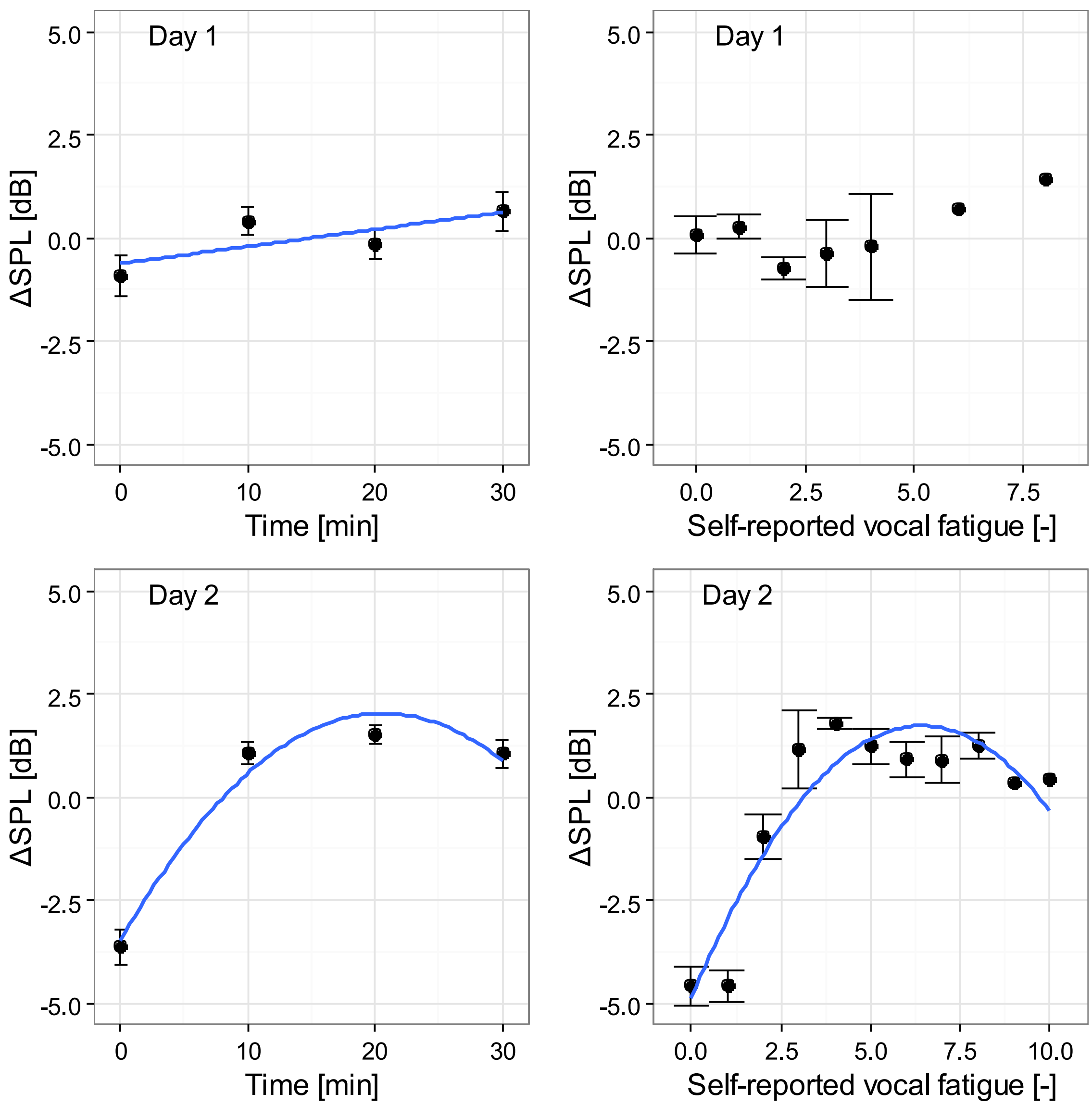

Figure 6. ΔSPL (dB) in Non-Fatiguing task (Day 1) and in Fatiguing Task (Day 2) versus time and self-reported vocal fatigue ratings.

4.8 f_0 Over Time During Non-Fatiguing and Fatiguing Subjective Tasks

Over the course of the fatigue tasks, participants changed their pitch (Figure 7). The linear model was ideal for f_0 over time completed during subjective vocal fatigue task (My vocal fatigue level is…) for Day 1. Alternatively, the quadratic model was ideal for f_0 over time completed in the same task for D2. This was calculated with LME models with the response variable as f_0 and as fixed factor the time for D1 and D2 separately. The random effect for this model was the participant. Null, linear and quadratic models were compared for enhanced understanding of the relationship between f_0 and time. Between them the simplest was chosen after likelihood-ratio tests indicated that the inclusion of more complex ones did not improve the model fit ($p > 0.1$). Table 7 indicates the results from this model.

For D1 the variation in f_0 was not associated to self-reported vocal fatigue as the null model was preferred. In D2 the relationship between f_0 and vocal fatigue is quadratic. Figure 7 shows associations of both models. LME models were run with the response variable f_0 and as fixed factor self-reported vocal fatigue for D1 and D2 separately. The random effect for the model was the participant. Table 8 indicates the results from this model.

Table 7. A LME model fit by REML for the response variable f_0 (Hz) and as fixed factor the time, for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	*(Intercept)*	212	4.1	12.5	54.4	<0.001***
	Time	0.22	0.11	29	2.03	0.051 .
2	*(Intercept)*	225	6.1	9	37.2	<0.001***
	Time	52.2	12.5	28	4.2	<0.001***
	Time^2	-38.5	12.5	28	-3.1	0.005**

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

Table 8. A LME model fit by REML for the response variable f_0 (Hz) and as fixed factor, self-reported vocal fatigue, for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	-	-	-	-	-	-
2	*(Intercept)*	225	6.3	9	35.9	<0.001***
	Vocal fatigue	64.7	13.8	30	4.7	<0.001***
	Vocal fatigue^2	-36.4	12.6	29	-2.9	0.007**

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

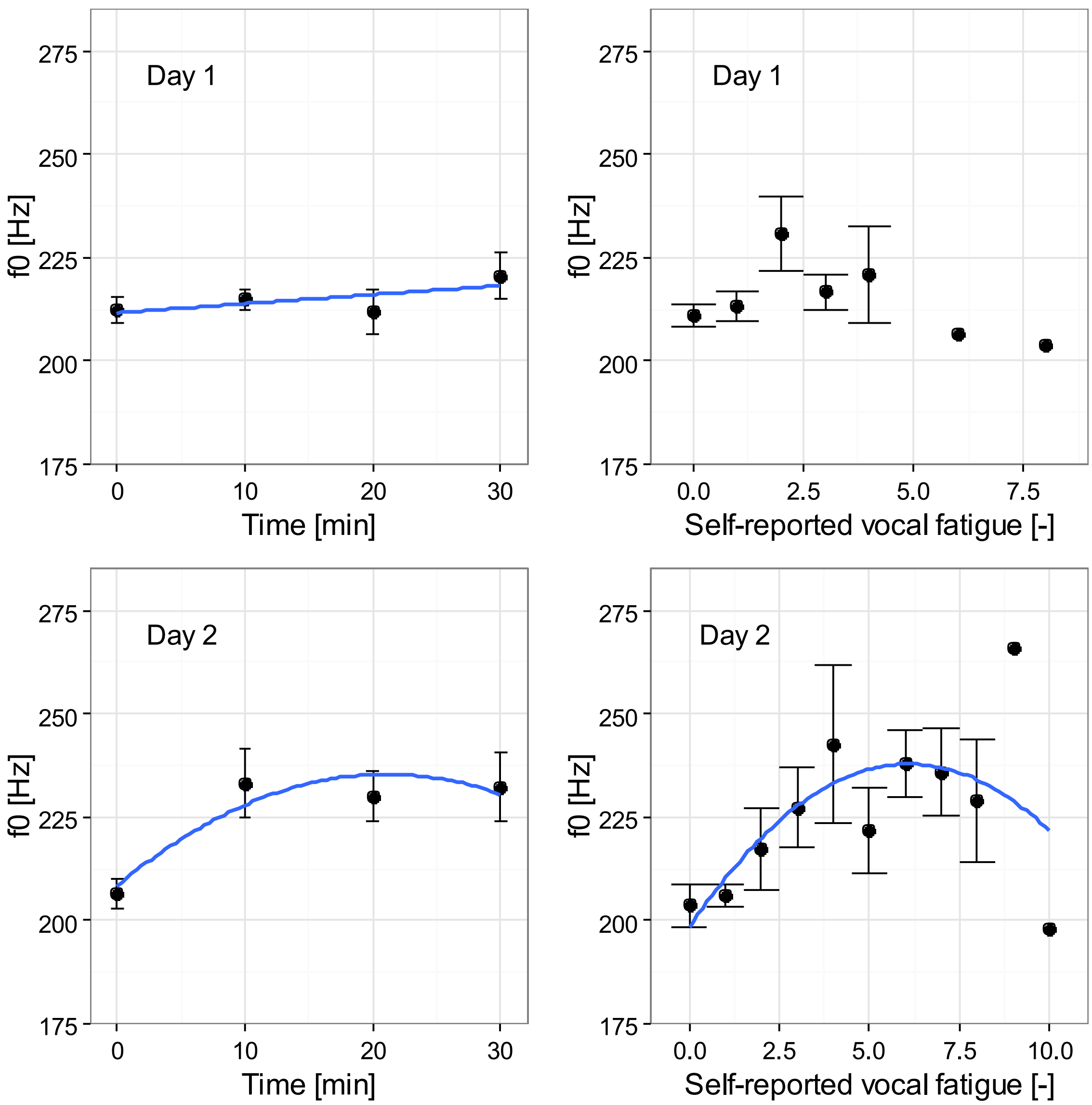

Figure 7. f_0 (Hz) in Non-Fatiguing task (Day 1) and in Fatiguing Task (Day 2) versus time and self-reported vocal fatigue ratings.

4.9 ΔSPL and f_0 Pre and Post Speech Tasks in Non-Fatiguing and Fatiguing Tasks

The relationship between the variation in ΔSPL and f_0 before and after speech tasks (Diapix and Rainbow Passage) in D1 and D2 is shown in Figure 8. There was an increase in SPL of 0.79 dB comparing before and after the task in D1, while the increase of 0.85 dB obtained during D2 was non statistically significant. There was a non-significant increase in f_0 comparing before and after the task in D1, while the increase of 6.4 Hz obtained during D2 was statistically significant (Figure 8). This was conducted with LME models with the response variable as ΔSPL and as fixed factor the time (Pre/Post task) for D1 and D2 separately. The random effect for this model was the participant. Model results are shown in Table 9 for ΔSPL and in Table 10 for f_0.

Table 9. A LME model fit by REML for the response variable ΔSPL (dB) and as fixed factor the time (Pre/Post task), for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	*(Intercept)*	-0.39	0.26	40	-1.55	0.130
	Time Post	0.79	0.36	40	2.19	0.035*
2	*(Intercept)*	-0.43	0.33	40	-1.28	0.209
	Time Post	0.85	0.47	40	1.81	0.078 .

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

Table 10. A LME model fit by REML for the response variable f_0 (Hz) and as fixed factor the time (Pre/Post task), for Day 1 and Day 2 separately.

Day	*Fixed factors*	*Estimate*	*Std. Error*	*df*	*t*	*p*
1	*(Intercept)*	205.5	4.08	11	50.33	<0.001***
	Time Post	1.8	1.54	30	1.15	0.261
2	*(Intercept)*	205.2	3.73	13	54.96	<0.001***
	Time Post	6.4	2.56	30	2.50	0.018 *

Signif. Codes: '***'<0.001 '**'<0.01 '*'<0.05 '.'<0.1

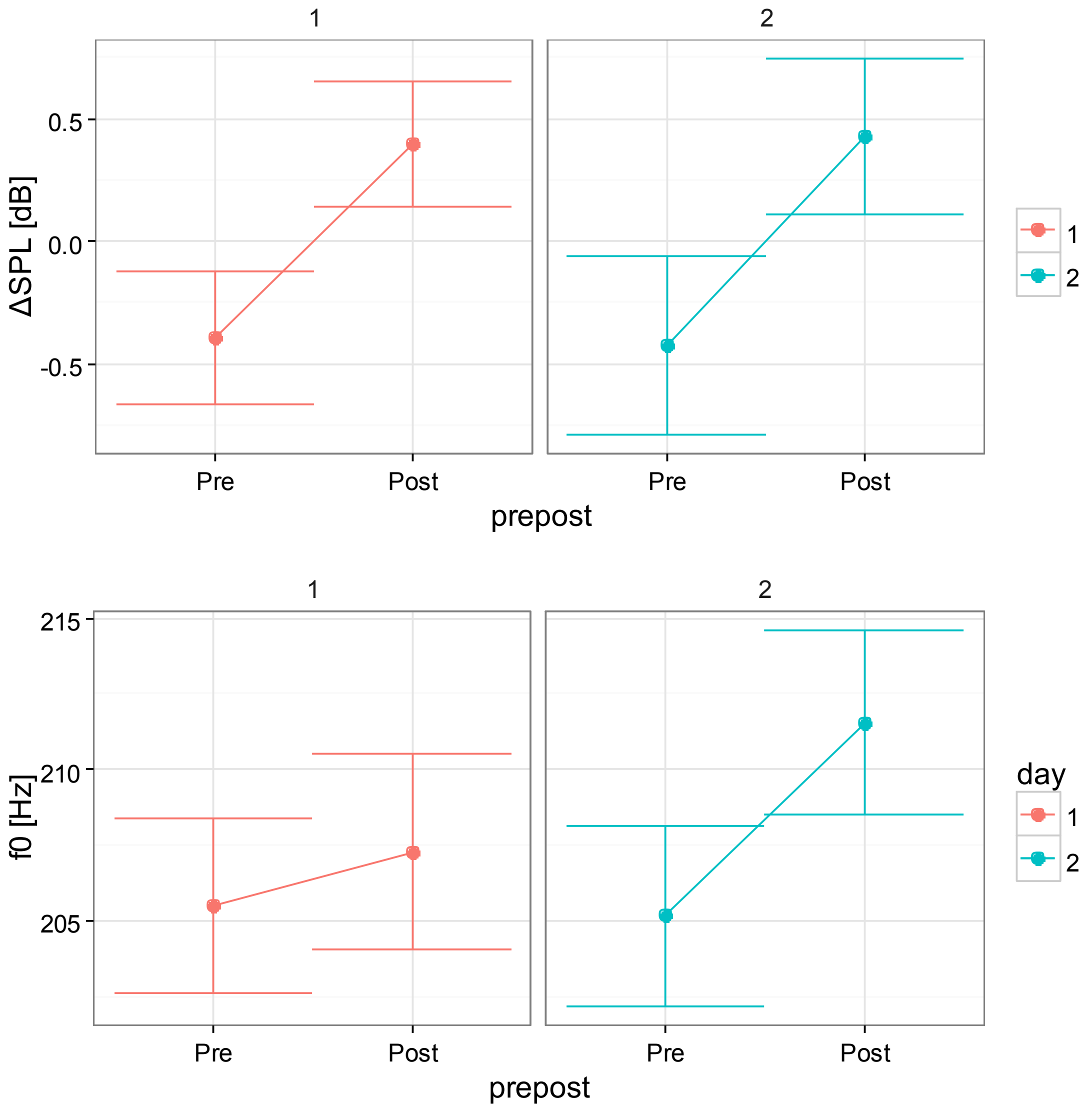

Figure 8. ΔSPL (dB) and f_0 (Hz) in Day 1 and in Day 2 Pre and Post task.

CHAPTER 5: DISCUSSIONS AND IMPLICATIONS

5.1 Vocal Fatigue versus Time

As expected, participants were aware of the effects of the prolonged reading task (vocal fatigue) and their subjective rating increased over time during the task. This awareness was quantified by a statistically significant positive relationship when comparing self-reported vocal fatigue ratings and reading time during the task on D2. During the non-fatiguing task on D1 there was a also a statistically significant negative relationship between self-reported vocal fatigue ratings and time. This may have been due to initial anxiety of the participant when they started the study and became more relaxed and familiarized with the investigator. Most importantly these results confirmed that the participants felt that the reading task did induce vocal fatigue. Clinically, individuals who have incurred vocal fold trauma either from a surgery or excessive voice use are the population for which vocal rest is generally recommended. From the study results though it can be concluded that even for individuals with no vocal abnormalities a short period of vocal rest can be effective.

5.2 Vocal Fatigue versus Pulmonary Function

It was hypothesized that an inverse relationship between PFT values and vocal fatigue would occur. Individuals with lower PFT results would have greater vocal fatigue after a long vocal loading task compared to individuals with higher PFT results. The only PFT measure that indicated statistical significance ($p < 0.05$) when compared to self-reported vocal fatigue was predicted lung age. "Lung age has been proposed as a comprehensive indicator for respiratory function (Okamura et al., 2016)". Equations used to calculate lung age vary, but they take into account FEV1 values compared to predicted values of FEV1 based on norms for healthy individuals and include personal information such as age, height, gender and race (Morris & Temple, 1985). For example, Toda et al. (2009) used the equation "Lung age" = (0.022 × height (cm)-0.005-FEV1 (L))/0.022 for Japanese females. Usually, it appears, that predicted lung age has been used as physiological tool to promote smoking cessation in smokers by demonstrating their current lung function (Parkes et al., 2008). Yet within the current experiment all participants were of self-reported normal respiratory health and indicated that they had no history of smoking or were current smokers. The correlation between vocal fatigue and predicted lung age over time was also apparent with an increased slope observed when participants with older lung ages were compared to participants with younger lung ages. So, potentially, it could be hypothesized that other factors in an individuals environment may be contributing to FEV1 function, rather than the typically used pulmonary disease, thus affecting predicted lung age. Another option is that predicted lung age is a more comprehensive measure of lung function, which comes into affect when investigating the correlation with vocal fatigue. These results are interesting as predicted lung age is a measure with very limited use in pulmonary function research and essentially no investigation in relation to vocal fatigue. Further research is clearly warranted based on preliminary results and could provide implications for PFTs as a screening tool to assess individuals with a higher risk for vocal fatigue. The potential for PFT measures, specifically lung age, to demonstrate a relationship with other voice disorders, diagnoses or severity, should be considered as well.

5.3 Acoustic Measures versus Pulmonary Function

Acoustic measures of ΔSPL and f_0 were collected from vocal tasks during D1 and D2. They were compared against the same pulmonary function results as vocal fatigue ratings. In this case, the only relationships observed to be approaching statistical significance ($p < 0.1$) were PEF and lung age when compared to f_0. ΔSPL did not show relationships with any pulmonary function measures. While this study indicated, direct correlation of ΔSPL and f_0 to pulmonary function results may not be the most successful indicator of vocal fatigue it is possible that other acoustic measures may have a stronger relationship. Measures of jitter and shimmer have also shown some relationship to vocal fatigue (Laukkanen et al., 2008) and could be used in the future to investigate correlation with PFT measures.

5.4 Vocal Fatigue versus Acoustic Measures

Previous literature has investigated acoustic measures in conjunction with vocal fatigue. Increases in ΔSPL and a higher f_0, greater activity in the laryngeal muscles, have both been noted as acoustic characteristics that might relate to vocal fatigue (Schloneger & Hunter, 2017). Results found within this research generally matched the trends for these two measures already established.

The ΔSPL compared to time demonstrated a statistically significant relationship ($p<0.05$) during the non-fatiguing subjective task of D1. Interestingly in the non-fatiguing task the two factors demonstrated a positive linear relationship. This is contradictory to what would have been expected from previous research and results within the study that showed a strong negative correlation between time and subjective vocal fatigue ratings. In the non-fatiguing task of Day 1, f_0 compared to time did show a linear relationship as well but was not statistically significant nor was f_0 compared to self-reported vocal fatigue. Anxiety at the start of the study could have increased ratings and pitch initially with the participants relaxing over the 30-minute time period would echo the slope of the line in Figure 7. The ΔSPL compared to self-reported vocal fatigue did not demonstrate a relationship in the non-fatiguing task of D1. This is consistent with previous research, as participants were not undergoing vocal fatigue during the D1 non-fatiguing task, which was proven in self-reported measures compared to time.

In the subjective fatiguing task of D2, there was a statistically significant quadratic relationship ($p < 0.001$) between ΔSPL and time. The results here generally matched previous research, which verify the correlational relationship between these two factors. The greatest ΔSPL occurred at approximately 20 minutes into the fatiguing task. In the fatiguing task of D2, f_0 compared to time did show a statistically significant quadratic relationship ($p < 0.001$). The ΔSPL and f_0 compared to self-reported vocal fatigue in the fatiguing task of D2 presented a statistically significant quadratic relationship ($p < 0.001$). The greatest ΔSPL and f_0 occurred at a subjective rating of approximately 6 on a 0-10 scale.

Looking at ΔSPL and f_0 compared to time and self-reported vocal fatigue the trends are similar. Specifically in the graphs of D2, quadratic curves showing ΔSPL and f_0 compared to time appear to mirror each other with the greatest change in both measures occurring within the first 20 minutes. This may lead to possible implications supporting a shortened experimental time, 20 minutes, in research studies to estimate factors associated vocal fatigue. The setup of the *lingWAVES* program could possibly have acted as a contributing factor to the time where an increase of vocal fatigue has been observed. Participant's response to *lingWAVES* cueing to maintain set SPL goals through cycles does correspond with the 20-minute time point, which could be incidental or correlated. The *lingWAVES* system protocol may also have impacted the measure of f_0, although not entirely, since an increased pitch in participant's voices may have been needed to read at a raised level. Additionally, participant's psychological perception of their vocal fatigue changes (i.e. effort, discomfort, tiredness) may have reached a plateau after initially increasing. Another hypothesis is that the cyclic model as proposed by McCabe and Titze (2002) could be supported by the results of this particular vocal fatigue study. Changes in the neuromuscular tissue and soft tissues, such as increased vocal fold stiffness, described in the model may result around the time point of 20 minutes resulting in a plateau of the ΔSPL, f_0 and self-reported vocal fatigue levels. Neuromuscular changes described in the model may result around the time point of 20 minutes resulting in a plateau of the ΔSPL, f_0 and self-reported vocal fatigue levels. However, a possible question may be whether sustaining vocal fatigue over an even longer period of time would continue to show a decreased in ΔSPL, f_0 and self-reported vocal fatigue or a plateau. Additionally the graphs of D2, the quadratic curves showing ΔSPL and f_0 compared to self-reported vocal fatigue appear to mirror each other as well. The vertex of each parabola occurs at approximately the same location, a 6 on a 0-10 scale.

The change in acoustic measures of ΔSPL and f_0 was compared to pre and post vocal tasks (Diapix and Rainbow Passage) in D1 and D2. In D1, ΔSPL compared to pre and post tasks was determined to be statistically significant as was D2 when f_0 was compared to pre and post tasks. While the variation in ΔSPL and f_0 is still present in pre and post vocal tasks (Diapix and Rainbow Passage it was not to the degree that occurred during the fatiguing task. This indicates that acoustic measures obtained during a fatiguing task may be a more accurate representation than pre and post measures. Participants completing the vocal tasks pre and post may have become fatigued during the vocal tasks, which could have added to the change in acoustic measurements. Of the two acoustic measures conducted pre and post task, f_0 showed a greater change in the slope of the lines from D1 to D2.

CHAPTER 6: LIMITATIONS AND FUTURE DIRECTIONS

Looking ahead to continuation of this experiment, some changes and improvements could be made to provide increased insight into the results. First, ideally, a greater number of participants would be included in the sample size to enhance the magnitude of the study and thus provide a more accurate sampling of the population. Within that increased sample size, it could be assumed that a larger variation in lung function (or predicted lung age) would be observed contributing to results with broader implications. As justified by the recent findings, a more frequent sampling of participant's subjective ratings of vocal fatigue throughout the non-fatiguing and fatiguing tasks could be included. This would be collected to gain greater understanding into the potential relationship between correlation of timing and vocal fatigue. Furthermore, the limitation of subjective ratings is, of course, that they are variable. Numerous uncontrollable factors in the study could have potentially affected participant's self-reported ratings of vocal fatigue. Even participants' awareness that they were undergoing a fatiguing task could have impacted their results, however this is not believed to be the major effect contributing to their subjective ratings. Self-reported vocal fatigue ratings have been used previously in studies showing increased vocal fatigue after a vocal loading task (Chang, 2004; Vintturi, Alku, Sala, Sihvo, & Vilkman, 2003). Other studies (Solomon et al., 2003; Welham & Maclagan, 2004) have not supported this effect, hence continued investigation into the validity of this measures is necessitated.

In the future, modifying a vocal fatiguing task to fit each individual subject may provide a more realistic experience of vocal fatigue. Individuals speak with a preferred vocal intensity, which is considered their baseline. In an attempt to fatigue each participant equally, a measure of their baseline intensity could be collected and then adjusted. For example, a participant who spoke at a higher vocal intensity initially would be required to speak at higher levels to induce vocal fatigue. Alternatively, the distance of the microphone from the participant within the vocal fatiguing task could be adjusted to compensate for various levels of vocal intensity.

Various other subsets of the population could be studied using the same or a similar outline of experimental measures to allow for comparison and a collective sampling of the entire population upon completion of various subsets. Some potential populations could include: males, individuals within occupations requiring intensive voice use (i.e. teachers, call center workers, speech-language pathologists) and individuals diagnosed with pulmonary function disorders (i.e. chronic obstructive pulmonary disease, asthma, bronchitis, etc.) Currently being investigated is the relationship vocal fatigue and pulmonary function in geriatric individuals as direct continuation of this research.

CHAPTER 7: CONCLUSIONS

As stated in previous research, the multifaceted problem of vocal fatigue has many varying biological and physiological components. This research investigated breath support and lung function as possible contributing factors. Specifically, the experiment studied the female population who make up a large portion of occupational voice users diagnosed with vocal fatigue. The two-day study was conducted in order to gain insight into the possible relationship between vocal fatigue metrics and PFT results. Results showed a relationship between lung age and subjective vocal fatigue ratings. Throughout the study time also had a statistically significant affect when compared with other variables. For acoustic measures of variations in ΔSPL and f_0 compared to subjective vocal fatigue ratings and time there was shown to be steady increase until approximately 20 minutes into the fatiguing task. This may be attributed to participant's responses to the *lingWAVES* program, participant's perceptions of their psychological and physiological fatigue or increased vocal fold stiffness. Additionally, acoustic measures of variations in ΔSPL and f_0 demonstrated to act as more accurate measures of vocal fatigue when assessed within a vocal loading task.

Clinical implications of the results of the study can be expanded across the spectrum of disorders and treatments in the field of speech language pathology. For individuals with voice disorders decreased breath support could contribute to increased dysphonia. For this population, PFTs could act a simple tool to measure lung function. As a method to return to baseline function for a portion voice disorder diagnoses has not yet been identified, targeting breath support may be effective treatment tool to improve an individual's current voicing. Another voice treatment method commonly used clinically is the Lee Silverman Voice Treatment (LSVT) which is a program directed towards speech disorders associated with Parkinson's disease. This technique works on increasing vocal intensity from an individual's baseline thus exaggerating the voice. Simultaneously, this act could also be enhancing lung function, possibly improving their measure of predicted lung age. Furthermore, the finding of subjective and acoustic measures of vocal fatigue reaching a plateau at the 20-minute time point could trigger the inquiry for setting a minimum or maximum time for this treatment. Extending beyond LSVT, 20-minutes may be the "ideal" time point for the onset of vocal fatigue so it could be implicated as a landmark to use, to watch or to a measure patient's status over time. Motor speech disorders are impacted by the inability to plan, program, control or coordinate airflow to execute speech and another area that the results of the study may be applied. PFTs, specifically looking at the measure of predicted lung age, may be a method to test the presence of these disorders or as an objective measure to assess the severity of an individual's disorder. If decreased functioning is observed in PFT measures, quantifiable results showing improvement from clinical treatment, in the form of improved pulmonary function measures, could aid in treatment justification. This is just a sampling of the implications for clinical application in diagnosis and treatment that are generated from the results of this study.

One approach for additional investigation into vocal fatigue would be to account for an individual's baseline vocal intensity in a fatiguing task. This could potentially result in a more equal standard of vocal load placed upon each participant. Furthermore, a more frequent sampling of self-reported vocal fatigue reports within a fatiguing task could provide a more precise point where participants reached a plateau in subjective and acoustic measurements. Continued research into the relationship between pulmonary function and vocal fatigue in a wider variety of populations is also warranted.

APPENDICES

APPENDIX A. Consent Form

Research Participant Information and Consent Form

You are being asked to participate in a research study. Researchers are required to provide a consent form to inform you about the research study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Study Title: Gender Differences in Speech Accommodations in Occupational Settings: The Relationship Between Pulmonary Function and Vocal Fatigue
Researcher and Title: Dr. Eric Hunter, Associate Professor.
Department and Institution: Dept. of Comm. Sciences and Disorders at Michigan State University
Address and Contact Information: 113 Oyer, East Lansing 48823, 517.353.8641
Sponsor: Michigan State University

1. PURPOSE OF RESEARCH
We ask you to participate in a research study designed to understand a potential relationship between a short breathing function test and the vocal quality changes that may occur after a prolonged speaking task.

2. ELIGIBILITY CRITERIA
- You must be between 18-40 years of age.
- You must be a native English speaker.
- No history of prior or current vocal, pulmonary, or hearing problems requiring medical intervention (including therapy).

3. ALTERNATIVE OPTIONS
There are no alternative options to this study.

4. WHAT YOU WILL DO
You may asked to participate in up to 2 sessions for about an hour each, for a total of 2-3 hours of participation time. You may be asked to do some or all of the following:
- Complete questionnaires about your voice and voice use.
- Answer questions about your vocal habits and history of vocal fatigue.
- Asked about current medication related to asthma, allergies or heartburn; if you don't want to respond to these questions, just say so and we will skip them.
- Complete a short hearing screen to ensure that your hearing is within normal limits.
- Perform simple vocal tasks, such as a sustained "ah" vowel, pitch glides, and reading a passage.
- Complete a pulmonary function test using a device (spirometer) to assess your lung function, this may be repeated up to three times. For this test, you will be asked to breath in deeply and blow into a device to collect measurements about your lung ability. Also, your breathing while speaking will be observed (no devices used) to indicate how breath while speaking.
- Complete an endoscopic exam to check your larynx (voice box). For this, a small rigid tube with a camera will be inserted in your mouth just past the spot where a tongue depressor would normally be placed to look over your tongue and at your upper airway to confirm that there are no noticeable abnormalities which would exclude you from the study.
- Perform a prolonged speaking tasks consisting of reading for a period of up to 30 minutes.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 07/21/16 – valid through 06/01/17. This version supersedes all previous versions. IRB # 16-689.

5. POTENTIAL BENEFITS
You may benefit from a broader understanding of how the voice works and pulmonary function. In addition, your participation in this study will contribute to the understanding of voice disorders and lead to the development of better approaches for reducing the risk of voice disorders.

6. POTENTIAL RISKS
You may experience vocal fatigue, but this should resolve with vocal rest. You may experience some minor discomfort during the endoscopy, but this should resolve after the task is completed.

The testing performed in this project is not intended to find abnormalities, and the images or data collected do not comprise a diagnostic or clinical study. The investigators and Michigan State University are not responsible for failing to find abnormalities. Undetected vocal abnormalities are rare but it is possible that the investigators may perceive a vocal abnormality. When this occurs, you are advised to consult with a licensed physician to determine whether further examination or treatment would be prudent. The investigators, specialist, and Michigan State University are not responsible for any decision you make with regard to examination or treatment. Because the recordings and images collected for this research project do not comprise a diagnostic or clinical study, the images will not be made available for diagnostic or clinical purposes.

7. PRIVACY AND CONFIDENTIALITY
The data for this study are being collected confidentially. Data from this study will be stored in a locked cabinet in a locked room or a password protected computer in the locked laboratory. Research information and data will be labeled with a code representing you and the key to this code (that links data to your name) will be kept separately and securely. All identifying information will be kept for a minimum of three years after the project closes. Only trained researchers under the jurisdiction of this project and MSU HRPP will have access to the data collected in the study. Information about you will be kept confidential to the maximum extent allowable by law. Although we will make every effort to keep your data confidential there are certain times, such as a court order, where we may have to disclose your data. Identifying information will not be attached to any of your individual responses when reporting results from the surveys. You will not be asked to give your name or any other information that will allow you or your place of employment to be identified in your audiotaping. All results will be kept in a secured location accessibly only to those involved in the study. The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

Participation in this study requires audio and video recordings of your voice and, potentially, of the individual sessions. Your consent to participate implies consent to both types of recording.

Playback of recordings in other experiments and at presentations of the results at scientific meetings are sometimes useful.

I agree that these recordings can be used in future listening experiments.

□ Yes □ No

Initials ___________

I agree that these recordings can be used in reports and presentations.

□ Yes □ No

Initials ___________

8. YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to answer specific questions or to stop participating at any time. Whether you choose to participate or not will have no effect on your grade or evaluation.

9. COSTS AND COMPENSATION FOR BEING IN THE STUDY

- If you are enrolled in a course that requires you to participate in a research study, and the course accepts SONA credit, you will have the option to receive SONA credit for study participation.
- If you choose not to receive SONA credit, you will be offered compensation at a rate of $10 per hour for each of two visits (about an hour each visit for a total of between $20-$40). If you register through the Paid SONA Research Pool, you will be compensated at $10 per hour. An additional $5 will be added to the compensation amount on the second day of the study if students complete in both day 1 and day 2. You will always be paid the rate of $10 per hour even if you do not complete the full study.

As an incentive to participate, subjects/students who participate in this research will be allowed to earn MSU SONA credit through http://msucas.sona-systems.com. For those enrolled in such courses, students can also find alternative assignments to earn extra credit if they choose not to participate in this research study but wish to earn extra credit.

In the SONA system, 1 hour of research participation is worth 1 SONA credit and this credit is pro-rated in 15-minute increments. It is up to individual course instructors to determine how many points this converts to in their classes (this should be specified in the syllabus for each course). In order to receive credit for participation you MUST be registered for this study.

Participation in this study is voluntary. You may withdraw at any time without penalty. This means that no SONA credits will be deducted from your account, nor will withdrawal have any effect on your relationship with any of your instructors. Instructors will not know what studies participants are involved in, nor will researchers know what other SONA studies participants are involved in.

10. THE RIGHT TO GET HELP IF INJURED

In the unlikely event that you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. You may contact Dr. Eric Hunter at 517.353.8641 with any questions or to report an injury.

11. CONTACT INFORMATION
If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher(s):

- Dr. Eric Hunter, Michigan State University, 113 Oyer, East Lansing, MI 48823, 517-353-8641, ejhunter@msu.edu

-Callan Gavigan, Michigan State University, 6 CAS, East Lansing, MI 48823, 248-921-8911, gaviganc@msu.edu

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

12. DOCUMENTATION OF INFORMED CONSENT
Your signature below means that you voluntarily agree to participate in this research study.

____________________________________ __________________________
Signature Date

You will be given a copy of this form to keep.

This consent form was approved by a Michigan State University Institutional Review Board.
Approved 07/21/16 – valid through 06/01/17. This version supersedes all previous versions. IRB # 16-689.

APPENDIX B. General Participant Information

Here are some general information and voice questions asked to all participants.

1. Do I commonly experience symptoms of reflux or heartburn

2. Am I experiencing reflux symptoms today?

3. Do I commonly experience symptoms of seasonal allergies?

4. Am I experiencing allergy symptoms today?

5. In the last two weeks, have you taken any herbal, over the counter or prescribed medication for symptoms of asthma, allergies, upper respiratory infections, heartburn/reflux or anything that might affect your hearing, airway, or sinuses?

6. Are you a native speaker of American English?

7. Do you have an accent?

8. If you have an accent, where did you grow up?

9. Do you have any history of voice training, hearing disorders, pulmonary disorders or speech/language therapy?

10. What is your race?

11. What is your gender?

Table 1A. Participants responses to general information and questions about voice.

Participant Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	10
Q1	Yes	No	No	No	No	No	No	No	No	No
Q2	No	No	No	No	No	No	No	No	No	No
Q3	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Q4	No	No	No	No	Yes	Yes	Yes	No	No	No
Q5	No	No	No	No	Yes	No	No	No	No	No
Q6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q7					Yes					
Q8	NA	NA	NA	NA	Southern Texas	NA	NA	NA	NA	NA
Q9	No	No	No	No	No	No	No	No	No	No

Table 1A. (continued)

Q10	White	White	White	Native Hawaiian or Other Pacific Islander	White	White	White	Asian	White	White
Q11	F	F	F	F	F	F	F	F	F	F

APPENDIX C. Vocal Health Survey Statistics

Table 2A. Summary of participant responses collected from vocal health surveys conducted in the screening task of Day 1.

Name	*V-RQOL*	*VFI*	*VHI-10*	*BFI-10*
Average Total	12.33	37.92	16.33	34.42
Average per Question	1.23	3.79	1.63	3.13
Maximum	17	61	22	37
Minimum	10	22	10	30

APPENDIX D. Voice Handicap Index-10 (VHI-10)

Completed to assess participant ratings of vocal function (Rosen, Lee, Osborne, Zullo, & Murry, 2004).

Instructions: These are statements that many people have used to describe their voices and effects of their voices on their lives. Circle the response that indicates how frequently you have the same experience.

0 = never, 1 = almost never, 2 = sometimes, 3 = almost always, 4 = always

1. My voice makes it difficult for people to hear me.	0	1	2	3	4
2. I run out of air when I talk.	0	1	2	3	4
3. People have difficulty understanding me in a noisy room.	0	1	2	3	4
4. The sound of my voice varies throughout the day.	0	1	2	3	4
5. My family has difficulty hearing me when I call them throughout the house.	0	1	2	3	4
6. I use the phone less often than I would like to.	0	1	2	3	4
7. I'm tense when talking to others because of my voice.	0	1	2	3	4
8. I tend to avoid groups of people because of my voice.	0	1	2	3	4
9. People seem irritated with my voice.	0	1	2	3	4
10. People ask, "What's wrong with your voice?"	0	1	2	3	4

APPENDIX E. Voice-Related Quality of Life Measure (V-RQOL)

Completed to assess the impact of vocal problems on quality of life (Hogikyan & Sethuraman, 1999).

Instructions: We are trying to learn more about how a voice problem can interfere with your day-to-day activities. On this paper, you will find a list of possible voice-related problems. Please answer all questions based upon what **your** voice has been like over the past **two weeks**.
Considering both how severe the problem is when you get it, and how frequently it happens, please rate each item below on how "bad" it is (that is, the **amount** of each problem that you have). Use the following scale for rating the amount of the problem:

1 = None, not a problem, 2 = A small amount, 3 = A moderate (medium) amount,
4 = A lot, 5 = Problem is as "bad as it can be"

Because of my voice,

1. I have trouble speaking loudly or being heard in noisy situations.	1	2	3	4	5
2. I run out of air and need to take frequent breaths when talking.	1	2	3	4	5
3. I sometimes do not know what will come out when I begin speaking.	1	2	3	4	5
4. I am sometimes anxious or frustrated (because of my voice).	1	2	3	4	5
5. I sometimes get depressed (because of my voice).	1	2	3	4	5
6. I have trouble using the telephone (because of my voice).	1	2	3	4	5
7. I have trouble doing my job or practicing my profession (because of my voice).	1	2	3	4	5
8. I avoid going out socially (because of my voice).	1	2	3	4	5
9. I have to repeat myself to be understood.	1	2	3	4	5
10. I have become less outgoing (because of my voice).	1	2	3	4	5

APPENDIX F. Vocal Fatigue Index (VFI)

Completed to identify individuals with vocal fatigue based on symptoms of voice problems (Nanjundeswaran et al., 2015).

These are some symptoms usually associated with voice problems. Circle the response that indicates how frequently you experience the same symptoms

0- never, 1- almost never, 2- sometimes, 3- almost always, 4- always

Part 1

1. I don't feel like talking after a period of voice use	0	1	2	3	4
2. My voice feels tired when I talk more	0	1	2	3	4
3. I experience increased sense of effort with talking	0	1	2	3	4
4. My voice gets hoarse with voice use	0	1	2	3	4
5. It feels like work to use my voice	0	1	2	3	4
6. I tend to generally limit my talking after a period of voice use	0	1	2	3	4
7. I avoid social situations when I know I have to talk more	0	1	2	3	4
8. I feel I cannot talk to my family after a work day	0	1	2	3	4
9. It is effortful to produce my voice after a period of voice use	0	1	2	3	4
10. I find it difficult to project my voice with voice use	0	1	2	3	4
10. My voice feels weak after a period of voice use	0	1	2	3	4

Part 2

1. I experience pain in the neck at the end of the day with voice use	0	1	2	3	4
2. I experience throat pain at the end of the day with voice use	0	1	2	3	4
3. My voice feels sore when I talk more	0	1	2	3	4

4. My throat aches with voice use	0 1 2 3 4
5. I experience discomfort in my neck with voice use	0 1 2 3 4

Part 3

1. My voice feels better after I have rested	0 1 2 3 4
2. The effort to produce my voice decreases with rest	0 1 2 3 4
3. The hoarseness of my voice gets better with rest	0 1 2 3 4

APPENDIX G. Big Five Inventory -10 (BFI-10)

Completed to assess personality characteristics in a research setting (Rammstedt & John, 2007).

Instructions: How well do the following statements describe your personality?

1= disagree strongly, 2= disagree a little, 3=neither agree nor disagree, 4= agree a little, 5= agree strongly

I see myself as someone who…

1.	Is reserved	1	2	3	4	5
2.	Is generally trusting	1	2	3	4	5
3.	Tends to be lazy	1	2	3	4	5
4.	Is relaxed, handles stress well	1	2	3	4	5
5.	Has few artistic interests	1	2	3	4	5
6.	Is outgoing, sociable	1	2	3	4	5
7.	Tends to find fault with others	1	2	3	4	5
8.	Does a thorough job	1	2	3	4	5
9.	Get nervous easily	1	2	3	4	5
10.	Has an active imagination	1	2	3	4	5

APPENDIX H. Pulmonary Function Test Results

Table 3A. Preliminary analyses of a set of pulmonary function test results from college-aged females in a Michigan State Kinesiology class collected prior to current study.

	FVC (liters)	*FEV1 (liters)*	*FEV1/FVC (percentage)*
Mean	4.09	3.5	85.58
Maximum	5.02	4.58	98
Minimum	2.92	2.34	66

Table 4A. Pulmonary function test results from this study compared to Occupational Safety and Health Standards (OSHA, 2017).

	FVC (liters)	*FEV1 (liters)*	*FEV1/FVC (percentage)*	*PEF (liters/second)*	*Lung Age (years)*
Mean	3.57	3.04	85.1	6.85	29.25
*OSHA Predicted Norms**	3.78	3.15	-	-	-
Maximum	4.57	3.82	91	8.44	58
Minimum	2.86	2.47	71	5.34	20
Standard Deviation	.39	.35	5.04	.98	11.35

*Based on gender (female), mean age (23.8 years) and height (64.5 inches) for participants within this study.

Table 5A. Pulmonary function test results from this study for each participant.

Participant ID	*Day*	*FEV1 (liters)*	*FEV1 (% predicted)*	*FVC (liters)*	*FVC (% predicted)*	*PEF (liters/ second)*	*PEF (% predicted)*	*Lung Age (years)*
S001	1	3.23	96	3.66	94	8.44	120	24
S001	2	3.17	94	3.72	95	8.06	114	24
S002	1	2.69	88	3.08	87	6.99	106	46
S002	2	2.7	89	3.16	90	6.62	100	45
S003	1	2.79	84	3.14	80	6.05	85	54
S003	2	2.47	75	2.86	73	5.94	83	58
S004	1	2.97	93	3.68	100	6.12	91	24
S004	2	3	94	3.69	101	5.91	88	24
S005	1	3.31	103	3.8	103	7.85	115	20
S005	2	3.18	99	3.69	100	7.65	112	26
S006	1	3.82	104	4.57	106	8.13	107	24
S006	2	3.81	104	4.24	98	8.38	111	24
S007	1	2.96	85	3.32	82	6.24	86	24
S007	2	2.91	84	3.31	82	6.27	86	24
S008	1	3.18	103	3.69	105	6.59	100	24
S008	2	3.18	103	3.68	104	6.92	105	24
S009	1	2.661	79	3.73	95	5.34	76	24
S009	2	2.70	80	3.66	94	5.34	76	24
S010	1	3.01	85	3.3	82	6.9	97	24
S010	2	2.99	84	3.38	84	7.36	103	24

APPENDIX I. Self-Reported Vocal Fatigue Ratings

Table 6A. Self-Reported Vocal Fatigue Ratings from this study for each participant.

Participant ID	*Day*	*Timing (minutes)*	*Vocal Fatigue Level (0-10 scale)*
S001	1	0	2
S001	1	10	1
S001	1	20	0
S001	1	30	0
S001	2	0	2
S001	2	10	5
S001	2	20	7
S001	2	30	9
S002	1	0	0
S002	1	10	0
S002	1	20	0
S002	1	30	0
S002	2	0	1
S002	2	10	3
S002	2	20	5
S002	2	30	7
S003	1	0	8
S003	1	10	6
S003	1	20	3
S003	1	30	0
S003	2	0	2
S003	2	10	5
S003	2	20	8
S003	2	30	10
S004	1	0	4
S004	1	10	3
S004	1	20	2
S004	1	30	2
S004	2	0	3
S004	2	10	6
S004	2	20	7
S004	2	30	8
S005	1	0	1
S005	1	10	1
S005	1	20	0
S005	1	30	0
S005	2	0	1
S005	2	10	2
S005	2	20	3
S005	2	30	3
S006	1	0	1
S006	1	10	2
S006	1	20	1
S006	1	30	0
S006	2	0	0

Table 6A. (continued)

S006	2	10	4
S006	2	20	6
S006	2	30	8
S007	1	0	0
S007	1	10	0
S007	1	20	0
S007	1	30	0
S007	2	0	0
S007	2	10	2
S007	2	20	3
S007	2	30	3
S008	1	0	4
S008	1	10	3
S008	1	20	1
S008	1	30	0
S008	2	0	0
S008	2	10	4
S008	2	20	5
S008	2	30	6
S009	1	0	2
S009	1	10	1
S009	1	20	1
S009	1	30	1
S009	2	0	2
S009	2	10	5
S009	2	20	5
S009	2	30	7
S010	1	0	3
S010	1	10	3
S010	1	20	1
S010	1	30	0
S010	2	0	1
S010	2	10	4
S010	2	20	6
S010	2	30	6

APPENDIX J. Acoustic Measures Results

Table 7A. Acoustic measurements of ΔSPL (dB) for each participant during “My vocal fatigue level is…” statement.

Participant ID	*Day*	*ΔSPL (dB) Mean*	*ΔSPL (dB) Standard Deviation*
S001	1	4	2.5E-10
S001	2	4	1.4E-17
S002	1	4	2.8E-17
S002	2	4	5.6E-17
S003	1	4	-3.5E-17
S003	2	4	1.4E-17
S004	1	4	2.5E-10
S004	2	4	6.9E-17
S005	1	4	-2.5E-10
S005	2	4	2.5E-10
S006	1	4	0.0E+00
S006	2	4	-5.6E-17
S007	1	4	0.0E+00
S007	2	4	5.6E-17
S008	1	4	2.5E-10
S008	2	4	-2.5E-10
S009	1	4	2.8E-17
S009	2	4	3.5E-17
S010	1	4	0.0E+00
S010	2	4	2.5E-10

Table 8A. Acoustic measurements of f_0 (Hz) for each participant during “My vocal fatigue level is…” statement.

Participant ID	*Day*	*f_0 (Hz) Mean*	*f_0 (Hz) Standard Deviation*
S001	1	4	222.84
S001	2	4	256.86
S002	1	4	200.52
S002	2	4	219.27
S003	1	4	204.64
S003	2	4	195.45
S004	1	4	239.90
S004	2	4	228.12
S005	1	4	205.01
S005	2	4	213.31
S006	1	4	218.21
S006	2	4	241.22
S007	1	4	211.32
S007	2	4	237.94
S008	1	4	206.77
S008	2	4	204.47
S009	1	4	215.00
S009	2	4	215.80

Table 8A. (continued)

S010	1	4	224.78
S010	2	4	242.66

Table 9A. Acoustic measurements of ΔSPL (dB) for each participant during vocal tasks (Diapix and Rainbow Passage).

Participant ID	*Day*	*Pre/Post Vocal Loading Task*	*ΔSPL (dB) Mean*	*ΔSPL (dB) Standard Deviation*
S001	1	Pre	2	1.33
S001	1	Post	2	-1.33
S001	2	Pre	2	-0.08
S001	2	Post	2	0.08
S002	1	Pre	2	-0.75
S002	1	Post	2	0.75
S002	2	Pre	2	1.81
S002	2	Post	2	-1.81
S003	1	Pre	2	0.10
S003	1	Post	2	-0.10
S003	2	Pre	2	0.97
S003	2	Post	2	-0.97
S004	1	Pre	2	1.13
S004	1	Post	2	-1.13
S004	2	Pre	2	-1.36
S004	2	Post	2	1.36
S005	1	Pre	2	-0.63
S005	1	Post	2	0.63
S005	2	Pre	2	-1.69
S005	2	Post	2	1.69
S006	1	Pre	2	0.18
S006	1	Post	2	-0.18
S006	2	Pre	2	-0.82
S006	2	Post	2	0.82
S007	1	Pre	2	-1.50
S007	1	Post	2	1.50
S007	2	Pre	2	-1.44
S007	2	Post	2	1.44
S008	1	Pre	2	-1.25
S008	1	Post	2	1.25
S008	2	Pre	2	-1.81
S008	2	Post	2	1.81
S009	1	Pre	2	-0.72
S009	1	Post	2	0.72
S009	2	Pre	2	1.23
S009	2	Post	2	-1.23
S010	1	Pre	2	-1.84
S010	1	Post	2	1.84
S010	2	Pre	2	-1.05
S010	2	Post	2	1.05

Table 10A. Acoustic measurements of f_0 (Hz) for each participant during vocal tasks (Diapix and Rainbow Passage).

Participant ID	*Day*	*Pre/Post Vocal Loading Task*	*f_0 (Hz) Mean*	*f_0 (Hz) Standard Deviation*
S001	1	Pre	2	221.67
S001	1	Post	2	221.77
S001	2	Pre	2	229.71
S001	2	Post	2	228.81
S002	1	Pre	2	200.73
S002	1	Post	2	201.05
S002	2	Pre	2	208.73
S002	2	Post	2	195.11
S003	1	Pre	2	190.61
S003	1	Post	2	201.33
S003	2	Pre	2	194.53
S003	2	Post	2	202.13
S004	1	Pre	2	213.97
S004	1	Post	2	214.92
S004	2	Pre	2	208.00
S004	2	Post	2	226.25
S005	1	Pre	2	189.59
S005	1	Post	2	188.35
S005	2	Pre	2	199.04
S005	2	Post	2	205.14
S006	1	Pre	2	227.31
S006	1	Post	2	227.71
S006	2	Pre	2	221.81
S006	2	Post	2	219.64
S007	1	Pre	2	210.19
S007	1	Post	2	212.34
S007	2	Pre	2	204.07
S007	2	Post	2	218.04
S008	1	Pre	2	197.69
S008	1	Post	2	193.24
S008	2	Pre	2	191.42
S008	2	Post	2	193.23
S009	1	Pre	2	194.97
S009	1	Post	2	189.65
S009	2	Pre	2	192.14
S009	2	Post	2	204.45
S010	1	Pre	2	208.22
S010	1	Post	2	222.24
S010	2	Pre	2	202.08
S010	2	Post	2	222.65

APPENDIX K. The Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach his friends say he is looking for the pot of gold at the end of the rainbow." First paragraph of the Rainbow Passage (Fairbanks, 1960)

APPENDIX L. Day 1 Protocol Instructions

SUBJECT NUMBER:_________________
DATE:_____________________________
TIME:______________________________
"Hello and welcome to our study! I want to make sure you know this will be a two-day study. Before we continue, would you be able to come in some time soon to complete the 2nd half of the study? --- Do you have any questions before we begin?"

☐ Seat the subject
"Please read and sign this consent form. Let me know if you have any questions."
Hand subject consent form

☐ Give the subject a copy of the consent form for their records
Hand subject consent form

☐ Ask subject to silence or turn off phone

☐ Attach head mounted microphone – start recording

☐ Start lingWAVES recording

☐ Do a sound check
"Participant number __ (PFF_VF_S00X), Day 1, Date, and Time"

❖ ENDOSCOPIC EXAM

OFFER SIP OF WATER

❖ VOCAL SCREENING

☐ TASK 1: RAINBOW
Equipment: Rainbow Passage Sheet
"For this next task I am going to ask you to read a passage in a comfortable voice. Begin when you are ready." Present the Rainbow Passage.
OFFER SIP OF WATER

☐ TASK 2: DIAPIX
Equipment: Diapix pictures
"Now please look at this pictures and describe what is happening. Describe the picture in detail, as if you wanted your listener to be able to pick this picture from a group of pictures. Please describe this for thirty seconds. When the timer goes off you are finished."
Completed picture: ___________

☐ TASK 3: STEADY VOWELS (MAXIMUM PHONATION TIME)
Equipment: timer

“For this task, I would like you to count to five slowly, 1 2 3 4 5, then say “ah” at the same pitch as the “i” in five and hold it steady for several seconds.”
“Now, I would like you to take a deep breath and say “ah” for as long and as steady as you can at a comfortable pitch. We will do this three times. You can start whenever you are ready.”
(have the subject repeat this three times, and take a bit of a break in between)
Time 1:______
Time 2:______
Time 3:______

☐ “I would like you to say “AFA” four times at a comfortable volume and pitch. Like this…. Okay and repeat that again.”

OFFER SIP OF WATER

☐ TASK 4: SUBJECTIVE & INABILITY TO PRODUCE SOFT VOICE

1. “First, I want you to rate your voice in several ways. On this scale please mark with a line to indicate how tired your voice feels, if any, from not at all to extremely.”
Present vocal fatigue
2. “On this scale please mark with a line how much effort does it take for you to produce your voice? From not at all to extremely.”
Present vocal effort
3. “Now I would like you to tell me how much discomfort you feel in your throat, if any, on the same scale from not at all to extremely.”
Present discomfort in throat
4. “Please swallow hard and try to feel where the discomfort is located. Is it inside your throat, outside your throat, in both places, or neither place?”
Location of discomfort (inside) (outside) (inside & outside) (neither)(other)

“Now I would like you to complete some vocal tasks. Then, rate your voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to produce the sound to difficult to produce the sound.”

“Sustain the vowel /i/ (“ee”) for 5 seconds on a comfortable pitch”
“Glide on the vowel /i/ (“ee”) from low pitch to high pitch like this ‘heee’”
“Please say “ee-ee-ee-ee-ee-ee-ee about 6-7 times on a comfortable pitch”
“Please sing a few bars of “Happy Birthday as quietly as you can” on a comfortable pitch.”
VAS to mark ability to produce sound (easy to difficult)
“I would like you to repeat those same tasks, but as quietly as possible. Do not try to get louder – if your voice stops, that’s ok. The goal is to use a high pitch but keep your voice as soft as possible without whispering. Then, rate your soft voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to difficult.”
“Sustain the vowel /i/ (“ee”) for 5 seconds on a high pitch as softly as possible”
“Glide on the vowel /i/ (“ee”) from low pitch to high pitch like this ‘heee’ as softly as you can”

"Please say "ee-ee-ee-ee-ee-ee-ee about 6-7 times on the highest pitch you can and as quietly as you can"
"Please sing a few bars of "Happy Birthday as quietly as you can and in the highest pitch you can"

VAS to mark ability to produce sound (easy to difficult)

OFFER SIP OF WATER

☐ Before we begin, every ten minutes throughout the study you will be asked to rate your vocal fatigue. A light will flash on and off of the poster to signal you to read the phrase and respond. As you can see the phrase states "My vocal fatigue level is….". We would like you to read that phrase and then state your vocal fatigue on a scale from 0 to 10. With 0 being no level of fatigue and 10 being the greatest. Please state your current level of fatigue now using the prompt.
Other than that during the next 30 minutes I would like you to talk as little as possible. Please use post it notes or hand gestures to communicate.

☐ Start Timer

❖ BREATHING SCREENING

☐ TASK 5: BREATHING

Mark results on respiration screening form

Table 11A. Breathing screening form used to evaluate participants during Day 1.

Type of breathing		Score	
		Present	Absent
Diaphragmatic	The belly pushes out with an inhale		
Thoracic	During inhale the chest expands to accommodate the air that has been sucked into the lungs		
Clavicular	During inhale the clavicle goes up to accommodate the air that has been sucked into the upper part of the lungs		
Paradoxical	The chest compresses on the inhale rather than expands and vice versa		

Type of respiration cycle in non-speech:

Oral-Oral	
Nasal-Nasal	
Oral-Nasal	

Coordination of respiration-voice:

Adequate	
Not Adequate	

❖ HEARING SCREENING

☐ TASK 6: HEARING TEST

Mark results on screening form (25dB)

Table 12A. Hearing screening form used to evaluate participants during Day 1.

LEFT EAR	RIGHT EAR
☐ 1,000 Hz	☐ 1,000 Hz
☐ 500 Hz	☐ 500 Hz
☐ 250 Hz	☐ 250 Hz
☐ 125 Hz	☐ 125 Hz
☐ 1,000 Hz	☐ 1,000 Hz
☐ 2,000 Hz	☐ 2,000 Hz
☐ 4,000 Hz	☐ 4,000 Hz
☐ 8,000 Hz	☐ 8,000 Hz

☐ TASK 7: SURVEYS

☐ Subject completes surveys (PI, V-RQOL, VHI-10, VFI, BFI-10)

”Use this remaining time to completely fill out the questionnaires on this online survey.” *Direct subject to online surveys*

☐ WAIT UNTIL END OF LINGWAVES TO BEGIN

Time:	0 minutes	10 minutes	20 minutes	30 minutes
Fatigue level:				

❖ VOCAL SCREENING

☐ TASK 8: RAINBOW

<u>Equipment</u>: *Rainbow Passage Sheet*

“For this next task I am going to ask you to read a passage in a comfortable voice. Begin when you are ready.” Present the Rainbow Passage.

OFFER SIP OF WATER

☐ TASK 9: DIAPIX

<u>Equipment</u>: Diapix pictures

"Now please look at this pictures and describe what is happening. Describe the picture in detail, as if you wanted your listener to be able to pick this picture from a group of pictures. Please describe this for thirty seconds. When the timer goes off you are finished."

Complete picture: ___________

☐ TASK 10: STEADY VOWELS (MAXIMUM PHONATION TIME)

<u>Equipment</u>: timer

"For this task, I would like you to count to five slowly, 1 2 3 4 5, then say "ah" at the same pitch as the "i" in five and hold it steady for several seconds."

"Now, I would like you to take a deep breath and say "ah" for as long and as steady as you can at a comfortable pitch. We will do this three times. You can start whenever you are ready."

(have the subject repeat this three times, and take a bit of a break in between)

Time 1:______

Time 2:______

Time 3:______

☐ "I would like you to say "AFA" four times at a comfortable volume and pitch. Like this…. Okay and repeat that again."

OFFER SIP OF WATER

☐ TASK 11: SUBJECTIVE RATING & INABILITY TO PRODUCE SOFT VOICE

1. "First, I want you to rate your voice in several ways. On this scale please mark with a line to indicate how tired your voice feels, if any, from not at all to extremely."

    Present vocal fatigue

2. "On this scale please mark with a line how much effort does it take for you to produce your voice? From not at all to extremely."

    Present vocal effort

3. "Now I would like you to tell me how much discomfort you feel in your throat, if any, on the same scale from not at all to extremely."

    Present discomfort in throat

4. "Please swallow hard and try to feel where the discomfort is located. Is it inside your throat, outside your throat, in both places, or neither place?"

    Location of discomfort (inside) (outside) (inside & outside) (neither)(other)

"Now I would like you to complete some vocal tasks. Then, rate your voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to produce the sound to difficult to produce the sound."

"Sustain the vowel /i/ ("ee") for 5 seconds on a comfortable pitch"

"Glide on the vowel /i/ ("ee") from low pitch to high pitch like this 'heee'"
"Please say "ee-ee-ee-ee-ee-ee-ee about 6-7 times on a comfortable pitch"
"Please sing a few bars of "Happy Birthday as quietly as you can" on a comfortable pitch."

VAS to mark ability to produce sound (easy to difficult)

"I would like you to repeat those same tasks, but as quietly as possible. Do not try to get louder – if your voice stops, that's ok. The goal is to use a high pitch but keep your voice as soft as possible without whispering. Then, rate your soft voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to difficult."
"Sustain the vowel /i/ ("ee") for 5 seconds on a high pitch as softly as possible"
"Glide on the vowel /i/ ("ee") from low pitch to high pitch like this 'heee' as softly as you can"
"Please say "ee-ee-ee-ee-ee-ee-ee about 6-7 times on the highest pitch you can and as quietly as you can"
"Please sing a few bars of "Happy Birthday as quietly as you can and in the highest pitch you can"

VAS to mark ability to produce sound (easy to difficult)

❖ PULMONARY FUNCTION TEST

☐ TASK 12: PFT

"First, I'm going to give you some instructions to follow for the test. Then, I'm going to model how to complete the procedure…..Please inhale as much and as deeply as you can as quickly as you can. Then, exhale as fast as you can pushing all the air out of your lungs. Do not pause between the inhalation and exhalation. Feel free to use the rest of your body to move as much air as possible."
(Perform exaggerated demo and give patient nose clip.)

Offer participant copy of PFT results

OFFER SIP OF WATER

"Thank you for coming. We are finished for today. We'll go ahead and set up your return time for the second part of the study." ...

APPENDIX M. Day 2 Protocol Instructions

SUBJECT NUMBER:_________________
DATE:_____________________________
TIME:_____________________________
"Hello and welcome back to our study. This will be the final day of the study. Thank you for your continued participation. Do you have any questions before we begin?

☐ Seat the subject

☐ Ask subject to silence or turn off phone

☐ Attach head mounted microphone – start recording

☐ Start lingWAVES recording

☐ Do a sound check
"Participant number __ (PFF_VF_S00X), Day 2, Date, and Time"

❖ VOCAL SCREENING

☐ TASK 1: RAINBOW
Equipment: Rainbow Passage Sheet
"For this next task I am going to ask you to read a passage in a comfortable voice. Begin when you are ready." Present the Rainbow Passage.
OFFER SIP OF WATER

☐ TASK 2: DIAPIX
Equipment: Diapix pictures
"Now please look at this pictures and describe what is happening. Describe the picture in detail, as if you wanted your listener to be able to pick this picture from a group of pictures. Please describe this for thirty seconds. When the timer goes off you are finished."
Complete picture: ___________

☐ TASK 3: STEADY VOWELS (MAXIMUM PHONATION TIME)
Equipment: timer
"For this task, I would like you to count to five slowly, 1 2 3 4 5, then say "ah" at the same pitch as the "i" in five and hold it steady for several seconds."
"Now, I would like you to take a deep breath and say "ah" for as long and as steady as you can at a comfortable pitch. We will do this three times. You can start whenever you are ready."
(have the subject repeat this three times, and take a bit of a break in between)
Time 1:______
Time 2:______
Time 3:______

☐ "I would like you to say "AFA" four times at a comfortable volume and pitch. Like this…. Okay and repeat that again."

OFFER SIP OF WATER

☐ TASK 4: SUBJECTIVE RATING & INABILITY TO PRODUCE SOFT VOICE

1. "First, I want you to rate your voice in several ways. On this scale please mark with a line to indicate how tired your voice feels, if any, from not at all to extremely."

    Present vocal fatigue

2. "On this scale please mark with a line how much effort does it take for you to produce your voice? From not at all to extremely."

    Present vocal effort

3. "Now I would like you to tell me how much discomfort you feel in your throat, if any, on the same scale from not at all to extremely."

    Present discomfort in throat

4. "Please swallow hard and try to feel where the discomfort is located. Is it inside your throat, outside your throat, in both places, or neither place?"

    Location of discomfort (inside) (outside) (inside & outside) (neither)(other)

"Now I would like you to complete some vocal tasks. Then, rate your voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to produce the sound to difficult to produce the sound."

"Sustain the vowel /i/ ("ee") for 5 seconds on a comfortable pitch"
"Glide on the vowel /i/ ("ee") from low pitch to high pitch like this 'heee'"
"Please say "ee-ee-ee-ee-ee-ee-ee about 6-7 times on a comfortable pitch"
"Please sing a few bars of "Happy Birthday as quietly as you can" on a comfortable pitch."

VAS to mark ability to produce sound (easy to difficult)

"I would like you to repeat those same tasks, but as quietly as possible. Do not try to get louder – if your voice stops, that's ok. The goal is to use a high pitch but keep your voice as soft as possible without whispering. Then, rate your soft voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to difficult."

"Sustain the vowel /i/ ("ee") for 5 seconds on a high pitch as softly as possible"
"Glide on the vowel /i/ ("ee") from low pitch to high pitch like this 'heee' as softly as you can"
"Please say "ee-ee-ee-ee-ee-ee-ee about 6-7 times on the highest pitch you can and as quietly as you can"
"Please sing a few bars of "Happy Birthday as quietly as you can and in the highest pitch you can"

VAS to mark ability to produce sound (easy to difficult)

OFFER SIP OF WATER

❖ SPEAKING TASK

☐ Before we begin, every ten minutes throughout the study you will be asked to rate your vocal fatigue. A light will flash on and off of the poster to signal you to read the phrase and respond. As you can see the phrase states "My vocal fatigue level is….". We would like you to read that phrase and then state your vocal fatigue on a scale from 0 to 10. With 0 being no level of fatigue and 10 being the greatest. Please state your current level of fatigue now using the prompt.

❖ ☐ Start lingWAVES system

☐ TASK 5: SPEAKING

"Please read the provided material as if you were speaking to a classroom of students. Attempt to make your voice animated and engaging to your listeners while reading at the level dictated by the program. The program tries to guide you to speak at two different speaking volumes, which will imitate what a teacher may do in front of students. At times, the program will guide you to speak at a normal volume, and then it will guide you to speak at a raised volume. It does this with a line for you to match with your voice. If your speaking volume falls below the desired speaking level, a large arrow will appear on the screen indicating that you need to raise your voice a little. Please increase your speaking volume until you match the line and the arrow disappears. Throughout the test, the speaking volume level will alternate."

REMOVE WATER FROM ROOM

Time:	0 minutes	10 minutes	20 minutes	30 minutes
Fatigue level:				

❖ VOCAL SCREENING

OFFER SIP OF WATER

1. "First, I want you to rate your voice in several ways. On this scale please mark with a line to indicate how tired your voice feels, if any, from not at all to extremely."
   Present vocal fatigue
2. "On this scale please mark with a line how much effort does it take for you to produce your voice? From not at all to extremely."
   Present vocal effort
3. "Now I would like you to tell me how much discomfort you feel in your throat, if any, on the same scale from not at all to extremely."
   Present discomfort in throat
4. "Please swallow hard and try to feel where the discomfort is located. Is it inside your throat, outside your throat, in both places, or neither place?"
   Location of discomfort

☐ TASK 6: RAINBOW

<u>*Equipment*</u>*: Rainbow Passage Sheet*

"For this next task I am going to ask you to read a passage in a comfortable voice. Begin when you are ready." Present the Rainbow Passage.

OFFER SIP OF WATER

☐ TASK 7: DIAPIX

Equipment: Diapix pictures
"Now please look at this pictures and describe what is happening. Describe the picture in detail, as if you wanted your listener to be able to pick this picture from a group of pictures. Please describe this for thirty seconds. When the timer goes off you are finished."
Complete picture: ___________

☐ TASK 8: STEADY VOWELS (MAXIMUM PHONATION TIME)

Equipment: timer
"For this task, I would like you to count to five slowly, 1 2 3 4 5, then say "ah" at the same pitch as the "i" in five and hold it steady for several seconds."
"Now, I would like you to take a deep breath and say "ah" for as long and as steady as you can at a comfortable pitch. We will do this three times. You can start whenever you are ready."
(have the subject repeat this three times, and take a bit of a break in between)
Time 1:______
Time 2:______
Time 3:______

☐ "I would like you to say "AFA" four times at a comfortable volume and pitch. Like this…. Okay and repeat that again."

OFFER SIP OF WATER

☐ TASK 9: SUBJECTIVE RATING & INABILITY TO PRODUCE SOFT VOICE

1. "First, I want you to rate your voice in several ways. On this scale please mark with a line to indicate how tired your voice feels, if any, from not at all to extremely."
Present vocal fatigue
2. "On this scale please mark with a line how much effort does it take for you to produce your voice? From not at all to extremely."
Present vocal effort
3. "Now I would like you to tell me how much discomfort you feel in your throat, if any, on the same scale from not at all to extremely."
Present discomfort in throat
4. "Please swallow hard and try to feel where the discomfort is located. Is it inside your throat, outside your throat, in both places, or neither place?"
Location of discomfort (inside) (outside) (inside & outside) (neither)(other)

"Now I would like you to complete some vocal tasks. Then, rate your voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to produce the sound to difficult to produce the sound."

"Sustain the vowel /i/ ("ee") for 5 seconds on a comfortable pitch"

“Glide on the vowel /i/ (“ee”) from low pitch to high pitch like this ‘heee’”
“Please say “ee-ee-ee-ee-ee-ee-ee about 6-7 times on a comfortable pitch”
“Please sing a few bars of “Happy Birthday as quietly as you can” on a comfortable pitch.”

VAS to mark ability to produce sound (easy to difficult)

“I would like you to repeat those same tasks, but as quietly as possible. Do not try to get louder – if your voice stops, that’s ok. The goal is to use a high pitch but keep your voice as soft as possible without whispering. Then, rate your soft voice production by making a tick on the scale that matches your ease of phonation after performing the tasks from easy to difficult.”
“Sustain the vowel /i/ (“ee”) for 5 seconds on a high pitch as softly as possible”
“Glide on the vowel /i/ (“ee”) from low pitch to high pitch like this ‘heee’ as softly as you can”
“Please say “ee-ee-ee-ee-ee-ee-ee about 6-7 times on the highest pitch you can and as quietly as you can”
“Please sing a few bars of “Happy Birthday as quietly as you can and in the highest pitch you can”

VAS to mark ability to produce sound (easy to difficult)

OFFER SIP OF WATER

❖ PULMONARY FUNCTION TEST

☐ TASK 10: PFT

“First, I’m going to give you some instructions to follow for the test. Then, I’m going to model how to complete the procedure…..Please inhale as much and as deeply as you can as quickly as you can. Then, exhale as fast as you can pushing all the air out of your lungs. Do not pause between the inhalation and exhalation. Feel free to use the rest of your body to move as much air as possible.”
(Perform exaggerated demo and give patient nose clip.)

Offer participant copy of PFT results

OFFER SIP OF WATER

Thank you for coming…

APPENDIX N. IRB Approval Documents

MICHIGAN STATE UNIVERSITY

Revision Application Approval

July 21, 2016

To: Eric Hunter
1026 Red Cedar Road
Room 113, Oyer Speech & Hearing Building
East Lansing, MI 48824

Re: **IRB# 16-689** Category: EXPEDITED 4, 7
Revision Approval Date: July 21, 2016
Project Expiration Date: June 1, 2017

Title: Gender Differences in Speech Accommodations in Occupational Settings: The Relationship Between Pulmonary Function and Vocal Fatigue (CGA# 136350)

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **the revision has been approved**.

This letter notes approval for the revised participant information sheet and consent form. This letter also notes approval to add a hearing screening and additional pulmonary function tests.

The review by the committee has found that your revision is consistent with the continued protection of the rights and welfare of human subjects, and meets the requirements of MSU's Federal Wide Assurance and the Federal Guidelines (45 CFR 46 and 21 CFR Part 50). The protection of human subjects in research is a partnership between the IRB and the investigators. We look forward to working with you as we both fulfill our responsibilities.

Renewals: IRB approval is valid until the expiration date listed above. If you are continuing your project, you must submit an ***Application for Renewal*** application at least one month before expiration. If the project is completed, please submit an ***Application for Permanent Closure***.

Revisions: The IRB must review any changes in the project, prior to initiation of the change. Please submit an ***Application for Revision*** to have your changes reviewed. If changes are made at the time of renewal, please include an ***Application for Revision*** with the renewal application.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects, notify the IRB office promptly. Forms are available to report these issues.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

Ashir Kumar

Ashir Kumar, M.D.
BIRB Chair

c: Callan Gavigan, Pasquale Bottalico, Simone Graetzer, James Pivarnik, Russell Banks, Peter LAPINE, Mark Berardi, Lady Catherine Cantor Cutiva

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