5-2022

Acoustic and Perceptual Effects of Mask-Wearing on Voice and Communication in Healthcare Practitioners

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ACOUSTIC AND PERCEPTUAL EFFECTS OF MASK-WEARING ON VOICE AND COMMUNICATION IN HEALTHCARE PRACTITIONERS

A Thesis

by

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Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Major Subject: Communication Sciences and Disorders

The University of Texas Rio Grande Valley

May 2022

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ON VOICE AND COMMUNICATION IN

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May 2022

ABSTRACT

Ortiz Garcia, Astrid C., Acoustic and Perceptual Effects of Mask-Wearing on Voice and Communication in Healthcare Practitioners. Master of Science (MS), May, 2022, 117 pp., 10 tables, references, 66 titles.

The purpose of the present study aims to determine the perceptual and acoustic effects of masks use in the voices and communication abilities of healthcare practitioners during the COVID-19 pandemic. A total of 19 participants completed recordings and were assigned to experimental group (E) or control group (C). Additionally, 17 subjects completed the survey portion.

To gather perceptual data, a survey was created addressing voice effects, mask use, and demographics. To identify acoustic-measure changes, various acoustic measures were analyzed, using PRAAT software. Comparisons between control and experimental groups were completed to determine discrepancies that may provide insight on hydration and its role in addressing different vocal symptoms.

Findings indicated affected communication, increased effort to phonate, and different vocal experiences. Acoustic measures expressed impacted vocal health in participants. When comparing control and experimental groups, effects were noted on certain measures of the experimental group, indicating hydration may have impacted acoustic values.

DEDICATION

The completion of this degree would not have been possible without the constant love and support of my family, friends, and boyfriend. This accomplishment is as much yours as it is mine: I could not have done it without your unwavering support. Thank you for sticking with me and being encouraging till the end.

And to my grandmother—who always led by example and showed us what a true warrior looks like—This one's for you.

ACKNOWLEDGMENTS

Dr. Crutchfield:

Without your support, dedication, and guidance this thesis would not have been possible. A thank you is not enough for giving me the opportunity to challenge myself and see all I can accomplish once I set my mind to it. May you continue to enrich the minds of all those you come across.

Dr. Stewart and Mr. Culbertson:

Thank you for all the encouragement and enthusiasm you expressed regarding this study: your input, time, and assistance in the completion of this thesis does not go unnoticed.

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CHAPTER I

BACKGROUND

Introduction

Prolonged mask use following COVID-19's establishment as a pandemic resulted in increased reports of vocal symptoms by healthcare practitioners in the past year. Experiences of expanding patient caseload paired with continued demands to provide quality care despite limited facility occupancy, strict PPE guidelines, and recommendations of maintaining a 6-foot distance from other individuals resulted in elevated reports of the taxing mental, emotional, and physical effects experienced by healthcare practitioners as they navigated this novel situation (CDC, 2021).

Voice was indicated to be one of the many affected areas, and it is no surprise that an influx in strict requirements to wear a facemask resulted in adverse effects in this population's vocal quality and communication ability (Unoki et al., 2021). In order to better understand this topic, this thesis will discuss the perceptual and acoustic effects in the voices of healthcare practitioner secondary to mask use in order to identify various aspects of vocal sensations experienced and if these experiences correlate with acoustic measures.

COVID-19—A Pandemic and its Statistics

Coronavirus, also referred to as COVID-19, is a severe acute respiratory infection caused by the SARS-CoV-2 virus (World Health Organization [WHO], n.d.). This disease—identified by the World Health Organization's (WHO) Country Office in the Peoples Republic of China—was discovered following an increase of pneumonia cases in the city of Wuhan. Prior to this infection's recognition as a novel coronavirus on January 11, 2020, the cause of the pneumonia was unknown (Centers for Disease Control and Prevention [CDC], 2021, 2021 in press). However, COVID-19's physical manifestations were noted and ranged from fevers, coughing and loss of taste and smell, to more serious symptoms including difficulty breathing, chest pains, loss of speech, loss of mobility and death. This—paired with its highly contagious nature, rising fatalities, and novelty—caused concern in professionals and the public alike (CDC, 2021; WHO, n.d.).

Following the declaration of COVID-19 as a pandemic on January 30th, 2020, by the WHO (n.d.)—countries responded by establishing mandates and guidelines to contain and diminish the spread via use of personal protective equipment (PPE), social distancing, increasing hand washing, and limiting touching of the mouth, nose, and eyes (WHO, n.d.). Masks were specifically mandated for situations where close contact with other individuals was likely to occur. These included but were not limited to social gatherings, work, and routine outings to public spaces (such as grocery shopping). This change led to a sudden rise in mask use amongst the general public. According to Fischer et al. (2021), implementation of masks for the public was seen in less than half of the U.S states as early as April 1st through October 31st, 2020—roughly 2 months after COVID had been deemed a pandemic. At that point in time, one-third of U.S states were yet to make recommendations—primarily due to each state's responsibility in establishing its own guidelines (Fischer et al., 2021). However, by August 2020, majority of U.S states had set mandates, and by November 2020 remaining states like Wyoming, Utah, North Dakota, New Hampshire, and Iowa had guidelines set in place (Ballotpedia, n.d.; CDC, 2021; Fischer et al., 2021; Multistate, 2021; WHO, n.d.).

Just as mask mandates varied from state to state and country to country, the enforcement of mask-wearing varied as well. As per the American Association of Retired Persons (AARP), mask were shown to range from being “recommended” during social situations to being reinforced through citations and fines when individuals were noncompliant (AARP, 2022). A study by Ribeiro et al. (2020) further indicated that enforcement of mask use varied similarly in places outside the U.S, such as Brazil, where punishments for noncompliance were based on state regulations and carried out by health surveillance teams (Ribeiro et al., 2020). Currently, mask mandates are no longer in place for the majority of U.S. states. Only Washington, Oregon, New Mexico, and Illinois continue requiring masks for all individuals despite vaccination status (Ballotpedia, n.d.; MultiState, 2021).

The type of face coverings made available to the public varied as well. Masks seen during the pandemic—and until now—included cloth masks of varying thicknesses and fabrics, simple disposable masks (surgical/medical procedure mask), and respirators (KN95’s, N95, FFP3, KN100, KP95 etc.). These masks were all recommended with their specific considerations, benefits, and contraindications by the CDC (CDC, 2021). Recommendations of alternative mask types were partially created secondary to the explosive demand following recommendations of the KN95’s, N95’s and surgical masks due to their efficacy in decreasing transmission of airborne diseases. This led to the CDC’s approval of cloth masks in order to conserve supplies for healthcare workers experiencing mask shortages (CDC, 2021; Lyu & Wehby, 2020).

Furthermore, the variance in mask types created an interest in not only the efficacy of the different options available, but their ability to diminish the spread of coronavirus compared to other face masks and respirators (CDC, 2021).

Although the use of masks have been heavily encouraged for their ability to reduce transmission of COVID-19 and other diseases, the literature expresses some disadvantages to their prolonged use. Recent literature suggests that face coverings have an impact on communication (CDC, 2021; Unoki et al., 2021). Voice attenuation—or dampening of voice—is noted to be exacerbated by mandate requirements such as social distancing as well, resulting in dampened or 'muffled' speech. This idea was explained via the inverse square rule which states that as distance is doubled, the intensity of noise is reduced by half. Comparisons between the use of a cloth mask and N95 respirator in 3- and 6-feet distances yielded a reduction of 3-10 dB in sounds above 1000 Hz (Giuliani, 2020). Attenuation was also cited to occur anywhere from 3-12 dB in frequencies between 2000 and 7000 Hz, to more significant disparities such as 19-27 dB for frequencies above 2000 Hz when comparing using to not using a mask (Heider et al., 2021; Ribeiro et al., 2020; Radonovich et al., 2010; Toscano & Toscano, 2021). Although most studies indicated that the type of mask played a role in the degree of sound dampening (Gantner et al., 2021; McKenna et al., 2021; Toscano & Toscano, 2021), a study by Hampton et al. (2020) and Nguyen et al. (2021) demonstrated no difference in voice effects or acoustic measures based on the type of mask subjects wore.

History of Mask Use—The Past and Present

Although mask use may seem a fairly modern topic, their implementation has been recorded for centuries, with reports dating as early as the Middle Ages and the Renaissance. During this time, 'plague doctors' who treated patients suffering from the bubonic plague were believed to wear them. This face mask rendition was depicted as covering the entire face and coming to a beak-like point, which was filled with various herbs to protect the wearer from miasma or ‘blight’—an unpleasant vapor believed to have caused the epidemic. Although plague doctors have been popularized figures, there is limited evidence of their existence with only two masks similar in nature having been excavated in the past (Matuschek et al., 2020; Strasser & Schlich, 2020).

More well-documented face and nose coverings—documented as ‘mouth protectants,’ ‘mouth bandages,’ ‘facial veils’ and ‘face masks’—were introduced with the turn of the 20^{th} century. A publicized collaboration in 1897 between surgeons Carl Friedrich Flugge and Johannes von Mikulicz’s regarding the use of mouth bandages for surgical intervention described a single-layered mask tied to the surgical cap. This piece of cloth was suspended over the nose and mouth to prevent the spread of germs so as to reduce the need for chemicals. Hubner—an assistant of Mikulicz—similarly described a double layered gauze used to prevent ‘driblet spread’ and the British surgeon, Berkeley George Andrews Moynihan, provided an illustrated iteration of a gauze mask as being suspended from lens frames via hooks in 1906 (Matuschek et al., 2020; Strasser & Schlich, 2020).

More prominent use of mask-wearing by surgeons, nurses and doctors was practiced until the year 1923 despite existing literature discussing germ theories. By the year 1935, the majority of individuals in hospital settings were photographed wearing facemasks. This shift was believed to have been influenced by the Manchurian plague of 1920 and the Influenza pandemic of 1918, both of which led to the increased use of masks by individuals outside of the medical field, such as police and residents, who were encouraged to wear them to reduced transmission of diseases.

It was at this point that face masks became a means of protecting the wearer of infection rather than its original purpose in the surgical ward (Matuschek et al., 2020; Strasser & Schlich, 2020).

The use of masks during the influenza pandemic had resulted in a decrease of the virus's spread, further encouraging individuals to don the mask. The shift to disposable face masks catapulted the medical industry into a 'total disposable system' initiated in the 1930's. At this point in time, masks began being constructed out of paper, fleece, muslin, and other synthetic materials—a change from the previously used cotton and metal masks that were easily sterilized and meant to be kept for longer periods of time (Matuschek et al., 2020; Strasser & Schlich, 2020).

A recent study by Karagkouni (2021), discussing use of face masks indicated that 62% of participants reported mask usage between 4-8 hours, while 13.1% used masks for over 8 hours a day during the COVID-19 pandemic. According to participant reports, 40.6% wore a cloth mask, 21.9% used disposable medical masks, 12.3% used face shields and 6.4% used transparent masks. Double masking—in which the user wears one mask over another—was practiced by 10% of subjects with an additional 9.3% stating they specifically used two protective face masks. In healthcare settings specifically, similarly high numbers of mask use was noted with 90.95% of subjects using a facemask anywhere from 8 to 12 hours a day. Majority of subjects specifically reported the use of surgical masks and self-filtering masks (Karagkouni, 2021).

Healthcare Practitioners—A Population in Demand

In order to address the topic of this thesis, it is important to specify the population which this paper will focus on. Healthcare practitioners are considered to be occupation voice users as they are professionals who require verbal communication to meet the demands of their occupation. According to McKenna et al. (2021) and Boone et al. (2020) these individuals may include, but are not limited to: singers, teachers, coaches, clergy, and healthcare professionals. According to the U.S Bureau of Labor Statistics, the umbrella terms ‘healthcare professional’ includes the following: audiologists, speech-language pathologists, occupational therapists, physical therapists, nurses (registered, licensed practical and licensed vocational) Ear, Nose and Throat specialists, paramedics, personal care aides and medical doctors—all of whom diagnose, treat, and manage various conditions in various settings including hospitals, in-patient and out-patient clinics, home-health, and nursing homes.

This population was noted to be at the frontlines of the pandemic. With the rise of COVID 19 cases and mask mandates worldwide, an increase in mask use across settings—especially healthcare settings—was seen. This also led to skyrocketing occupancy and patient care overnight following COVID’s pandemic status with thousands of patients being given the diagnosis leading to peak hospitalizations. According to the Office of Inspector General (OIG), some hospitals reported a 90% occupancy rate for inpatient care and over 90% occupancy for patients in the intensive care unit (ICU). This increase in patient volume resulted in instances where hospital’s occupancy was indicated to be so full patients were sent home due to inadequate space for care. This increasing stressful situation paired with the concern for personal wellbeing and strict PPE requirement resulted in healthcare professionals reporting adverse physical, mental, and emotional effects including but not limited to rashes, acne, headaches, palpitations, increased stress, trauma, impaired cognition, and emotional and mental fatigue (Grimm, 2021; Heider et al., 2021; Lyu & Wehbly, 2020; Rosner, 2020; Unoki et al., 2021). In a scoping review by Unoki et al. (2021) assessing various effects of prolonged mask use, voice disorders (31.3%) and breathing difficulties (60.0%) were deemed a concern by healthcare practitioners. Other literature mimicked the same findings for this population, with symptoms such as vocal fatigue, vocal effort, decreased intelligibility and decreased coordination of breathing and phonating being mentioned.

Literature

This thesis aims to highlight and expand on literature addressing the impact prolonged mask use has had in the voices and communicative abilities of healthcare professionals during the COVID-19 pandemic. The topic of hydrations role in vocal health will be discussed as well to better understand this method of addressing differences in voice. This information will aid in having a more comprehensive understanding of voice effects, communication impacts and acoustic changes reported by this population. Based on the current literature, topics related to this discussion included areas such as functional voice disorders, acoustics thresholds, voice and communication effects of healthcare practitioner's voice, and hydration's impact on the vocal mechanism.

CHAPTER II

LITERATURE REVIEW

Voice Disorders vs Different Vocal Symptoms

Before addressing the topic of different vocal symptoms, it is important to differentiate subjective vocal experiences from a diagnosed voice disorder—and in some cases—from a pre-existing condition as well. The American Speech-Language-Hearing Association (ASHA) defines a voice disorder as a condition affecting an individual's vocal quality, pitch, and loudness (American Speech-Language-Hearing Association [ASHA], n.d.). A voice disorder can be further divided into two distinct categories: organic and functional voice disorders.

Conditions that fall under an organic voice disorder are those that impact the integrity of the larynx and its associated structures due to underlying physiological or anatomical changes. This type of disorder branches out to include structural (i.e., physical alterations to the voice mechanism) and neurogenic (i.e., abnormalities affecting the central or peripheral nervous systems) etiologies. Changes like those mentioned above can sometimes result in individuals having a dysphonic (or 'abnormal') voice. Examples of the aforementioned conditions can include cysts and ulcers, malignant tissue changes, paralysis, or paresis secondary to a cerebrovascular accident, or impaired vocal fold movement related to progressive neurodegenerative diseases like Amyotrophic Lateral Sclerosis or Parkinson's disease. This list is non-exhaustive and is beyond the scope of the present study. (ASHA, n.d.; Boone et al., 2020). Functional voice disorders on the other hand are defined as occurring despite an otherwise healthy laryngeal mechanism, meaning there are no impaired structural or neurological changes that can explain the individual's impacted voice. This type of disorder encompasses conditions like muscle tension dysphonia (MTD) or ventricular dysphonia, both of which are noted to express high degrees of tension in the neck and laryngeal musculature. Furthermore, symptoms from both types of voice disorders can be similarly experienced by individuals with common ailments like allergies, reflux, or the casual flu (Teixeira et al., 2013). This can, potentially, lead to difficulties with appropriate differential diagnoses and treatment of voice disorder if approaches are aimed at addressing the wrong condition causing vocal concerns (Boone et al., 2020; Fernandes & Lopes, 2013; Teixeria et al., 2013).

Regarding the present study's topic, it is important to consider that different vocal symptoms—such as strain, pain, hoarseness, fatigue, roughness, and voice breaks—may be caused by vocally abusive behaviors that can be confused with symptoms associated with laryngeal pathologies (Fernandes & Lopes, 2013). In a study prior to the COVID-19 pandemic by Hartley et al. (2016), 46% of participants indicated the presence of a voice problem—39% of which lasted anywhere between 1 to 6 days—due to increasing vocal demands. None of these individuals had an existing voice disorder diagnosis.

To better understand how serious voice concerns need to be taken, statistical data demonstrates that during their lifetime, one third of the U.S. population (33.9%) will experience a voice disorder. This statistic, which estimated more than one hundred million affected individuals, emphasized not only the importance of appropriate diagnosis and treatment, but the value of raising awareness to prevent these concerns from causing more vocal quality deterioration and voice disorder diagnoses (Alves et al., 2017; Hartley et al., 2016)

This preventative mindset is especially relevant when considering that vocal abuse is noted as the most common disorder in children and adults. Due to lacking organic or functional causes to explain the discomfort, these disorders are understood to occur secondary to poor vocal hygiene and habitual abusive behaviors such as yelling, effortful talking, excessive throat clearing or simply from overuse. With consistent phono-traumatic behaviors, the possibility of developing voice disorders increases (Teixeira et al., 2013). This is especially relevant during the current pandemic as we consider the inclusion of face coverings and social distancing which potentially exacerbate negative behaviors as individuals attempts to compensate for perceptions of reduced intensity, intelligibility, or limited expression (Boone et al., 2020). Due to the current pandemic, healthcare practitioners are noted to be a population particularly at risk of abusing the vocal mechanism due to increased use of face coverings. Additionally, this population being cited as occupation voice users further exacerbates vocal health (Hamdan et al. 2022).

Acoustics of Voice

Voice acoustics is defined as the study of the physical production, control, transmission, reception, and effects of voice via use of acoustic analyses including, but not limited to, waveform analysis, voice onset time and formant frequency measurements (Nasser & Salehi, 2006; Wolfe et al., 2009). These analyses asses the two vital processes that make speech possible: the source of sound (referred to as phonation) and the modification of sound (referred to as articulation). The vocal folds—described as a pair of layered membranous folds housing the vocalis muscle—are the source of phonation. When we produce voiced sounds, the vocal folds reach midline—an action referred to as ‘adduction’—and phonate. During breathing or production of voiceless sounds, our vocal folds come slightly apart from midline allowing air to pass through them. This is referred to as ‘abduction.’ Changes to our voice is then directly impacted by our vocal folds. Pitch changes, for example, are a result of alterations to the rate, tension, and mass of the vocal folds. On the other hand, changes to the intensity of our voice depend on alterations to subglottic pressure, degree of adduction and compression of the vocal folds, and the duration and speed of vocal fold undulation. Once we phonate, our modifiers (the articulators and resonating cavities) subsequently help shape the sound into speech—a process we call 'articulation' (Boone et al., 2020; Wolfe et al., 2009). For this particular study, a focus will be placed on acoustic measures including fundamental frequency, frequency range, voice perturbation measures (jitter, shimmer, Harmonics-to-Noise, and Noise-to-Harmonics) and smoothed cepstral peak prominence (CPPS).

Fundamental Frequency and Frequency Range

Just as there are subjective qualities to our voice that we may described as 'loud,' 'soft,' 'breathy,' 'rough,' 'high pitched,' 'low pitch' and so on, there are acoustic equivalences to identify and measure these aspects of voice objectively. Pitch, for example, is the relative measure of frequency and is described as the number of sound waves within a set unit of time (Harmonicity, 2003; Teixeira & Fernandes, 2014). It is measured in Hertz (Hz). Fundamental frequency (F0) is of particular importance and looks at the number of vocal fold vibrations (or sound wave cycles) when phonating. The more vibrations per second, the higher the individuals pitch will be perceived, while less vibrations indicate a lower pitch (Boone et al., 2020).

Voice Perturbation Measures

There are a variety of perturbation measures that can be implemented to assess vocal quality, these include: Harmonic-to-Noise ratios (HNR), Noise-to-Harmonics ratio (NTH), shimmer and jitter. Harmonics-to-noise ratio addresses the relationship between the complex periodic and aperiodic components of voicing. Periodic sound waves are regular and repetitive while aperiodic are described as ‘noise.’ This introduction of noise during phonation leads to irregular adduction of the vocal folds; the more noise in an utterance, the less clarity a voice has and the hoarser the voice will appear. Voices with high HNR are sonorant and harmonic while those with low HNR are asthenic and dysphonic voice (Teixeira et al., 2013; Teixeira & Fernandes 2014). This particular measure is noted to be higher in females as compared to males and may lower with age (Felippe et al., 2006; Fernandes et al., 2018). Noise-to-Harmonics similarly measures the degree of hoarseness in a person’s voice. The relationship between HNR and NTH regarding vocal quality is expressed as inversive (Fernandes et al. 2019). A higher HNR and a low NHR is said to indicate functional vocal quality as opposed to a dysphonic voice whose measures are typically noted to express the opposite (Teixeira et al., 2013). As per the literature, NHR parameters were shown to correlate with the ‘G’ and ‘R’ components of the GRBAS scale—an auditory-perceptual voice evaluation composed of 5 different areas: Grade, Roughness, Breathiness Aesthenia and Strain (Bhuta et al., 2003; Boone et al., 2020). The ‘G’ which stands for grade, specifically addresses the perception of hoarseness while ‘R’ measures the perception of roughness via a 0-3 scale where 0 is ‘normal’ and 3 is ‘severe’ (Omori, 2011).

Other voice perturbation parameters often cited include shimmer and jitter. Whereas shimmer corresponds to the variations of sound wave amplitude, jitter corresponds to the variation of sound wave cycles (or frequency). A study by Teixeira & Fernandes (2014) showed that jitter values are affected by vocal cord vibrations. Individuals who express higher values of jitter typically express affected control of vocal fold vibration resulting in high jitter values. Shimmer values were shown to be affected by reduced glottal resistance and lesions of the vocal cords resulting in higher emission of noise, roughness in vowels and a breathy noise quality which can be expressed with lower values (Fraile & Godino-Llorente, n.d.; Teixeira & Fernandes, 2014). There is limited evidence for the efficacy of these parameters, however a study by Farrus et al. (n.d.) showed shimmer and jitter measures helped verify spectral and prosodic features of voice when using a Switchboard-I database.

Smoothed Cepstral Peak Prominence

Cepstral peak prominence smoothed (CPPS)—the smoothed version of cepstral peak prominence (CPP)—is an acoustic measure that helps assess vocal quality and differentiate between healthy vs. unhealthy voices via analysis of two power spectrums within a single cepstrum domain. The first power spectrum looks at the frequency distribution of a signal's energy, while the second power spectrum looks at the periodicity of the harmonic components within said spectrum. Based on a study by Castellana et al. (2018), CPPS has been noted to be a promising index for determining severity of vocal quality and indicating the presence of dysphonia in meta-analyses. A meta-analysis by Maryn et al. (as per Castellana et al., 2018), specifically expressed CPPS's relevance for correlating coefficients between perceptual reports and acoustic measures. Unlike other measures, one advantage for CPPS is its ability to be applied to both continuous speech and sustained vowel or consonant phonation, and this measure not being affected by gender. However, this statement is challenged by reports by Lopes et al. (2019) who pointed out that sustained vowels would demonstrate lower overall CPPS as a result of prosodic, articulatory, cultural, and contextual aspects interacting upon running speech resulting in deviations leading to lower CPPS values. To add, CPPS was shown to express significance in identifying the presence and intensity of impacted vocal quality in a study by Lopes et al. (2019). This same study also demonstrated low CPPS values correlating with the R (roughness) in the GRBAS scale due to both assessing a quality where higher noise and lower harmonicity occurs. When the opposite was seen, breathiness would correlate. These conclusions were similarly seen in Castellana et al. (2017) and Castellana et al. (2018) where CPPS helped identify the presence of breathiness and roughness in recorded voices.

Besides being used to identify impacted vocal acoustics, CPPS was reported to be used to evaluate the effectiveness of treatment methods for patients following a thyroidectomy. Another important result from the literature indicated that—when looking at CPPS measurements—those collected using PRAAT software were noted to be significant predictors of voice disorder status with an 82% accuracy as compared to those using ADSV whose accuracy was 75% (Sauder et al., 2017).

Parameters of Acoustic Measures

In order to differentiate between functional and dysphonic phonation, it is important to establish a 'threshold of pathology' for comparison of data measures. Williamson (2014) used the term 'threshold of pathology' to refer to any 'departure or deviation from expected typical functioning'. It is important to note that this deviation is not indicative of any particular pathology—it simply refers to any changes in the usual functioning of a system (in this case, phonation). These measures, however, varies depending on variables such as the program used, the algorithms selected within the program, the type of recording equipment used to collect data, what the individual is phonating (sustained vowels, the type of vowels phonated, running speech etc.) and factors such as a person's age, gender, and the culture they belongs to (Williamson, 2014). What may be considered 'normal' to one culture may be the opposite for another. Because of this degree of variability, it is important to attempt to seek normative data in order to best understand and separate acoustic measures into 'functional' or 'within normal limits' and 'different'.

Fundamental frequency, for example, is dependent on the gender and age of the individual recorded and is reported to lie anywhere between 85-196 Hz for adult men and 155-334 Hz in adult women (Williamson, 2014). The Voice Clinic (2018) expressed similar numbers with male's F0 ranging from 80-150 Hz and adult females being shown to fall between 175- 250 Hz. Castellana et al. (2018) supports these numbers, with this study's average adult male F0 ranging between 80-180 Hz and female adults ranging from 160-260 Hz. Typical frequency ranges as per Williamson (2014) demonstrated 85-196 Hz for males and 155-334 Hz for females. Regarding frequency of particular vowels, Felippe et al. (2006), further validated the statement of gender and type of vowels affecting the fundamental frequency of subjects where the production of the /a/ phoneme in female participants demonstrated a fundamental frequency of 205.82 Hz while their males' counterparts demonstrated an average of 119.84 Hz. For data analysis, fundamental frequency will be expanded to include both gender and will be considered to be within the range if averages are anywhere between 80 Hz and 334 Hz.

Based on Williamson (2014) and threshold perturbation measures listed on the PRAAT software guide (Harmonicity, 2003), values of <=1.040% for jitter (local) and <=3.810% for shimmer were indicated. The Voice Clinic (2018) listed typical thresholds for jitter and shimmer as falling below 1% and 5% respectively, while Teixeira et al. (2013) cited typical jitter and shimmer to be below the range of 0.5-1.0% and below 3% respectively. Interestingly, when looking at jitter and shimmer values of different vowels, Williamson (2014) reported threshold measurements of local jitter to be below 1.040%. and 3.810% for shimmer in PRAAT software. A study by Felippe et al. (2006) using the CSL-4300 software from Kay-Elemetrics demonstrated slightly different jitter measures of 0.62% in females and 0.49% in males. Shimmer measures in the same study were noted to be 0.22 dB for both females and males during sustained phonation of the /a/ phoneme. For the purpose of data analysis and establishing norms, jitter and shimmer will be indicated to be within normal limits when values are below 1.040% and 0.350 dB respectively.

When addressing thresholds for HNR and NTH, HNR measures during a sustained /a/, /i/ and during connected speech were stated to be 20 dB (anything below this number indicates hoarseness), while sustained /u/ should have a HNR of 40 (Harmonicity, 2003; Fernandes et al., 2018; Williamson, 2014). According to The Voice Clinic (2018), NTH is normally less than 0.2%, which was noted to translate to 9.56 dB and 11.04 dB for males and females respectively. When analyzing data, HNR and NTH will be considered ‘normal’ when values for /i/, /a/ and connected speech are over 20 dB and under 0.2% respectively.

When looking at the values for CPP and its smoothed version: CPPS, a study by Murton et al. (2020) demonstrated cutoff values of 14.45 dB during sustained /a/ and 9.33 dB thresholds during reading of ‘the rainbow passage’ using the PRAAT program. Anything below this was concluded to indicate the presence of a voice disorder with a 94.5% accuracy. A study by Delgado-Hernandez et al. (as per Murton et al., 2020) reported similar CPPS cutoff values of 13.69 dB for and 8.37 for sustained vowels and connected speech respectively. This number was close to Castellana et al. (2022) who reported CPPS threshold values of 15.1 dB with values below this indicating an ‘unhealthy’ voice. Saunders et al. (2017), on the other hand, reported overall higher average CPPS values of 20.11 dB for non-dysphonic voices with a rage of 16.47 dB-22.99 dB. Subjects with 1 standard deviation measure above average (which would be 20.49 dB) were hypothesized to be 14% less likely to have a voice disorder as compared to dysphonic voices which demonstrated a mean of 17.49 dB and a range of 14.71 dB-20.31 dB. A lower average value of 11.66 dB with a minimum of .89 and maximum of 17.68dB was noted using

PRAAT from a study by Maryn & Weenink, 2015. Thus, values will be considered within normal limits when sustained phonation values are above 13.69 dB and vowels are above 8.37 dB.

Acoustic Effects of Voice and their Prominence in Healthcare Practitioners

Studies assessing acoustic effects in healthcare practitioners were limited; however, a study by McKenna et al. (2021)—which included healthcare professionals who completed pre and post workday recordings—demonstrated higher HNR measures post workday and reduced RFF with an offset of 10 in participants wearing N95 masks. Nguyen et al. (2021) also found significant effects in HNR when wearing any type of face mask. Whereas McKenna's study indicated changes in intensity—Nguyen reported non-significant effects. Additionally, CPPS was noted to lack significant effects as well with reports varying. A study by Fiorella et al. (2021) added that, in a group of 60 healthy ENT hospital workers, acoustic parameters (shimmer, jitter, and HNR) did not express significant effects. In a study by Parsa & Jamieson (2001) prior to the COVID-19 pandemic, the authors stated that shimmer and jitter measures varied in their ability to identify and classify normal vs. abnormal speech. This study reported that sustained phonation in particular may not be the most appropriate speaking task for capturing acoustic data. This was due to sustained phonation being more similar to singing as opposed to talking resulting in pathological aspects being missed by acoustic measures.

Another study prior to the COVID-19 pandemic, such as Laukkanen et al. (2008), compared acoustic and perceptual effects of vocal fatigue in teachers pre- and post-workday and had similar results as newer studies like McKenna et al. (2021). Laukkanen et al. (2008) demonstrated increased F0 when subjects were asked to read aloud. Production of vowels yielded similar increases in F0 and SPL and decreases in jitter and shimmer. Although there were speculations about acoustic measures indicating vocal fatigue and hyperfunction, the results were not significant enough to correlate with the perceptual reports obtained from participants which supported previously inconclusive results from cited works.

Mixed results following vocal tasks were cited in an older study by Solomon (2009). In this study, vocal fatigue was reported to increase F0 in men as compared to women. Solomon added that previous studies have shown similar inconclusive results regarding the relationship of reported voice effects and acoustic measures. This sentiment was discussed by Finger et al. (2014) who stated that a big reason for this variance in findings—when we take typical voice's diversity into consideration—was a lack of standardization in the types of instruments and software's being used to analyze data. It is important to note that limited literature was available addressing these topics, therefore research prior to the COVID-19 pandemic was implemented to support present studies. Previous literature also aided in noting any changes between pre- and post-COVID data.

Voice and Communication Effects in Healthcare Practitioners

As per the literature, voice and communication effects experienced by healthcare practitioners point to some degree of impact for the speaker and listener alike. Areas like intelligibility, auditory feedback, vocal effort, vocal fatigue, and difficulties with coordinating breathing and speaking, were some of the most cited experiences among this group in recent reports within the last two years, indicated a possible relationship between mask use and perceived voice attenuation (Gantner et al., 2021; Hampton et al., 2020; Heider et al., 2021; Karagkouni et al., 2021; McKenna et al., 2021; Phyland & Miles, 2019; Ribeiro et al., 2020).

A recent study by Ribeiro et al. (2020) comparing the effects of mask use between the working group (WG) and essential activities group (EAG), yielded higher reports of vocal fatigue symptoms and pneumo-phono-articulatory incoordination in the WG. The WG reported higher rates of a tired or impaired voice, more instances of avoiding use of their voice, higher frequency and intensity of vocal tract discomfort, increased effort to speak, and difficulties with speech intelligibility. When comparing the perception of these subjects with and without a mask, majority of them indicated that all the areas above were affected when a mask was used. This was theorized to be caused by the dampening effects masks have on voice which can result in a disparity of 3-4 dB for simple masks and upwards of 12 dB for N95 masks in the 2000 and 7000 Hz range—a range that is vital for speech intelligibility (Ribeiro et al., 2020).

Interestingly, Heider et al. (2021) pointed out that in order for a listener to understand the speaker's message with 90% accuracy, speech has to be delivered 10 to 15 dB over the environment's noise level. This information further emphasized the importance of the setting the professional finds themselves in as well as the attenuation from wearing a mask. These two dampening effects may create a disparity of over 20 dB, potentially requiring the speaker to compensate not just for their mask, but for the noise levels of the environment in order to transmit 90% clarity—a habit that could exacerbate voice symptoms if done over long periods of time. This study, which assessed the prevalence of voice disorders in healthcare workers in a hospital via a questionnaire and the VHI, indicated that 21.56% and 11.10% of subjects had reported mild and moderate to severe voice symptoms respectively. Questions targeting vocal fatigue and vocal effort yielded the highest scores and results of the VHI scores expressed abnormality for 26.24% of participants. Those who did not report a voice disorder but were experiencing vocal symptoms demonstrated a changing VHI score from a 5.66 to a 12.48

indicating higher perception of symptoms. When answering statement, participants gave higher scores for questions addressing difficulties being understood in noisy environments and the subjects voice not being able to effectively relay information (Heider et al., 2021).

Recent reports regarding effects on voice following mask use were cited by Gantner et al. (2021) who indicated that the use of face coverings impacted aspects of speech by lowering the spatial distribution and sound pressure of high frequency sounds resulting in decreased speech intelligibility. This may have resulted in an increased need for repetition and effort to communicate; a point addressed by Heider et al. (2021) when discussing patient care for geriatric populations. Gantner's study—which targeted caregivers working in a municipal home for the elderly—indicated high rates of discomfort as per a questionnaire and the vocal tract discomfort scale (VTD). Reported sensations included that of dryness (64.1%), irritability (54.7%) tightness (45.3%) hoarseness (46.9%) and vocal stress (57.8%), two of which (hoarseness and vocal stress) were selected by half of the subjects. Sensations like tickling (23.8%) and soreness (23.4%) were reported less. When subjects were asked about the onset of their symptoms, 80% responded that they had not experienced them prior to the pandemic, however it is worth pointing out—as the author of the study did—that this question requires subjects to recall previous information making reports less accurate. Additionally, inclusion of previous literature—such as Phyland & Miles who discussed additional internal and external communication factors affecting voicing such as posture, condition of the air in a room and the acoustics of a building—further expressed the complexity of attenuated voice especially for those working in settings where the professional must keep in mind not just who they are speaking to, but the conditions they are speaking in (Phyland & Miles, 2019).

A study prior to COVID-19 by Radonovich et al. (2010) supports impacts of communication and voice seen in more recent study's such as Ribeiro et al. (2020). Radonovich et al. (2010) demonstrated decreased intelligibility when using various types of masks and respirators, indicating the impact of face coverings since before their implementation during the pandemic. This data was obtained via reports by 16 nurses using 8 different types of face masks (common disposable respirators/FFP's like the N95 and surgical mask, elastomeric respirators, and powered air purifying respirators (PAPR)). Participants were tested using the modified rhyme test (MRT) in both the ICU setting and ICU simulations to indicate any effects on intelligibility with increased noise.

Compared to the 95% intelligibility shown by the control group (who did not wear any type of face covering), N95 masks, surgical masks and PAPR masks presented with an 85% intelligibility rate while elastomeric respirator presented with a 72% intelligibility rate. This indicated an average 1%-to-17%-word intelligibility loss when using any type of face covering. However, unlike previous studies, comparison of surgical masks, duck-billed N95's and cup-shaped N95's without a valve for exhalation yielded no significant difference in intelligibility indicating that the mask type—at least for this study—was not a factor in voice effects (Radonovich et al., 2010).

An important point mentioned by the authors regarding speech intelligibility in the medical setting—especially in the ICU—was the ramifications of decreased intelligibility where a misunderstanding could potentially lead to some uncertain degree of clinical significance not represented using the MRT test. The difference between hen and pen—words included in the MRT—may not be of importance to tell apart, however confusion between the words 'stethoscope' and 'otoscope' could prove to be significant. This observation was vital to point out and the authors subsequent emphasis on establishing and using common medical words and phrases when testing intelligibility for this setting for the purpose of more accurate and relevant results was a great recommendation for future studies (Radonovich et al., 2010).

Like Radonovich, a recent study by Hampton et al. (2020) found affected intelligibility in ENT clinicians who were asked to read the Bamford-Kowal-Bench word list while simulated background noise was played. All clinicians in the study recited the word list wearing their mask, wearing a mask and raising their voice, and without a mask at a 2-meter distance. Results indicated no significant differences among the different PPE types utilized, however intelligibility was noted to be affected in louder environments (such as the ICU setting) when compared to offices and other emergency departments. These conclusions were drawn as per simulated environments set at a noise level of 70dB. When compared to those without PPE, the difference in intelligibility was noted to be significant, however raising the intensity of the voice resulted in scores that were not significantly different from those of the clinicians not wearing PPE. An important piece of information in this study was the author's note on intelligibility not being affected by noise level alone—but by the lack of expression and lip reading when wearing a mask. This connection between reduced facial expression was similarly mentioned in previous studies as well (Hampton et al., 2020).

Another recent study by Karagkouni et al. (2021) which had 25.8% of subjects listed as medical field personnel—demonstrated effects of mask use across the majority of subjects. Based on a Greek translation of the VHI and five groups of questions (language difficulty group, speech difficulty group, mask related behaviors group, voice perceptual features group, and vocal tract discomfort group), mild breathing difficulties (29.4%), moderate loudness (33.6%), moderate intelligibility (34.3%) and moderate overall communication (27.3%) was affected in participants. This moderate effect in their communication abilities secondary to mask use resulted in subjects having to talk louder (73.4%) and repeat themselves more often (53.1%), which could potentially explain the 37% of participants who stated they experienced fatigue and required a 'breath break' (33.5%). When asked if they felt that they were understood, 56.6% claimed they had difficulties effectively expressing their feelings and 51% added that it was hard being heard. Based on the above, it is not surprise that 32.1% of subjects found it difficult to communicate when wearing a mask.

When considering the increased fatigue, intensity, respiration and need for repetition for speaking, it is fitting that most of the participants indicated their perceived voice alterations to be moderate in nature. 36.9% of participants felt their voice was hoarse, 34.7% had changes in volume, 31.5% experienced pitch changes and 28.4% had difficulties with volume stability. Regarding discomfort, majority of the participants experienced moderate to severe dryness, no to moderate aching, mild to moderate clearing of the throat, moderate to severe sensation of lumps in the throat and no to moderate soreness and tightness of the throat. Breathiness was for the most part expressed as a moderate to severe. All of these symptoms were stated to be exacerbated with the use of a face mask. The frequency and severity of vocal discomfort was mild to moderate based on participant reports. Findings by McKenna et al. (2021)—who looked at the voice effects of wearing a face mask pre and post workday—further supported the above literature. Results of the study indicated findings of increased effort to speak when wearing a mask by participants. The score for this question received an average of 4.06 out of 5.

Hydration, Voice and Outcomes

Hydration—defined by Hartley & Thibeault (2014) as 'the current state of water balance within an individual'—has long been recognized as an important factor in proper bodily functioning and overall health. All systems of the body are known to be affected down to the cellular level by the amount of water we consume and replenish throughout the day. With the role of building block, solvent, medium for transportation, regulator of temperature, lubricant, and shock absorber to the body—it is no wonder why water closely relates to health and maintenance of homeostasis within the body.

Although the relationship between hydration and other anatomical systems has been previously discussed and accepted, the relationship between hydration, laryngeal function, and vocal health has had a less clear outcome, specifically regarding the recommendation of systemic and surface hydration when treating different voice symptoms. Previous studies have indicated hydration as a method for improving viscoelastic, aerodynamic, and acoustic measures during vocal fold activity. However, the benefits of increasing hydration has shown varying, and oftentimes contradictive, results when taking acoustic and perceptual measures into consideration (Franca & Simpson, 2009; Hartley & Thibeault, 2014; Sivasankar & Leydon, 2010; Verdoloni-Marston et al., 1994).

Before considering the evidence for hydration, it is important to assess effects of dehydration on vocal fold activity. In a study using excised canine vocal folds by Finkelhor et al. (as per Verdolini-Marston et al. 1994), dehydrating conditions were noted to result in increased effort required for phonation by the vocal folds. It is important to note, however, that this degree of dehydration is not possible or replicable for a living human to experience. However, the effects of dehydration within this study addressed the relationship between viscosity and hydration and pinpointed the importance of adequate hydration for appropriate vocal fold oscillation. In vivo studies by Verdoloni-Marston et al. (1994) indicated that subjects exposed to dehydration conditions reported increased symptoms of vocal fatigue, dryness in the throat and correlating acoustic measures indicative of vocal effort which were alleviated when hydration was reintroduced. Additionally, reports of reduced vocal fold thickness, incomplete glottal closure and a glottal gap was observed in patients with induced xerostomia (Sivasankar & Leydon, 2010).

This complicated relationship between hydration and vocal fold movement is best summarized by Titze's theoretical framework (as cited by Alves et al., 2017; Verdoloni-Marston et al., 1994) which states that increased hydration potentially resulted in decreased viscosity of the vocal fold's tissue, thereby decreasing the amount of energy required for the vocal folds to vibrate. If dehydrated, the vocal folds would be 'too stiff,' 'dry' or 'sticky' to oscillate effectively. This was supported by Sataloff, whose study demonstrated an improvement in 'scratchy voice' and 'tickling cough' when nasal breathing was implemented (Alves et al., 2017; Verdoloni-Marston et al., 1994). Additionally, more recent reports by Hanson et al. stated that dehydration affected the lamina propria's (a layer of the vocal fold's) ability to regain water balance.

Based on literature, hydration interventions can be either systematic, (via ingestion of water) superficial (by exposing patients to more humid environments) or a mix of the two for added benefits such as implementing mucolytic drugs with increased ingestion of water or electrolytic drinks. The results expected from these approaches, according to Titze, included a decrease in energy needed for phonation, a decrease in effort needed for longer oscillation of the vocal folds, and a possible decrease in tissue becoming injured secondary to more 'stiff' vocal folds which could result in excessive coughing and throat clearing. (Franca & Simpson 2009; Verdolini-Marston et al., 1994). For the purpose of this study, acoustic and perceptual effects of systematic hydration in voice are of particular interest. It is important to note that current literature addressing this topic during the COVID-19 pandemic was not available. Therefore, studies cited within this section are all prior to the COVID-19 pandemic and were used to better understand the current stance on hydration and voice overall.

Retrospective studies by Alves et al., (2017), indicated that, when systematic hydration (such as drinking water) were implemented, subjects demonstrated significant effects in their voice as per acoustic parameters. This included NHR, shimmer, jitter, hoarseness and phonatory effort. These effects were similarly noted in another retrospective study by Hartley & Thibeault (2014). Their study indicated varied reports on systemic hydration with some cited evidence reporting attenuated PTP measured (which relate to the degree of vocal effort), improved shimmer and jitter, decreased open and closed phase time of the vocal folds, decreased appearance of viscous vocal folds, increased amplitude of mucosal wave, and possible benefits for polyp and nodule treatment. (Alves et al., 2017; Franca & Simpson 2009; Hartley & Thibeault, 2014; Leydon et al., 2009; Verdolini-Marson et al., 1994). Interestingly, in regard to pitch, some studies indicated pitch to demonstrate significant effects in the high pitches, while other studies reported all pitches to be affected. Others indicated pitch to be of no consequence to implemented hydration leading to mixed results. While there were some indications of hydration benefits, not all studies reported effects with some pointing out that hydration resulted in limited benefits to subjects. It is worth noting that majority of studies implemented more than one form of hydration (mucolytic drugs, increased water intake, use of saline and electrolytic drinks, increased hydrating environments etc.) as well as limiting dehydrating conditions (reduced caffeine and alcohol intake, consumption of antihistamines etc.) making it difficult to identify if ingestion of water was a significant contributor to the benefits indicated in some of the studies.

Regarding perceptual effects of systemic hydration, a study by Solomon & Dimattia and Verdolini-Marston et al. (1994) indicated increased perception of vocal improvements following hydration treatments, however in spite of a placebo, subjects reported similar improvements pointing to hydration not being entirely beneficial. A criticism of the studies mentioned was their lack of hydration measurements to identify if subjects reporting improvements were hydrated or if their experienced was a placebo effect.

Summary

To conclude, with the rise of COVID-19, healthcare workers experienced an increase in not just demands to continue providing quality patient care but added guidelines to follow for decreased transmission of the coronavirus infection (CDC, 2021; WHO, n.d.). With the increase of mask mandates and mask use, reports by healthcare practitioners indicated rising experiences of vocal attenuation offset by the increased use of masks led to an influx of studies addressing these concerns. Studies assessing perceptual reports by healthcare professionals—and other professionals who use their voice to meet occupational demands—indicated perception of vocal discomfort such as increased effort and fatigue, decreased intelligibility, reduced auditory feedback, and decreased coordination for breathing and speaking when face masks were worn. Additionally, subjects reported feeling like they had difficulty being understood as well as understanding their communicative partner secondary to wearing a mask (Fiorella et al., 2021; Fischer et al., 2021; Gantner et al., 2009; Giuliani, 2020; Hampton et al., 2020; Hartley et al., 2014; Karagkouni, 2021; Radonovich et al., 2010; Ribeiro et al., 2020; Solomon 2009).

This perceptual data was shown to somewhat correlated with studies evaluating acoustic parameters (Bhuta et al., 2003; McKenna et al., 2021; Nguyen et al., 2021). As per the literature, reports indicated increased dampening of voice via mask use as well as environmental factors further decreasing reduced intelligibility based on the degree of noise subjects were in. Significant acoustic measures included vocal frequency, intensity and HNR however, similar studies yielded inconclusive results correlating perceived vocal fatigue, effortful speaking, and decreased speech clarity with acoustic parameters indicating further research on the matter.

In this study, hydration and its effects on voice were included to provide evidence for increased water intake by healthcare professionals who engaged in mask-wearing in the control group. Previous evidence in the literature yielded mixed results with some authors indicating systematic hydration as benefiting perceptual and acoustic aspects of voice while other studies demonstrated no changes or changes that varied from subject to subject—emphasizing the need for more research (Alves et al., 2017; Franca & Simpson, 2009; Hartley & Thibeault, 2014; Leydon et al., 2009; Verdoloni-Marston et al., 1994).

Previous evidence in the literature showed that although masks were stated to affect the perception of vocal effort, fatigue and decreased intelligibility reported by healthcare professionals, and their reported symptoms did not consistently correlate with acoustic measures (Fiorella et al., 2021; Fischer et al., 2021; Gantner et al., 2009; Giuliani, 2020; Hampton et al., 2020; Hartley et al., 2014; Karagkouni, 2021; Radonovich et al., 2010; Ribeiro et al., 2020; Solomon 2009). For this reason, the present study will address reports of vocal differences, acoustic measures, and hydration to assess if perceived vocal effects changed acoustically when systemic hydration was introduced to the subjects. Thus, providing novel data that is specific for healthcare practitioners who engage in mask-wearing and are occupational voice users.

CHAPTER III

RESEARCH QUESTIONS AND HYPOTHESES

The present study aims to investigate

I. Healthcare practitioners' communication effects secondary to mask use.

II. Healthcare practitioners voice effects secondary to increased mask use.

III. If these voice effects are supported by acoustic measures.

IV. If voice effects experienced by said healthcare practitioners change following increased intake of fluids via use of control and experimental groups for comparison of results.

The following research questions were addressed in the current study:

1.) Does the use of masks result in reports of impacted communication in healthcare practitioners?

2.) Does the use of masks yield outstanding reports of different vocal effects in healthcare practitioners?

3.) Do healthcare practitioner's reports of vocal effects relate to a significant relationship with objective acoustic data?

4.) Does increasing fluid intake result in significantly favorable changes to acoustic measures?

Based on the current literature, it was hypothesized that:

I. The use of face masks by healthcare professionals will result in reports of different vocal symptoms.

II. It was hypothesized that communication is impacted by use of masks.

III. Experiences of different vocal experiences will correlate with acoustic measures, indicating that healthcare professional's reports have objective data backing up their claims.

IV. The increase of fluid intake by the experimental group will result in less acoustic measure differences, signifying more functional/non-dysphonic acoustic measures when compared to those in the control group.

CHAPTER IV

METHOD

Participants

Following approval from the University of Texas Rio Grande Valley's Social and Behavioral Science Institutional Review Board (IRB) (See Appendix A), recruitment of participants commenced via distribution of a flyer (see Appendix B)) across various healthcare practitioner-focused social media groups. Said flyer contained the contact information of the primary investigator, a summary of the current study, and inclusionary criteria that needed to be met in order to be considered for participation. Word of mouth was used to further raise awareness and encourage healthcare practitioners to volunteer. In this particular study, healthcare practitioners is a broad term being used to refer to any individual currently providing healthcare services within a facility including anywhere from professionals who hold a certificate or license to practice to graduate students working under the license of a professional.

Following initial contact, the primary investigator responded with a consent form, email recruitment form and an instructional PDF explaining tasks to be completed. Once consent forms were signed and submitted, participant were instructed to respond to the email thread with 'I want to participate' to receive the Qualtrics survey link and be assigned into their respective group. Placement into either experimental or control groups was contingent on the interval in which subjects turned in consent forms. Individuals who submitted their forms at an odd interval (first, third, fifth etc.) were assigned into the experimental group while those who turned in consents on an even interval (second, fourth, sixth etc.) were assigned into the control group.

Once completed, the primary investigator requested subjects to follow the instructional PDF which outlined instructions for each participant's respective group, general instructions of tasks to be completed (including the optimal time and way for data to be submitted), and a copy of the rainbow passage. Additionally, subjects were encouraged to reach out to the primary investigator if any questions or concerns arose throughout their volunteer experience.

Demographics

In the survey portion of this study, a total of 17 responses were obtained relating to gender expression with a majority of individuals indicating they self-identified as female (*n*=13, 76.47%) while the remaining four participants (23.53%) identified as male. Subject's ages (Q1) were between 24 years to 53 years of age. Of this range, most participants fell into the 25-35 years age group (*n*=9, 52.94%), followed by 36-45 years of age (*n*=5, 29.41%), 18-24 years of age (*n*=2, 11.76%) and 46-54 years of age (*n*=1, 5.88%). No subjects under the age of 18 were included in the study as per inclusionary criteria. When asked about their race (Q5), more than two-thirds of participants specified that they were of Hispanic/Latino descent (*n*=14, 77.78%) while 3 reported they were Asian (16.67%), and one indicated they were White (5.56%). When asked about culture (Q4), 55% of participants selected the option Mexican (*n*=11) as the culture that best described them, followed by American (*n*=6, 30%) and Filipino (*n*=3, 15%). The option 'other' could be selected and filled in with the subject's preferred race and culture if the option was not listed within the survey. This allowed for accurate representation of each individual providing responses.

Regarding profession, most participants indicated they were practicing speech language pathologists (*n*=6, 42.86%), followed by speech pathology graduate students (*n*=3, 21.43%), physical therapists (*n*=2, 14.29%), occupational therapists (*n*=1, 7.14%), physical therapy techs (*n*=1, 7.14%) and audiologists (*n*=1, 7.14%). More than half of the subjects reported working (Q6) in rehabilitation clinics (*n*=10, 58.82%) and of these individuals, 9 (90%) indicated working in an outpatient rehab while 1 (10%) specifically reported working in a pediatric outpatient rehabilitation clinic. Five participants stated they worked in a hospital setting (29.41%) and of these 5, 1 (20%) specifically indicated working in an acute care hospital. The remaining two participants worked in a private practice (*n*=1, 5.88%) and the schools (*n*=1, 5.88%). Table one displays a summary of demographic information acquired from the survey.

Table 1

Participant demographic information

Demographics	*n=x*	%
	n=17	
Gender		
Female	13	76.47%
Male	4	23.53%
Other	0	0%
Age		
18-24	2	11.76%
25-35	9	52.94%
36-45	5	29.41%
46-54	1	5.88%
	n=18*	
Race		
Hispanic/Latino	14	77.78%
White	1	5.56%
Black/African American		0%

Table 1, cont.

American Indian/Native Alaskan	0	0%
Native Hawaiian/Other Pacific Islander	0	0%
Asian	3	16.67%
Other	0	0%
Prefer not to say	0	0%
	n=20*	
Culture		
Mexican	11	55%
Indian	0	0%
American	6	30%
French	0	0%
African	0	0%
Japanese	0	0%
Spanish	0	0%
Filipino	3	15%
Korean	0	0%
German	0	0%
Chinese	0	0%
Canadian	0	0%
Italian	0	0%
Other	0	0%
	n=14**	
Current Profession		
Speech-Language Pathologist	6	42.86%
Physical Therapist	2	14.29%
Occupational Therapist	1	7.14%
Audiologist	1	7.14%
Physical Therapy Tech	1	7.14%
Speech pathology Graduate Student	3	21.43%
Setting	*n*=17	
Rehabilitation Clinic	10	58.82%
Outpatient	(9)	(90%)
Pediatrics	(1)	(10%)
Hospital	5	29.41%
Acute care	(1)	(20%)

Table 1, cont.		
Private Practice	1	5.88%
School	1	5.88%

**Indicates a total of 20 individuals opened the survey but did not complete the survey in its entirety resulting in variations in total 'n' reported.*

*** Indicates totals where individuals skipped questions.*

A total of 19 participants completed recordings for the present study. Of the 19, more than two-thirds of subjects were female (n=15, 78.95%) while the remaining 4 were male (21.05%). As per analyzed data in Excel, more than half of participants were assigned to group E (n=10, 52.63%) while group C consisted of 9 subjects (47.37%). Of the 19 subjects—each of whom received a respective code for confidentiality purposes—participant S5 did not submit pre and post work week recordings of the vowel /u/, S7 did not submit pre- or post-workweek recordings of vowels, and S17 did not submit post-workweek vowel and connected speech recordings. The remainder of participants completed all assigned recordings.

The following healthcare practitioners were successfully recruited for participation:

I. Speech Language Pathologists

II. Occupational Therapists

III. Physical Therapists

IV. Physical Therapy Techs

V. Audiologists

VI. Speech Pathology Graduate Students

These individuals were specifically targeted for three reasons: 1. this population relies heavily on using their voice to provide services (Boone et al. 2020). 2. the literature—and previous reports following the onset of COVID-19 as a global pandemic—highlighted the increasing demands for quality care this population was experiencing despite rising reports of mental, physical and emotional difficulties and strict requirements to wear PPE at all times (Grimm, 2021; Unoki et al., 2021) and 3. Healthcare practitioners were required to wear PPE for long periods of time and have been cited to be experiencing vocal fatigue, breathing difficulties, impacted communication and other signs of vocal abuse following prolonged mask use (Gantner et al., 2021 ; Radonovich et al., 2010; Ribeiro et al., 2020). It is worth mentioning that other healthcare practitioners were targeted as well, such as medical doctors, nurses, and dieticians as per the U.S Bureau of Labor Statistics (2021), however no contact was initiated by aforementioned professionals besides those listed above.

Inclusion criteria for participants in the current study included those who:

I. Are healthcare practitioners currently providing services including but not limited to the following settings: hospitals, in-patient rehabilitation centers, out-patient rehabilitation centers, private practices, and schools.
II. Reside and are currently practicing within the Rio Grande Valley, Texas, United States.
III. Are over the age of 18
IV. Wear a facemask during service delivery.

A total of 17 participants were noted to have completed the survey based on Qualtrics data sheets and 19 participants submitted recordings for acoustic analysis.

Survey Procedures

To address the perceptions of healthcare practitioners, a survey was created and administered via Qualtrics Software. Questions were constructed following a thorough review of relevant existing surveys and the current literature to include and expand on questions targeting information of interest. Questions used from other survey studies are noted by an asterisk in APPENDIX F. Once a rough draft of the survey was completed, the primary investigator shared the survey with the thesis advisor and co-chairs for feedback. Changes were improved upon accordingly. Following final approval, the survey was published on Qualtrics, and a link was shared with participants after consent forms had been submitted.

Instructions within the consent form and the email recruitment script briefed the participant on the purpose of the present study, inclusionary criteria, tasks to be completed once consent was reached and the use of coding data for maintenance of confidentiality and anonymity. Additionally, subjects were informed of their right to cease participation at any point throughout the study without penalty as participation was entirely voluntary. Also included within the consent form was information regarding lack of payment for subject's time and cooperation, as well as the possibility of participants being removed from the study due to not meeting the outlined inclusionary criteria. If any concerns were expressed regarding the study, the primary investigator's personal phone number and email address, as well as the thesis advisors contact information, was shared for ease of contact. Should subjects express concerns regarding fair treatment by the researcher, the IRB's contact information was provided as well.

The present survey—which was provided only in English and was composed of 16 questions—aimed to collect data in the following areas: demographic information, mask types and use, preexisting conditions, perception of vocal symptoms, hydration, communication, and degree of effort when vocalizing and breathing.

Acoustic Measure Procedures

Participants were divided into 2 groups for this portion of the research study: experimental—denoted by an 'E'—and control—denoted by a 'C'. Participants were placed on their respective groups depending on the time consent forms were submitted to the primary investigator. Those who turned in consent forms at odd intervals (e.g., first, third, fifth and so on) were assigned into the experimental group, whereas those who turned in their consent at even intervals (second, fourth, sixth etc.) were placed in the control group. Those in the experimental group were required to increase fluid intake by 32 oz. daily, however all other aspects of recording instructions were the same across all participants. Additionally, all participants were filed under a code for confidentiality purposes.

As per instruction, there are two overall sets of acoustic data: pre work week and post work week. Each category includes two recordings: one of the vowels /i/, /a/, and /u/ and another of a portion of the rainbow passage highlighted and included within the instructional PDF. The rainbow passage was specifically chosen as it is used to assess vocal functioning, breathing abilities and patterns of speech due to various unusual consonants, combinations of vowels and alliterations being included within the text (Wright, 2002). All instructions were sent to participants and explained tasks to be completed as well as recommendations for best recording practices.

Once recordings were completed, participants were told to submit data to the primary investigator at the end of their work week. Following submission, participants were released from the study and the primary investigator initiated data analysis via PRAAT—a software program used to analyze speech and its acoustic measures. The following measures were specifically analyzed: cepstral peak prominence smoothed (CPPS), harmonics-to-noise (HTN), noise-to-harmonics (NTH), shimmer, jitter and fundamental frequency (Boersma, n.d.).

Descriptive Analysis of Participant Acoustic Measures

In order to analyze recordings, instructions from the PRAAT website, as well as a YouTube video outlining appropriate navigation and use of the software, was implemented for accurate acquisition of acoustic data (SIUE Phonetics, 2017). All settings within PRAAT were left on the software's standard settings and the following acoustic measures were collected for analysis of sustained vowels: F0, jitter, shimmer, HNR, NTH and CPPS, while connected speech acoustic measures included the following: F0, HNR, NTH and CPPS. Data results were collected and compiled into the following categories for comparison: overall pre- and post-week vowel averages, overall pre- and post-workweek connected speech averages, experimental group vowel averages, experimental group connected speech averages, control group vowel averages, and control group connected speech averages.

Threshold of Normative Acoustic Measures

As per the current literature, parameters were established for all acoustic measures and a 'threshold of differing voice' was created for comparison of overall pre- and post-workweek data and for the purpose of identifying discrepancies between the control and experimental group averages. Thresholds were established by selecting values relative to applicable sustained vowels and connected speech as per the literature review. Additionally, the most inclusive values across all studies was selected to allow for a larger margin of error as recorded data collection was not standardized for this research study. For fundamental frequency, thresholds based on the current literature were selected as 80-334 Hz. Values that were within this range will be stated to be within normal limits. This range was expanded in order to include frequencies of male and female speakers which fell between 80-196 Hz and 155-334 Hz respectively (Castellana et al. 2018; Finger et al, 2009; The Voice Clinic, 2018; Williamson, 2014).

HNR was considered within normal range if values fell above 20 dB for vowels, specifically for /a/ and /i/ ("Harmonicity", 2003; Fernandes et al. 2018; Finger et al, 2009; Williamson 2014). Meanwhile, the threshold for /u/ was indicated to be 40 dB with values being 'within normal limits' if they were above this number (Finger et al, 2009 ;"Harmonicity", 2003; Teixeira et al, 2013; Williamson 2014). It is important to note, as per Williamson (2014), that PRAAT further indicates that all HNR measures below 20 dB are indicative of 'hoarseness' excluding the /u/ phoneme. Due to this, the threshold of 20 dB will be used for connected speech as well. The measure of NTH was reported to be within normal limits if values remain under 0.2% whereas perturbation measures of shimmer and jitter were shown to have thresholds of 0.350 dB and 0.5% respectively. Values above these perturbation values were reported to indicate deviation from established normative ranges (Finger et al, 2009 ; Naufel de Felippe et al, 2006; Teixeira et al, 2013; Williamson, 2014). The last measure, CPPS, presented variations of reported thresholds. Based on compiled literature, normative values of 13.69 dB and 8.37 dB were selected for sustained vowels and connected speech respectively (Castellana et al, 2018; Castellana et al, 2022; Lopes et al, 2018; Murton et al, 2020; Sauder et al, 2017). Any value below these numbers were stated to be indicative of a different voice. During the analysis of collected data, the Greek letter delta (Δ) will be used to indicate a difference between values.

Analytical Plan

Following completion of the survey, results were submitted anonymously on Qualtrics, and descriptive statistics of participants responses, central tendencies and standard deviations were summarized into data report sheets in Qualtrics. All survey information within Qualtrics data sheets was compiled into tables for analysis. Collected recordings were analyzed via PRAAT software and measures were quantified in an Excel document. The following chapter discusses results of all information collected.

CHAPTER V

RESULTS

Descriptive Analysis of Participants Survey Reports

This portion of the chapter provides a descriptive analysis of data collected from the survey portion of the present study. Results addressed the following areas: demographic information, mask types, their use and perception of vocal symptoms, preexisting conditions, hydration, communication, and degree of effort during vocalization and breathing.

Survey Question Distribution

Based on Qualtrics data report sheets and collected consent forms, a total of 17 subjects were shown to participate in the survey. All 17 participants completed the survey. The survey consisted of the following types of questions: 5 text-entry questions (Q: 1, 3, 6, 8, 11), 5 multiple choice questions that allowed for selection of more than one item (Q: 4, 5, 7, 12, 13), a 6-item Likert scale addressing voice and communicative impacts and a 2-item Borg scale that assessed the degree of effort required for breathing and voicing (Q: 15, 16). Four questions were standard multiple-choice questions (Q: 2, 9, 10, 14). A copy of the survey is included in APPENDIX F.

Mask Types and Use

A total of 5 questions were incorporated in the survey addressing mask types and their use (Q7, Q8, Q9, Q10, Q11). When asked the type of mask participants were wearing, half of subjects reported using a surgical mask (*n*=10, 50%), 8 selected N95/KN95 (40%), 1 reported using a cloth mask (5%) and 1 reported ‘other’ (5%) with no further specification. More than half of participants stated they used only one mask (*n*=10, 71.42%) while 4 indicated they were double masking (28.57%). One participant responded ‘no’ to this question, however their response was not included within the results as it was not an appropriate or clear answer.

Regarding number of hours worked daily and the amount of time wearing a mask during those hours, a total of 16 responses were collected and placed in four groups: those who worked 8 or less hours a day, those who worked 9 or more hours day, those with unknown reported daily hours and a final group composed of inappropriate responses. Results showed 10 (62.50%) individuals working 8 hours or less daily. Of these 10 individuals, 8 (80%) reported wearing a mask 6 hours or more, 1(10%) reported wearing a mask for 5 hours or less, and 1 (10%) response did not indicate the number of hours they wore a mask during their working day. One individual (6.25%) reported working 9 or more hours daily and stated they wore a mask for 6 hours or more a day. One participant (6.25%) reported their hours on a weekly basis (40 hours a week) and stated they wore a mask 7 hours a day. The last four responses (25%) were labeled as inappropriate and listed numbers without indicating if they were weekly hours worked. Additionally, none of the inappropriate responses included the amount of time a mask was used during their workday or week.

Due to COVID-19’s status as a pandemic, questions targeting the perception of COVID-19’s impact on mask-use were included. Participants were asked if their use of masks had increased as a result of this novel situation (Q9). More than two-thirds of subjects (*n*=14, 87.50%) stated their mask use had increased while the remaining 2 subjections (12.50%) stated otherwise. When asked if they used masks prior to the pandemic (Q10), 13 participants (86.67%) stated they had not used a mask, 1 participant (6.67%) stated they did use masks, and 1 participant (6.67%) reported 'sometimes' using a mask.

When asked what vocal symptoms were experienced during prolonged voice use while wearing a mask (Q13), 'dryness' was mostly selected (*n*=7, 22.58%), followed by 'fatigue/weakness' (*n*=6, 19.35%), 'decreased volume' (*n*=4, 12.90%), 'increased throat clearing' (*n*=4, 12.90%), 'strain/tightness' (*n*=3, 9.68%), 'other' (n=3, 9.68), 'hoarseness' (*n*=2, 6.45%), 'breaks/voice 'gives out' (*n*=1, 3.233%), and 'pitch changes' (*n*=1, 3.23%). The options 'pain/tension' and 'loss of voice' were also provided but where not selected by any participant. Table 2 provides a summary of responses for this particular group of questions.

Table 2

Participant responses regarding mask type, use and perception of vocal symptoms

Survey Question/Statement	*n*=x	%
What type of mask do you currently use?	*n*=20*	
Cloth	1	5%
Surgical	10	50%
N96/KN95	8	40%
Other	1	5%
Do you wear one mask or two (double mask) during work?	*n*=14**	

Table 2, cont.

One mask	10	71.42%
Double mask	4	28.57%
	n=16**	
Has your mask use increased since the COVID pandemic?		
Yes	14	87.50%
No	2	12.50%
	n=15**	
Did you use masks prior to the COVID pandemic?		
Yes	1	6.67%
No	13	86.67%
Sometimes	1	6.67%
	n=31***	
After talking all day using a mask, I experience ___, Circle all that apply.		
Fatigue/weakness	6	19.35%
Hoarseness	2	6.45%
Strain/tightness	3	9.68%
Pain/tension	0	0%
Breaks/Voice ‘gives out’	1	3.23%
Pitch changes	1	3.23%
Loss of voice	0	0%
Decreased volume	4	12.90%
Increased throat clearing	4	12.90%
Dryness	7	22.58%
Other	3	9.68%

Table 2, cont.		
In the last year, how many hours a day did you work and of those hours how many are you wearing a mask for?	*n*=16**	
<8 hours a day	10	
<5 hours of mask use	(1)	62.50%
>6 hours of mask use	(8)	(10%)
undefined mask use	(1)	(80%)
		(10%)
>9 hours a day	1	
		6.25%
<5 hours of mask use	(0)	
>6 hours of mask use	(1)	(0%)
undefined mask use	(0)	(100%)
		(0%)
unknown daily work hours	1	
<5 hours of mask use	(0)	6.25%
>6 hours of mask use	(1)	(0%)
undefined mask use	(0)	(100%)
		(0%)
Inappropriate responses	4	
<5 hours of mask use	(0)	25%
>6 hours of mask use	(0)	(0%)
undefined mask use	(0)	(0%)
		(0%)

**Indicates a total of 20 individuals opened the survey but did not complete the survey in its entirety resulting in variations in total 'n' reported.*

*** Indicates totals where individuals skipped questions.*

****Indicates questions that allowed for multiple responses.*

Pre-existing Conditions and Hydration Status

To identify any medical conditions experienced during the last year, participants were asked to select from a list of health concerns that have been previously associated with impacted vocal quality (Q12). This list included acid reflux, sinus infections and allergies. Subjects were also provided with the option ‘other’ and a text-entry box for further specification regarding condition they experienced that were not immediately listed. Half of the participants indicated allergies as a concern (50%), followed by ‘other’ (*n*=5, 22.73%), acid reflux (*n*=3, 13.64%) and sinus infections (*n*=3, 13.64%). The selection ‘other’ was not specified by any participant who selected it. Question 14 addressed hydration and whether participants felt they drank adequate amounts of water during working hours. Of the 14 responses, 8 (57.14%) stated that they properly hydrated, while the remaining 6 (42.86%) indicated they did not. Table 3 summarizes reported pre-existing conditions and patient’s perception of their hydration status.

Table 3

Reports of pre-existing conditions and hydration status

Survey Question/Statement	*n*=x	%
In the last year, have you experienced any of the conditions listed below? Circle all that apply.	*n*=22***	
Acid reflux	3	13.64%
Sinus infection	3	13.64%
Allergies	11	50%
Other	5	22.73%
Do you drink adequate amounts of water during working hours?	*n*=14**	
Yes	8	57.14%
No	6	42.86%

**Indicates a total of 20 individuals opened the survey but did not complete the survey in its entirety resulting in variations in total 'n' reported.*

*** Indicates totals where individuals skipped questions.*

****Indicates questions that allowed for multiple responses.*

Communication and Voice

A six-item Likert-type scale was implemented to allow participants to rate their perceived communicative and vocal impact. A scale from 0 to 5 was applied where '0' represented a behavior 'never' occurring and '5' represented a behavior 'always' occurring. This question was formatted as such in order to comprehend how strongly each participant felt about each statement. When asked if more effort was required to talk when wearing a mask, 15 total responses were recorded with a mean rating of 3.93 (*SD*=1.12, *v*=1.26). When asked if participants found they needed to repeat themselves more often when wearing a mask, 16 total responses were recorded with a mean score of 4.06 (*SD*=1.14, *v*=1.26). Participant responses (*n*=15) when asked if alternative means of communication were required to effectively communicate information yielded a mean score of 3.60 (*SD*=1.14, *v*=1.31). Fourteen participants responses resulted in a mean score of 2.71 when asked if they felt their vocal health was directly impacted following mask use. The standard deviation of this response was 1.33 and its variance was 1.78. When asked about participant's ability to understand communicative partners wearing a mask, 15 responses were recorded. This question yielded a mean score of 2.93 and a standard deviation and variance of 1.24 and 1.53 respectively. The statement 'I find I have trouble breathing when wearing a mask' yielded 16 responses with a mean score of 3 and a standard deviation and variance of 1.46 and 2.13 respectively. Table 4 notes information regarding responses to question 15.

Table 4

Participant responses regarding vocal integrity, communication, and mask use

Survey Statement	*n*=x	Min	Max	Mean	SD	Variance
Please rate the following questions from 0 (never) to 5 (always). In the last year…						
I find myself using more effort to talk while wearing a mask.	*n*=15*	1	5	3.93	1.12	1.26
I find I have to repeat myself more often when using a mask.	*n*=16*	1	5	4.06	1.14	1.31
I find myself implementing alternative forms of communication (e.g., hand gestures, charts/graphs, visual, brochures etc.) in order to communicate information to others (patients, coworkers etc.) while wearing a mask.	*n*= 15*	1	5	3.60	1.14	1.31
I feel like my vocal health has been impacted after using a mask.	*n*=14*	0	5	2.71	1.33	1.78
I have trouble understanding people when they are wearing a mask.	*n*=15*	1	5	2.93	1.24	1.53
I find I have trouble breathing when wearing a mask.	*n*=16*	1	5	3	1.46	2.13

**Indicates a total of 20 individuals opened the survey but did not complete the survey in its entirety resulting in variations in total 'n' reported.*

A two item Borg-like scale was also implemented for the last question (Q16), which addressed degree of effort used for voicing and breathing. A scale of 6 to 20 was implemented where ‘6’ represented ‘easy/no effort’ needed to complete a task, and ‘20’ represented maximal effort for completion of a task. Vocal effort received a total of 16 responses with a mean score of 13.69. The standard deviation was noted to be 3.13 with a variance of 9.84. Breathing received 16 responses and yielded a mean of 13.19 and a standard deviation and variance of 3.13 and 9.78 respectively. Table 5 addresses responses from question 16.

Table 5

Healthcare practitioner reports on effort required for breathing and vocalizing

Survey Statement	*n*=x	Min	Max	Mean	SD	Variance
Please rate the following from 6 (easy/no effort) to 20 (maximal effort) to indicate degree of effort for the following.						
Vocal effort	*n*=16*	9	20	13.69	3.14	9.84
Breathing	*n*=16*	8	20	13.19	3.13	9.78

**Indicates a total of 20 individuals opened the survey but did not complete the survey in its entirety resulting in variations in total ‘n’ reported.*

Overall Acoustic-Measure Comparison

Pre- and Post-workweek Vowel Comparison

Vowel /i/. Averages of sustained vowel /i/ expressed differences in all acoustic measures when comparing overall pre- and post-workweek data, however only CPPS, pre-workweek HNR, and shimmer demonstrated deviating values relative to normative thresholds. Pre-workweek CPPS had an average of 9.450 dB which increased to 11.359 dB—expressing a difference of 1.909 dB between both data points. As per established normative values for CPPS—in which sustained vowels were indicated to be ‘normal’ when measures remained above 13.69 dB—neither pre- nor post- values were shown to meet the threshold; indicating overall impacted vocal acoustics. This was, however, more significant in pre-workweek-to-threshold differences(Δ=4.25 dB) as opposed to the post-workweek average-to-threshold difference (Δ=2.331 dB). HNR on the other hand had an overall average of 19.049 pre-workweek which rose to 20.360 dB post-workweek by 1.311 dB. Pre-workweek recordings were specifically noted to fall below the threshold by 0.951 dB, indicating impacted values. NTH pre (n=0.038%) and post-workweek (n=0.028%) measures had a decreasing difference of 0.01% and were both within the normative threshold of 0.2% or below. On the other hand, initial and final shimmer values—which decreased from 0.637 dB to 0.532 dB by 0.105 dB respectively—were noted to be above the established threshold, indicating an overall unhealthy voice. When looking at jitter, values decreased from 0.57% (pre-workweek) to 0.52% (post-workweek) by 0.05%. Neither data set expressed different values from the normative threshold. Lastly, fundamental frequency values pre- (203. 701 Hz) and post-workweek (213.191 Hz) were shown to have an increasing difference of 9.49 Hz, however both values fell within the normative pitch range during both data points.

Vowel /a/. Acoustic averages of the vowel /a/ demonstrated differences during comparison of all pre- and post-workweek values. Values that demonstrated deviation from established normative thresholds included the following measures: CPPS, HNR, shimmer, and pre-workweek jitter. All other acoustic measures expressed differences between pre- and post-workweek measures only. CPPS had an initial average of 11.915 dB which rose to 12.899 dB by

0.984 dB during post-workweek. When comparing measures to the threshold of 13.69 dB, neither pre- nor post-workweek values were within the normative threshold, indicating impacted vocal quality for both data sets with values falling below the threshold by 1.775 dB (pre-workweek) and 0.791 dB (post-workweek). HNR similarly expressed a significant difference of 1.116 dB between pre-workday (17.773 dB) and post-workday (18.889 dB) values. When comparing the threshold of 20 dB to recorded averages, both pre- and post-workweek values fell below the threshold by 2.227 dB and 1.111 dB respectively, indicating impacted vocal quality. NTH measures had decreasing values of 0.042% pre-workweek to 0.030% post workweek with a difference of 0.012%. Both measures were noted to fall under the threshold of 0.2 indicating non-outstanding values. Shimmer—which had values increasing from 0.494 dB (pre-workweek) to 0.465 dB (post-workweek) by 0.029 dB—expressed differences of 0.144 dB (pre-workday) and 0.115 dB (post-workday) above the 0.350 dB threshold, demonstrating impacted acoustic values. Jitter, however, had averages decrease from 0.53% to 0.47% by 0.06%. Although the initial value deviated above the normative threshold by 0.03%, post-workweek was within the threshold by 0.03%, thereby expressing a normative value. Lastly, fundamental frequency was noted to decrease from 208.948 Hz to 201.031 Hz by 7.917 Hz which were both noted to be within the established normative range.

Vowel /u/. Based on recorded averages, vowel /u/ demonstrated differences in all pre- and post-workweek measure comparisons as well as deviations from established thresholds in CPPS, HNR, , shimmer and jitter. CPPS had a pre-workweek average of 8.158 dB which increased to 10.114 dB by 1.956 dB. When looking at the normative threshold of 13.69 dB, both values fell below this number by 5.532 dB (pre-workweek) and 3.576 dB (post-workweek). Pre (*n*=22.565 dB) and post-workweek (*n*=25.166 dB) HNR data demonstrated a 2.601 dB increase between both acoustic values, however both were below the threshold limits of 40 dB—indicating lower-than-average measures of harmonic data. On the other hand, NTH had a decreasing difference of 0.017% when comparing pre- (*n*=0.030%) and post-workweek (*n*=0.013%) averages, however values were within the NTH threshold. Perturbation measures of shimmer and jitter both demonstrated differences in values between pre- and post-workweek. Shimmer had an initial recording average of 0.518 dB which decreased to 0.388 dB by 0.13 dB. Both acoustic measures were shown to be above 0.350 dB—pointing to possibly affected vocal quality. Jitter, which expressed a decreasing difference of 0.12% between pre-(*n*=0.64%) and post-workweek (*n*=0.52%) measures, yielded impacted values for both data values with measures being above the thresholds by 0.15% (pre) and 0.02% (post)—indicating deviating acoustic values. Fundamental frequency, which increased from 206.603 Hz to 216.078 Hz by 9.475 Hz, was noted to be within the normative pitch range for both data points.

Table 6

Participant's average pre- and post-workweek sustained vowel measures

Acoustic Measure	Pre-Workday /i/	Post-Workday /i/	Pre-Workday /a/	Post-Workday /a/	Pre-Workday /u/	Post-Workday /u/
CPPS (dB)	9.450	11.359	11.917	12.899	8.158	10.114
HNR (dB)	19.049	20.360	17.773	18.889	22.565	25.166
NTH%	0.038	0.028	0.042	0.030	0.030	0.013
Shimmer (dB)	0.637	0.532	0.494	0.465	0.518	0.388
Jitter (%)	0.57	0.52	0.53	0.47	0.64	0.52
F0 (Hz)	203.701	213.191	208.948	201.031	206.603	216.078

All measures have been rounded to the nearest hundredth.

Pre- and Post-workweek Continuous Speech Measures

Data analysis of overall continuous speech averages yielded differences between both pre- and post-workweek recordings and as well as deviations in average-to-normative-threshold comparisons for CPPS and HNR only. All other values demonstrated differences in pre- and post-workweek measure comparison only. Based on collected data, CPPS had a pre-workweek value of 2.770 dB and a post-workweek value of 3.662 dB with an increasing difference of 0.892 dB. Both pre- and post-workweek values were noted to fall below the 8.37 dB threshold by 2.770 dB (pre-workweek) and 3.662 dB (post-workweek) indicating unhealthy voices for both sets of data. HNR demonstrated pre-workweek measure of 11.116 dB which increased by 0.541 dB to 11.657 dB post-workweek. Both of these measures, like CPPS, were below the normative threshold of 20 dB by 8.884 dB (pre-workweek) and 8.343 dB (post-workweek) indicating abnormal acoustic values. Measures of NTH were shown to initially be recorded at 0.192% and increased by 0.017% for a post-workweek measure of 0.175%. Both data sets were below the 0.2% threshold, indicating a normative NTH value. Lastly, fundamental frequency pre-workweek was cited at 178.951 Hz and increased to 182.241 Hz by 3.29 Hz. This measure was within normal limits and did not express a deviating voice, however it is important to note that an increase in averages was seen from initial to final data points.

Table 7

Participant's average pre- and post-workweek continuous speech measures

Acoustic Measures	Pre-Workweek	Post-Workweek
CPPS (dB)	2.770	3.662
HNR (dB)	11.116	11.657
NTH%	0.192	0.175
F0 (Hz)	178.951	182.241

All measures have been rounded to the nearest hundredth.

Experimental vs Control Group Acoustic Measure Comparison

Vowel /i/

Pre-workweek control vs pre-workweek experimental. Pre-workweek comparison of experimental and control group averages during production of the sustained /i/ vowel expressed differences between all acoustic measures, with only CPPS, control group HNR, shimmer and jitter values deviating from the established normative thresholds.

CPPS was noted to have a higher overall average of 9.710 dB (C) as compared to the experimental group (*n*=9.290 dB), with a difference of 0.42 dB. Both values deviated below the 13.69 dB threshold, however the control average had a smaller difference (Δ=3.98 dB) as compared to the experimental average (Δ=4.4 dB). HNR, on the other hand, had a higher experimental group average (*n*=20.249 dB) than the control (*n*=17.848 dB) with a difference of 2.401 dB. Only the experimental group HNR value was within the threshold. The control group was, however, noted to deviate 2.152 dB below the normative data. Both measures of NTH were within the threshold, with the control group average (n=0.045%) being higher by 0.014% than the experimental group (*n*=0.031%). Both measures of shimmer, like CPPS, deviated from the threshold—however, the control average (*n*=0.759 dB) was noted to have a larger difference (Δ=0.409 dB) as compared to the experimental (*n*=0.514 dB) difference (Δ=0.164 dB). When comparing both measures, the control average was higher (Δ=0.245 dB) when compared to the lower experimental average. Control jitter (*n*=0.60%) and experimental jitter (*n*=0.54%) had a difference of 0.06%, and both values deviated from the threshold by 0.10% and 0.04% respectively. Lastly, F0 was noted to be higher by 1.197 Hz when comparing the control group (*n*=204.299 Hz) to the experimental group (*n*=203.102 Hz). Both values fit within the normative range.

To summarize, pre-workday measures were overall shown to be higher in the control group, with only HNR being higher in the experimental group. Additionally, values shown to be within the normative thresholds included NTH, F0 and experimental HNR. All other measures deviated from the norm—indicating impacted vocal acoustics. More apparent differences between average measures and established thresholds were noted in experimental CPPS, shimmer and jitter.

Post-workweek control vs post-workweek experimental. Control and experimental group averages of sustained vowel /i/ demonstrated differences during comparison of all acoustic measures, with only CPPS, control HNR, control shimmer, and control jitter deviating from the established normative threshold.

When comparing experimental CPPS (*n*=11.431 dB) and control CPPS (*n*=11.296 dB), a difference of 0.135 dB was noted between averages in which experimental expressed a higher value. Although neither measure was within the threshold, experimental was noted to have a smaller difference (Δ=8.569 dB) from the norm than control (Δ=8.704 dB). HTN measures expressed a similar trend, with experimental having a higher overall value (*n*=23.408 dB) than control (*n*=17.651 dB) with a difference of 5.757 dB. The control group average was 2.349 dB below the threshold and experimental was noted to be within normal limits. NTH averages were noted to be larger in the control group (*n*=0.042%) than the experimental group (*n*=0.012%) by 0.03%. Both of these values were within the normative threshold. Shimmer values expressed a similar trend in which the control group average (*n*=0.720 dB) was higher (Δ=0.399 dB) compared to the experimental average (*n*=0.321 dB). However, whereas shimmer values were both within the threshold, only the experimental average remained within the normative values established. Control averages, on the other hand deviated 0.37 dB over the threshold. Jitter values in the control groups were noted to be higher (*n*=0.62%) than experimental (*n*=0.41%) by 0.21%. Although experimental jitter remained within the normative threshold, control jitter deviated 0.12% from the norm. When comparing control F0 (*n*=199.941 Hz) and experimental F0 (*n*=228.098 Hz) averages, there was a notable difference of 88.157 Hz between both values, however both were indicated to fall within the normative threshold range.

To summarize, post-workweek averages demonstrated positively impacted values in experimental group measures as compared to control group measures, which demonstrated more deviations from the established norms for CPPS, HTN, shimmer and jitter. Experimental measures demonstrated deviations in only CPPS, with the remaining measures being within normal limits.

Within-group comparisons. ***Experimental.*** When looking at averages of the /i/ vowel, experimental values demonstrated increasing differences from pre- to post-workweek in CPPS, HNR and F0, while NTH, shimmer and jitter values demonstrated a decreasing trend. Most values were noted to be within the established normative thresholds, except for HNR—whose value increased from pre- to post but remained deviated from the normative measures—and shimmer and jitter which both started off with deviating values but demonstrated 'normal' measures post-workweek.

CPPS measures expressed an increasing trend with pre-(*n*=9.290 dB) and post-workweek (*n*=11.431 dB) values having a difference of 2.141 dB. Neither value was within the normative threshold, however it was noted that post-workweek had a smaller difference (Δ=2.259 dB) than pre-workweek (Δ=4.4 dB) when comparing both measures. HNR had a similar upwards trend with pre- (*n*=20.249 dB) to post-workweek (*n*=23.408 dB) values demonstrating a difference of 3.159 dB. Both values were shown to be within the normative range, with initial measures being over the minimal threshold of 20 by 0.249 dB (pre) and 3.408 dB (post). NTH on the other hand had a decreasing trend when comparing pre- (*n*=0.031%) and post (*n*=0.012%) values which expressed a difference of 0.019%. Both of these values were within the less-than-0.2% established threshold. Shimmer measures also had a decreasing trend with a difference (Δ=0.193 dB) between initial (*n*=514 dB) and final (*n*=0.321 dB) values. Pre-workweek NTH deviated over the threshold by 0.164 dB, while post-workweek was shown to be within the threshold. Both measures of jitter were noted to meet the established norms and demonstrated a decreasing trend from initial (*n*=0.54%) to final measures (*n*=0.41%) with a difference of 0.13%. F0 had an increasing trend of 203.102 Hz to 228.098 Hz with a difference of 24.996 Hz. Both pre- and post-workweek values were within the normative fundamental frequency range.

To summarize, experimental pre- to post-workweek comparison demonstrated overall acoustic changes, with measures that require lower values—such as NTH, shimmer, and jitter—decreasing, and values that require higher values increasing (CPPS and HNR). Although CPPS did increase, neither pre- nor post values were within the normative threshold, however an increase from pre- to post-values is worth mentioning as the difference between the minimum threshold value decreased from a difference of 4.4 dB (pre) to 2.259 dB (post). Another measure that demonstrated a change was that of shimmer, with pre- to post-workweek averages going from deviating to falling within the normative threshold. Jitter demonstrated a similar trend as shimmer, with initial values being over the threshold, but decreasing to meet the norm by post-workweek. All other values were within the normative threshold and changes demonstrated more appropriate acoustic measures.

Control. Averages of the control group sustained /i/ demonstrated differences between pre- to post-workweek measures, with CPPS, HTN, shimmer, and jitter values being outside the established threshold for each respective measure, indicating impacted vocal acoustics.

CPPS measures demonstrated an increasing trend, with values going from 9.710 dB (pre) to 11.296 dB (pre). Although there was an increase between both values (Δ=1.586 dB), neither met the normative threshold. It is worth noting however, that the post-workweek value demonstrated a smaller difference (Δ=2.394 dB), than the initial difference of 3.98 dB, showing a positive increase, nonetheless. HNR on the other hand demonstrated a decrease of 0.197 dB when comparing pre- (*n*=17.848 dB) to post-workweek (*n*=17.651 dB) values. It is noted that neither met the normative threshold and, in fact, post-workweek had a larger gap (Δ=2.349 dB) than pre-workweek (Δ=2.152 dB). NTH has a similar decreasing trend, where a difference (Δ=0.003%) between pre- (*n*=0.045%) and post-workweek (*n*=0.042%) measures was noted. Both measures were within the threshold and only a slight change was seen between values. Shimmer, on the other hand had neither value meet the threshold. Both pre- (n=0.759 dB) and post measures (n=0.720 dB)—which had a decreasing difference of 0.039 dB—were above the threshold by 0.409 dB (pre) and 0.37 dB (post). Jitter demonstrated an increase of 0.02% when comparing pre- (n=0.60%) to post-workweek (n=0.62%) values, however neither value was below the threshold and deviated above by 0.10% (pre) and 0.12% (post). F0 had a decreasing trend as well, with the initial value of 204.299 Hz falling to 199.941 Hz by 4.358 Hz. Both values were noted to be within the normative pitch range established.

To summarize, control group comparison of pre- to post-workweek averages expressed deviating values from the threshold in the following measures: CPPS, HNR, shimmer and jitter. It is worth noting that HNR and jitter were noted to have a larger gap from the threshold during post-workweek, whereas CPPS and shimmer had slight increases although not significant enough to meet the threshold. Changes between initial and final values between all measures were noted to show increases in measures that needed to increase—such as CPPS—however most changes widened the gap post-workweek from the threshold indicating declining vocal acoustic values.

Overall. When looking at pre- and post-workweek averages of the /i/ vowel, comparisons yielded higher positive acoustic changes in the experimental group measures as compared to the control group. Whereas some values increased and met the normative thresholds in the experimental, the opposite was seen in control, with post-workweek values increasing their gap from the threshold.

Vowel /a/

Pre-workweek control vs pre-workweek experimental. Comparison of pre-workweek experimental and control group data demonstrated difference between all measures with values deviating from the normative thresholds for CPPS, HNR, shimmer and jitter.

When looking at collected data, the CPPS average for the experimental group (*n*=10.867 dB) was noted to be 2.1 dB below the control groups value of 12.967 dB. Both measures were below the normative threshold; the control group by 0.723 dB and the experimental group by 2.823 dB. HNR, on the other hand, had a higher experimental group average (n=17.916 dB) compared to control (*n*= 17.629 dB) with a difference of 0.287 dB between the two groups. Both measures deviated below the established threshold by 2.371 dB (C) and 2.084 dB (E) indicating impacted vocal acoustic measures. NTH demonstrated a higher average for the control group (*n*=0.045%) than experimental (*n*=0.039%) with a difference of 0.006%. Both values were shown to be within the established normative threshold. Measures of shimmer both deviated from the established norm. The control group exceeded the threshold by 0.137 dB and the experimental by 0.209 dB. When comparing both groups, the average of the experimental group (0.559 dB) was higher than the control (0.487 dB) by 0.072 dB. The experimental jitter value (*n*=0.54%) was shown to be 0.03% higher than the control (*n*=0.51%), however both groups were above the threshold, the control group by 0.01% and the experimental by 0.04%. F0 on the other hand had a higher control average of 212.599 Hz than the experimental (*n*= 205.296 Hz) by 7.303 Hz and both values were within the threshold pitch range.

To summarize, comparison of pre-workday averages between the control and experimental group yielded overall varying averages. Both groups had adequate values for F0 and NTH and both values had deviating CPPS, HNR, shimmer, and jitter values. It is worth noting that control CPPS was higher than experimental, however both were still under the normative threshold.

Post-workweek control vs post-workweek experimental. Post-workweek comparison of control and experimental groups yielded differing values between both groups for all measures. Measures that deviated from the established threshold included the following: experimental CPPS, HNR, shimmer, and control jitter.

When comparing control and experimental groups, CPPS was noted to have a higher overall average in the control group (*n*=13.951 dB) than in the experimental (*n*=11.715 dB) with a 2.236 dB difference between values. When compared to the established threshold, only the control group met the norm, while experimental deviated 1.975 dB under. HNR, on the other hand, had a higher experimental average of 19.961 dB and a control average of 17.937 dB with a difference of 2.024 dB. Although experimental averages demonstrated a smaller gap to the threshold (Δ=0.039 dB), both control and experimental values deviated from the established norms. NTH demonstrated a higher control group average of 0.036% and an experimental of 0.023%. The difference between both values was 0.013%. Additionally, both were within the established norms and indicated within normal limits acoustic measures. Control group shimmer (*n*=0.550 dB) was higher than experimental shimmer (*n*=0.369 dB) by 0.181 dB. Based on normative data, both values deviated from the threshold by 0.2 dB (C) and 0.019 dB (E)—based on these numbers we can see that the closer value to the threshold was the experimental group. Jitter was shown to be higher in the control group as well with a value of 0.54% and an experimental average of 0.39%. Both values had a 0.15% difference. When comparing these measures to the normative data, experimental jitter is noted to be within the threshold while control is deviating by 0.04%. Lastly, F0 was higher in the experimental group (*n*=209.585 dB) by 16.158 Hz than in the control (*n*=193.427 Hz), and both were within the normative threshold pitch range.

To summarize, post-workweek value comparison of control and experimental averages expressed more favorable outcomes for experimental HNR, shimmer and jitter, while more favorable averages for CPPS were noted for the control group. Both groups had within normal limit F0 and NTH.

Within-group average comparisons. ***Experimental.*** When comparing pre- to post-workweek averages in the experimental group, appropriate decreasing and increasing trends were noted in values that needed to change to have within normal limit values. The only value that deviated from the normative data was CPPS and HNR, while all other measures demonstrated appropriate averages.

When looking at pre- to post-workweek CPPS, there is an increasing trend with pre- (*n*=10.867 dB) and post values(*n*=11.715 dB) demonstrating an increasing difference of 0.848

dB. Although both values were noted to be below the necessary threshold, it is worth mentioning that the gap between the experimental (Δ=1.975 dB), is smaller than that of the pre-workweek average (Δ=1.823 dB). A similar increasing trend was noted for HNR in which the initial average (*n*=17.916 dB) and the final average (*n*=19.961 dB) had a difference of 2.045 dB. Although neither value met the normative threshold, like CPPS, the gap between the post-workweek average (Δ=0.0039 dB) was smaller than that of the initial average (Δ=2.084 dB), indicating the value had become more ‘normal’. NTH, whose values did not deviate from the normative data, demonstrated an increasing trend. The pre-workweek average (*n*=0.039%) was noted to be 0.016% higher than the final average (*n*=0.023%). Shimmer demonstrated a decreasing trend as well, with pre (*n*=0.559 dB) and post (*n*=0.369 dB) showing a difference of 0.19. Neither value was within the threshold however, like previous measures, post values showed a smaller difference (0.019 dB) from the norm as compared to that of the pre-workweek average (Δ=0.209 dB). This indicated the value was closer to the normative threshold. Like, shimmer, jitter showed a similar decreasing trend where the initial value (*n*=0.54%) expressed a difference of 0.15% from the post-workweek average (*n*=0.39%). The initial jitter average was noted to be above the normative threshold by 0.04%, however this changed post-workweek where the value decreased and was within the threshold. F0 was noted to have an increasing trend. The pre-workweek average (*n*=205.296 dB) was 4.289 Hz smaller than post-workweek (*n*=209.585 Hz). Both of these values were within the normative threshold range.

To summarize, experimental pre- and post-workweek comparison yielded impactful changes for all values discussed. Although CPPS and HNR increases during post-workweek still did not meet the normative threshold value, these changes placed these measures closer to the threshold and are worth noting. Jitter and shimmer similarly started off with values that deviated from the norm, however decreases were seen when comparing initial and final values, which placed post-workweek measures within the normative data. Some changes were noted when comparing pre and post NTH and F0, however both were noted to have remained within normal limits at all times. Overall, increases and decreases were noted for all measures indicating more appropriate vocal acoustic values in final averages as compared to initial averages.

Control. Control group comparison of pre- and post-workweek measures indicated less impactful changes for both data sets. Increasing trends were noted for CPPS, HNR, shimmer, and jitter, while decreasing trends were seen in NTH and F0. The following measures were noted to deviate from the established threshold values: pre-workweek CPPS, HNR, shimmer and jitter.

CPPS values were shown to have an increasing trend. The initial average (*n*=12.967 dB) demonstrated a difference of 0.983 dB from the post-workweek average (*n*=13.951 dB). The initial CPPS value was noted to not be within the normative threshold, however, post-workweek was shown to fall within the norm—indicating a significant change between both data averages. HNR expressed a similar increasing trend, where the initial value (*n*=17.629 dB) increased (Δ=0.308 dB) to 17.937 dB (post-workweek). Neither one of these values were within the established threshold, however the gap between the final average (Δ=2.063 dB) and the threshold is smaller than that of the initial average (Δ=2.371 dB), however it is worth mentioning that the increase is limited between pre and post differences. NTH had a falling trend similar to previous measures. A difference of 0.009% was noted between the pre- (*n*=0.045%) and post average (*n*=0.036%). Both of these measures where within normal limits. Neither pre- nor post-workweek shimmer average were within the normative threshold. In fact, values were noted to get further from the normative data when comparing initial (*n*=0.487 dB) and final averages (*n*=0.550 dB). Differences between averages and the norm were higher in post (Δ=0.2 dB) as opposed to pre (Δ=0.137 dB), indicating values becoming more impacted. Jitter experienced a similar pattern, where neither value was within the normative threshold. Like shimmer, pre- (*n*=0.51%) and post (*n*=0.54%) values became more affected, with differences from the threshold being higher in post (Δ=0.04%) as opposed to pre-workweek (Δ=0.01%) values. F0 was noted to experience a decrease of 19.172 Hz when comparing initial (n=212.599 Hz) to final averages (n=193.427 Hz). Both values were within the normative thresholds.

To summarize, control group comparison of pre- and post-workweek averages demonstrated overall negatively impacted acoustic measures. Shimmer and jitter measures all experienced increases that caused values to get further from the normative thresholds indicating declining vocal acoustics for these particular measures. CPPS and HNR were noted to increase, however only CPPS met the normative threshold. F0 and NTH remained within the normative thresholds during both pre- and post-workweek comparison.

Overall. Experimental changes from pre- to post-workweek were noted to express more significant changes. Measures that needed to either rise or fall doing so, causing values to be within the normative threshold for most measures that were deviating during pre-workweek averages. It is worth mentioning that post-workweek control CPPS increased enough to be within the normative threshold, and F0 and NTH values were within normal limits as well—however shimmer and jitter were impacted, and pitch was noted to decrease as well.

Vowel /u/

Pre-workweek control vs pre-workweek experimental. Pre-workweek comparison of the experimental and control groups yielded differences between both data points as well as differing values for CPPS, HNR, shimmer and jitter.

When looking at experimental CPPS, the control group demonstrated a higher average (*n*=8.355 dB) than the experimental group (*n*=7.938 dB) with a difference of 0.417 dB. Both values were noted to be below the normative threshold, however the control group had a smaller gap (Δ=5.335 dB) than that of the experimental group (Δ=5.752 dB), indicating an overall less impacted value. HNR on the other hand had a higher experimental value of 23.443 dB, with the control group average being noted to be 21.786 dB—1.657 dB under the experimental. Neither one of these values were within the normative threshold, with experimental and control measures being reported to have a gap of 16.557 dB (E) and 18.214 dB (C) from the normative threshold. Experimental NTH (*n*=0.029%) and control NTH (*n*=0.031%) were both within the normative threshold and demonstrated a difference of 0.002% between each other. Shimmer, like CPPS, had a higher control average (*n*=0.578 dB) than experimental (*n*=0.451 dB) with a difference of 0.127 dB. Both values deviated above the normative threshold, however the experimental average-to-threshold gap was noted to be smaller (Δ=0.101 dB) than the control's (Δ=0.228 dB). Experimental jitter (*n*=0.67%) was shown to be higher (Δ=0.05%) than the control (*n*=0.62%), with both values being demonstrated to deviate above the threshold. A larger average-to-threshold gap was noted in the experimental average (Δ=0.17%) than the control (Δ=0.12%), indicating that pre-workweek experimental measures were further from the norm. Lastly, F0 was noted to have a higher average in the control group (*n*=214.041 Hz) than experimental (*n*=198.235 Hz) with both values being within the established pitch range threshold. It is worth noting, however, that the experimental F0 had a 15.806 Hz difference from the control.

To summarize, both the experimental and control group demonstrated impacted acoustic measures in all values except NTH. It is worth noting that control group demonstrated more appropriate (but still affected) CPPS and jitter, while the experimental group experienced the same with HNR and shimmer. F0 and NTH were both within normal limits for these values.

Post-workweek control vs post-workweek experimental. Comparison of post-workweek control and experimental values expressed differences in all acoustic measures. Impacted averages as compared to the established normative thresholds included CPPS, HNR, control shimmer and control jitter. F0 and NTH were within normal limits for both groups, with the experimental being notably higher.

The CPPS control average (*n*=10.198 dB) was noted to be 0.191 dB higher than the experimental group (*n*=10.007 dB), however neither one of these values were within the normative values, with control and experimental showing a 3.492 dB 3.683 dB difference respectively. Although there is a slightly smaller gap in the control, both differences are close in number. HNR on the other hand, had a larger experimental value (*n*=28.78 dB) compared to the control (*n*=22.356 dB), demonstrating a difference of 6.424 dB between measures. Both values were additionally noted to be below the normative threshold, however experimental expressed a smaller difference (Δ=11.22 dB) than the control (Δ=17.644 dB). NTH demonstrated a larger control group average (*n*=0.019%) than that of the experimental (*n*=0.005%) by 0.014%. Both averages where within the established thresholds, indicating no deviations. Shimmer, on the other hand, demonstrated a difference of 0.308 dB between the experimental (*n*=0.215 dB) and control group (*n*=0.523 dB). Although the control group was above the normative threshold by 0.0.173 dB, the experimental was indicated to be within the normative threshold. Jitter had a similar trend as shimmer, with experimental values (*n*=0.34%) being lower (Δ=0.31%) than the control (*n*=0.65%), indicating a deviating control average and a within-normal-limits experimental average. Although both fundamental frequency values were within the normative threshold range, it is worth mentioning that the control group (*n*=197.955 Hz) and experimental (*n*=239.379 Hz) had a large difference of 41.424 Hz.

To summarize, the experimental group demonstrated more within-normal-limit values of shimmer and jitter. Both groups had average F0 and NTH and deviating CPPS and HNR values, however it is worth noting that the F0 of the control group was notably lower than that of the experimental and that CPPS similarly had a higher notable difference in the same group.

Within-group average comparisons. ***Experimental.*** When looking pre- to post-workweek experimental value comparison, it is noted that values were shown to increase and decrease appropriately when considering the normative threshold values for each individual measure included. Measures that required higher values, such as CPPS and HNR, were noted to increase while measures like shimmer and jitter, which required lower values, were noted to decrease.

When looking at CPPS data points, an increasing difference of 2.069 dB was shown between pre- (*n*=7.938 dB) and post-workweek values (*n*=10.007 dB). As per the established threshold, neither value was noted to be within the norm however, it is important to mention that values increased from one data point to the next and demonstrated a smaller difference post-workweek (Δ=3.683 dB) as compared to pre-workweek (Δ=5.752 dB). A similar trend was seen for HNR, where initial (*n*=23.443 dB) and final values (*n*=28.78 dB) had a rising difference (Δ=5.337 dB). Although there was a notably higher average post-workweek—and subsequently a smaller difference (Δ=11.22 dB) from the normative threshold—neither one of the values met the normative threshold. On the other hand, NTH demonstrated a decreasing trend when comparing initial and final values. The pre-workweek average (*n*=0.029%) was notably larger than the post-workweek (*n*=0.005%) by 0.024%. Although there is a large difference between data points, values remained within the normative data for both. Shimmer demonstrated a decline as well, with the initial value (*n*=0.451 dB) being 0.236 dB larger than that of the post-workweek value (0.215 dB). Both averages were shown to be within the normative threshold. Similarly, shimmer demonstrated a lower pre-workweek average (*n*=0.451 dB) than post-workweek (*n*=0.215 dB) by 0.236 dB. It was noted that the initial average deviated above the normative threshold by 0.101 dB, however, the post-workweek average decreased significantly and was within the established normative measure. Jitter also decreased from 0.67% (pre-workweek) to 0.34% (post-workweek) by 0.33%. The initial value was also over the threshold by 0.17%, and like shimmer, the post-workweek average was noted to be within the established threshold. F0 was shown to have a notable increase from the initial (*n*=198.235 Hz) to final data point (*n*=239.379 Hz) by 41.144 Hz. Although there was a difference between both values, neither was shown to deviate from the established threshold range.

To summarize, experimental pre- and post-workweek comparison demonstrated increases and decreases in appropriate values, with shimmer and jitter being noted to go from being over the threshold during pre-workweek to within the normative values during post-workweek. CPPS and HNR had notable increases from one data point to another, however neither reached the threshold. F0 and NTH on the other hand, were noted to be within the normative range for both pre- and post-workweek averages.

Control. Comparison of pre and post work-week control averages yielded overall difference between both data points, with increases in CPPS, HNR and jitter and decreases in NTH, F0 and shimmer. Based on normative thresholds, CPPS, HNR, shimmer and jitter all deviated during both averages, with only F0 and NTH being within the norms.

CPPS averages were noted to demonstrate an increasing trend, with the initial value (*n*=8.355 dB) having a difference of 1.843 dB from the final average (*n*=10.198 dB). Although there was an increase from one average to the other, the change was not significant enough for values to be within the normative data. Similarly, HNR had an increase of 0.57 dB in pre- (*n*=21.786 dB) to post-workweek values(*n*=22.356 dB), however this increase was noted to not be significant enough to meet the threshold. A difference between pre- and post-averages and threshold values were indicated to be 18.215 dB and 17.644 dB respectively. NTH on the other hand demonstrated a declining trend, where the initial value (*n*=0.031%) expressed a difference of 0.012% from the final average (*n*=0.019%). Both values were within the normative measure despite any changes between both data points. Shimmer values were noted to be higher pre-workweek (*n*=0.578 dB) as opposed to post-workweek measures (*n*=0.523 dB) with a difference of 0.055 dB. Both values were noted to deviate over the established normative measures with average-to-threshold differences of 0.228 dB (pre-workweek) and 0.173 dB (post-workweek). Jitter expressed increasing pre- (n=0.62%) to post-workweek (*n*=0.65%) averages with a difference of 0.03%. Neither value was shown to be within the normative measure, with pre- and post-workweek averages having differences of 0.12% and 0.15% to the threshold.

To summarize, comparison of pre-to-post-workweek control averages yielded overall small increases and decreases of values. CPPS and HNR were shown to have slight increases from initial-to-final data points, however this increase did not yield significant changes. Shimmer and jitter were noted to continue to deviate from the established norms. In fact, the averages were shown to somewhat increase—indicating values getting further from the threshold. F0 and NTH were shown to remain within the normative measure for both data points, however it is worth mentioning that F0 had a notable decrease from pre-to-post values.

Overall. When comparing pre- and post-workweek control and experimental group averages, it is noted that the experimental groups demonstrated overall more appropriate values during both data points—especially for post-workweek which was shown to have more significant changes as compared to the control group. The control group was shown to have less significant changes and had values getting further from the normative thresholds post-workweek for jitter.

Table 8

Average pre- and post-workweek measures of sustained vowels (control group)

Acoustic Measure	Pre-Workday /i/	Post-Workday /i/	Pre-Workday /a/	Post-Workday /a/	Pre-Workday /u/	Post-Workday /u/
CPPS (dB)	9.710	11.296	12.967	13.951	8.355	10.198
HNR (dB)	17.848	17.651		17.937	21.786	22.356
NTH%	0.045	0.042	17.629	0.036	0.031	0.019
Shimmer (dB)	0.759	0.720	0.045	0.550	0.578	0.523
Jitter	0.60%	0.62%	0.487	0.54%	0.62%	0.65%
F0 (Hz)	204.299	199.941	0.51%	193.427	214.041	197.955
			212.599			

All measures have been rounded to the nearest hundredth.

Table 9

Average pre- and post-workweek measures of sustained vowels (experimental group)

Acoustic Measure	Pre-Workday /i/	Post-Workday /i/	Pre-Workday /a/	Post-Workday /a/	Pre-Workday /u/	Post-Workday /u/
CPPS (dB)	9.290	11.431	10.867	11.715	7.938	10.007
HNR (dB)	20.249	23.408	17.916	19.961	23.443	28.78
NTH%	0.031	0.012	0.039	0.023	0.029	0.005
Shimmer (dB)	0.514	0.321	0.559	0.369	0.451	0.215
Jitter	0.54%	0.41%	0.54%	0.39%	0.67%	0.34%
F0 (Hz)	203.102	228.098	205.296	209.585	198.235	239.379

All measures have been rounded to the nearest hundredth.

Comparison of Continuous Speech

Pre-workweek Control vs Pre-workweek Experimental

In order to analyze the differences between experimental and control group averages during running speech, a comparison of pre-workweek measures was completed. Differences between both groups were noted in CPPS, HNR, and F0 values with measures being shown to also deviate from the established threshold for CPPS and HNR. The experimental group demonstrated a CPPS average of 3.173 dB, 0.807 dB higher than the value of the control group (*n*=2.366 dB). Both of these values were noted to be below the threshold with differences being 5.197 dB (E) and 6.004 dB (C) under the established norm. Based on these values, it is noted that there is a higher CPPS in the pre-workweek experimental group and that this same group had a smaller decibel difference from the threshold as compared to the control. Similarly, the experimental group's HNR demonstrated an overall higher value (*n*=11.344 dB) as compared to the control groups measure of 10.863 dB. The difference between these two measures was 0.481 dB. The experimental group value was noted to be higher than the control and also expressed a smaller difference from the threshold. NTH, interestingly, remained the same for both groups and was also within the normative threshold indicating no differences between groups and no deviation from the established norm. Lastly, F0 demonstrated a lower value (*n*=170.587 Hz) for the experimental group as compared to the control group (*n*=188.243 Hz), however neither value was outside of the threshold.

To summarize, pre-workweek experimental values were overall noted to express lower differences to established threshold for CPPS and HNR, thereby indicating this group had measures that were closer to the established threshold norms when compared to the values demonstrated by the control group. NTH was exactly the same for both groups and did not have any deviations from the thresholds. Similarly, fundamental frequency values for both control and experimental group was within the established norm range, however it was noted that the experimental group had an overall lower average than that of the control group.

Post-workweek Control vs Post-workweek Experimental

During post-work week comparison of both groups, there were differences between both group average for all acoustic measures, however, only CPPS and HNR had values that were deviating from the threshold. Experimental CPPS values were noted to be at 3.464 dB as compared to the control group (*n*=3.859 dB), demonstrating a difference of 0.395 dB. Both values were below the threshold, with the control group demonstrating a smaller difference (Δ=4.511 dB) compared to the experimental group (n=4.906 dB). HNR on the other hand demonstrated an overall higher average in the experimental group (*n*=12.380 dB) than that of the control (n=10.935 dB) with a difference of 1.445 dB. Neither of these values were within the threshold, however, experimental showed a smaller difference from the threshold (Δ=7.62 dB) compared to control (Δ=9.065 dB). NTH, like CPPS, had higher values in the control group (*n*=0.193%), than those of the experimental (*n*=0.157%) with a difference of 0.036%. Both values, however, were within the norm. Fundamental frequency was also noted to have a higher control group value (*n*=183.791 Hz), than that of the experimental (*n*=180.691 Hz), however the difference between both was noted to be small (Δ=3.1 Hz). Neither group had F0 values outside of the threshold range.

To summarize, averages of acoustic measures demonstrated overall higher values in the control group, with only the HNR average of the experimental group being higher than that of the control group. CPPS and HNR had values that were below the established normative threshold, in which CPPS control and HNR experimental were noted to have the smaller difference to the threshold. All other values were within the normative ranges.

Within-group Average Comparisons

Experimental. When looking at the data sets of the experimental group alone, it is noted that increasing differences from pre- to post-workweek values were noted in all acoustic measures except NTH. Additionally, only CPPS and HNR were outside the established threshold values. An increasing difference (Δ=0.291 dB) was noted from pre- (*n*=3.173 dB) to post-workweek (*n*=3.464 dB) and neither value met the threshold, with differences of 5.197 dB (pre) and 4.906 dB (post). HNR demonstrated a similar trend, with pre- (*n*=11.344 dB) to post-workweek (*n*=12.380) values showing an increasing difference of 1.036 dB. Neither threshold, like CPPS, was within the normed values. NTH values, on the other hand expressed a decreasing difference (Δ=0.035%). Neither of these were outside of the threshold values, in fact-this decrease places the post-workweek average further from the NTH threshold demonstrating a more favorable number. F0 demonstrated an increasing difference (Δ=10.104 Hz) between pre- (*n*=170.587 Hz) and post-workweek (*n*=180.691 Hz) measures. Both values were within the normative range. Overall, average measures demonstrated increasing trends for values that needed a higher value to fit the range—such as CPPS and HNR—and falling trends for values that required being smaller to fit the normative thresholds (such as NTH).

Control. Averages of the control group pre- to post-workweek data demonstrated increasing trends for CPPS, HNR, and NTH, with only F0 showing a decreasing trend. Only CPPS and HNR had values for both sets of data outside of the thresholds while NTH and F0 reported within normal limits values. CPPS demonstrated an increasing pre-(*n*=2.366 dB) to post-workweek (*n*=3.859 dB) difference of 1.493 dB. Neither of these measures met the threshold. Similarly, HNR—with an initial value of 10.863 dB and a final value of 10.935 dB—had a rising difference of 0.072 dB and was also noted to not be within the threshold criteria. NTH on the other hand, did have measures within the normative values and had an initial value (*n*=0.192%) that increased by 0.001%. F0 had a decreasing trend, with pre-(*n*=188.243 Hz) and post-workweek (*n*=183.791 Hz) differing by 4.452 dB. Both of these were within the normative threshold range.

Overall. When comparing analyzed data above, it is noted that overall, higher increasing and decreasing differences between pre- and post-workweek data were expressed by the experimental group, with only CPPS values showing a larger difference in the control group. Although this is the case, it is important to note that the pre-workweek value was smaller in the control group compared to the experimental group.

Table 10

Average pre- and post-workweek measures of continuous speech (experimental vs control)

Acoustic Measures	Pre-Workweek (E)	Post-Workweek (E)	Pre-Workweek (C)	Post-Workweek (C)
CPPS (dB)	3.173	3.464	2.366	3.859
HNR (dB)	11.344	12.380	10.863	10.935
NTH%	0.192	0.157	0.192	0.193
F0 (Hz)	170.587	180.691	188.243	183.791

All measures have been rounded to the nearest hundredth.

CHAPTER VI

DISCUSSION

The purpose of the present study aimed to analyze healthcare practitioner's reports regarding prolonged mask use and its impact on vocal quality and communicative abilities during the COVID-19 pandemic. The inclusion of acoustic-measure averages derived from pre- and post-week recordings was implemented to allow for a more comprehensive understanding of the relationship between participant experiences and objective acoustic data, and whether this relationship was significant. This is especially important and relevant as COVID-19's taxing effects on the mental, emotional, and physical wellbeing of healthcare practitioners has been heavily discussed and reported throughout the last few years with voice being an area of impact (Unoki et al. 2021; Toscano & Toscano, 2021).

Additionally, this study attempted to provide further data on the efficacy of increasing fluid intake when addressing vocal differences; a common practice used by speech-language pathologists within the same study. Assigning subjects to a control and experimental group helped compare data points and establish significant differences between acoustic measures. Due to controversial reports of hydration's effectiveness in treating different vocal symptoms, this research tries to provide more evidence regarding its capacity for addressing vocal differences as it is noted to be an easy, accessible, and conservative approach for treating vocal symptoms. Results of the present study yielded the following responses to the study's research questions.

The first research question focused on the topic of masks and whether their use yielded indications of affected vocal symptoms in healthcare practitioners. It was hypothesized that participants in the present study would report vocal differences after extended periods of time using facial coverings, thereby demonstrating a positive correlation between impacted voice and face mask use—a finding seen in previous studies completed during the pandemic (Gantner et al., 2021; Heider et al., 2021; Hamdan et al.,2022; Karagkouni et al., 2021; Radonovich et al., 2010; Rosner, 2020). Responses from the linked Qualtrics survey demonstrated that more than three-fourths of participants linked the pandemic to their increased use of face masks. This statement correlates with previously enforced mask-use via mandates and guidelines across the U.S and foreign countries (Ballotpedia, n.d.; CDC, 2021; Fischer et al., 2021; Multistate, 2021; Ribeiro et al. 2020; WHO, n.d.) leading to an overall increase of PPE use in both healthcare practitioners and the general population alike. This statement is further supported by over three-fourths of participants reporting that prior to the pandemic, they had not used masks, thereby singling out the pandemic's role in higher instances of face coverings.

When asked 'What type of mask do you currently use?,' half of the responses stated they used surgical masks, closely followed by KN95 masks, cloth masks and an unspecified 'other'. More than half of these participants reported specifically wearing one mask while the remaining 4 stated they were double masking during working hours. This data is relevant to the present study due to the literature suggesting that the type of mask can directly impact the degree of attenuation experienced by the wearer (Gantner et al., 2021; Nguyen et al., 2021) and adds the variable of double-masking which can further impact vocal intensity. This brings attention to decreased attenuation and its effects on speakers who may over-compensate for their voice sounding 'softer.' This effect was cited in previous studies to result in participants voicing louder for extended periods of time—such as during treatment, parent/caregiver education or staff meeting—thereby resulting in unknowingly (and continuously) participating in vocally abusive behaviors as this population attempt to communicate effectively (Heider et al., 2021; Ribeiro et al., 2020).

Besides knowing the type of mask, it was important to consider how long participants were wearing their masks. When asked to indicate the number of hours worked per day—and how long masks were used during those hours—most participants indicated they worked 8 or more hours a day and wore a mask for at least 5 hours a day. These results suggest that subjects who responded to this survey question had a mask on for the majority of their workday, indicating overall prolonged periods of mask use. This information ties into a study by Ribeiro et al. (2020), which expressed higher reports of vocal fatigue symptoms and pneumo-phono-articulatory incoordination for individuals in the 'working group' (WG) as compared to those in the essential activities group (EAG). It was theorized that the dampening effects caused by masks were involved in these symptoms due to impacted intelligibility and subjects overcompensating.

When asked to rate the statement 'I feel like my vocal health has been impacted after using a mask.' participant reports expressed a variance of vocal effects, with some participants rating this as something they did not experience at all, to others indicating they experienced it often. This is an interesting disagreement as responses were in some instances polar opposites, showing just how varied effects of masks can be across different individuals within the same population. Regardless, the mean was shown to fall just below the half-way point of the scale, indicating the presence of vocal effects after using a face-mask. This was noted in recent studies during the COVID-19 pandemic by Gantner et al. (2021) and Heider et al. (2021), where participants reported similar experiences of affected voice. Interestingly, when asked to rate the degree of vocalization effort, participants had an average rating that fell above the halfway point in the scale, indicating that a significant number of individuals reported higher ratings of effort needed for vocalizing overall. This is further supported by the lowest rating selection being 9, 3-points higher than the lowest overall rating, indicating that participants demonstrated more than the minimum degree of effort being needed to voice.

When provided with a list of symptoms, most participants indicated ‘dryness’ as the most commonly experienced vocal effect followed closely by ‘fatigue/weakness’, ‘decreased volume’, ‘increased throat clearing’, ‘strain/tightness’, an unspecified ‘other’, ‘hoarseness’, ‘pitch breaks’ and ‘breaks/voice gives out’ after voicing for long periods of time when using a face-mask. It is important to mention that the options for ‘pain/tension’ and ‘loss of voice’ were not selected by any participant; however, all other options were chosen at least once, suggesting that participants experienced vocal effects as a direct result of talking for prolonged period of time while using face coverings. Gantner et al. (2021) had similar reported symptoms by subjects, including but not limited to dryness, tightness, and hoarseness.

Because voice can be impacted by various health concerns, a question targeting previously experienced conditions was included. This question yielded results indicating that half of participants experienced allergies. The next most common condition was an unspecified condition, followed by acid reflux and sinus infections. This information is important to consider as the conditions included within the survey can oftentimes be associated with vocal symptoms (Boone et al., 2020). This piece of information is also important because it provides an added possibility of sensations being exacerbated by conditions that are already affecting voice overall—indicating that mask use may not be the only cause of different voices in this particular group of subjects when there are reports of conditions listed above (Boone et al., 2020).

Research question two addressed whether healthcare practitioner reports had yielded indications of communicative impact following prolonged mask use. It was hypothesized that communication would be affected due to suggestions by the current literature regarding masks and their role in voice attenuation and intelligibility. According to Ribeiro et al. (2020) and Heider et al. (2021), using specific type mask could lead to sound dampening—or attenuation—of upwards of 20 dB between the 2000 and 7000 Hz range once environmental sounds and mask types are considered. This decrease in how we perceive our voice was noted as a cause of high reports of communicative breakdowns as intelligibility was impacted by 1%-17%—especially in settings like the hospital and the ICU that have added environmental sounds like machines and other hospital-grade equipment (Grimm, 2021; Hamdan et al., 2022; Hampton et al., 2020; Jaragkouni, 2021; Radonovich et al., 2010).

When asked to rate a variety of statements using a Likert scale between 0 (never) to 5 (always), individuals indicated at least some degree of impact for all statements within the survey. For the statement 'I find I have to repeat myself more often when using a mask.' a total of 16 participants reported a mean of 4.06. This number demonstrated that every participant experienced some frequency of repetition when wearing a face mask. The mean of this statement showed that most participants had reported higher ratings of this occurring overall. This correlates with previous studies' results such as those by Karagkouni et al. (2021) whose participants indicated instances of repetition when using a face mask.

When asked if alternative forms of communication were used to share information when wearing a face mask, responses yielded a mean that was over the halfway point of the rating scale. This indicated that every subject experienced at least some degree of needing other means of sharing information besides speaking to communicate information to coworkers and patients. In the statement ‘I have trouble understanding people when they are wearing a mask,’ speaker reports yielded a mean of 2.93. This was noted to be lower than the previous responses but remains above the halfway mark in the scale indicating that every participant had at least some degree of difficulty understanding others wearing a mask (Radonovich et al., 2010). This is especially relevant when considering how important it is for healthcare practitioners to share information that may impact the wellbeing and quality of care of their patients.

Overall, it was noted that the statements presented to participants all yielded some degree of communicative impact on speakers. It is important to note that previous questions, such as those targeting the type of mask used and the number of hours the individual wore it can additionally impact communication. Previous studies suggested that attenuation and the environment in which individuals work can impact the ability to effectively share information (Hampton et al., 2020; Radonovich et al., 2010; Toscano & Toscano, 2021). To take the above into consideration, a question looking at settings indicated that the highest reported setting was rehabilitation clinics (n=10, 58.82%) followed by hospitals (n=5, 29.41%), private practice (n=1, 5.55%) and schools (n=1, 5.55%). These settings have previously been cited by studies mentioned above to present with additional noise such as beeping machines, increased staff members, added noise from intercoms, varying interactions with patients and caregivers by staff, and in some cases populations—such as geriatric or acute patients—that may further impact the amount and degree of communicative breakdowns occurring (Boone et al., 2020).

The third research question focused on identifying if a relationship existed between reported vocal sensations and objective acoustic measures and whether this relationship—if one was noted—was significant. It was hypothesized that a relationship did exist between reported vocal health and acoustic data collected. Additionally, this link was hypothesized to be significant. The following paragraphs explain the findings.

When looking at data acquired from the survey, it is noted that there were reports of vocal sensations including, but not limited to: hoarseness, strain, pitch breaks, fatigue, overall experiences of impacted vocal health, and instances of higher degrees of effort being required to voice. These reports correlated with acoustic averages during pre-workweek data points for sustained phonation and connected speech tasks in participants overall, participants in the control group, and participants in the experimental group. It is important to add that symptoms expressed by participants were all in some way represented by the acoustic measures included in this study. Deviations from the norm in CPPS were reported to indicate dysphonic voice characteristics, impacted HNR is stated to indicate hoarse and asthenic (or weak) voices, and impacted NTH could point to too much noise in the acoustic signal. Although a certain degree of shimmer and jitter is normal, affected measures may indicate glottal emissions and irregular vocal fold vibrations leading to a rough, breathy, or hoarse vocal quality (Fernandes et al., 2019; Finger et al., 2009; Lopes et al., 2019; Sauder et al., 2017; Teixeira et al., 2013).

Averages of acoustic data for all participants demonstrated overall affected values for CPPS (in vowels and connected speech), HNR (in all pre-workweek vowels and post workweek /i/ and /a/), and all shimmer and jitter vowels. The measures that remained within normal limits throughout both averages were F0—which was noted to increase in connected speech and vowels /i/ and /u/ during pre-and post-workweek comparison—and NTH, which decreased from initial to final values thereby indicating decreased noise as compared to harmonics in the acoustic signal. Reports of CPPS, HNR, shimmer, and jitter were stated to indicate vocal quality that is dysphonic, asthenic, hoarse, breathy, and in some cases rough. This correlates with reports of said symptoms by participants in the survey, indicating a relationship between what individuals reported and what their average acoustic measures were analyzed as.

Findings above are important as they raise awareness on the presence of different vocal acoustics overall, indicating an unhealthy voice which can turn into a more serious disorder if not addressed properly. None of the individuals within this study reported a voice disorder, thus it is possible that these symptoms and their correlating affected acoustic values may be directly impacted either by vocally abusive behaviors, abusive behaviors exacerbated by mask use, pre-existing conditions such as allergies or acid reflux indicated in the survey, or another factor not included within this research study. It is important to add that this group of professionals is cited as 'occupational voice users' and this variable may also affect results (Boone et al., 2020; Unoki et al., 2021).

The final research question addressed whether increased fluid intake had resulted in changes to acoustic measures in either group during comparison of values and, if one group demonstrated a more substantial change. It was hypothesized that due to the daily increase of fluids by participants in the experimental group, there would be a more significant impact in acoustic measures as compared to those from the control group during sustained phonation and connected speech tasks. This idea was supported by previous literature regarding hydration and its effects on the vocal folds and associated acoustic measures (Alves et al., 2017; Franca & Simpson, 2009; Hartley & Thibeault, 2014; Leydon et al., 2009; Verdolini-Marson et al., 1994). Although some studies did point to positive changes in shimmer, jitter, HNR, and F0, other studies reported less conclusive findings (Franca & Simpson, 2009; Hartley & Thibeault, 2014; Sivasankar & Leydon, 2010; Verdoloni-Marston et al., 1994) opening the possibility for similarly inconclusive results for the present study. To address perceptions of hydration, the survey included a question asking if participants felt they drank an adequate amount of water during working hours. This yielded a response that was almost split halfway with more participants stating they were sufficiently hydrated. This question was selected to identify if dehydration was being experienced as this was stated to contribute to short-term experiences of vocal symptoms (Sivasankar & Leydon, 2010; Verdoloni-Marston et al., 1994).

Based on acoustic data analysis, the hypothesis was—to some degree—correct; however, results varied amongst measures with some expressing more changes than others. It was noted that experimental post-workweek sustained vowels and connected speech were impacted significantly in shimmer, jitter, and post /i/ HNR values. No significant changes were noted in the control group. In fact, jitter, and shimmer did not change positively as they did in the experimental group. When looking at CPPS and HNR, which remained impacted for all groups, CPPS increased in all initial-to-final value comparisons of speaking tasks across groups; however, this increase was not significant enough to place post-workweek averages within the established normative values for either group. Differences from averages-to-thresholds were seen to vary amongst the groups with the control having a smaller difference for continuous speech and vowel /a/ CPPS, while the experimental group had smaller differences in vowels /i/ and /a/. These varying results point to the presence of dysphonic vocal characteristics for all groups across tasks and data points.

Like CPPS, HNR had varying results as well, with only one vowel meeting the threshold: experimental post-workweek /i/. Although this does indicate that the experimental group had a more significant change—these results were not seen for any other vowel or during connected speech for this group. However, it’s important to note that the average for experimental post-workweek /a/was close to meeting the threshold and deviated by 0.039 dB. Although this was the case, the gap between the normative threshold and experimental averages was smaller post-workweek as compared to the control group, indicating that although measures suggested an impacted voice for both groups, the degree of this impact was lower in the experimental group which could have been associated with increased fluid intake during the week of participation in the study.

Although NTH and F0 were both within normal limits overall, it is worth mentioning that F0 was shown to increase in the experimental group across all phonation tasks during pre- to post-workweek data point comparison, while the opposite happened for the control group. This increase and decrease in F0 were mentioned by Solomon (2009); however, that study indicated that changes were inconclusive when compared to perceptual reports. In this case, the changes were not significant enough for values to fall outside of the normative pitch range, however, it does indicate that during hydration, pitch was noted to increase. NTH demonstrated similar outcomes where values remained within the threshold overall. It was however noted that NTH is typically preferred to remain under 0.2%, thus smaller numbers are more appropriate. Decreases in NTH were seen more notably in the experimental vowels and connected speech.

To summarize the results above, values that demonstrated the largest impact were perturbation measures shimmer and jitter, and to some degree HNR. The experimental group was noted to demonstrate decreases in shimmer and jitter measures which resulted in post-workweek values falling within normal limits—indicating a possible beneficial relationship between hydration and perturbation measures. This was an important observation to make as this degree of impact was not noted in the control group.

These findings were not expected base upon previous review of the literature which demonstrated inconclusive and, in some cases, polarizing results across studies (Franca & Simpson, 2009; Hartley & Thibeault, 2016; Leydon et al., 2009; Sivasankar & Leydon, 2010). As noted from the survey, this population did report having increased effort to vocalize along with experiences of impacted voice and communication difficulties. Additionally, findings of the relationship between reported voice effects and acoustics—as well as the inclusion of hydration—provided a further insight of healthcare practitioner experiences, whether these perceptions indicated similar objective outcomes, and whether these outcomes (if any were noted) had any changes following hydration. This combination of data was not seen within a single research study included in cited literature.

Clinical Implications

Results of the present study demonstrated implications for healthcare practitioners' well-being and their ability to provide quality care while maintaining healthy voices during a time when mask use continues to be encouraged for decreasing transmission of COVID-19 and other infectious diseases. Data results expressed varying degrees and types of vocal symptoms experienced by participants that correlated with objective acoustic averages, thereby indicating that perceived vocal impact is more than just a perception in this group of individuals. Although this population may rely on their voice for service delivery, it should be emphasized that addressing vocal symptoms is important to prevent further damage that could potentially lead to a voice disorder diagnosis that could have been prevented with proper care. It is more beneficial to address these symptoms before the individual continues to engage in vocally abusive behaviors that will further affect their voice. This preventative suggestion can be implemented by listening to healthcare workers' concerns (Unoki et al., 2021) and addressing said concerns with treatment whether it be through increased fluid intake, vocal rest, or implementing other forms of sharing information to prevent more impact. This is especially relevant when we take COVID-19 and the degree and frequency of reported mental, emotional, and physical impact being expressed by healthcare practitioners (Unoki et al., 2021).

This topic ties in with treatment methods, with water being the treatment-of-choice of this research study. Although water has previously demonstrated inconclusive and polarizing results, this study did indicate beneficial decreases and increases in acoustic measures with shimmer and jitter experiencing sufficient changes in the experimental group. Implementing more water into healthcare practitioners' daily routine and encouraging hydration during working hours may be a form of addressing concerns that is easy to implement, conservative, and accessible.

Lastly, the occurrence of communicative breakdowns cited within this study—as well as those indicated in previous literature—highlights the hypothetical impact voice and communication effects could pose not just for the individual, but during the exchange of information in healthcare settings. A study by Radonovich et al. (2010) discussed this theme where the possibility of mixing up medical terminology could result in consequences that may gravely affect patient care. This decrease in intelligibility can additionally cycle back and affect vocal quality in subjects who are already experiencing hoarseness, fatigue, strain, and roughness . The more that individual engages in vocally abusive behaviors as they attempt to overcompensate their communication impact—the more they will affect their vocal health (Boone et al., 2020; Gantner et al., 2021; Radonovich et al., 2010).

Limitations of the Present Study

The present study is primarily limited by its small sample size, which impacted the degree of relevance as well as its ability for results to be applied to a more generalized population of healthcare practitioners. Although the number of subjects for both experimental and control groups were equal, it is worth noting that the ratio of female to male participants was skewed with more than 75% of participants identifying as females—further limiting the ability of results to be generalized—specifically to male healthcare practitioners who were not appropriately represented in this study. The lack of varying professions within the study only represented a small part of healthcare practitioners. Because of this, it is not possible to relate acquired data to individuals outside of the following professions: occupational therapists, audiologists, physical therapists, and speech-language pathologists. Regarding the survey distributed, a limitation included subjects being able to move past questions without answering them, which created an unbalanced number of responses during analysis of data.

A lack of standardization of recording setups outside of those mentioned within the general instructions make it possible for data collected for acoustic analysis purposes to be inaccurate amongst participants. This could be due to factors such as the subject's method of collecting their data, the device (Jannetts et al., 2019; Manfredi et al., 2017) and applications used, the time of day they recorded, the degree of sustained phonation, whether the recording device was being held from the mouth as instructed and the environmental conditions during recording. All of these can affect the integrity of the data amongst all participants. An example of this is cited in Castellana et al. (2018), who stated that perturbation methods may be inaccurate due to incorrect performance of speech tasks. Similar reports were seen in Jannetts et al. (2019) who stated that although some phones are adequate for collection of data, calibration and standardization of placement are still important and affect the integrity of accurate data collection. The decision to allow participants to record themselves was decided upon due to rising COVID-19 cases at the time of this study. As such, the primary investigator was not present during recordings and could not control the aforementioned variables. Participants were encouraged to reach out for guidance at any time during the study.

Any other independent variables affecting the validity of data may in turn have affected the acoustic measures acquired, such as pre-existing conditions, any illnesses at the time of the study, and factors such as the participant's typical vocal use at the time of the recordings as opposed to their 'typical' use. As such, all findings must be scrutinized. Additionally, acoustic analysis requires ample experience of the software and the settings used during the analysis of data. As such is it important to note that the primary investigator had limited experience with PRAAT, and standard settings were strictly used during the completion of acoustic analysis which may have further impacted the accuracy of measures. This topic leads to the importance of standardization in acoustic analyses as pointed out by Finger et al. (2019) who stated that although normal voices had a wide range, the goal should still be to establish a standardized method and program for research comparison and better comprehension of findings across studies.

Another point to be made is the lack of hydration measures collected. Because this study wanted to better understand hydration's role in vocal quality, individuals in the experimental group were asked to increase their fluid intake daily. Although this was instructed, participants' hydration was not measured pre- and post-workweek to identify whether hydration had increased or if there were individuals within the control group who were perhaps hydrating more than those in the experimental. A log was also not implemented to keep track of fluid intake by participants; therefore, it is possible that participants in the experimental group did not increase their fluid intake as instructed by the primary researcher.

Implications for Future Research

As per results, the present study builds on previous acoustic and perceptual studies that aim to increase our understanding of the impact masks have on vocal wellbeing from a subjective and objective point of view. Further research into acoustics is required to better understand what measures can help separate normal from impacted vocal characteristics, however, a first step would be to increase efforts in standardizing methods of data analysis for more consistent and conclusive results across studies. Additionally, more research into hydration and its role in treating different vocal symptoms need to be completed. Research included within this study had overall positive results in the experimental group, however these results still varied and are not outside scrutiny. Another area to help generalize and increase our understanding of the topic would be conducting a study with a larger sample size that includes more male subjects as well as a more diverse group of healthcare practitioners in order to include perspectives and data from other professionals.

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APPENDIX A

APPENDIX A

IRB APPROVAL

The University of Texas
Rio Grande Valley
Institutional Review Board

November 17, 2021

Astrid Ortiz
College of Health Professions
Via Electronic Routing System

Dear Ms. Ortiz:

RE: APPROVAL FOR HUMAN SUBJECTS RESEARCH IRB-21-0385 "Thesis: Effects of wearing masks in the voices of healthcare practitioners"

The study referenced above has been reviewed and approved though Expedited Review procedures under the following categories:

6. Collection of data from voice, video, digital, or image recordings made for research purposes.
7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Approved number of subjects to be enrolled: 30-50 participants.

This project is not subject to continuation review.

Recruitment and Informed Consent: You must follow the approved recruitment and consent procedures.

Modifications to the approved protocol: Modifications to the approved protocol (including recruitment methods, study procedures, survey/interview questions, personnel, consent form, or subject population), must be submitted to the IRB for approval. Changes should not be implemented until approved by the IRB.

Data retention: All research data and signed informed consent documents should be retained for a minimum of 3 years after completion of the study.

Closure of the Study: Please be sure to inform the IRB when you have completed your study, have graduated, and/or have left the university as an employee. A final report should be submitted for completed studies or studies that will be completed by their respective expiration date.

If you have any questions, please contact the Human Subjects Protection Program/IRB by phone at (956) 665-3598 or via email at irb@utrgv.edu.

Sincerely,
Institutional Review Board for the Protection of Human Subjects in Research
ORC/ska

Brownsville • Edinburg • Harlingen

APPENDIX B

APPENDIX B

FLYER

APPENDIX C

APPENDIX C

RECRUITMENT EMAIL FOR PARTICIPANTS

The University of Texas Rio Grande Valley

Email Recruitment

Hello,

My name is Astrid Ortiz, I am a graduate student from the Department of Communication Sciences and Disorders at the University of Texas Rio Grande Valley (UTRGV). I would like to invite you to participate in my research study looking at the perceptual and acoustic effects of voice in mask-wearing healthcare practitioners across the Rio Grande Valley.

This research study has been reviewed and approved by the Institutional Review Board for the Protection of Human Subjects (IRB) at the University of Texas Rio Grande Valley.

In order to participate you must be 18 years or older. Participation in this research is completely voluntary, you may choose not to participate without penalty.

As a participant, you will be asked to complete an online survey which should take about 10 minutes to complete. Participants will be asked to complete two voice recordings using a personal recording device pre-workday on the first day of their week and a final recording post-workday after the last day of their work week. These recordings will be sent to me—the primary investigator. Additionally, every odd-numbered participant will be required to increase their water intake by a minimum of 32oz daily until the final recording is completed. If selected for the experimental group, you will be informed by the Primary Investigator. All data will be treated as confidential, and recordings will be coded upon being received by the primary investigator to keep anonymity and confidentiality.

If you would like to participate in this research study, please read the consent page carefully and respond to this email with the text "I want to participate" for further instructions.

If you have any questions or concerns related to the research study, please contact me (via telephone:(956)223-7933 or email: astrid.c.ortiz01@utrgv.edu) or my faculty advisor (via telephone (956)665-5273 or email: ruth.crutchfield@utrgv.edu) for further instructions.

Thank you for your cooperation!

Best Wishes,
Astrid Ortiz B.S.

APPENDIX D

APPENDIX D

CONSENT FORM

The University of Texas
Rio Grande Valley

INFORMED CONSENT FORM

Study Title: Perceptual and Acoustic Effects of Voice in Mask-wearing Healthcare Practitioners Pre and Post Workday

Principal Investigator (PI):	Astrid Ortiz B.S.	**Telephone:** PI: (956)223-7933 FA: (956)665-5273
Faculty Advisor (FA):	Ruth Crutchfield, SLP.D., CCC-SLP	
		E-mail: PI: astrid.c.ortiz01@utrgv.edu FA: ruth.crutchfield@utrgv.edu

Key points you should know

- We are inviting you to be in a research study we are conducting. Your participation is voluntary. This means it is up to you and only you to decide if you want to be in the study. Even if you decide to join the study, you are free to leave at any time if you change your mind.
- Take your time and ask to have any words or information that you do not understand explained to you.
- We are completing this study to learn of the acoustic and perceptual effects healthcare practitioners experienced secondary to wearing masks during the COVID-19 pandemic across the Rio Grande Valley.
- Why are you being asked to be in this study?
    - You are being asked to be in this study because you have indicated that you are a current healthcare practitioner who wore a face masks during the COVID-19 pandemic.
- What will you do if you agree to be in the study?
    - Participation in this study requires completion of two audio recordings pre and post workday in a quiet room using any recording application. Participants will be asked to read the rainbow passage and sustain an /a/, /i/ and /u/ vowel for both

Page 1 of 3

recordings. Additionally, participants will be required to complete a questionnaire looking at healthcare practitioner's perception of their voices when wearing a face mask. Every odd numbered participant will be placed in the experimental group which will require the participant to increase their water intake by 32 ounces a day. By signing this consent form, you are giving us permission to make and use these recordings as data for the aforementioned study.
Please indicate whether you will allow us to do so by initialing one of the following:

- _____ (initials) Yes, I give permission for [videotaping/audiotaping]
- _____ (initials) No, I do not give permission for audiotaping.

- Can you be harmed by being in this study?
  - Being in this study involves no greater risk than what you ordinarily encounter in daily life.
  - If we learn something new and important while doing this study that would likely affect whether you would want to be in the study, we will contact you to let you know what we have learned.

What are the costs of being in the study?

- There will be no additional costs to you by participating in this study.

Will you get anything for being in this study?

- You will not receive any payments for taking part in this study.

- Could you be taken out of the study?
  - You could be removed from the study if you meet exclusionary criteria such as not being a healthcare professional or stating that you are not required to wear a mask throughout the day.

Can the information we collect be used for other studies?

We will not use or distribute information you gave us for any other research by us or other researchers in the future.

What happens if I say no or change my mind?

- You can say you do not want to be in the study now or if you change your mind later, you can stop participating at any time.
- No one will treat your differently. You will not be penalized.

How will my privacy be protected?

- We will share your information only with those involved in the research study.
- Your information will be stored with a code instead of identifiers (such as name, date of birth, email address, etc.).
- Even though we will make efforts to keep your information private, we cannot guarantee confidently because it is always possible that someone could figure out a way to find out what you do on a computer.
- No published scientific reports will identify you directly.
- If it is possible that your participation in this study might reveal behavior that must be reported according to state law (e.g. abuse, intent to harm self or others); disclosure of such information will be reported to the extent required by law.

Who to contact for research related questions

For questions about this study or to report any problems you experience as a result of being in this study contact Astrid Ortiz at (956)223-7933 or astrid.c.ortiz01@utrgv.edu.

Who to contact regarding your rights as a participant

This research has been reviewed and approved by the University of Texas Rio Grande Valley Institutional Review Board for Human Subjects Protections (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-3598 or irb@utrgv.edu.

Signatures

By signing below, you indicate that you are voluntarily agreeing to participate in this study and that the procedures involved have been described to your satisfaction. The researcher will provide you with a copy of this form for your own reference. To participate, you must be at least 18 years of age. If you are under 18, please inform the researcher.

_______________________________ ____/____/_____

Participant's Signature Date

APPENDIX E

APPENDIX E

INSTRUCTIONAL GUIDE FOR PARTICIPANTS

Research Study Information Sheet

(Please keep this information for your reference)

Study Title: Acoustic and Perceptual Effects of Voice in Healthcare Practitioners Pre and Post Workday

Research contact information:
Name: Astrid Ortiz
Title: Graduate Student/ Primary Investigator
Dept: Communication Sciences and Disorders
The University of Texas Rio Grande Valley
Phone: (956) 223-7933
Email: astrid.c.ortiz01@utrgv.edu

Name: Ruth Crutchfield
Title: Faculty Advisor
Dept: Communication Sciences and Disorders
The University of Texas Rio Grande Valley
Phone: (956)655-4622
Email: ruth.crutchfield@utrgv.edu

You must be 18 years or older to participate. *If you are not 18 years or older, please inform the researcher and do not complete the survey.*

Instructions for ALL research participation:

Prior to participation: • The primary investigator will send a consent form and an email recruitment form. • Email the primary investigator the completed consent form and respond to the email with "I want to participate'. • Once this is completed, the primary investigator will inform you if you are part of the control group or the experimental group. • Depending on the group, please follow the instructions outlined below. *Thank you for your cooperation!*
ALL participants must complete: • A series of voice recordings on the first day of their work week **prior** to beginning their shift and on the last day of their work week **after** their shift. • A linked survey
There will be a total of **4** recordings to turn in: **2** recordings for *pre*-workday and **2** recordings *post*-workday Recordings include: 1.) Reading the first paragraph of 'The Rainbow Passage' (the paragraph is outlined in red) 2.) Sustaining an /i/ ('i' as in sleep) for 5 seconds, an /a/ ('a' as in apple) for 5 seconds and an /u/ ('u' as in 'tube') for 5 seconds *The 'Rainbow Passage' is provided below on page 3.
Participants will complete a linked survey on the final day of their work week after the final recordings are completed.
All recordings must be emailed to the Primary Investigators and the survey must be completed *no later than 2 days following the final recordings of the work week.*
Once all necessary data is emailed to the primary investigator, participants may resume normal work week.

Subjects may use any recording device including:

- Phone
- Tablet
- Computer/Laptop
- Digital voice recorder

Phones, tablets and computers/laptops have various recording applications that can be downloaded via the app store. Examples include Voice Recorder Pro, Voice Recorder & Audio Editor, Voice Memos etc. No videos will be accepted, only voice recordings, in order to keep subject's data confidential.

When recording:

- Hold the recording device 5-12 inches *away* from the mouth.
- Use your normal pitch and volume.

Instructions for **Experimental Group**:

Individuals in the experimental group will be informed by the primary investigator.
If selected participants must: • Increase water intake by a minimum of 32 oz. *daily.* • The experimental group participants will begin drinking the additional 32 oz. beginning on the first day of the work week until the last day of the work week. • Participants in the experimental group will complete the same recordings tasks and survey as the control group. Instructions are outlined on the box on page 1.

For any questions or concerns, please contact the PI or the graduate student faculty advisor.

Thank you so much for your participation!

THE RAINBOW PASSAGE

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

APPENDIX F

APPENDIX F

PARTICIPANT SURVEY

Default Question Block

Age

Gender:

Male
Female
Other:

List your profession

What culture do you identify with?

Mexican
Indian
American
French
African
Japanese
Spanish
Filipino
Korean
German
Chinese
Canadian
Italian
Other:

What best describes you?

Hispanic/Latino

Asian
White
Black/African American
American Indian/Native Alaskan
Native Hawaiian/Other Pacific Islander
Other:

Prefer not to say.

What setting are you currently working in?

What type of mask do you currently use?

Cloth
Surgical
N95/KN95
Other:

Do you wear one mask or two (double mask) during work?

Has your mask use increased since the COVID pandemic?

Yes
No

Did you use masks prior to the COVID pandemic?

Yes
No
Sometimes

In the last year, how many hours a day did you work, and out of those hours how many are you wearing a mask for?

In the last year, have you experienced any of the conditions listed below? Circle all that apply.

Acid reflux

Sinus infection

Allergies

Other:

After talking all day using a mask, I experience vocal_____. Circle all that apply

Fatigue/weakness	Loss of voice
Hoarseness	Decreased volume
Strain/tightness	Increased throat clearing
Pain/tension	Dryness
Breaks/voice 'gives out'	Other:
Pitch changes	

Do you drink adequate amounts of water during working hours?

Yes

No

I don't know

Please rate the following questions from 0 (never) to 5 (always). In the last year…

0 1 2 3 4 5

	0	1	2	3	4	5
I find myself using more effort to talk while wearing a mask						
I find I have to repeat myself more often when using a mask.						
I find myself implementing alternative forms of communication (e.g., hand gestures, charts/graphs, visuals, brochures etc.) in order to communicate information to others (patients, coworkers etc.) while wearing a mask.						
I feel like my vocal health has been impacted after using a mask.						
I have trouble understanding people when they are wearing a mask.						
I find I have trouble breathing when wearing a mask.						

Please rate the following from 6 (easy/no effort) to 20 (maximal effort) to indicate the degree of effort for the following

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Vocal effort															
Breathing															

BIOGRAPHICAL SKETCH

Astrid Carolina Ortiz Garcia was born in Reynosa, Tamaulipas Mexico and immigrated to the Rio Grande Valley in 2002 at the age of 7. Astrid is bilingual and speaks both English and Spanish. Her interests include dysphagia, voice disorders, neurogenic disorders, early intervention, and ASD. Astrid received a Bachelor of Science degree with a major in Communication Sciences and Disorders from the University of Texas Rio Grande Valley in May 2020, and subsequently obtained a Master of Science degree with a major in Communication Sciences and Disorders from the University of Texas Rio Grande Valley in May 2022. Research in all areas of Speech-Pathology are of particular interest.

Astrid hopes to complete a doctorate degree in the future and plans to obtain her certificate of clinical competence from the American Speech-Language-Hearing Association as well as become a licensed speech-language pathologist after completion of her clinical fellowship.

Astrid can be contacted at astrid.ortiz78@gmail.com for further inquiries.