IMMEDIATE EFFECTS OF SEMI-OCCLUDED VOCAL TRACT EXERCISES AND THE IMPLICATIONS FOR CLINICAL PRACTICE

By

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ABSTRACT

IMMEDIATE EFFECTS OF SEMI-OCCLUDED VOCAL TRACT EXERCISES AND THE IMPLICATIONS FOR CLINICAL PRACTICE

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There has been a wealth of research investigating semi-occluded vocal tract exercises (SOVTs) from a theoretical perspective. The physiologic mechanisms underlying these popular voice rehabilitation and training exercises have been studied primarily through modelling studies and non-functional imaging studies (e.g. CT/MRI). More functional research, analyzing acoustic, aerodynamic, EGG, EMG, endoscopic, auditory-perceptual, and self-perceptual effects of SOVTs, have produced variable results. The primary goal of this dissertation was to address the variability of these results and fill in gaps in the literature through four experiments. Experiment 1 sought to identify trends in the prescription practices of SOVTs across speech-language pathologists using a web-based survey. Experiments 2 and 3 aimed to assess the immediate acoustic, auditory-perceptual, and self-perceptual effects of two SOVT exercises (straw phonation and straw phonation into a cup of water) delivered remotely through telepractice. Experiment 4's objective was to explore the physiologic vocal fold vibratory characteristics that occur during SOVT production, using high-speed videoendoscopy (HSV). Results revealed that clinicians are very knowledgeable about underlying physiology of SOVTs, despite not feeling prepared to prescribe them following their graduate programs. Other interesting findings regarding the effect of clinician experience level on the types of SOVTs being prescribed will be discussed. Acoustically, a statistically significant decrease in shimmer ($p=.016$) was noted following straw phonation. Auditory-perceptual analysis, performed by three experienced SLP raters, revealed a statistically significant increase (p=.009) in the perception of strain following straw phonation into a cup of water. While no significant differences were found between SOVT tasks in self-perception of vocal effort, a statistically significant increase (p=.006) in self-perception of vocal loudness was reported following straw phonation into a cup of water. Descriptive analysis of HSV revealed increases in glottal attack time and glottal offset time following SOVTs. Glottal contact closed quotient provided mixed results. Future research should continue to advance functional outcomes of SOVTs including the study of the underlying physiology using innovative methods such as HSV.

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KEY TO SYMBOLS AND ABBREVIATIONS

SOVT Semi-occluded vocal tract

SOVTs Semi-occluded vocal tract exercises

COVID-19 Coronavirus disease

LMRVT Lessac-Madsen Resonant Voice Therapy

VFE Vocal Function Exercise

PTP Phonation threshold pressure

MFDR Maximum flow declination rate

MADR Maximum area declination rate

TA Thyroarytenoid

CT Cricothyroid

EGG Electroglottography

EMG Electromyography

CT Computed tomography

SPL Sound pressure level

PAS Phonatory aerodynamic system

NHR Noise to harmonic ratio

CQ Contact quotient

CQ_r Contact quotient range

LCA Lateral cricoarytenoid

MRI Magnetic resonance imaging

HSV High-speed videoendoscopy

VHI Voice Handicap Index

CAPE-V Consensus Auditory-Perceptual Evaluation of Voice

GRBAS Grade, Roughness, Breathiness, Asthenia, & Strain

IRB Institutional Review Board

ASHA American Speech-Language-Hearing Association

SIG-3 Special Interest Group-3

SENTAC Society for Ear, Nose, and Throat Advances in Children

PSHA Pennsylvania Speech-Hearing Association

MSHA Michigan Speech-Hearing Association

NP New professional

EP Established professional

VP Veteran professional

FFT Fast Fourier Transform

CPP Cepstral peak prominence

CR Category ratio

GAT Glottal attack time

GCCQ Glottal contact closed quotient

LTAS Long-term average spectrum

CHAPTER 1: Introduction

This dissertation provides a thorough investigation of a very specific voice therapy/training technique, semi-occluded vocal tract (SOVT) exercise. Because of the specificity of this investigation, it may be appropriate to begin with a discussion of SOVT exercise within a much broader context.

While science-based evidence and knowledge is essential in underlying the clinical skills required to work with voice users, voice rehabilitation and habilitation is as much an art as it is a science. The reason for this is that the voice, itself, is a construct. While science attempts to operationalize the construct into measurable concepts and variables, there is a definitive art in the application of the variables. Some semblance of operationalizing the art of voice therapy can be garnered by distinguishing between approaches to therapy.

Although symptomatic, psychogenic, etiologic, and physiologic approaches tend to overlap, SOVT exercise fits squarely into the physiologic approach. This popular approach emphasizes establishing a balance between the three subsystems of voicing (respiration, phonation, and resonance), with a focus on improving the function of laryngeal structures (Stemple, Lee, D'Amico, & Pickup, 1994). Few voice techniques in the clinician's toolbelt are as readily accessible to address underlying physiology as SOVTs. By narrowing, but not completely occluding, the vocal tract at one end (e.g. the lips), a backpressure is created, which assists in coupling the source (vocal fold vibration) and the filter (vocal tract) of voicing. This coupling results in various physiologic changes which collectively have profound impact on voice production. Additionally, these exercises are uniquely straightforward to conceptualize, which reduces cognitive load requirement (i.e. the straw does the work for the patient). Although this can make generalization of the technique into functional contexts more difficult, the compromise is worth it, as patients tend to be more motivated by the relative ease of the exercise.

One of the challenges of subscribing to the physiologic approach, however, is that it leaves much to the interpretation of the clinician. Practitioners across disciplines have used SOVT exercise in differing ways to access similar goals, as described in the subsequent section. This variability may contribute to inconsistent clinical prescription practices, which this dissertation aims to address. Practitioners' understanding and comfort level with the underlying physiology of SOVTs is also studied for the effect on clinical prescription practices. Also addressed in this dissertation is whether immediate effects of SOVT exercise are observable (acoustically, auditory-perceptually, self-perceptually, or videoendoscopically) and whether telemedicine is feasible to study/treat using SOVT exercise. Understanding this capability is essential due to the presently unknown nature of the COVID-19 pandemic. Never has there been more emphasis placed on the future of telemedicine.

This dissertation intends to provide a concise, controlled investigation of a well-established voice therapy/training technique and its impact on various aspects of voice production. The research design was specifically developed to skew heavily towards clinically feasible variables, so that practitioners can immediately use this data to inform clinical practice. Chapter 2 provides relevant background information on the topic and a review of the current literature, further conveying the significance of this project. Chapter 3 presents the methodological design, including the research questions and hypotheses for each experiment. Chapters 4 and 5 present the results of the hypothesis testing within each experiment and a discussion of these results, respectively. References and appendices will be found within the final pages of this document.

CHAPTER 2: Literature Review

2.1. Use of Semi-Occluded Vocal Tract Exercises in Voice Training and Therapy

The practical use of semi-occluded vocal tract (SOVT) techniques/exercises long predates the thorough understanding of the physiologic underpinnings and, certainly, the advanced application to therapy for voice disorders. The origins of SOVT exercises relate to vocal performance training. Dating back to the early 1900s, SOVT exercises were used to improve efficiency of voicing for stage acting (Engel, 1927). While it was observed that the narrowing of the oral cavity created by the tongue tip posturing against the alveolar ridge produced more efficient voicing, empirical support was lacking. These concepts were widely used throughout the 30s, 40s, and 50s and adapted to other semi-occluded vocal tract postures, including the occlusion of the oral cavity by placing the hand over the lips (Aderhold, 1963). SOVT exercises then expanded into singing voice training (Coffin, 1987), elaborating on early techniques and incorporating lip trills (vibration of the lips off of one another), tongue trills (vibration of the tongue off of the alveolar ridge and parts of the palate), raspberries (a combination of tongue and lip trills) (Nix, 1999; Linklater, 1976), and humming (nasal consonants) (Westerman, 1996).

Simultaneously with the advancement of SOVT exercises in the performance voice literature, researchers were studying the effects of phonating into tubes and straws of varying diameters and lengths. Some of the research focused on the application to remediate neurologic and functional voice disorders (Gundermann, 1977; Habermann, 1980; Spiess, 1899; Stein, 1937; Tapani, 1992); whereas, some focused on the application to habilitative voice training (Bele, 2005; Laukkanen, 1992a;

Laukkanen, Lindholm, & Vilkman, 1995a) and describing/classifying voice types (Sovijarvi, 1964). Various other manipulations have been performed including the material of the tube (i.e. glass, silicon, or plastic straw) (Laukkanen, 1992a; Titze, 2002; Tyrmi, Radolf, Horacek, & Laukkanen, 2017) and whether the end of the tube remained freely in the air or was placed in water (water resistance therapy) (Guzman, Castro, Testart, Muñoz, & Gerhard, 2013a; Horacek, Radolf, & Laukkanen, 2019; Simberg & Laine, 2007). A similar technique that uses the principles of water resistance therapy is blowing bubbles into a small cup of water (without a straw) (McCullough et al., 2012). This technique is often overlooked in the SOVT literature because it is typically classified as a part of "flow phonation" therapy, since its primary goal is to coordinate airflow efficiently, bubbling smoothly and avoiding spillage of the water out of the cup. However, this should not preclude inclusion in the SOVT literature, as the underlying physiology of this technique is very similar to SOVT standards, such as lip trills and straw phonation. Although they can be considered therapeutic paradigms, in and of themselves, SOVT exercises are also the underlying physiologic basis of many voice therapy protocols that exist as clinical standards in our field.

Many of the principles of SOVT exercises are evident in Boone's facilitative techniques (Boone, 1977), which have informed other voice therapy techniques/programs over time. Particularly, chant-talking and tone focusing are based on similar principles of "shifting" voice production to a narrower place of articulation (e.g. oronasal mask region). An extension of these principles is demonstrated through a widely used voice treatment using bilabial, voiced fricative productions (Laukkanen, 1992b). Similarly, Lessac-Madsen Resonant Voice Therapy (LMRVT) involves humming and the production of semi-occluded consonants (e.g. /m/ and /n/) (Verdolini-Marston, Burke, Lessac, Glaze, & Caldwell, 1995). These speech sounds are produced with the velopharyngeal port open and the oral cavity closed in an area that is typically open during speech production (e.g. lips, alveolar ridge). This allows airflow to be redirected, and therefore phonation to be resonated, through the nostrils, which become the point of semi-occlusion.

Another common voice therapy protocol that is based on the principles of SOVT exercise is the vocal function exercise (VFE) program (Stemple, 1993; Stemple, Lee, D'Amico, & Pickup, 1994). VFEs are a series of five treatment exercises which include a breathing warm-up, requiring patients to breath diaphragmatically, and four vocal exercises, which require the “funneling” of nasal sounds, through the oronasal mask, into vowel productions (e.g. “knoll”). Patients are asked to maintain this vocal posture through the vocal warm-up (i.e. sustained vowel), stretching exercise (i.e. high pitch glide), contraction exercise (i.e. low pitch glide), and adductory power exercise (i.e. gradually increasing pitch in a stepwise motion, breathing between intervals). Often, the “knoll” productions are replaced with a more direct SOVT exercise (e.g. lip trill, tongue trill), depending on the patient’s individual performance and needs. Throughout the years, vocal training has been considered as much an art as it is a science, which may have contributed to the early reluctance to investigate the underlying physiologic mechanisms of the exercises that were being applied in practice. In recent years, however, science has advanced to the point that the underlying mechanisms are routinely being analyzed. This trend will likely continue and proceed at a pace that is commensurate with technological and theoretical innovation in this field.

2.2. Physiologic Mechanisms Underlying SOVT Exercise

The physiologic underpinnings of SOVT exercises have been well-represented throughout the literature. Most of the mechanisms have been explained through modeling and theoretical constructs. The underlying mechanisms can be characterized by acoustic and aerodynamic effects, vocal economy and efficiency, laryngeal biomechanics, and sensory biofeedback. Each of these areas are interrelated and have overlapping boundaries, but the next section of this text will attempt to parse out the areas, in an effort to concisely describe the totality of the physiologic mechanisms involved.

2.2.a. Acoustics, Aerodynamics, and Laryngeal Biomechanics

The two primary physical components of SOVT exercises are the semi-occlusion/narrowing at an end of the vocal tract and the elongation of the vocal tract either by natural (e.g. lip trill) or artificial (e.g. straw phonation) means. Both of these components contribute to the concept of impedance matching. In general terms, impedance matching (within this context) describes the coupling of the vibratory/glottal source and the vocal tract (Story, Laukkanen, & Titze, 2000; Titze & Story, 1997). This acoustic phenomenon has been shown to have a positive impact on the aerodynamics and laryngeal biomechanics of phonation (Titze, 1988), as detailed in the subsequent paragraphs.

One of the major aerodynamic concepts underlying SOVT exercises is the concept of increased vocal tract inertance, which is described as the vocal tract acting as a mass of air accelerating and decelerating as a unit (Rothenberg, 1981). This principle, along with acoustic impedance matching as described above, has been shown to lead to decreased phonation threshold pressure (PTP) (Kang et al., 2019; Titze, 1988), the minimum amount of airflow required to drive the vocal folds into vibration. Maximum flow declination rate (MFDR) is another aerodynamic variable that has been shown to increase as a result of SOVT exercises. This increase in MFDR translates into larger spectral energy at higher harmonics (Titze, 2006a).

One of the most apparent impacts of SOVT exercises on laryngeal and pharyngeal biomechanics is the supraglottic and intraglottic pressures (correlated with the intraoral pressure), created by the occlusion of the vocal tract, bearing down on the superior surface of the vocal folds. This positions the vocal folds more laterally when they are displaced, yielding a reduced collision pressure and vibrational amplitude during adduction (Laukkanen, Titze, Hoffman, & Finnegan, 2008). Essentially, the back pressure created by the semi-occlusion keeps the top edges of the vocal folds more separated during phonation, which makes the contact between folds less abrupt. This phenomenon contributes to the overall "squaring-up" shape of the vocal folds that is produced as a result of the SOVT posture (Titze, 2014). Another dimension of the "squaring-up" is contributed by the intrinsic laryngeal musculature.

Thyroarytenoid (TA) muscle activity has been shown to increase relative to cricothyroid (CT) muscle activity in response to SOVT exercises (Laukkanen et al., 2008). This effect can be explained by SOVTs yielding less adduction at the superior edges of the vocal folds, which causes TA activation to move the inferior edges. There was also a correlation found in this study between high TA/CT ratio and measures of vocal economy and vocal efficiency. The delicate balance of the TA and CT muscle activity draws the medial surface of the true vocal folds to a parallel or near-parallel position, without “pressing” the vocal folds together using other intrinsic muscles (e.g. overactivation of the lateral cricoarytenoid) (Titze, 2018). The increased TA activity also has a thickening effect on the vocal folds and loosens the vocal fold cover (the epithelium, and superficial and intermediate layers of the lamina propria), resulting in more durable and pliable vocal fold tissues (Yumoto et al., 1995).

SOVT exercises may have an impact on general features of the laryngeal and pharyngeal structures, as well. It has been reported in the literature that these exercises may contribute to lowering of the vertical position of the larynx and relaxing laryngeal and pharyngeal muscles, including extrinsic muscles (e.g. strap muscles) (Bele, 2005). These changes occur particularly during SOVT protocols requiring voiced, bilabial plosive productions. Interestingly, the tube/straw phonation and water resistance therapy literature has not mentioned whether these biomechanical features occurred with such SOVT exercises.

2.2.b. Vocal Economy and Efficiency

The aforementioned aerodynamic effect of increased MFDR also contributes to improved vocal economy, which can be described as the trade-off between optimal vocal output and the amount of mechanical stress placed on the true vocal folds in order to achieve a higher sound output (Titze, 2006b). In other words, vocal economy is the ratio of MFDR/MADR. The caveat to increased MFDR improving vocal economy is that this assumes the maximum area declination rate (MADR) of the glottis does not proportionally increase with MFDR. Importantly, MADR is proportional to glottal contact velocity during true vocal fold adduction.

Vocal efficiency is a similar ratio measure, but it compares the amount of power radiating from the lips to aerodynamic power (pressure x flow) (Schutte, 1980, 1984). Measures of vocal efficiency are not accurately descriptive in the context of SOVT exercises because only a very small amount of acoustic power is radiated at the lips during vocal tract occlusion (Titze, 2006). Most of the acoustic power is transferred back into the vocal tract, yielding percentages so small, they would be considered inefficient by definition. While vocal efficiency may be an inappropriate measure of SOVT exercise, it is referenced here because it is often cited in the literature along with measures of vocal economy. The concept of vocal efficiency must be interpreted very cautiously in the study of SOVT exercises.

2.2.c. Sensory Biofeedback

An often-overlooked component of the effectiveness of SOVT exercises is the inherent nature of the exercise to promote physiologic sensations that can be used as biofeedback to inform accuracy of the exercise and optimal vocal technique, in general. Sensory biofeedback is a very commonly applied clinical technique that is not specific to SOVT exercises or even voice therapy itself. It is an essential element to promote generalization of non-speech tasks into speech tasks and functional conversation. A prime example of a therapy protocol that recognizes the importance of sensory biofeedback is Lessac-Madsen Resonant Voice Therapy (previously described in the opening section of this text). Using this approach, therapy emphasizes not only how the voice sounds to the patient, but also how the voice feels. Patients should concentrate on feeling the “buzz” in their facial tissues during phonation (Verdolini, 2000). SOVT exercises present a unique opportunity for users to feel sensations such as vibration of the lips, tongue, velum or oronasal mask. Additionally, vibration against a hand, tube, straw, or cup of water can also be used as biofeedback. For some users, the biofeedback of the back pressure built by phonating through a coffee stirrer, for example, compared to a drinking straw, can significantly ease the perception of phonatory effort.

2.3. Treatment Effects of SOVT Exercise

The therapeutic effects of SOVT exercises have been studied in various capacities throughout the literature. There was an overt paradigm shift noted from habilitative efforts to improve the voice of vocal performers to the treatment of voice disorders using SOVT exercises. While early investigations focused solely on hyperfunctional voice disorders (Guzman et al., 2013a; Guzman et al., 2013b), improvements were later demonstrated in conditions such as unilateral vocal fold paralysis (Guzman et al., 2016). The literature also trended towards more specific identification of the effects based on the type of SOVT exercise (e.g. straw phonation, lip trill), as well as stimulus material variation (e.g. straw/tube material, length, and diameter, water resistance therapy). In a comprehensive study, intraoral pressures were variable across 13 different SOVT exercises. Results indicated a 10:1 change compared to natural lung pressures during phonation. The most effective postures were water resistance therapy, straw phonation, raspberries, and lip trills (Maxfield, Titze, Hunter, & Kapsner-Smith, 2015). In another study, improvements were noted following each trialed SOVT exercise, when compared to habitual phonation. More prominent changes were observed with narrow straw phonation (compared to a wider straw) and water resistance therapy (Guzman et al., 2016). In general, it seemed that the narrower the occlusion of the SOVT exercise, the greater impact it had on voice production (Guzman et al., 2013c; Robieux, Galant, Lagier, Legou, & Giovanni, 2015). Finally, generalization of the technique was addressed by investigating short-term and long-term effects, during, immediately after, and some time after the use of SOVT exercise. By in large, immediate improvement given SOVT exercise has been demonstrated, but these effects do not seem to last. Transient changes in aerodynamic pressure/flow, muscle activity, glottal resistance, and glottal area; as well as, acoustic and perceptual improvements, have been demonstrated to last between 1-5 minutes following SOVT exercise (Costa, C., Costa, L., Oliveira, & Behlau, 2011; Croake, Andreatta, & Stemple, 2017; Enflo, 2013; Guzman et al., 2013b; Laukkanen et al., 1995a; Laukkanen, Lindholm, & Vilkman, 1995b; Sampaio, Oliveira, & Behlau, 2008; Vampola, Laukkanen, Horáček, & Švec, 2011). After 5-10 minutes, however, these effects seem to dissipate or even disappear, except for increased transglottal airflow, which seems to last up to 20 minutes (Kang et al., 2019).

2.4. Measurement of SOVT Effects

There have been many techniques used, throughout the literature, attempting to measure the effects of SOVT exercises. While there has been an impressive breadth of measurement techniques employed, assessing SOVTs from multiple different perspectives, the depth of the techniques is only remarkable in a few areas. The primary techniques used have been modeling, aerodynamics, acoustics, and electroglottography (EGG) analysis. The lesser used techniques have been electromyography (EMG), self-perceptual measures, auditory-perceptual assessment, and laryngeal imaging. There may be obvious explanations for the lack of self-perceptual and auditory-perceptual measurement, but the lack of laryngeal imaging studies represents a profound gap in the literature.

2.4.a. Modeling

Both computerized and physical modeling has been used to study SOVT exercises. A computerized model, which was initially used to explain general vocal tract physiology (Story & Titze, 1995; Titze & Laukkanen, 2007), was adapted to manipulate the vocal tract at each end. The glottal end simulated the general shape of the glottal area during SOVT exercise and the labial end simulated a semi-occlusion (Titze, 2006). Acoustic and aerodynamic air pressures and airflows were collected, accounting for biomechanical parameters (e.g. muscle activation, vocal fold thickness), energy losses, and subglottal characteristics. The specific dependent variables were glottal flow, mean intraglottal pressure, mean and peak glottal area, and two measures which were ratios of the aforementioned pressures and flows, MFDR and MADR. The effects of these variables were previously reported in the underlying physiology section of this text. Computerized modeling has also been used to demonstrate improved vocal economy and efficiency when thyroarytenoid muscle activity outweighs cricothyroid muscle activity during phonation, as is the case during SOVT exercise (Laukkanen et al., 2008). This result of improved vocal economy was also reported in another modeling study that used 3D finite element models derived from CT scan imaging measurements (Vampola et al., 2011). Another study modeled the effect of a resonance tube on acoustic variables and vocal tract inertance. Results indicated a significant decrease in the first formant (F1) value from 300 Hz to 150 Hz, a tripling of intraoral acoustic pressure, and a doubling of vocal tract inertance (Titze & Laukkanen, 2007).

While most of the modeling results were based solely on computerized modeling, many researchers have used physical modeling to simulate the tissue, pressure, and flow dynamics of the vocal tract more broadly. The majority of those studies fall outside the scope of this review, but positive effects of vocal tract inertance on phonation threshold pressure (PTP) has been demonstrated using this type of modeling (Chan, I. Titze, & M. Titze, 1997). Vocal tract models attached to excised canine larynges have also been used to demonstrate the decrease in PTP given SOVT exercise (Conroy et al., 2014). Another physical modeling study measured the effect a resonance tube had on airflow. Keeping the input flow rate constant, there was a 10x increase in oral pressure when the resonance tube was in place and submerged in 10cm of water. Also, subglottal pressure increased by 1.4x and flow resistance increased by 1.5x (Horáček, Radolf, Bula, & Laukkanen, 2014). The most recent physical modeling study reported a 67% decrease in F1 when the distal end of a resonance tube was in free air and a 91-92% decreased F1 when its end was submerged in water (Horacek, Radolf, Laukkanen, 2019). A crucial consideration in evaluating the results of modeling studies is whether the models incorporate the influence of the pliable soft tissues of the vocal tract. The reported decrease in F1 values achieved by SOVT exercise may be attributed to the rigidity of the vocal tract model being used, rather than actual therapeutic effect (Radolf et al., 2016).

2.4.b. Aerodynamic Measurement

In many ways, direct aerodynamic measurement of SOVT exercises is somewhat paradoxical. The traditional vocal tasks performed in order to assess aerodynamic properties (e.g. /pa/ repetitions), through a pneumotachograph mask for example, can be considered SOVT exercises, in and of themselves. This may complicate conclusions made that desirable effects were a result of the researcher's SOVT test performance, rather than the SOVT used for assessment itself.

In addition to the derived, composite measures (e.g. MFDR) discussed previously in this text, common output variables prevailed throughout the aerodynamic literature. Intraoral, intraglottal, and subglottal air pressures have all been shown to increase given SOVT exercises (Maxfield et al., 2015; Robieux et al., 2015). Increases have also been demonstrated in mean airflow, minimum airflow, and sound pressure level (SPL) (Croake et al., 2017; Dargin & Searl, 2015). The reported results may be relatively unsurprising based on information gleaned from modeling studies, but the recent finding of increased minimum airflow is intriguing. This measure may indicate that SOVT users are less likely to hold back airflow, even in a situation that may encourage that behavior. This may also be a function of the underlying physiology of the glottal area (i.e. the vocal folds remaining slightly separated during phonation due to the supraglottic pressures built in the vocal tract).

The instrumentation collecting these measures was fairly similar throughout the literature. Most studies used some form of pneumotachograph mask, with pressure transducers, connected to a software package (e.g. Glottal Enterprises, Pentax PAS). One study measured actual subglottal pressure using a tracheal puncture, rather than deriving measures from intraoral pressure (Robieux et al., 2015). Despite obvious disadvantages, the advantage of this was that the oral cavity was entirely free to perform SOVT exercises. This also solved the issue of having to measure effects of SOVT exercises based on another SOVT posture (e.g. /pa/). This problem was also addressed by an innovative study that proposed an alternative to the traditional measurement of phonation threshold pressure (PTP) by extrapolating airflow from a bilabial plosive. Instead, a semi-occlusion of the vocal tract was produced by phonating into a 2.5-mm straw. Results concluded that PTP could be measured in this fashion, but that it may be more beneficial to obtain this measure through a fixed, less variable posture of the vocal tract (e.g. complete occlusion) (Titze, 2009).

2.4.c. Acoustic Measurement

The previously mentioned considerable lowering of the first formant frequency (F1), while maintaining continuous airflow during SOVT exercises (Story et al., 2000), has been thoroughly supported by the literature base. Additionally, SOVT exercise contributes to formant changes that present a formant cluster around F3, F4, and F5 (Guzman et al., 2013b; Laukkanen, Horáček, & Havlík, 2012), as identified by computed tomography (CT) imaging studies. In other words, SOVT exercise may establish a “singer’s formant” (or in this case, a “speaker’s formant”), taking advantage of optimal resonance patterns, providing an acoustic “ring” to the voice (Bartholomew, 1934). Fundamental frequency (F_0) changes were also investigated by attempting to map the effects of SOVT exercise onto a voice range profile, a traditional acoustic voice assessment tool which plots maximal F_0 range against maximal vocal intensity range. Acoustic results indicated that F_0 and intensity ranges were not limited by SOVT exercise (Titze & Hunter, 2011). Generally, F_0 has been shown to decrease as a result of SOVT exercise (Sampaio et al., 2008), although other studies have reported no significant changes in this variable (Costa et al., 2011). As far as cepstral measures, increases in smoothed cepstral peak prominence (CPPs), have been observed in sustained vowels, paragraph level text, and conversational speech, following SOVTs (Wu & Chan, 2020).

A remarkably limited number of studies analyzed the effect of SOVT exercise on perturbation measures. One such study reported improvements in jitter (cycle-to-cycle frequency variation), and shimmer (cycle-to-cycle amplitude variation) percentages. No such improvements were reported in the control group, indicating an actual therapeutic effect of the test parameter (SOVT exercise) (Fantini et al., 2017). No significant findings were observed in noise-to-harmonic ratio (NHR), a calculation of aperiodic noise in the acoustic signal.

2.4.d. Electroglottographic Measurement

Most reviewed studies that reported acoustic and aerodynamic effects of SOVT exercises also used EGG to measure glottal source characteristics, such as true vocal fold closure. There were conflicting findings throughout the EGG literature, mostly centering around glottal contact quotient. Many studies revealed that closed quotient percentage (%CQ) increased following SOVT exercise (Cordeiro, Montagnoli, Nemr, Menezes, & Tsuji, 2012; Dargin & Searl, 2015; Gaskill & Erickson, 2010; Gaskill & Quinney, 2012; Guzman et al., 2016). These results are somewhat surprising, as the theoretical data proposes that the vocal folds remain partially separated during phonation with a SOVT. This would seemingly contribute to increases in open quotient, rather than %CQ. Conversely, support was offered for increased open quotient (or decreased closed quotient) following SOVT exercises (Andrade et al., 2014; Guzman et al., 2013a; Hamdan et al., 2012; Titze, 2009; Vampola et al., 2011). Most of the authors attributed the contradictory findings to individual differences among SOVT users or perhaps the tool producing the semi-occlusion (e.g. straw) providing too much resistance for adequate vocal fold abduction. The interpretation of the EGG signal during supraglottic constriction has been cautioned against due to the increase in supraglottic pressure skewing the data (Rothenberg & Mahshie, 1988). One study attempted to define a more sensitive measure to address the variability in results. Contact quotient range (CQr) was reported, which was operationalized as a variation between open and closed contact quotients (e.g. maximum %CQ-minimum %CQ) within one token. A large CQr was interpreted as unsteady vocal fold vibration and a small CQr would indicate steady vibration. This variable was found to increase provided SOVT exercises. Rather than jumping to the conclusion that SOVT exercises cause unsteadiness in vocal fold vibration, the authors related this result to the physiologic change caused by the semi-occlusion itself (i.e. increased intraoral pressure causing a "massage effect" for the larynx) (Andrade et al., 2014).

2.4.e. Electromyographic Measurement

A previously referenced modeling study tuned their computerized model to muscle activity differences given SOVT exercise based on electromyography (EMG) of a single-subject. Increased muscle activity was observed in the thyroarytenoid (TA) muscle, compared to the cricothyroid (CT) and lateral cricoarytenoid (LCA) muscles. Higher TA/CT ratios were observed given SOVT exercises. A less clear-cut relationship was found between the TA and LCA, both adductor muscles of the vocal folds. The lack of EMG studies investigating SOVT exercises was striking, especially considering that many of the theoretical models base their registrations of simulated muscle activity on this one, single-subject experiment (Laukkanen et al., 2008).

2.4.f. General Imaging

The primary general imaging technique used to investigate SOVT exercises has been computed tomography (CT), but general vocal tract findings have been reported through magnetic resonance imaging (MRI) (Gracco, Sasaki, McGowan, Tierney, & Gore, 1994) and x-ray technology (Roers, Mürbe, & Sundberg, 2009). This reliance on CT is probably unsurprising, considering the lack of spatial resolution and practical disadvantages (e.g. inability to move during imaging) of the other imaging techniques mentioned. SOVT postures also do not require incredible temporal resolution as movements are relatively stable, once initiated. Most of the CT studies revealed more complete velopharyngeal closure, lower laryngeal vertical position, and increased area of the oral cavity, oropharynx, and hypopharynx (Guzman et al., 2013c; Vampola et al., 2011). Similar results were found using MRI (Laukkanen et al., 2012; Laukkanen, Horáček, Krupa, & Švec, 2012). One significant caveat to these findings are that the largest sample size of any of these studies included two participants. There was a more recent CT study, however, that found identical results with a sample size of ten participants (Guzman et al., 2017). An additional study attempted to replicate the CT findings, but found no prominent trends across two participants (Hampala, Laukkanen, Guzman, Horáček, & Švec, 2015).

2.4.g. Laryngeal Imaging

While general imaging of vocal tract changes resulting from SOVT exercise has been adequately explored, literature utilizing laryngeal imaging has been scarce. Most of the reported results, across types of laryngeal imaging, are complicated by significant inter-and intra-subject variation. SOVT changes were demonstrated on high-speed videoendoscopy (HSV; captured at 4,000 frames per second) as decreased amplitude-to-length ratio, harmonic-to-noise-ratio, and spectral flatness (derived from the glottal area waveform). Results for contact quotient were variable (Guzman et al., 2017). In another study, increased open quotient derived from HSV (captured at 4,000 frames per second) was demonstrated on a kymograph; as well as, increased amplitude modulation derived from the glottal area waveform (Granqvist et al., 2015). Conversely, a high-speed image (captured at 1,900 frames per second) demonstrated reduced open quotient following SOVT exercise (Laukkanen et al., 2007). This, again, highlights the variability of the contact quotient measure, especially when using various image processing techniques within the domain of HSV.

Findings from laryngoscopy and stroboscopy studies were even more variable and potentially, less sensitive to the physiologic change resultant from SOVT exercises. One study found no significant laryngoscopic changes (Costa et al., 2011), and another found stroboscopic changes in almost every physiologic metric possible (i.e. amplitude, mucosal wave, laryngeal height, phase closure, supraglottic squeeze behavior). The magnitude and direction of change varied across each of the four participants (Dargin, DeLaunay, & Searl, 2016). Needless to say, a larger evidence base supporting laryngeal imaging may contribute to more consistent findings.

2.4.h. Self-Ratings and Auditory-Perceptual Analysis

Perhaps the most consistent results following SOVT exercise are auditory-perceptual assessment and self-ratings. Most of the reviewed studies reported significant improvements in self-perceived vocal effort, vocal discomfort, and voice quality (Costa et al., 2011; Fantini et al., 2017; Guzman et al., 2018; Meerschman et al., 2019; Sampaio et al., 2008; Schwarz, & Cielo, 2009). A few studies used standardized instruments designed to assess these variables. Significant improvements were noted on the Voice Handicap-Index (VHI) (Jacobson et al., 1997), a self-rating of how severely voice function handicaps daily function and VHI-10 (Arffa, Krishna, Gartner-Schmidt, & Rosen, 2012), a simplified version (Denizoglu, Sahin, Bayrak, & Uygun, 2018; Kapsner-Smith, Hunter, Kirkham, Cox, & Titze, 2015; Meerschman et al., 2019). As for auditory-perceptual analysis, improvements were reported by expert listeners on visual analog scales (Enflo, Sundberg, Romedahl, & McAllister, 2013) and dichotomous ratings (better voice/no change) (Guzman et al., 2013b). Improvements were also noted on the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) (Kempster, Gerratt, Verdolini Abbott, Barkmeier-Kraemer, & Hillman, 2009) and the GRBAS (De Bodt, Wuyts, Van de Heyning, & Croux, 1997), both widely used auditory-perceptual instruments. Specifically, reductions in roughness (Kapsner-Smith et al., 2015; Meerschman et al., 2019) and dysphonia grade (Denizoglu et al., 2018; Meerschman et al., 2019) were noted as a result of SOVT exercise. In counterpoint, there were a few studies that reported no significant auditory-perceptual changes (Costa et al., 2011; Fadel et al., 2016).

2.5. Summary of Gaps in Current Knowledge

Relative strengths and weaknesses of the current literature have been presented throughout this text, but explicit emphasis of the gaps in knowledge is warranted. The primary gaps include a lack of kinematic data supporting the underlying physiologic mechanisms of SOVT exercise and a need for further evidence promoting long-term therapeutic effects. Due to the lack of kinematic data, very little is known about the impact of SOVT exercise on vibratory characteristics of the vocal folds. Most of the studies reviewed inferred such effects based on theoretical aerodynamic modeling or EGG, rather than direct laryngeal imaging. High-speed videoendoscopy (HSV), using a transnasal, flexible endoscope, seems to be the most promising laryngeal imaging method to improve the validity of SOVT effects. The capability of HSV to capture at high frame rates make it appropriate for visualizing aperiodic or transient vibratory characteristics. Surprisingly, only one of the reviewed HSV studies used transnasal endoscopy (Granqvist et al., 2015), which may improve reliability of the measurement by insuring uninterrupted performance of the SOVT exercise. The other studies used specialized equipment to insert rigid endoscopes through the material used for semi-occlusion (Guzman et al., 2017; Laukkanen et al., 2007). This instrumentation may have introduced some glaring confounding variables, such as the participants' limited use of the tongue and overall discomfort with the procedure.

The demonstrated absence of long-term effects of SOVT exercise likely has more to do with how we have been measuring the effects, rather than the actual efficacy itself. Some have posited that this absence may be due to difficulty generalizing non-speech tasks to speech activity (Kapsner-Smith et al., 2015; Titze, 2006), but many of the field's most efficacious voice therapy approaches (e.g. LMRVT) hinge upon the development of this skill. The onus is on clinicians to bridge SOVT exercises into functional/conversational speech activities and on researchers to design experiments that accurately elicit this type of behavior. Increased performance of SOVT exercises in actual speech contexts may help generalize the transient effects into more long-lasting effects. To elucidate this argument, it would not be expected for a patient to have long-lasting voice improvements from one session of voice therapy that focused solely on humming/chanting. Why should researchers expect SOVT exercises to have this type of therapeutic impact? This does not allow for the adoption of the principles of motor learning or any theories of skill development (Kumaran & McClelland, 2012; Schmidt, 1975), which underly most behavioral therapies. The mechanism for SOVT effects becoming long lasting is not well-understood and is of significant interest. The aims of this project should contribute some evidence of what this mechanism is. Likely it is grounded in a combination of the principles of motor learning (described above), the acquisition of accurate self-perception of optimal vocal technique, and the ability to match targets that are established by auditory perception of self- and clinician-based models.

An additional gap in current knowledge arose during the development of this project. While it was not an official aim of this project, necessity presented an opportunity to evaluate the delivery of SOVTs in a remote setting. There are currently very few (if any) investigations, specifically analyzing SOVT exercises provided through telepractice, but there are a fair number of investigations of voice therapy, in general, delivered in this capacity. Largely, it seems that this type of delivery can provide similar outcomes as traditional voice therapy, although an extensive literature review of the subject was not performed.

CHAPTER 3: Methodology

This dissertation project was designed to test the research questions and hypotheses stated in Sections 3.1, 3.2, and 3.3, through four separate experiments. In this section, the methodological design of each experiment is described with regard to the participants and procedures, the instrumentation used to complete the experiment, and a thorough description and operationalization of the variables being studied. Experiments 2 & 3 are grouped, as they share identical participants, procedures, and instrumentation, but differ in the outcome variables that are of interest.

3.1. Experiment 1

This experiment consisted of an online survey, which was distributed to speech-language pathologists. The objective of this experiment was to identify trends in the prescription practices of semi-occluded vocal tract exercises for rehabilitative and training purposes. There has been great variety in the way practitioners have used SOVTs over the years and this experiment aimed to understand how SOVTs were currently being applied in the clinical setting. Any similarities or differences may potentially reveal significant gaps in knowledge or understanding of the underlying physiology of the exercises, or the practical application to clients. While forms of SOVT exercise are used across many disciplines (e.g. speech-language pathology, singing pedagogy, theatre), this experiment was intentionally focused on speech-language pathology clinicians. Responses were still collected from non-SLP voice professionals, but their data were not included in the final analysis. This decision was made to keep data-driven conclusions as concise as possible; however, this data can certainly be extended to related disciplines and populations. This experiment was designed to test the following research questions and hypotheses:

Q1: How are semi-occluded vocal tract exercises currently being prescribed by speech-language pathologists/voice clinicians?

H1: At least 80% of respondents will report use of SOVTs, in isolation or in conjunction with other voice therapy approaches (e.g. vocal function exercises), with at least "regular" frequency.

H2: Respondents will report using straw phonation most frequently compared to other SOVT exercises.

H3: Respondents will use SOVT exercises to treat hyperfunctional disorders more than other types of voice disorders.

Q2: How knowledgeable are clinicians about the underlying physiology of SOVT exercises?

H4: At least 80% of respondents will feel at least "knowledgeable" with the underlying physiology of SOVT exercises.

H5: Level of knowledge about the underlying physiology of SOVTs will be greater for respondents with a personal/professional background of singing.

The independent variables for this experiment were the amount of years of experience working with voice users and personal/professional singing background. The dependent variables included SOVT use frequency (relative to other voice techniques), the type of SOVT most often used (relative to other SOVTs), and respondents' level of knowledge about the underlying physiology and practical application of SOVTs. The type of voice disorders treated by respondents was used as both an independent and dependent variable. These variables are described in detail in Section 3.1.c.

3.1.a. Participants and Procedure

IRB approval was obtained from the Michigan State University Human Research Protection Programs Human Subject's Review Board. Participants were recruited using a combination of purposive sampling, convenience sampling and snowball sampling. Prior to full dissemination, the survey was sent to a small focus group of three speech-language pathologists, who were familiar with the objectives of this study and had varying levels of experience treating voice disorders using SOVT exercises. This focus group was intended to assess the face validity and content validity of the questions being asked, as they relate to clinical practice. Finally, the survey was distributed through various outlets including personal contacts of the authors, social media, and online/electronic mailing lists of the following regional and national organizations: the American Speech-Language-Hearing Association's Special Interest Group 3: Voice and Upper Airway Disorders (ASHA SIG 3), the Society for Ear, Nose, and Throat Advances in Children (SENTAC), the Pennsylvania Speech-Language-Hearing Association (PSHA), and the Michigan Speech Language Hearing Association (MSHA). Respondents were required to be at least two years past their terminal training to be included in the results. For speech-language pathologists, this would equate to having at least one year of unsupervised clinical experience following their clinical fellowship.

Informed consent was obtained prior to respondents receiving and completing the survey.

3.1.b. Instrumentation

The survey, itself, was a series of 16 questions that contained demographic information and content-based questions about the prescription tendencies of SOVT exercises. Most responses were provided in the form of Likert scales and visual analog scales. Both open-ended and close-ended questions were used (see Appendix A for the full survey). The survey was created using Qualtrics survey platform (Qualtrics, Provo, UT), which generated a direct link to be sent to potential respondents.

3.1.c. Experimental and Outcome Variables

For the purposes of this survey research, both the independent and dependent variables require explanation, as dictated by the fluidity of the concepts and constructs of clinical SOVT prescription practices.

Years of experience was operationalized broadly as the amount of years spent working with voice users. Respondents were instructed to begin counting years following terminal training (e.g. SLPs start with first year following their clinical fellowship). Respondents were grouped into new professionals (NP; ≤5 years), established professionals (EP; 6-9 years), and veteran professionals (VP; ≥10 years).

Personal/professional singing background was also defined liberally as any individual who has performed singing in an organized public forum after graduating high school and/or any individual who has participated in at least 3 sessions of private voice instruction. For the purposes of this study, this variable will be treated dichotomously (i.e. respondents with or without a singing background).

SOVT use frequency and *Type of SOVT most often used* were assessed using two cross-referenced measures: rank order scales and Likert scales. The rank order scales were used to achieve a general sense of which SOVTs are being used most frequently, relative to each other and to other voice techniques. This scale provided forced choice options, asking respondents to label voice techniques (1 to 5) based on how likely they are to use the technique in daily clinical practice. This response style was also used to assess the type of SOVT most often used, the types of disorders that respondents typically treat (generally), and the types of disorders that respondents typically treat with SOVT exercise. The Likert scales were used to discern interval-level characteristics of use frequency, accounting for the types of disorders being treated. For example, how much more likely are respondents to treat a hyperfunctional voice disorder than a structural disorder.

Knowledge level about the underlying physiology and practical application of SOVT exercise was also measured using Likert scales. Examples of such inquiries include: "How well prepared did you feel using SOVT exercises following your graduate education?" and "How knowledgable are you about the underlying physiology of SOVT exercise?," rating these questions on a scale from 1-4 ("Not at all knowledgeable" to "very knowledgeable"). Respondents were also provided open-ended queries such as "Describe your understanding of the physiology underlying SOVTs."

3.2. Experiments 2 and 3

The next two experiments were related in that they shared identical participant groups and experimental procedures, but they differed in the outcome variables of interest. Experiment 2 was primarily an investigation of the acoustic voice measures impacted by SOVT exercise and Experiment 3 was primarily an investigation of auditory-perceptual and self-perceptual voice measures following SOVTs. Both experiments consisted solely of participants with non-pathological voices. Experiment 2 was designed to test the following research question and hypotheses:

> Q3: What are the immediate effects of SOVT exercise on acoustic voice measures, when delivered remotely through telepractice?
>
> H6: There will be increased Singing Power Ratio (SPR) following SOVTs, indicating an increased presence of a singer's formant during sustained /a/ vowel phonation.
>
> H7: Jitter and shimmer will decrease following SOVT exercises.
>
> H8: Smoothed cepstral peak prominence (CPPs) and harmonic-to-noise ratio (HNR) will increase following SOVTs.
>
> H9: The observed magnitude of acoustic effects will be greater for straw in water phonation, compared to straw phonation alone.

The independent variables for this experiment are time (pre-task/post-task 1/post-task 2) and type of SOVT (straw phonation/straw in water phonation). The dependent variables are fundamental frequency, SPR, perturbation measures (jitter and shimmer), HNR, and CPPs. These measures are described in detail in Section 3.2.e. The research question and hypotheses for Experiment 3 are as follows:

Q4: What are the immediate effects of SOVT exercise on auditory-perceptual and self-perceptual voice measures, when delivered remotely through telepractice?

H10: Auditory-perceptual ratings will decrease in overall severity, roughness, strain, and breathiness, as measured by the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V), following SOVT exercise.

H11: Self-perceived vocal effort level will be less following straw in water phonation than straw phonation alone.

H12: Following SOVT exercises, self-perceived vocal quality semantic differential scales will trend towards looser voice > tighter, better voice > worse, smoother voice > scratchier, and louder voice > quieter, more so for straw in water phonation than straw phonation alone.

The independent variables are the same as for Experiment 2 and the dependent variables include: auditory-perceptual attributes (i.e. overall severity, roughness, strain, and breathiness) of the CAPE-V and self-perception of vocal effort and vocal quality. These measures are described in detail in Section 3.2.e.

3.2.a. Participants

IRB approval was obtained from the Michigan State University Human Research Protection Programs Human Subject's Review Board, which covered all aspects of human data collection. An a priori statistical power analysis was performed for sample size estimation, based on data from Wu & Chan (2020)'s, Effects of a 6-week straw phonation in water exercise program on the aging voice (n=37), comparing acoustic, auditory-perceptual, and self-perceptual voice measures following straw in water phonation. The effect size (with respect to cepstral measures) in this study (η_p^2) was .192. The projected sample size required to achieve 80% power, with an alpha level of .05 to achieve statistical significance, using this effect size, is n = 36 (GPower 3.1). Thus, the proposed sample size of 44 participants (22 males and 22 females) was more than adequate for the objectives of Experiments 2 & 3 and also allowed for attrition and controlling for possible mediating factors. Participants, between the ages of 18 and 70, were primarily recruited through SONA, an online recruiting and scheduling platform offered by the College of Communication Arts and Sciences at Michigan State University (Sona Systems, Ltd.). Participants were also recruited via convenience sampling via e-mail and social media platforms. Any participant with a known personal history of a speech, language, or voice disorder was excluded from the final analysis. Participants with any history of voice therapy or experience with SOVT exercises, through rehabilitative or training efforts, were also excluded. Participants were screened for any elements that may adversely affect speech production (e.g. breathing problems, hearing impairment). Following informed consent, the experiments began.

3.2.b. Instrumentation

Several instruments were used to collect and analyze data prior to, during, and following the experimental task. Pre-, post-, and experimental tasks were all remotely observed through a Zoom teleconferencing session (version 5.0.5 (26213.0602)). All sessions were encrypted, using a licensed, education account. Audio recordings were collected using Audacity software (version 2.4.1, sampling rate of 44.1 kHz, 24 bit, mono) and analyzed using Praat software (version 6.1.16, sampling rate of 44.1 kHz).

Various microphones, pre-amplifiers, and data acquisition devices were tested to be used in this experiment, based on specifications. Performance testing included: dynamic range, linear performance, bandwidth, sensitivity, and ease of shipping and installation. The following were the optimal settings resulting from the preliminary testing. A small-diaphragm cardioid condenser microphone AKG P170 (AKG Acoustics, Northridge, CA), with XLR cable connection, was used to capture the recording. The microphone was mounted to a Gator Frameworks GFW-MIC-0250 mini tripod desktop microphone stand and spaced 20 centimeters from the participant's mouth. The microphone was connected to an analog-to-digital audio recording interface (Focusrite Scarlett Solo 3rd Gen, Focusrite Novation Inc., El Segundo, CA) with built-in Phantom power supply and self-powered USB 3.0 digital output interface. The recordings were exported as WAV files and compiled in digital folders for review by expert listeners to perform auditory-perceptual analysis, as described in Section 3.2.e. Each listener received a Google Drive link to access their folder containing all the audio files, which were numbered and randomized. Participants were shipped a box containing all the materials necessary to complete the experiment including the microphone and a USB flash drive containing the Audacity software (Figure 3.1). The flash drive also contained a link to an online survey, which collected self-perceptual measures, and a PowerPoint presentation that provided visual time pacing prompts for the experimental tasks (Figure 3.2). Also, inside the box was a 19.7 cm plastic straw with a 5.59 mm diameter and an 8 oz disposable plastic graduated measuring cup.

Figure 3.1: Box that was shipped to participants. Contents of the box included the condenser microphone (with cables and stand), USB audio interface, USB flash drive, plastic straw, and plastic cup.

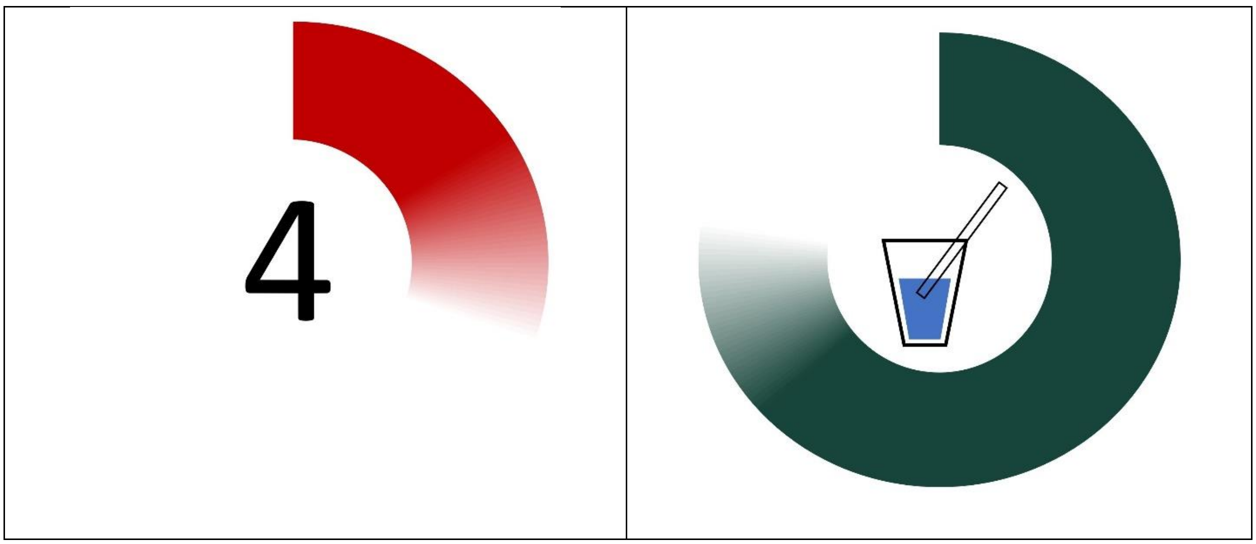


Figure 3.2: PowerPoint presentation displaying visual pacing prompts for the experimental tasks.

3.2.c. Pre- and Post-Task Procedure

Once the Zoom session was initiated, participants were briefly screened for any illnesses or other issues that may impact voice quality on the day of recording. They were asked to keep the camera and microphone unmuted in the Zoom window, so the researcher could confirm accurate performance of the tasks. Participants were then asked to open the box that was shipped to them. They were instructed on how to assemble, download, and configure all necessary software and hardware components. Participants were asked to fill the cup with 4 oz of water and unwrap the straw from its paper covering. All pre-, post-, and experimental tasks were explained in detail, and participants were given the opportunity to practice each task before initiating the experiment. This reduced any extraneous vocalization, potentially impacting the consistency of measurement once the experiment began. Prior to the first SOVT experimental task, a baseline battery of acoustic recordings was collected. These recordings were robust enough for post-hoc analysis of acoustic and auditory-perceptual voice quality. The tasks included a 5-second sustained /a/ vowel at a conversational pitch and loudness, the sentence utterance prompts from the CAPE-V (Appendix B), and a paragraph-length reading of the Rainbow passage (Fairbanks, 1960; Appendix C). Immediately following the baseline tasks, an additional, identical battery of tasks was conducted to serve as a double baseline for this experiment. This allowed for comparison of the baselines to perform pre-hoc descriptive analysis, capable of identifying the presence of a learning effect and helping to determine which baseline to compare to a post-task battery. The post-task battery consisted of identical speech tasks as the baseline batteries. Additionally, participants were asked to rate their perception of vocal effort and vocal quality following the experimental task by following a link to an online survey (Qualtrics, Provo, UT), which asked them about each of these parameters. These were measured using the scales described in Section 3.2.e. The two pre-task baselines and post-task battery were repeated following a second SOVT experimental task. After data were collected for all participants, the voice recordings were presented to trained listeners, in a randomized order, for auditory-perceptual analysis. The listeners consisted of three licensed speech-language pathologists, who had extensive experience in auditory-perceptual evaluation of voice. Listeners were instructed to review and rate the recordings using a digitally-modified version of the CAPE-V. This version took the form of a Qualtrics survey that provided several visual analog scales with only 0 and 100 markings at either end. The scales did not contain the "Mild," "Moderate," and "Severe" anchor markings. Listeners were instructed to review the audio recordings using earbuds or headphones to avoid extraneous background noise interfering with their judgement. Listeners were informed that the audio samples consisted of entirely non-pathological voices.

3.2.d. Experimental Task Procedure

Following the baseline battery of tasks, participants began the experimental tasks. The first SOVT experimental task (Condition A) consisted of 12, 10-second repetitions of straw phonation at a conversational pitch and loudness, with 10-second periods of rest/silence in between intervals. Participants were provided visual prompts to maintain the appropriate timing of tasks. The previously described post-task battery was administered, followed by a 5-minute period of rest/silence. This period of silence was included to allow for any SOVT treatment effect to dissipate prior to beginning the second SOVT experimental task. Condition A totaled two minutes of continuous SOVT exercise, excluding the periods of silence. This amount of time was chosen because it was the most frequently cited amount of time to perform SOVT tasks, that resulted in observable voice changes, throughout the literature (Costa et al., 2011; Sampaio et al., 2008). This procedure was repeated for the second SOVT experimental task (Condition

B), which was straw phonation into a cup of water. The presentation order of Conditions A & B was randomized.

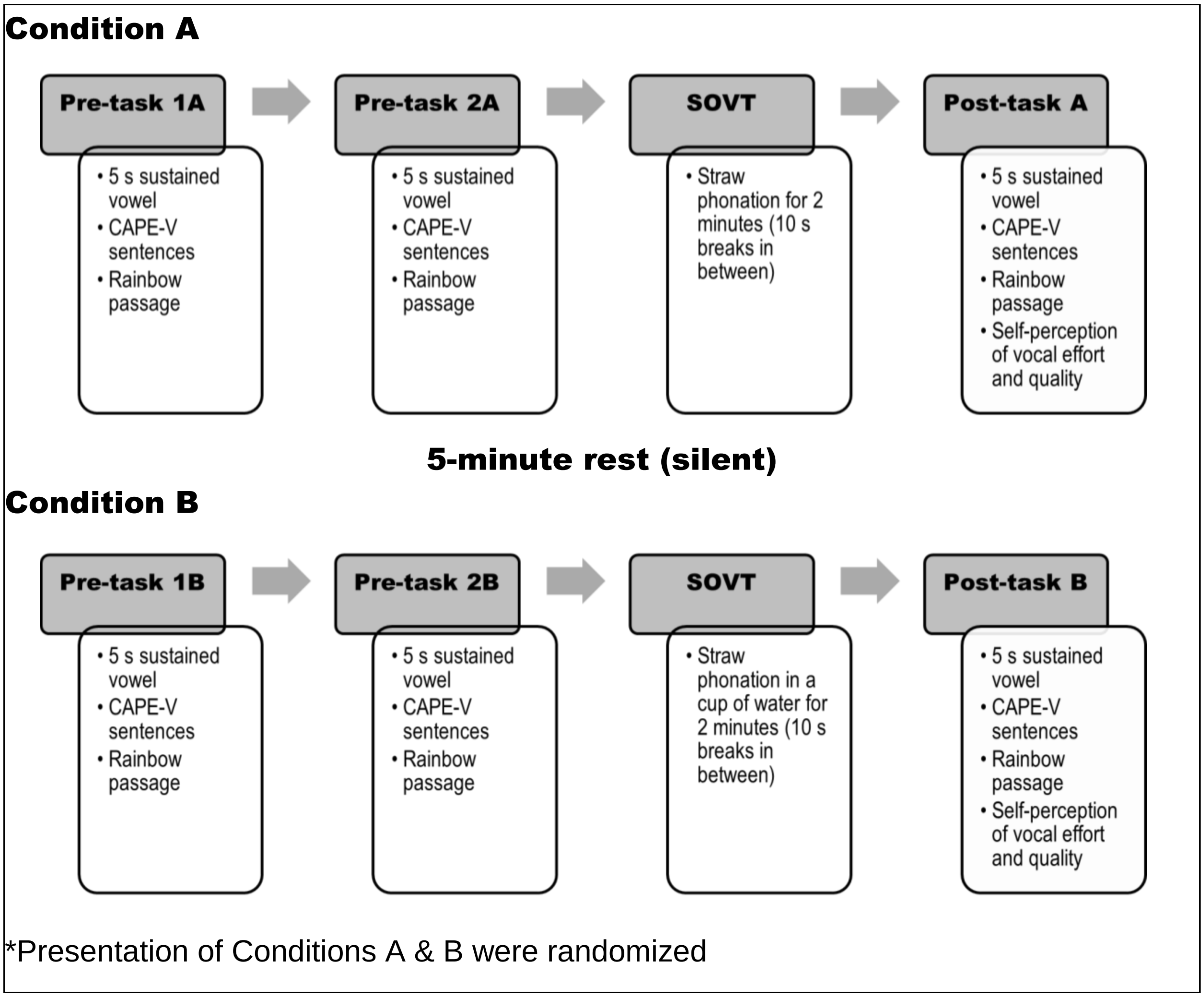


Figure 3.3: Procedural schematic of pre-, post-, and experimental tasks.

3.2.e. Outcome Variables

Smoothed cepstral peak prominence (CPPs) is an acoustic voice measure that relates to the periodicity of the vocal signal. It can be described as the most dominant peak, created by an average of the distance between inverted fundamental and harmonic frequency peaks, as identified by a regression line through the smoothed cepstrum (Maryn & Weenink, 2015). The cepstrum is defined as the fast Fourier transform (FFT) of the log magnitude power spectrum. Typically, a more pronounced cepstral peak indicates more harmonic energy, yielding a more periodic voice signal. This clinically applicable measure has been widely used as an acoustic correlate to vocal quality (Eadie & Baylor, 2006; Heman-Ackah, Michael, & Goding, 2002; Maryn, Corthals, Van Cauwenberge, Roy, & De Bodt, 2010; Hillenbrand, Getty, Clark, & Wheeler, 2005; Maryn et al., 2010). Wu and Chan (2020) observed improvements in CPPs following straw in water phonation in elderly individuals with subjective voice complaints. This may indicate the sensitivity of CPP measures to be able to detect subtle voice differences as a result of SOVT exercise.

Acoustic perturbation measures analyzed in this experiment were jitter, shimmer, and HNR. Jitter is the cycle-to-cycle variability in frequency, which correlates to the perception of pitch variability between and within cycles of vocal fold vibration. Shimmer is similar, but correlates to the cycle-to-cycle variability in amplitude. HNR is the ratio of harmonic energy to the noise energy in the acoustic signal, in the temporal domain. Collectively, these measures are considered research and clinical standards that have been used to evaluate many parameters of voice production, but they have also been used to investigate effects of SOVT exercise (Guzman et al., 2016; Fantini et al., 2017; Wu & Chan, 2020). For the purposes of this experiment, all perturbation measures will be analyzed during production of a sustained vowel.

Singing Power Ratio will also be analyzed during this experiment. This simple calculation identifies increased energy in the area a singer's formant would typically be located. This intriguing phenomenon has been cited repeatedly in the literature (Guzman et al., 2013; Laukkanen et al., 2012). The calculation requires a long-term average spectrum (LTAS) to be analyzed for the maximum harmonic peak between 0-2 kHz and also between 2-4 kHz. Subtracting these peak values will provide the increased or decreased presence of energy in the singer's formant area. Therefore, values closer to zero indicate more of a presence of singer's formant. This technique was introduced by Omori et al. (1996). The /a/ vowel was the most frequently used to determine presence/absence of a singer's formant, using SPR, throughout the literature. The /a/ vowel is also the most frequently used in acoustic voice analysis, especially when perturbation measures are computed. The selection of this vowel is likely related to its higher first formant frequency in the vowel space (750-850 Hz), while also maintaining a distinct difference between the first and second formant frequencies, providing for an ideal spectral environment for this type of analysis.

Auditory-perceptual analysis was conducted as part of Experiment 3. For this study, the CAPE-V (Kempster et al., 2009) was used to conduct the analysis. The CAPE-V is a psychometrically valid, standardized instrument that requires trained listeners to judge individuals' perceptual attributes of voice quality. Listeners are provided a 100mm line, with the anchors of "mildly deviant" to "severely deviant" listed below each line. The lines are used to rate perception of an individual's voice, based on 6 attributes (with space to add additional attributes, if necessary). The attributes are overall severity, roughness, breathiness, strain, pitch, and loudness. Specific definitions for each attribute are provided by the authors of the CAPE-V and can be found in Figure 3.4. The complete CAPE-V form can be found in Appendix D. For the purposes of this experiment, the pitch and loudness attributes were not rated. While the literature suggests the primary perceptual attributes that have improved following SOVT exercises have been roughness and strain (Kapsner-Smith et al., 2015; Meerschman et al., 2019), breathiness would also seemingly improve, which is why our hypotheses for this experiment include this attribute. Although the CAPE-V was established mainly to characterize disordered voices, there has been some validity and reliability established when analyzing normal voices, as well (Zraick et al., 2011). For the purpose of this experiment, a modified, digital version the CAPE-V was used, as described in Section 3.2.c.

Definitions of Vocal Attributes:
OVERALL SEVERITY: Global, integrated impression of voice deviance.
Roughness: Perceived irregularity in the voicing source.
Breathiness: Audible air escape in the voice.
Strain: Perception of excessive vocal effort (hyperfunction).
Pitch: Perceptual correlate of fundamental frequency. This scale rates whether the individual's pitch deviates from normal for that person's gender, age, and referent culture. The direction of deviance (high or low) should be indicated in the blank provided above the scale.
Loudness: Perceptual correlate of sound intensity. This scale indicates whether the individual's loudness deviates from normal for that person's gender, age, and referent culture. The direction of deviance (soft or loud) should be indicated in the blank provided above the scale.

Figure 3.4: Definitions of vocal attributes directly from the CAPE-V procedures document.

Self-perception of vocal effort has been previously measured using various instruments including visual analog scales and Likert scales (Costa et al., 2011; Fantini et al., 2017; Guzman et al., 2018; Meerschman et al., 2019; Sampaio et al., 2008; Schwarz, & Cielo, 2009), but one of the most promising instruments supported by the literature is the Borg Category Ratio-10 scale (Borg CR-10; Borg 1990). While this instrument was initially designed for measuring perception of general exertion and physical work, recent investigations used the Borg CR-10 to evaluate self-perceived vocal effort (Ford Baldner, Doll, & van Mersbergen, 2015; van Leer & van Mersbergen, 2017). This instrument uses a logarithmic scale which asks individuals to rate their effort from 1-10 using visual anchors such as "slight vocal effort" and "severe vocal effort." A disadvantage to using the Borg CR-10 to evaluate self-perceived vocal effort is that the scale is weighted to favor more difficult exertion (as may be the case when perceiving physical work), which can skew vocal effort ratings too severely for individuals with healthy voices. Berardi (2020) adapted the Borg CR-10 to a 100-point logarithmic scale to measure perceived vocal effort, which reportedly maintained the benefits of the Borg anchors, but provided higher resolution. This version of the Borg CR-100 (Figure 3.5) was used to analyze self-perception of vocal effort in this experiment. Importantly, self-perception of vocal effort will only be analyzed, comparing one type of SOVT (straw in water phonation) to another (straw phonation). Otherwise, an increase in vocal effort level may be expected because participants are likely to perceive the increased work of performing the SOVT task as increased vocal effort.

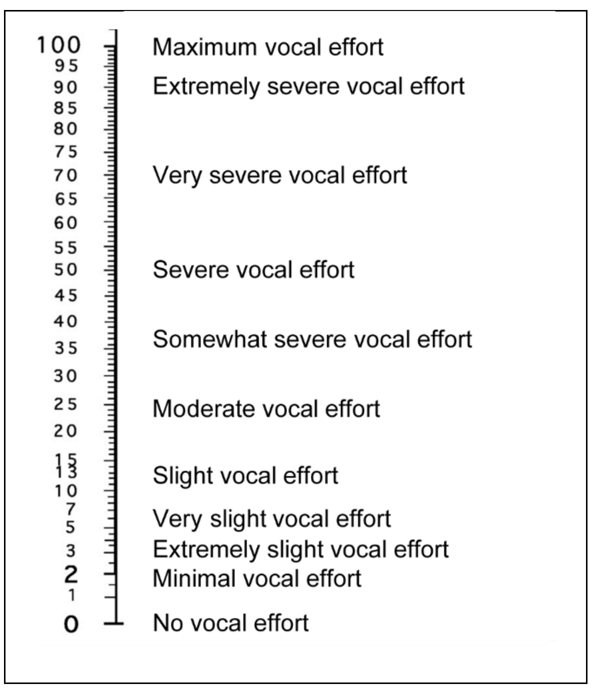


Figure 3.5: Borg CR-100 (adapted from Borg CR-10) for measurement of self-perceived vocal effort.

Self-perception of vocal quality has long been investigated within voice disorders research. Much like self-perception of vocal effort, most of the literature evaluating self-perceived vocal quality following SOVT exercise has relied on Likert scales and visual analog scales. These types of scales present challenges when used with individuals without voice complaints/disorders. For this reason, semantic differential scales were used to quantify self-perception of vocal quality in this experiment. These scales may be lesser used within the voice literature, but have been successfully applied to self-perception of voices that are not necessarily attributed to vocal impairment. Examples of this include perception of tracheoesophageal and esophageal speech (van As, Koopmans-van Beinum, Pols, & Hilgers; Nieboer, Graaf, & Schutte, 1988), gender presentation speech (Andrews & Schmidt, 1997), and synthesized speech (McGee, 1964). In this experiment, six semantic differential scales were provided, in which two polar adjectives were separated by seven points (Figure 3.6).

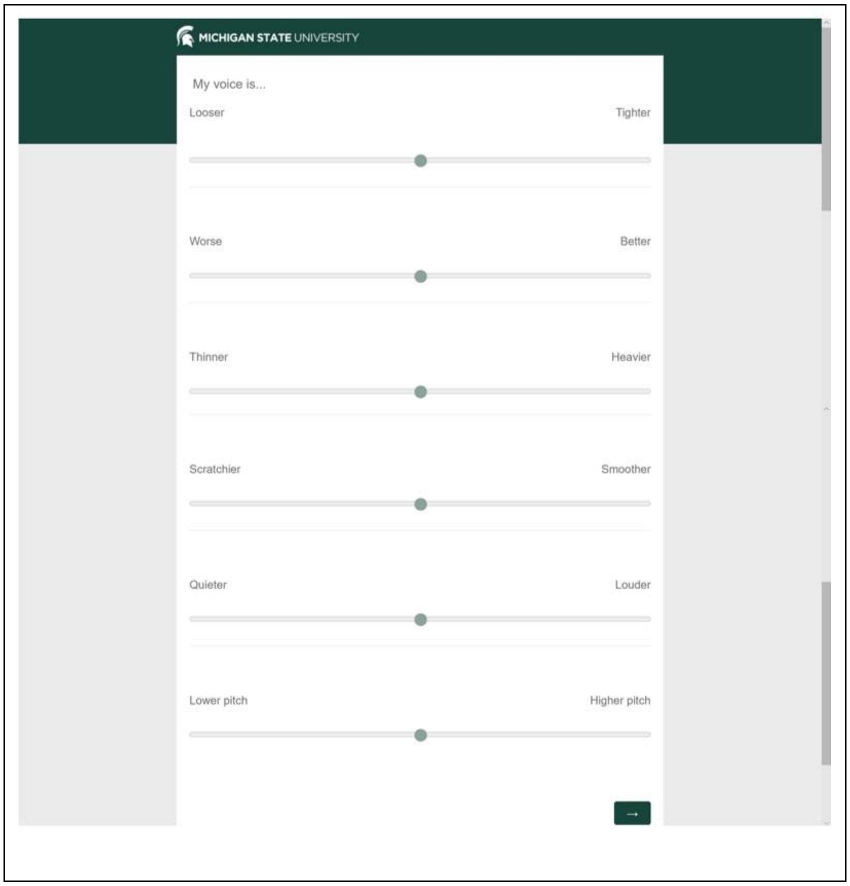


Figure 3.6: Semantic differential scales for measurement of self-perceived vocal quality.

The adjectives were chosen to depict concepts that were related to the way the voice sounded, although it can be argued that these concepts also described how their voice felt physically. In reality, it is nearly impossible for most people to separate the perception of the way their voice sounds from the way their voice feels. These particular adjectives were chosen specifically because of this difficulty.

3.3. Exploratory Experiment 4

This experiment was proposed as a potential aim, given the uncertain nature of how the COVID-19 pandemic would impact endoscopy procedures with human subjects. This experiment was designed to be more of an exploratory, qualitative proofof-concept, rather than a study of statistical significance. Many studies have investigated the effects resulting from SOVT exercise, including the previous two experiments of this dissertation. Typically, these studies are designed in a pre/post fashion, making judgements on measurements that occurred following SOVTs. The goal of this experiment was to provide more information about physiologic changes that happen *during* SOVT production, using direct laryngeal imaging. The purpose of this experiment was to test the following research question and hypotheses:

> Q5: What physiologic changes in vocal fold function occur during straw phonation and straw in water phonation, as measured by high-speed videoendoscopy (HSV)?
>
> H13: Glottal attack time (GAT) will increase during use of semi-occluded vocal tract postures, relative to sustained vowel phonation without semi-occlusion.
>
> H14: Glottal contact closed quotient (GCCQ) will decrease during SOVT postures, compared to sustained vowel phonation without semi-occlusion, more so for straw in water phonation, than straw phonation itself.

The independent variable for this experiment was the type of phonation task (i.e. straw phonation/straw in water phonation/sustained phonation). The dependent variables are GAT and GCCQ. While GAT is the primary measure to quantify glottal onset, adductory/abductory gestures are also likely to affect the offset of vowels. The effects on glottal offset have not been studied; however, HSV allows for measuring the glottal offset time (GOT). Although there are no preliminary GOT data to support formal hypothesis, observations in this study were made using GOT as a secondary dependent variable. Definitions for GAT, GCCQ, and GOT can be found in Section 3.3.d.

3.3.a. Participants

IRB approval to cover all aspects of direct interaction with human subjects for data collection was managed by Mayo Clinic Arizona. Informed consent and assent were obtained for all participants. This experiment consisted of two participants (one male and one female). The relatively small sample size is reflective of the experimental nature of this exploratory experiment. The goal of this experiment is to better understand the physiologic phenomenon that occurs during SOVT exercise and therefore significance was generated by the amount of physiologic observations (e.g. vibratory cycles), rather than the number of human participants. Participants were recruited among employees of Mayo Clinic-Arizona. Neither participant reported current voice, speech, medical, or behavioral impairments that may impact phonatory function, nor a history of voice rehabilitation or habilitation. Both participants had conversational hearing abilities.

3.3.b. Instrumentation

In this experiment, a dedicated high-speed videoendoscopy (HSV) system was utilized. This custom system was configured with a high-speed monochrome camera FASTCAM Mini AX200, M4 32GB (Photron USA, Inc., San Diego, CA) controlled by MSI GL63 8SE laptop camera control system, coupled with a 45-mm endoscope lens adapter Model 9117 (Pentax Medical, Montvale, NJ), a 3.5-mm flexible fiberoptic endoscope FNL-10RP3 (Pentax Medical), an audio recording interface (Focusrite

Scarlett 2i2 2nd Gen), and an AKG C420 headset condenser microphone for simultaneous capturing of the acoustic signals. The HSV system was used to record stimuli described in Section 3.3.c from vocally healthy adults before, during, and immediately after SOVT exercises at the speed of 4,000 frames per second (fps). The image analysis and measurements were performed using a video viewing software (PFV4 Photron FASTCAM Viewer, Photron USA, Inc., San Diego, CA), which allowed for variable playback speed, necessary to measure GAT and GCCQ for the recorded HSV data. The system recorded monochrome, flexible-fiberoptic HSV images with duration up to 99.85 seconds (399,384 frames) at the frame rate of 4,000 fps, spatial resolution up to 256 x 224 pixels and 12-bit (72 dB) dynamic range of the image pixels. The resulting HSV recordings had sizes up to 32GB each. The files were shared using a secure, on-demand file transfer system (Media Shuttle, Lexington, MA), maintained and operated by Mayo Clinic.

The SOVT materials used in this experiment were identical to the materials used in Experiments 2 & 3 (19.7 cm plastic straw with a 5.59 mm diameter and an 8 oz cup filled with 4 oz of water). The only instrumentation difference in this experiment was the physical presence of the participants and the fact that they were performing the SOVT with a flexible fiberoptic endoscope inserted transnasally.

3.3.c. Procedure

Participants were asked to produce the following tasks: a sustained vowel (/i/), sustained straw phonation, another repetition of the /i/ vowel, and straw phonation into a small cup of water. Each sustained vowel and straw phonation were produced at a conversational pitch and loudness for 5 seconds. The presentation order of straw phonation and straw in water phonation was randomized, but each type of SOVT was always preceded by sustained vowel production. Randomization was performed to ensure any observed effects could be attributed to the type of SOVT, rather than the presentation order of the exercise. The protocol amounted to 20 seconds of total recording time, which allowed for partitioning of the camera's memory into two, 10-second partitions. This partitioning was necessary to account for the buffering time of each video without an excessive amount of time spent with the scope in place. In order to follow such a precise protocol, participants were thoroughly coached on the experimental tasks prior to beginning the examination. The HSV recordings were subsequently processed and analyzed using specialized viewing software, as described in Section 3.3.b.

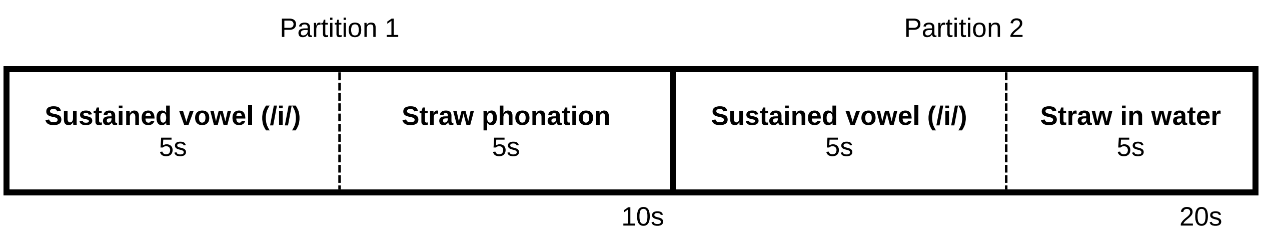


Figure 3.7: Schematic of memory partitioning of the HSV examination protocol.

3.3.d. Outcome Variables

The primary outcome variables in this experiment are measures of vocal fold vibratory behavior that can be directly analyzed using HSV. One has been well-established, based on previous literature; and the other is in development in conjunction with this project. GAT is defined as the time between the first vocal fold oscillation modulating the airflow and the first vocal fold contact (Orlikoff et al., 2009), as extracted manually using the PFV4 Photron software. GOT, which was treated as a secondary outcome variable, due to lack of reference data, is defined as the time between the final vocal fold contact and the final vocal fold oscillation.

GCCQ is referring to the intra-cycle ratio (%) the vocal folds spend in the closed phase, relative to the period. While these measures are frequently reported as derivations of EEG, HSV is a more appropriate tool to directly analyze closed quotient measures, given that it provides true intra-cycle vibratory information (Deliyski, 2010). For our measurement purposes, the glottal contact was considered complete when the medial surface of the true vocal folds was completely adducted. This measure was calculated by counting the number of frames the vocal folds spent in the closed phase and comparing this to the total number of frames in one glottal cycle. This procedure was performed for the first 10 glottal cycles of each task. Of the 10, the first five glottal cycles were omitted and the results for the last five were averaged. This omission was designed to ensure that the GCCQ calculation was capturing steady-state phonation, rather than glottal closure artifacts caused by differences in glottal onset.

CHAPTER 4: Results

Results are presented separately for each experiment within this study and will follow the same general format for each. Demographics and descriptive analyses will be discussed first, followed by inferential statistical analysis, where appropriate. Within each section, results are reported in order of statistical and clinical significance, rather than chronologically.

4.1. Experiment 1

4.1.a. Demographics

The survey was first sent to a small focus group of three speech-language pathologists to access face validity and content validity. One SLP had an extensive voice background and works with voice users regularly (>80% of caseload), one had a limited voice background and rarely works with voice users (25-50% of caseload), and the other had no voice background and never works with voice users (0% of caseload). All three SLPs had 10 or more years of professional experience.

Once the survey was fully disseminated, a total of 79 respondents opened the link to the survey, of which 24 participants were excluded from the final data analysis. Three were excluded because they were not speech-language pathologists and 21 were excluded because of incomplete or missing data. The survey was open for two months, but the majority of responses were collected within the first few days following the initial survey link being sent. Relevant demographic information for the 55 participants included in the final analysis can be found in Table 4.1.

Variable	Frequency	Percentage
Primary Work Setting		
Outpatient Facility	37	67.2%
Private Practice	12	21.8%
Academia	4	7.3%
Inpatient Facility	2	3.6%
Experience		
10+ years (VP)	31	56.4%
6-9 years (EP)	12	21.8%
5 years or less (NP)	12	21.8%
Singing Background		
Yes	33	60.0%
No	22	40.0%
Caseload Consistency		
> 80% of caseload are voice patients	31	56.4%
> 50% of caseload are voice patients	13	23.6%
> 25% of caseload are voice patients	8	14.5%
0-25% of caseload are voice patients	3	5.5%

Table 4.1: Relevant demographic information of survey respondents

4.1.b. Descriptive Statistics

The SLP Focus group completed Likert scales which asked them to rate aspects of face and content validity on a scale from 2 to -2 (“strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, and strongly disagree”). On average, the SLPs “somewhat agreed” that the breadth of the survey was adequate to describe prescription practices of SOVTs, the survey accurately captured the clinical environment of respondents, and that the survey addressed the aims it intended to, overall. The focus group recommended several additions to the survey including a request for respondents to describe their work setting (e.g. inpatient, outpatient, hospital, private practice, academia), as well as a question asking how respondents received their training in SOVT exercise (e.g. grad school, CEUs).

There were several descriptive statistics that relate directly back to the hypotheses of this experiment. When asked to rate the frequency with which they prescribe SOVTs across their caseload (0=never, 1=sometimes, 2=regularly, 3=often), 96.6% of respondents reported prescribing SOVTs with at least “regular” frequency. As far as the type of SOVT most frequently used among clinicians, respondents reported that they prescribe straw phonation into a cup of water most, followed by straw phonation, lip trills, nasal consonants, tongue trills, labial consonants, and blowing bubbles into a cup of water (in order from most prescribed to least). Respondents also reported they use SOVTs to treat hyperfunctional disorders more than other types of voice disorders. More detailed descriptive statistics can be found in Table 4.2.

Variable	Mean	SD	Mode
Type of SOVT most frequently used			
Straw phonation into cup of water	2.71	1.71	1
Straw phonation	2.78	1.71	2
Lip trills	3.40	1.61	3
Nasal consonants	4.09	1.76	3
Tongue trills	4.79	1.91	7
Labial consonants	5.12	1.57	7
Blowing bubbles into cup of water	5.12	2.02	7
Type of disorder most commonly treated with SOVTs			
Hyperfunctional	1.09	.283	1
Structural	2.24	.733	2
Neurologic	3.14	.576	3
Other	3.53	.731	4

Table 4.2: SOVT prescription practices by type of SOVT and type of disorder treated

Another variable of interest was clinicians’ knowledge of the underlying physiology of SOVTs. When asked to rate how knowledgeable they are (0=not at all knowledgeable, 1=somewhat knowledgeable, 2=knowledgeable, 3=very knowledgeable), 98.1% of respondents reported they are at least “knowledgeable” (i.e. ≥ 2). This high percentage was evidenced in the open-ended response asking respondents to explain the underlying physiology of SOVTs. Many responses were very detailed and vividly accurate. While this level of analysis is outside the scope of this dissertation project, a more comprehensive qualitative analysis may be performed in the future. These data were paradoxical when comparing to the response to how well-prepared respondents felt using SOVTs after their graduate education. Only 36.4% of respondents felt prepared or very prepared.

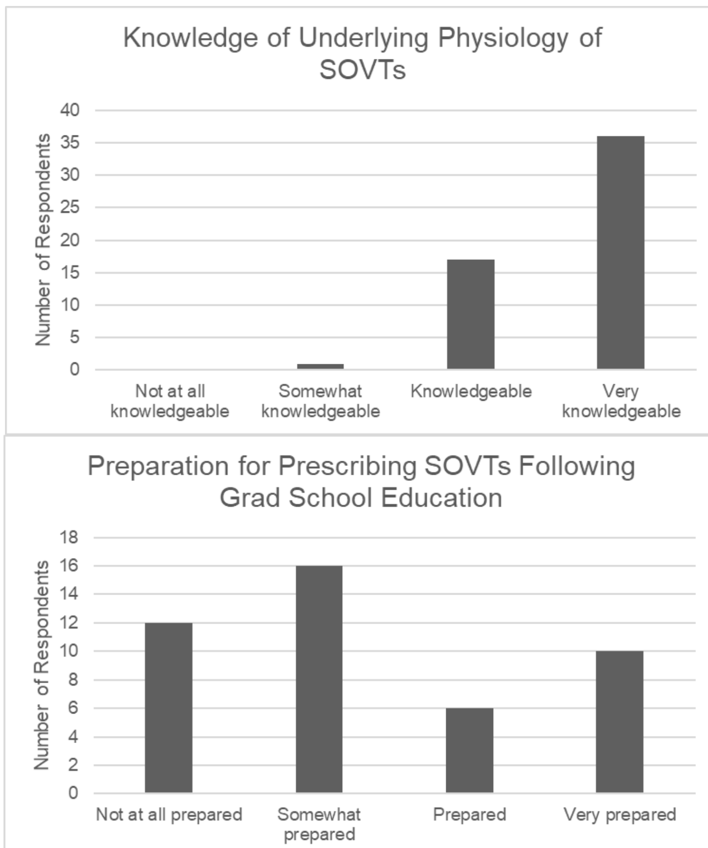


Figure 4.1: Visualized comparisons between knowledge of underlying physiology of SOVTs and how well-prepared clinicians felt prescribing SOVTs following grad school education

4.1.c. Inferential Statistics

To further examine variables impacting clinicians' knowledge of the physiology underlying SOVTs, an independent samples t-test was conducted evaluating the impact of the presence/absence of a singing background on knowledge level. No significant difference was found ($t(2) = -1.63$, $p = .11$) between the mean knowledge level of those with a singing background (m = 2.74, sd = .51) and those without a singing background (m = 2.50, sd =.51).

Another variable of interest was the effect of experience level on SOVT prescription practices. A one-way analysis of variance (ANOVA) was conducted exploring the effect of experience level (new professionals, ≤5 years; established professionals, 6-9 years; and veteran professionals, ≥10 years) on the frequency of prescribing SOVTs, relative to other voice techniques. No significant difference was found among the experience levels ($F(2,55) = 2.09$, $p = .13$). Another one-way ANOVA was conducted to examine the effect of experience level on the type of SOVT most frequently prescribed. A statistically significant difference among experience levels was found for the lip trill ($F(2,55) = 3.75$, $p=.03$). Tukey's HSD was used to determine the nature of the differences between experience levels. This analysis revealed that veteran professionals used lip trills in clinical practice significantly more frequently than new professionals ($p=.02$). They also used lip trills more frequently than established professionals, but this difference did not reach statistical significance ($p=.63$). Complete statistical analyses (including means and standard deviations) can be found in Table 4.3.

Variable	ANOVA			Descriptives (Mean (SD))		
	F	p	η^2	NP	EP	VP
Straw phonation	.345	.71	.01	2.58 (1.44)	2.54 (1.81)	2.94 (1.78)
Straw phonation into cup of water	2.14	.13	.07	1.92 (1.38)	2.54 (1.90)	3.06 (1.68)
Blowing bubbles into cup of water	.009	.99	<.001	5.08 (2.02)	5.08 (2.25)	5.15 (1.99)
Lip trill	**3.75**	**.03*** **	**.12**	**4.42 (1.16)**	**3.46 (1.71)**	**3.00 (1.71)**
Tongue trill	1.83	.17	.06	5.50 (1.78)	5.15 (1.34)	4.39 (2.08)
Nasal consonants	3.07	.74	.01	3.83 (1.90)	4.38 (1.98)	4.06 (1.66)
Labial consonants	1.21	.31	.04	4.67 (1.72)	4.85 (1.52)	5.39 (1.52)

Table 4.3: ANOVA results and descriptives for the effect of experience level on type of SOVT used

4.2. Experiment 2

4.2.a. Demographics

Since they share the same sample, demographic information in this section is presented for both Experiments 2 and 3. Although an a priori power analysis indicated a sample size of 36 would provide adequate power for this study, 44 participants were enrolled to allow for exclusion and attrition. Of the 44 participants, 8 were excluded due to incomplete data sets, yielding a final sample size of 36. Five participants were unable to meet the technical specifications (e.g. incompatible operating system, no USB drive, inadequate credentials/rights on PC to run software) and three participants experienced data corruption. The sample included 19 females and 17 males with a mean age of 39.9 years (sd = 14.6). For a complete breakdown of age ranges included in the sample, see Table 4.4.

	18-31 years	32-44 years	45-57 years	58-70 years
Females	6	6	4	3
Males	6	5	3	3

Table 4.4: Sample demographics for Experiments 2 and 3

4.2.b. Descriptive Statistics

Descriptive statistics for the seven acoustic variables studied in this experiment can be found in this section. Figure 4.2 visualizes the mean differences in pre-post SOVT task raw data for each acoustic variable. While the statistical results reported were mainly investigations of differences (in either direction) before and after each SOVT task, clinically significant "improvement" (i.e. associated with perceptible improvement in vocal quality/function) would be evidenced by a reduction in mean jitter, and shimmer, and an increase in mean SPR, HNR and CPP_S.

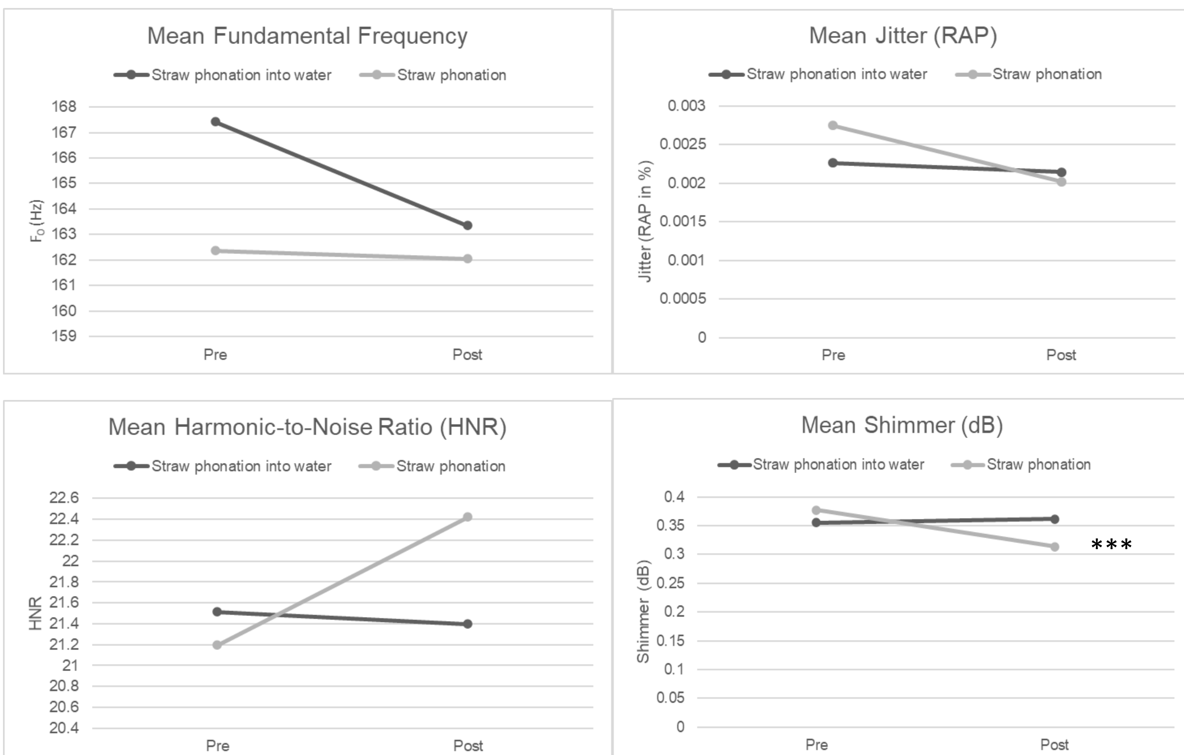
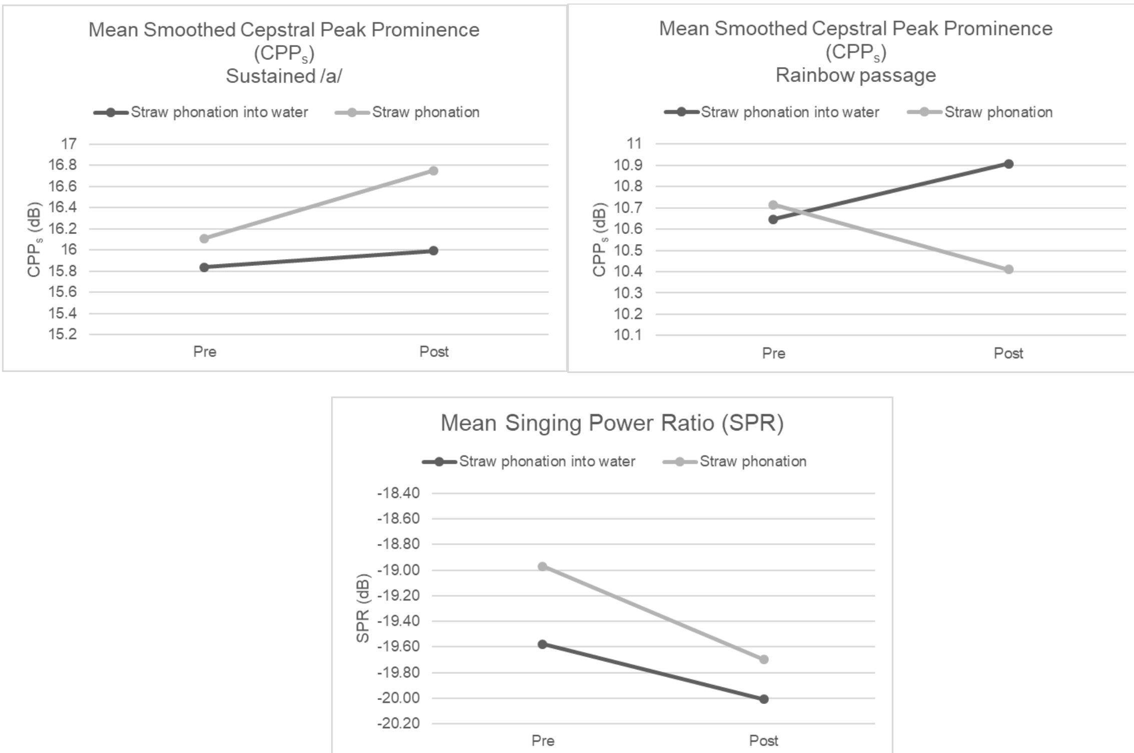


Figure 4.2: Visualizations of mean values for 7 acoustic variables before and after each SOVT task

Figure 4.2 (cont'd)



4.2.c. Inferential Statistics

A series of paired samples t-tests were performed to compare the means of each acoustic variable before and after straw phonation and straw phonation into a cup of water (see Table 4.5). To protect from Type I error inflation of conducting multiple t-tests, the Bonferroni adjustment was used, which made the adjusted alpha = .017. The mean shimmer (dB) before straw phonation was .377 (sd=.209), and the mean shimmer (dB) after straw phonation was .314 (sd=.186). A statistically significant decrease in shimmer (dB) was observed from before to after straw phonation ($t(35)=2.51$, $p=.016$). There were no other significant pre-post differences found across acoustic variables for either straw phonation or straw phonation into a cup of water. When comparing the two

SOVT tasks to each other (see Table 4.6), neither had a more significant effect than the other.

Variable	Pre/Post Straw in Water			Pre/Post Straw Phonation		
	t	p	95% CI	t	p	95% CI
F_0	.77	.48	-6.68-14.8	.05	.96	-20.8-13.3
Jitter (RAP)	.54	.60	.0003-.0006	1.72	.09	.0001-.0016
Shimmer (dB)	-.20	.85	-.070-.058	**2.51**	**.016*** **	**.012-.114**
HNR	.15	.88	-1.46-1.70	-1.78	.08	-2.63-.172
CPP_s (/a/)	-.61	.55	-.660-.355	-2.01	.05	-1.29-.006
CPP_s (Rainbow)	-.68	.50	-1.03-.512	1.42	.16	-.131-.739
SPR	1.50	.14	-.152-1.01	1.53	.14	-.241-1.70

Table 4.5: Paired-samples t-test results comparing acoustic variables pre/post SOVTs

Variable	∆ Straw in water vs. ∆ Straw phonation		
	t	p	95% CI
F_0	-.45	.66	-20.8-13.3
Jitter (RAP)	1.42	.17	-.0002-.0015
Shimmer (dB)	1.82	.08	-.008-.146
HNR	-1.36	.18	-3.36-.665
CPP_s (/a/)	-1.12	.27	-1.37-.395
CPP_s (Rainbow)	-.25	.80	-1.04-.803
SPR	.55	.58	-.802-1.40

Table 4.6: Paired-samples t-test results comparing which SOVT task had greater effect on acoustic variables

4.3. Experiment 3

4.3.a. Descriptive Statistics

Experiment 3 consisted of both auditory-perceptual analysis using the CAPE-V and self-perceptual analysis of vocal quality and vocal effort. The auditory-perceptual analysis was performed by three licensed speech-language pathologists, each with over 10 years of experience evaluating and treating individuals with voice disorders. Traditional measures of inter- and intra-rater reliability were not used because the data were very heavily skewed towards the mild end of the scale, as visualized in Figure 4.3. Instead, a measure of precision (i.e. standard error of the mean) for each perceptual attribute was calculated, within and across raters. Values for standard error of the mean are provided in Table 4.7. In general, the smaller values indicate better precision across ratings.

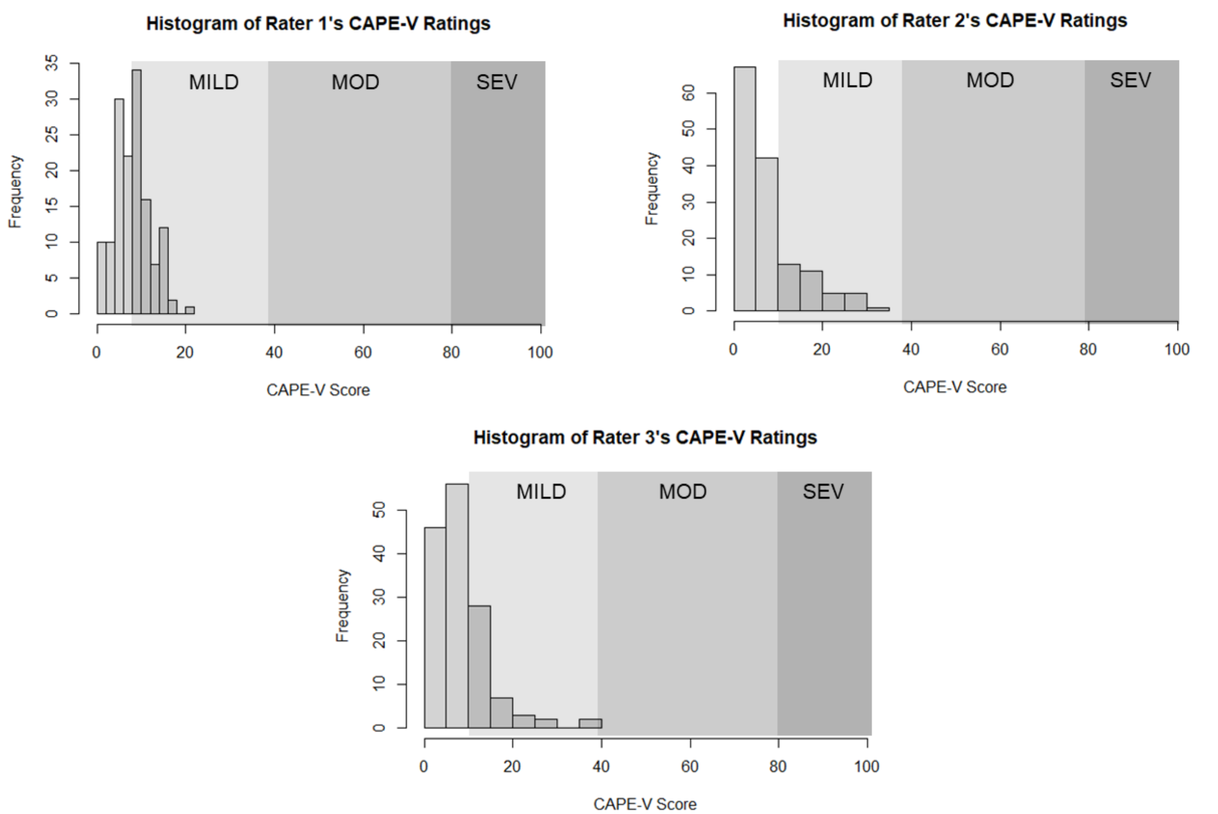


Figure 4.3: Histograms of each rater's overall severity CAPE-V ratings

	Overall severity	Roughness	Breathiness	Strain	Intra-rater average
Rater 1	.338	.768	.794	.917	.704
Rater 2	.588	.501	.502	.742	.583
Rater 3	.530	.455	.375	.390	.438
Inter-rater average	.452	.575	.557	.683	

Table 4.7: Standard errors across CAPE-V analyses for each perceptual attribute by rater

The data for self-perception of vocal effort also appeared skewed, upon visual inspection. A Shapiro-Wilk Test for Normality was calculated for the self-perception of vocal effort following each SOVT task. Results indicated that data for straw phonation into a cup of water were normally distributed (W = .94, p = .06); however, data for straw phonation alone, were not (W = .92, p = .01). Figure 4.4 depicts a histogram of the BORG-100 self-perceptual severity levels following each SOVT exercise.

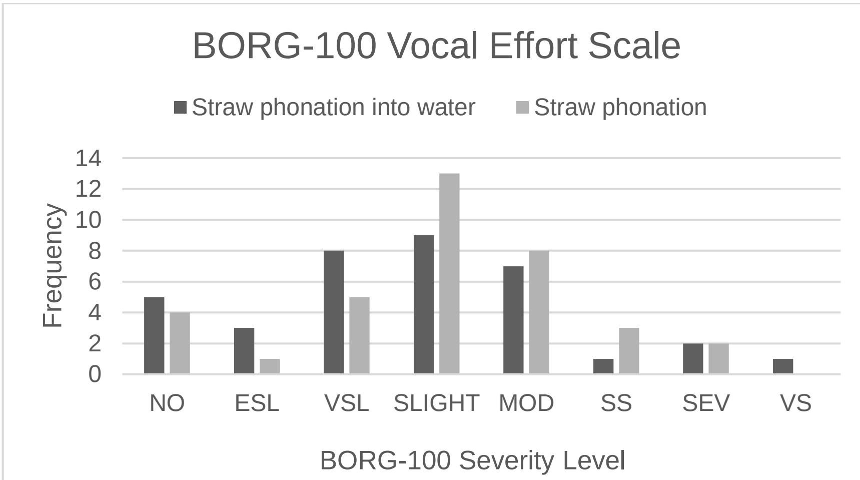


Figure 4.4: Histogram depicting the amount of participants reporting each severity level

The medians for the self-perception of vocal quality semantic differentials are presented in Table 4.8. There were two semantic differential scales that did not meet the assumption of normal distribution, so these scales were treated using nonparametric statistics. A Shapiro-Wilk Test for Normality revealed the “Thinner/Heavier” and “Quieter/Louder” scales, both following straw phonation into a cup of water, were not normally distributed (W = .93, p = .03; W = .92, p = .02). Generally, the observed magnitude of effects (i.e. higher median values) was greater for straw in water phonation than in straw phonation alone. The direction of self-perception of vocal quality following both SOVT tasks was the same for three variables and different for three. Self-perception of vocal quality following both tasks trended towards voices which were “looser,” “better,” and “heavier.”

Semantic differential scale	Straw phonation into water			Straw phonation		
	Median	Mean	SD	Median	Mean	SD
Looser / Tighter	-2	-.36	2.5	-.5	-.22	2.5
Worse / Better	+2	.92	2.3	+1	.75	2.2
Scratchier / Smoother	-2	.64	2.7	0	.31	2.6
Lower pitch/higher pitch	+2	-.94	2.0	-1	-.17	2.5
Thinner/Heavier	+2	.69	2.2	+1	.58	2.3
Quieter/Louder	-1	1.2	1.9	+1	.89	2.0

Table 4.8: Descriptive statistics for self-perception of vocal quality semantic differential scales

4.3.b. Inferential Statistics

A series of paired samples t-tests were performed to compare the means of each auditory-perceptual attribute before and after straw phonation and straw phonation into a cup of water. To protect from Type I error inflation of conducting multiple t-tests, the Bonferroni adjustment was used, which made the adjusted alpha = .017. The mean level of strain before straw phonation into a cup of water was 9.89 (sd=6.93), and the mean level of strain after straw phonation was 11.55 (sd=6.87). A statistically significant increase in strain was observed from before to after straw phonation into a cup of water ($t(2)=-10.755$, $p=.009$). There were no other significant pre-post differences found across auditory-perceptual variables, but when comparing strain before and after straw phonation, there was a decrease that approached statistical significance ($t(2)=3.95$, $p=.06$). There was also a nearly significant difference when comparing the two SOVT tasks to each other. Straw phonation seemed to have more impact on the strain attribute than straw phonation into a cup of water ($t(2)=7.16$, $p=.02$). Visualizations of these comparisons can be found in Figure 4.5.

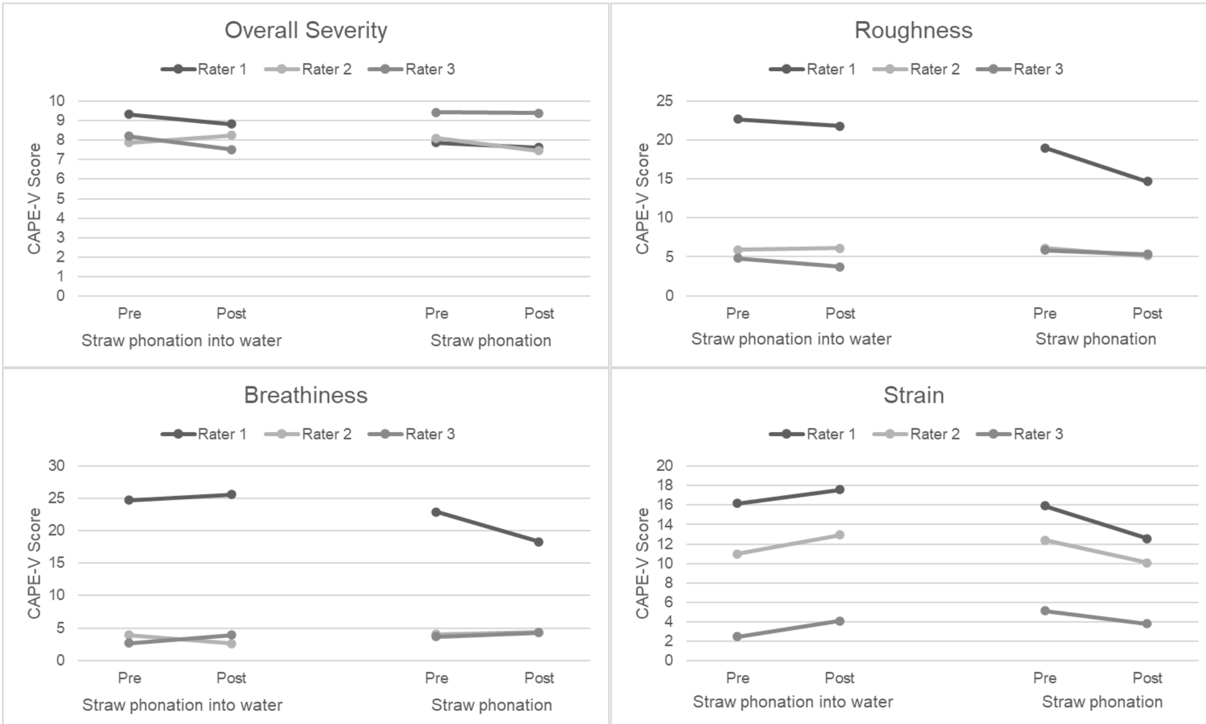


Figure 4.5: Visualizations of mean CAPE-V scores across 3 raters before and after each SOVT task

A Wilcoxon test examined the BORG-100 self-perception ratings. There was no significant difference between self-perceptual ratings following straw phonation into a cup of water compared to following straw phonation alone ($Z = 1.57$, $p = .12$). These ratings are visualized for all participants in Figure 4.6.

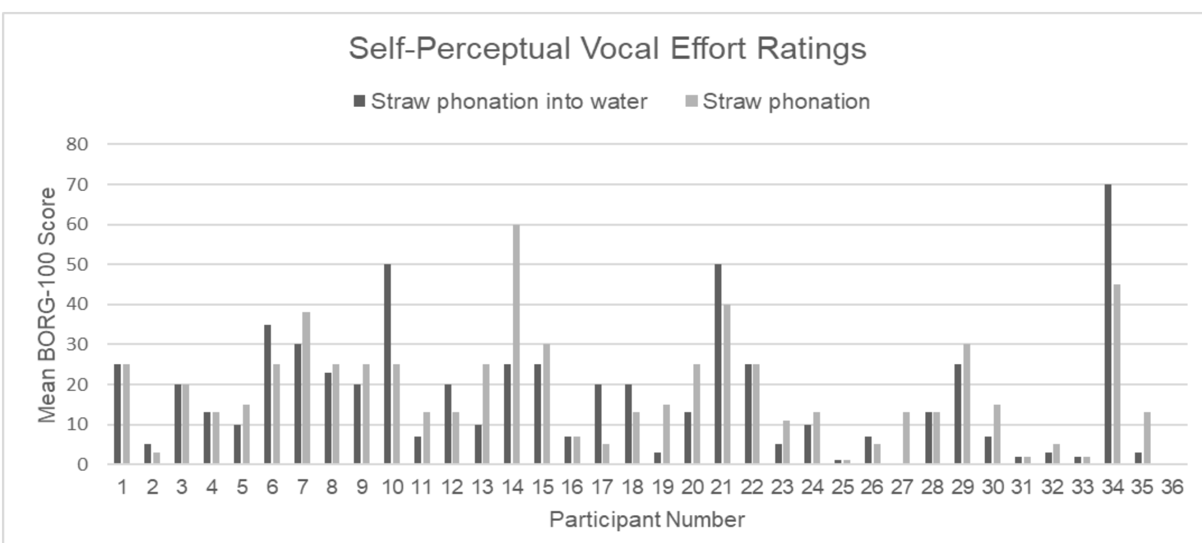


Figure 4.6: Visualization of mean self-perceptual vocal effort rating across participants

The semantic differential scale values, assessing self-perception of vocal quality, ranged from -5 to 5 and were transformed into a scale that was centered around 0 using z-scores. Paired samples t-tests were conducted for each of the semantic differential scales, using the z-scores. No statistically significant differences were found for any of the semantic differential scales. Complete results for each can be found in Table 4.9. As for the scales that were treated using nonparametric statistics, a Wilcoxon test revealed that participants rated their voice as significantly louder following straw phonation into a cup of water compared to straw phonation alone (Z=2.75, p=.006).

Semantic Differential Scale	t	p	95% CI
Looser / Tighter	.000	1	-.323-.323
Worse / Better	-.904	.37	-.422-.162
Scratchier / Smoother	-1.16	.26	-.539-.148
Lower pitch / higher pitch	1.36	.18	-.128-.649
	Z	p	
Thinner / Heavier	-.880	.38	-
Quieter / Louder	**2.75**	**.006**	-

Table 4.9: Paired-samples t-test and Wilcoxon test results comparing which SOVT task had greater effect on semantic differential ratings of vocal quality

4.4. Exploratory Experiment 4

4.4.a. Demographics

The very small sample of two participants consisted of a 43 year old female and a 43 year old male. Neither had difficulty tolerating the endoscope throughout the duration of the experiment. Complete descriptive sample information (e.g. inclusionary criteria) for this experiment can be found in Section 3.3.a.

4.4.b. Descriptive Analysis

As previously mentioned, the objective of this experiment was to begin to quantify effects *during* SOVT production. Therefore, the focus was on collecting HSV samples that contained the SOVT exercises studied in the previous experiments. Several samples of sustained vowel phonation were also collected, primarily to assure that the values of the outcome measures were comparable to previous research. Table 4.10 presents the values for GAT, GOT, and GCCQ. While complete normative values are not readily available for these measures, reference value measures for GAT have been reported by Orlikoff et al. (2009). In “comfortable” glottal onsets, vocal attack times ranged from -1.4 to 9.6 ms, in breathy glottal onsets, they ranged from 7.6 to 38.0 ms, and in hard glottal onsets, they ranged from -9.5 to -1.7 ms. Perhaps more important than the actual values is the concept that comfortable onsets are generally short and positive, breathy onsets are long and positive, and hard onsets are negative. The two unreported GOT values are because of offsets which were not captured due to anatomical structures obscuring the view of the glottis.

Variable	Participant 1 (M)			Participant 2 (F)		
	GAT	GOT	GCCQ	GAT	GOT	GCCQ
Straw phonation into water	8.8	8.8	.205	35.0	64.0	.023
Straw phonation	8.0	15.0	.019	12.0	26.0	.008
Pre-SOVT /i/	-13.0	7.7	.014	-12.0	-	.014
Post-SOVT /i/	14.0	15.5	.022	24.0	-	.011

*All values in milliseconds

Table 4.10: Objective vocal fold vibratory measures collected using HSV for each participant

In general, both participants’ GAT values trended toward longer, positive values during SOVT exercises, compared to sustained phonation pre-SOVT. This trend was more pronounced for straw phonation into a cup of water than for straw phonation alone. Both participants demonstrated negative GAT values consistent with hard glottal onsets, prior to SOVT production, and with breathy glottal onsets following SOVT production. GOT values cannot be interpreted due to missing data, but it appears the trend would be similar to GAT. The results for GCCQ were more variable with a sizable increase in time spent in the closed phase for participant 1 during straw phonation into a cup of water and a modest increase for straw phonation alone. A similar increase in GCCQ was noted for participant 2, but a decrease in GCCQ was noted for straw phonation alone. Figure 4.7 illustrates participant 2's increase in GCCQ from sustained phonation to straw phonation into a cup. It also demonstrates additional descriptive information that was consistent across both participants, the existence of supraglottic activity.

Although not objectively measured, visual inspection of the HSV data revealed anterior-posterior squeezing of the supraglottic structures during participant 2's sustained vowel phonation. This squeeze behavior was not present during either SOVT exercise. There was also lateral squeezing of the false vocal folds during participant 1's sustained vowel phonation, which was not present during the SOVT trials. The extent of the supraglottic activity was much less significant for participant 1 compared to participant 2.

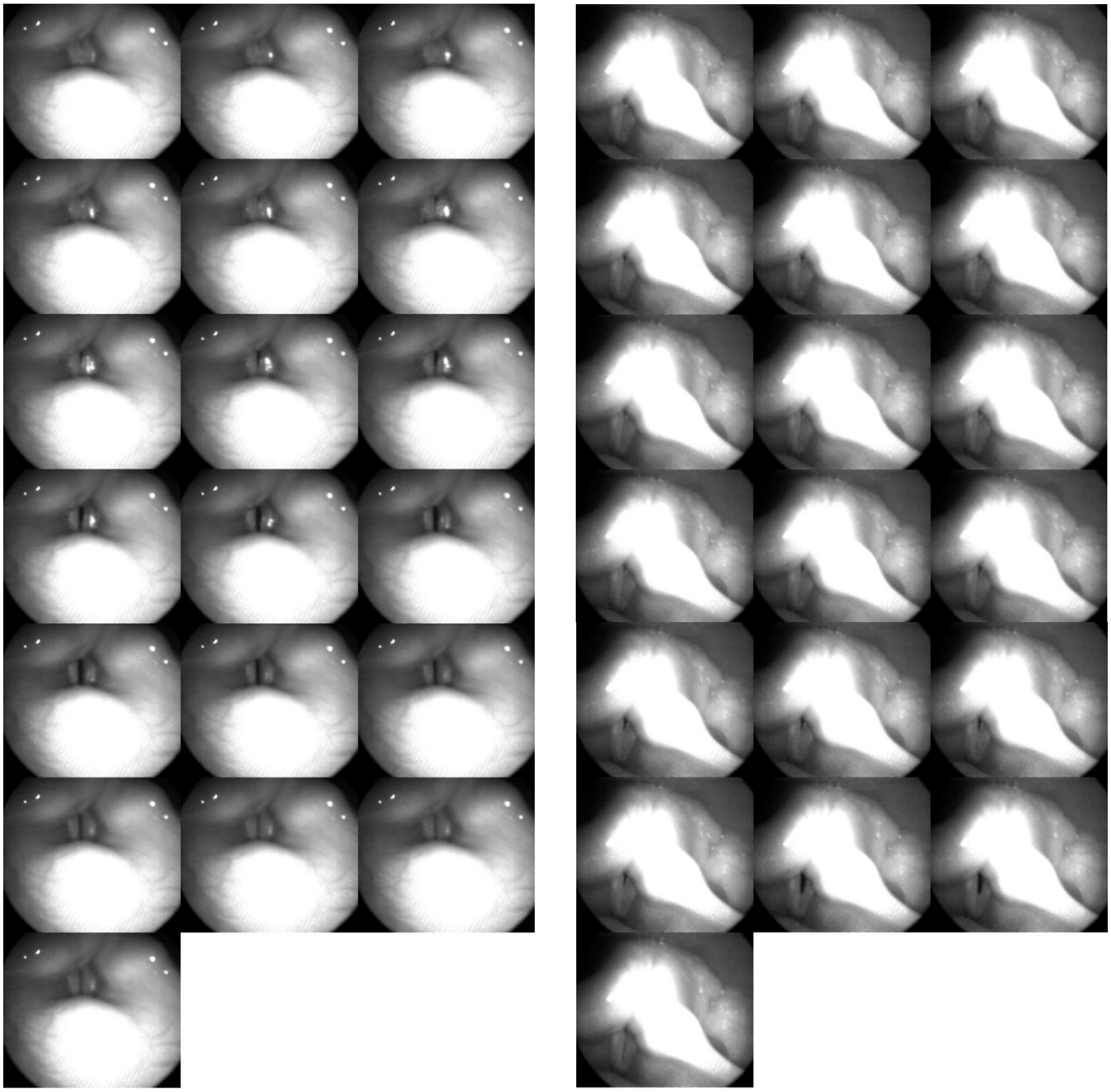


Figure 4.7: HSV images depicting GCCQ over 19 frames (one glottal cycle in this case) for sustained /i/ (left) and straw phonation into a cup of water (right)

CHAPTER 5: Discussion

Chapter 5 of this dissertation contains a thorough discussion of this study's results, clinical implications, limitations, and directions for future research. This chapter is divided into sections consisting of each clinical implication including: Clinical Prescription Practices of SOVT Exercise, Acoustic Effects of SOVT Exercise, Auditory-Perceptual and Self-Perceptual Effects of SOVT Exercise, High-Speed Videoendoscopic Effects of SOVT Exercise, and Remote Data Collection. The final section includes limitations and directions for future research, based on each of the experiments.

5.1. Clinical Prescription Practices of SOVTs

The primary objective of the first aim of this project was to thoroughly describe the prescription practices of SOVTs among speech-language pathology clinicians. The survey yielded many interesting results, some of which were explicitly related to the hypotheses of this aim and some were not. The first interesting finding was related to which types of SOVT exercises clinicians are prescribing most frequently. While it may be expected that straw phonation and straw phonation into water were the most commonly prescribed, based on their frequency of being cited in the literature (thus this project's design focusing on those exercises), it was surprising that labial consonants, tongue trills, and blowing bubbles into a cup of water were least prescribed. This may be indicative of clinicians not considering labial consonants and blowing bubbles into a cup of water SOVTs, as these techniques are also a primary component of another voice therapy technique, flow phonation. Tongue trills may be least commonly prescribed because many patients simply cannot perform tongue trills, which is not necessarily pathologic.

Another interesting conclusion can be drawn by investigating the paradoxical response that while clinicians felt exceedingly knowledgeable about the underlying physiology of SOVTs, few felt prepared to prescribe SOVTs following their graduate education. This underscores the notion that speech-language pathology clinicians are willing to pursue their own training (whether through conference attendance, self-study, or other methods) for popular therapy techniques. This statement likely generalizes to voice professionals, at large. It would be interesting to compare this result with how well prepared SLPs feel about other voice treatments following their graduate education. A surprising finding that relates to knowledge of the underlying physiology of SOVTs was that clinicians who had a singing background were no more knowledgeable than clinicians without a singing background (at least based on self-report). It was hypothesized that singers may have been more personally motivated to learn about underlying physiology, since that knowledge directly impacts the function of their "instrument," rather than being motivated purely by helping others alone.

Clinician experience level also revealed some interesting trends, with regard to SOVT prescription practices. While experience level did not have an effect on whether clinicians were more or less likely to prescribe SOVTs, differences were observed in the types of SOVTs being prescribed. Veteran professionals (VPs) prescribe lip trills much more frequently than experienced professionals (EPs), who prescribe them much more frequently than new professionals (NPs). Perhaps the less experienced clinicians feel more comfortable with the SOVT techniques that have been more extensively researched in recent years (e.g. straw phonation); or the trend could be generational. Perhaps the younger generation is more likely to rely on external devices, such as straws, rather than internal, bodily mechanisms. This could also explain why NPs are more likely to prescribe straw phonation into a cup of water, than EPs, who are more likely to prescribe this SOVT technique than VPs.

5.2. Acoustic Effects of SOVT Exercise

While only one of the studied acoustic variables demonstrated a statistically significant difference following SOVTs, several identified trends may be considered clinically significant. First and foremost, straw phonation appeared to have a consistent impact on acoustic variables. Just about every acoustic variable “improved,” to varying degrees, following straw phonation. There were reductions in jitter and shimmer, and increases in SPR, HNR and CPP_s of sustained vowels. The impact of straw phonation into a cup of water was less consistent, but a reduction was observed in jitter and increases were observed in SPR and CPP_s of sustained vowels. The consistency of results from the straw phonation exercise may be the reason it was so heavily preferred by clinicians in Experiment 1. It is important to reiterate that there was no statistically significant difference when the two SOVT exercises were directly analyzed against each other.

The statistically significant reduction in shimmer was a very promising result, both in support of straw phonation as an effective SOVT exercise and because of the implications for clinical measurement of the shimmer variable. Shimmer is a measure of perturbation of the vocal signal, which indicates some degree of abnormality in vocal fold vibration (Aronson & Bless, 2009). Shimmer may also be related to changes within the vocal tract (Colton, Casper, & Leonard, 2012). The results of this experiment clearly indicate that straw phonation had a positive impact on the voice signal, whether that be related to improving vocal fold vibration or vocal tract characteristics. Additionally, these results suggest shimmer is a measure that is susceptible to change following a relatively modest amount of manipulation. Perhaps, this variable can be reliably tracked therapy session to therapy session, or even within a given session. While jitter (another perturbation measure) also decreased following SOVT exercise, the degree of change was much less extreme than that of the shimmer variable. This may indicate that SOVTs have a more substantial impact on vocal tract characteristics than on vocal fold vibratory characteristics. This notion may seem like conjecture, but one of the physiologic differences between jitter and shimmer is that shimmer values are sensitive to vocal tract characteristics; whereas, jitter is more sensitive to vocal fold vibratory characteristics.

5.3. Auditory-Perceptual & Self-Perceptual Effects of SOVT Exercise

One of the most unexpected findings was that the auditory-perception of strain significantly increased following straw phonation into a cup of water. One of the hypotheses for this experiment anticipated decreased auditory-perception of strain following SOVTs. This was based on the assumption that the technique promoted relaxation and efficiency of the laryngeal musculature/structures, which would generalize into voicing following the task. While this may have been the case for straw phonation, although the effect of reduced strain was not dramatic for this technique, a lack of reduction of strain following straw phonation into a cup of water was not expected, much less an increase in strain following the task. There could be several explanations for this finding. It is plausible there could have been a “rebound” effect following straw phonation into a cup. This technique may have produced such an exaggerated increase in vocal tract inertance, due to the backpressure created by the straw opening in the water, that participants felt the need to strain in order to maintain such inertance without the assistance of the extreme backpressure. Another explanation may be related to our understanding of the auditory-perception of strain. While we traditionally consider strain a pathological finding, very little research exploring the strain attribute has been done compared to other auditory-perceptual attributes like breathiness and roughness (Anand et al., 2019). Perhaps, a slight increase in the auditory-perception of strain is a positive effect of the exercise in non-pathological voices. The increase may be reflective of some sort of additional effort to improve vocal technique, which would be difficult to otherwise classify.

The reduction of strain following straw phonation approached significance. This finding was more consistent with the hypotheses of this experiment. It is probably the more accurate representation of how SOVTs impact auditory-perception of strain, as the effect was more consistent during straw phonation than with straw phonation into a cup of water, when directly compared. Synthesizing results across experiments, it is curious that there was less perceived strain following straw phonation and a statistically significant reduction in shimmer. It is possible that there is some relation between perceived strain and shimmer, which may be appropriate for a future investigation. It is quite controversial (and may not even be possible) to assume direct correlations between acoustic variables and auditory-perceptual variables (at least within cycle-to-cycle measures), so future investigations should be developed with caution.

Although traditional measures of inter-and intra-rater reliability were not calculated, there were noticeable trends in precision ratings within and across raters in Experiment 3. Intra-rater precision seemed to be better, across perceptual attributes, for Raters 2 and 3 than for Rater 1. As far as the precision among different auditory-perceptual attributes, overall severity appeared to be most precise across raters and strain appeared to be least precise, by far. This is an interesting finding, as it may relate to the equivocal findings regarding the auditory-perception of strain being increased for straw phonation into a cup of water and decreased for straw phonation alone. This may demonstrate a larger concern about speech-language pathology training to identify strain through auditory-perceptual analysis. Additional research is necessary to elucidate this notion.

In terms of the self-perception of vocal effort ratings, there was no significant difference between the two SOVT exercises. In both cases, the ratings clustered around very slight, slight, and moderate following the SOVTs. Very few participants rated their vocal effort at the extremes (e.g. no vocal effort or very severe vocal effort). This finding may not be surprising, as individuals with healthy, non-pathological voices are probably unlikely to rate the amount of vocal effort they are using on the severe end of the spectrum. Also, the BORG-100 scale is weighted in a way that skews toward the mild end of the scale, since it was developed for individuals without voice problems.

The investigation of self-perceived vocal quality provided more interesting results compared to the self-perceived vocal effort findings. The statistically significant finding that individuals rated their vocal quality as louder following straw phonation into a cup of water, may provide the most pertinent clinical implications, which may relate back to other findings involving this particular SOVT exercise. To interpret this result, it is essential to consider the underlying contributions to the self-perceived increase in vocal loudness. Are individuals hearing a steadier vocal signal and perceiving that as increased loudness or are there true physiologic changes contributing to an actual increase? If there are true physiologic changes, are they a result of the SOVT posture itself or a compensatory behavior resultant from increased awareness of the sensations of the lips and vocal tract? Taken together, the findings of increased shimmer, auditory-perception of strain, and self-perception of vocal loudness may indicate that a true physiologic change is happening following straw phonation into a cup of water.

Another interesting trend observed in the self-perception of vocal quality data was that there appeared to be a greater magnitude of change for straw phonation into a cup of water than straw phonation. While this trend was not statistically significant, it was evident upon visual inspection of the medians for each semantic differential scale, except quieter/louder (Table 4.9). The magnitude of change was greater for straw phonation into a cup of water for individuals rating their vocal quality as “looser,” “better,” “scratchier,” “higher pitch,” and “heavier.”

5.4. High-Speed Videoendoscopic Effects of SOVT Exercise

Although the final experiment of this study was exploratory, the findings certainly provide valuable information about the underlying physiology of SOVT exercise. Firstly, the trend of increased GAT across both participants was exactly what was hypothesized. This finding directly supports the notion that there is a “cushioning” effect on vocal fold contact pressure during SOVT postures. The finding that GAT was longer during straw phonation into a cup of water compared to straw phonation alone was somewhat surprising. Though it is conceivable that the higher the resistance of the medium being blown into, the greater the effect of the SOVT; the assumption was that the denser water would have required more vocal fold collision pressure to overcome the resistance. This experiment may not provide a definitive conclusion, given the small sample size, but future studies should aim to clarify this notion.

A surprising finding was the larger than expected negative GAT values for both participants during the pre-SOVT sustained vowel. The negative values are consistent with hard glottal attack behavior. Previous literature suggests reference values for males using a hard glottal onset of approximately -9.5 ms to -3 ms and approximately -7 ms to -1.7 ms for females (Orlikoff et al., 2009). The GAT values, for sustained vowel phonation prior to SOVT, found in Experiment 4 were -13 ms for the male participant and -12 ms for female participant. These values are considerably outside the ranges given as reference values. The large negative values were related to transient pulses of airflow occurring prior to the initiation of phonation, as observed in these recordings. These transient pre-phonatory glottal openings were not observed in the reference study.

The variability of the GCCQ measure across the participants was somehow both expected and surprising. It was partially expected, as tremendous variability in contact quotient, as measured by EGG, was cited repeatedly throughout the literature (see section 2.4.d.). However, it was hypothesized that GCCQ would decrease, due to less “pressing” of the vocal folds during SOVT exercise. Paradoxically, GCCQ increased during straw phonation into a cup of water for both participants and during straw phonation for participant 1. The only decrease in GCCQ was observed during straw phonation for participant 2. Perhaps the reason for the increases in GCCQ is similar to the previously referenced assumption that the increased resistance provided by the SOVT technique requires additional muscle recruitment to overcome, contributing to a more “pressed” vocal fold posture. This explanation makes more sense for GAT and other measures of glottal onset, since any additional effort required to overcome the SOVT resistance is unlikely to have an impact on vocal fold vibration that persists cycle-after-cycle. Either way, the finding may indicate that the “work” of producing an SOVT may lead to maladaptive compensatory behaviors (e.g. pressing of the vocal folds), making SOVTs contraindicated for some individuals, or at least may provide pause to prescribe SOVTs without detailed explanation/assistance from a clinician.

The final finding that may have significant clinical implications was the supraglottic squeezing activity noted upon visual inspection of the HSV data. The general observation of less supraglottic squeeze behavior during SOVT exercise supports the notion that SOVTs can contribute to more relaxed TA and CT muscle activity. It would also support the use of SOVT exercise to treat hyperfunctional voice disorders, which typically consist of supraglottic squeezing activity. Interestingly, participant 1 demonstrated much less supraglottic squeezing than participant 2 during sustained vowel phonation, but had an almost identical GAT value. This may indicate that a modest amount of lateral squeezing of the false vocal folds (as evidenced by participant 1) has a more profound impact on vocal fold vibratory characteristics than an extensive amount of anterior-posterior squeezing (as evidenced by participant 2).

5.5. Remote Data Collection

One of the unforeseen implications of this study was that it demonstrated the feasibility of conducting acoustic analyses entirely remotely. There were many technical and practical considerations to this type of data collection. Technical considerations included which teleconferencing platform to use, how to configure the settings for the platform to be compatible with equipment that was designed for high-quality recording, and how to manage and share the large files that were being created. Each of these solutions needed to be robust to variations in operating system, device type, and amount of RAM/storage, as participants were using their own devices to collect the data. Practical considerations for this type of data collection included difficulty keeping the mouth-to-mic distance consistent, keeping the background environment quiet enough for audio recordings, and the participants' comfort level with technology. In addition, there were many logistical challenges such as establishing a schedule that allowed for shipping delays and maintaining the disinfection protocol before sending equipment to other participants. Provided researchers are incorporating these considerations into their designs, this study supports the feasibility that acoustic measures can be studied using this medium.

5.6. Limitations & Directions for Future Study

This project continually evolved from conception to completion. Navigating the ever-changing research climate caused by the COVID-19 pandemic was certainly challenging, but the resultant study was robust to many methodological challenges. In some ways, continually having to refine the methodological approach, due to COVID-19-related obstacles, allowed for ongoing revision of the project. However, one of the casualties of the fluctuating methodology was the loss of the direct study of long-term effects of SOVT exercise. While this can be addressed in future research, the absence made room to allow for more innovative practices. This study may be one of the first to thoroughly investigate SOVT exercises remotely through telepractice. While it is expected that results are generalizable based on what is known about in-person performance of SOVTs, future studies should compare outcomes across both modalities. While the innovative nature of remote data collection was a strength of this study, it could also be considered a limitation.

In addition to the general challenges of remote data collection outlined in Section 5.5, more specific limitations of this type of data collection yielded suggestions to improve future studies containing remote data collection. It is essential to be explicit about limiting background environment noise and distractions. Participants should be ready to make appropriate accommodations like silencing their home telephones, turning off appliances, and removing family pets from the room. Any programs being used during the study should not be run from flash drives, but rather downloaded to the participants' local computer. Any microphone drivers should be installed prior to initiating the teleconferencing session. This avoids conflict between your recording interface and the teleconferencing program, fighting for control of microphone settings. If possible, one microphone should be used to record the audio samples for data collection, and another should be used to record the teleconferencing session. It is also advisable to adjust any automatic noise-cancelling technology used by the teleconferencing platform. This contributed to times where the researcher was unable to monitor whether the SOVT exercises were being performed correctly because Zoom regarded the buzzing from the straw or bubbling from the cup of water as noise.

The general lack of statistically significant differences in the acoustic variables following SOVTs may also be a limitation inherent to the design of the project. Is it feasible to expect significant changes in acoustic measures following a relatively modest amount of manipulation and time? Also, changes in the vocal signal of individuals with non-pathological voices may be much more subtle than the sensitivity of such measures are capable of detecting.

Methodological limitations were also noted involving auditory-perceptual and self-perceptual measures. The CAPE-V may not have been the most appropriate instrument to rate auditory-perceptual characteristics of non-pathological voices. All of the data were considerably skewed towards the mild end of the scale, making analysis of inter-and intra-rater reliability very problematic. Perhaps, customizing a visual analog scale that was more sensitive to mild ratings or readjusting the CAPE-V anchors to rate 0-50 rather than 0-100 could be suggestions for future investigation. Another source of variability in inter-rater reliability was due to two raters having general agreement and the other's ratings being dramatically different. Perhaps a more homogenous panel of expert listeners should have been used for analysis. While the inclusionary criteria included any SLP familiar with voice disorders and CAPE-V administration, with over 10 years of experience, two raters had just over 10 years and the other had over 30 years of experience. Each of the raters were also at varying levels of current clinical practice. One was treating voice disorders fairly regularly; whereas, the other two were somewhat removed from clinical practice. These factors should be better controlled for in future investigations.

The self-perception of vocal effort data may have been more illuminating if data were compared at two time points (i.e. pre- and post-SOVT). The rationale for only assessing post-SOVT self-perception was based on the assumption that participants without voice disorders would rate their vocal effort level as zero at baseline. However, it may have been beneficial to have at least another rating following the first SOVT task, but before the second. In general, the self-perception of vocal effort may be better suited to assess the actual therapeutic or research task (e.g. identifying if a vocal loading task created an appropriate load), rather than assessing whether there was a true impact on voice production.

The limitations were similar with regard to self-perception of vocal quality. Future studies would benefit from explicit methods to ensure self-perceptual findings are actually a result of the experimental task(s). The design of this study could have benefitted from analysis of sound pressure level (SPL) before and after SOVTs, to identify correlations between the self-perception of increased vocal loudness and an actual increase in SPL. Additional efforts should also be made to improve the psychometric validity when using scales such as semantic differentials to describe vocal qualities. There was very little research available to support whether the identified vocal quality descriptors were exact polar opposites.

The technical and practical limitations of high-speed videoendoscopy, as a technology, are well-documented. The limitations expressed in this dissertation will focus explicitly on the actual clinical implementation, specific to the aims of this project.

Every effort was made to keep the endoscopy procedures consistent across participants. The same clinician used the same equipment in a very structured protocol. However, there were still imaging discrepancies between the two participants. The laryngeal structures and scope positioning provided a very low-light environment for one video recording. The other video recording contained vocal onsets that were obscured from view because of the supraglottal pressure momentarily altering scope tip positioning at the initiation of phonation. This made calculating objective measures of vocal onset very challenging.

The final limitation highlights the dire need for automated measures to analyze objective vocal fold vibratory characteristics from HSV data. There are many labs across the country dedicating time and resources to this worthy endeavor—and for good reason (Deliyski et al., 2019; Naghibolosseini et al., 2018, Ghasemzadeh et al., 2020). Each participant recording contained over 340,000 frames of video data. The manual segmentation of this data required judicious selection and manipulation of certain frames, by watching and re-watching the videos frame-by-frame. This process not only required an incredible amount of time, but it was also physically taxing to continuously click the mouse and analyze subtle characteristics that are notoriously difficult to visualize. These limitations were not oppressive in this context because this experiment contained only two participant videos. Future prospective studies with larger sample sizes will require the use of automated measures to improve the efficiency of data collection.

APPENDICES

APPENDIX A: EXPERIMENT 1 SURVEY

SOVT Use Survey

Study Title: Immediate Effects of Semi-Occluded Vocal Tract Exercise on Objective Measures of Voice Analysis
Researchers and Title: David S. Ford, Ph.D. Candidate, Anthony Strevet, M.A. Student, Dimitar Deliyski, Ph.D.
Department and Institution: Department of Communicative Sciences and Disorders at Michigan State University
Address and Contact Information: Oyer Speech & Hearing Bldg., 1026 Red Cedar Rd., East Lansing, MI 48824
Sponsor: Michigan State University

Purpose: You are being asked to participate in a research study to help understand the prescription practices of semi-occluded vocal tract (SOVT) exercises among voice clinicians, as well as, comfort level with understanding/explaining the underlying physiology of such exercises. This will assist in bolstering recommendations for SOVT use as a therapeutic protocol for individuals with voice disorders and as a training method for performers or those trying to improve their voice. This survey will take between 10 and 15 minutes.

Risks & Benefits: There are no risks associated with this component of the research project. There are no personal benefits expected, other than your contribution to science and clinical practice.

Privacy & Confidentiality: While no personally identifiable information will be obtained (e.g. name, practice location), the data for this project (e.g. how many years of experience you have) will be stored in a password-protected file on a password protected computer or within the password-enabled Qualtrics web-based platform. All information will be kept for at least three years after the close of the study. Only trained researchers under the jurisdiction of this project and MSU's Human Research Protection Program will have access to the data collected in the study. The results of this study may be published or presented at professional meetings.

Future Use of Data Collected: By agreeing to participate in this survey, you are agreeing that the data collected may be used for future projects within the Voice & Speech Lab at MSU. Additional informed consent will not be collected prior to future use.

Your Rights: Participation in this research project is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. You may choose not to answer specific questions or to stop participating at any time. Whether you choose to participate or not will have no impact on your relationship with the researchers at MSU. If you choose to participate, your responses will remain anonymous and no identifying information will be given to the research team. If you have any questions about this survey or participation, or to report an injury, please contact:

David S. Ford, M.S. CCC-SLP, Doctoral Candidate, Dept. of Communicative Sciences and Disorders, Michigan State University, forddav5@msu.edu

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 4000 Collins Rd, Suite 136, Lansing, MI 48910.

You indicate your voluntary agreement to participate by continuing to the next page and completing the survey.

Indicate your job title *(select all that apply)*:

- ☐ Speech-language pathologist (1)
- ☐ Physician (2)
- ☐ Singing voice specialist (3)
- ☐ Vocal coach (4)
- ☐ Other (please specify): (5) ____

Please describe your work setting *(select all that apply)*:

- ☐ Inpatient facility/hospital (1)
- ☐ Outpatient facility/hospital (2)
- ☐ Skilled nursing facility (3)
- ☐ School (elementary, HS, special needs) (4)
- ☐ Private practice (5)
- ☐ Academia (6)

What type of voice users do you typically work with most *(select only one)*?

○ Individuals with voice problems (1)

○ Singers (2)

○ Actors (3)

○ Students (4)

○ Other (please specify): (5) ____

How long have you worked with individuals attempting to habilitate or rehabilitate their voices? *For the purposes of this question, count experience by years following terminal training. For SLPs, you would begin counting years following your Clinical Fellowship.*

○ 5 years or less (1)

○ 6 - 9 years (2)

○ 10 + years (3)

Do you have a personal or professional singing background? *For the purposes of this question, "singing background" includes any individual who has performed singing in an organized public forum after graduating high school and/or any individual who has participated in at least 3 sessions of private voice instruction.*

○ Yes (1)

○ No (2)

If you are a speech-language pathologist, select the option that most applies to your current clinical role:

- ◯ > 80% of my caseload are voice patients (1)
- ◯ > 50% of my caseload are voice patients (2)
- ◯ > 25% of my caseload are voice patients (3)
- ◯ 0-25% of my caseload are voice patients (4)

Label the following voice disorders you treat most frequently *(1=most frequently, 4=least frequently)*:
_______ Hyperfunctional disorders (1)
_______ Structural disorders (2)
_______ Neurologic disorders (3)
_______ Other (4)

Label the following voice techniques/approaches, based on how likely you are to use them in daily practice *(1=most likely, 5=least likely)*:
_______ Lessac-Madsen Resonant Voice Therapy (LMRVT) (1)
_______ Vocal Function Exercises (VFEs) (2)
_______ Semi-occluded vocal tract exercises (SOVTs) (3)
_______ Confidential voice (4)
_______ Respiratory re-training (5)

Label the following voice disorders based on the likelihood that you would prescribe SOVTs to treat them *(1=most likely, 4=least likely)*:
_______ Hyperfunctional disorders (1)
_______ Structural disorders (2)
_______ Neurologic disorders (3)
_______ Other (4)

Label the following SOVT posture/exercise, based on how likely you are to use them in daily practice *(1=most likely, 7=least likely)*:
_______ Lip trill (1)
_______ Tongue trill (2)
_______ Nasal consonants (3)
_______ Labial consonants (4)
_______ Straw phonation (5)
_______ Straw phonation into a cup of water (6)
_______ Blowing bubbles in a cup of water (7)

Label the perspectives of voice therapy that you most subscribe to *(1=most, 5=least):*

______ Physiologic (1)
______ Psychogenic (2)
______ Symptomatic (3)
______ Etiologic (4)
______ Eclectic (5)

How frequently do you prescribe SOVTs (across your caseload)?

Never	Sometimes	Regularly	Often
0	1	2	3

How knowledgeable are you about the underlying physiology of semi-occluded vocal tract exercise?

Not at all knowledgeable	Somewhat knowledgeable	Knowledgeable	Very knowledgeable
0	1	2	3

How well prepared did you feel using SOVT exercises following your graduate education?

Not at all prepared	Somewhat prepared	Prepared	Very prepared
0	1	2	3

How did you receive your training using SOVTs? *(Select all that apply)*

- ▢ Grad school (1)
- ▢ Conferences (2)
- ▢ Other types of continuing education opportunities (3)
- ▢ Independent online research (4)
- ▢ Scholarly journal articles (5)
- ▢ Colleagues (6)

In your own words, describe the underlying physiology of SOVTs (i.e. how do they work?):

____

____

____

____

____

APPENDIX B: CAPE-V SENTENCES

The blue spot is on the key again

How hard did he hit him

We were away a year ago

We eat eggs every Easter

My momma makes lemon muffins

Peter will keep at the peak

APPENDIX C: 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. Throughout the centuries people have explained the rainbow in various ways. Some have accepted it as a miracle without physical explanation.

APPENDIX D: CAPE-V RATING FORM

Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V)

Name:____________________________ **Date:**__________

The following parameters of voice quality will be rated upon completion of the following tasks:

1. Sustained vowels, /a/ and /i/ for 3-5 seconds duration each.
2. Sentence production:
   a. The blue spot is on the key again.
   b. How hard did he hit him?
   c. We were away a year ago.
   d. We eat eggs every Easter.
   e. My mama makes lemon muffins.
   f. Peter will keep at the peak.
3. Spontaneous speech in response to: "Tell me about your voice problem." or "Tell me how your voice is functioning."

Legend: C = Consistent I = Intermittent
MI = Mildly Deviant
MO =Moderately Deviant
SE = Severely Deviant

				SCORE
Overall Severity	______________ MI MO SE	C	I	___/100
Roughness	______________ MI MO SE	C	I	___/100
Breathiness	______________ MI MO SE	C	I	___/100
Strain	______________ MI MO SE	C	I	___/100
Pitch	(Indicate the nature of the abnormality): ________ ______________ MI MO SE	C	I	___/100
Loudness	(Indicate the nature of the abnormality): ________ ______________ MI MO SE	C	I	___/100
________	______________ MI MO SE	C	I	___/100
________	______________ MI MO SE	C	I	___/100

COMMENTS ABOUT RESONANCE: NORMAL OTHER (Provide description):__________________

ADDITIONAL FEATURES (for example, diplophonia, fry, falsetto, asthenia, aphonia, pitch instability, tremor, wet/gurgly, or other relevant terms):

Clinician:____________________

APPENDIX E: COMPLETE SAMPLE DEMOGRAPHIC INFORMATION

PARTICIPANT ID	SEX	AGE	TASK 1ST	SCREENING	EXCLUSION REASON
001	F	30	Straw	WNL	
002	M	33	Cup	WNL	
003	F	66	Straw	WNL	
004	M	62	Cup	WNL	
~~005~~	~~M~~	~~39~~	~~Straw~~	~~WNL~~	Data corruption
006	F	28	Cup	WNL	
007	M	30	Straw	WNL	
008	F	60	Cup	WNL	
009	M	61	Straw	WNL	
~~010~~	~~F~~	~~55~~	~~Cup~~	~~WNL~~	Incorrect save procedure
011	M	34	Straw	WNL	
012	F	34	Cup	WNL	
013	M	32	Straw	WNL	
014	M	40	Cup	WNL	
015	M	49	Straw	WNL	
~~016~~	~~F~~	~~34~~	~~Cup~~	~~WNL~~	Data corruption
~~017~~	~~F~~	~~55~~	~~Straw~~	~~WNL~~	Insufficient PC rights
018	M	25	Cup	WNL	
019	M	20	Straw	WNL	
~~020~~	~~F~~	~~20~~	~~Cup~~	~~WNL~~	Data corruption
021	F	24	Straw	WNL	
022	M	24	Cup	WNL	
023	M	68	Straw	WNL	
024	F	33	Cup	WNL	
025	F	23	Straw	WNL	
026	M	42	Cup	WNL	
027	M	50	Straw	WNL	
028	F	38	Cup	WNL	
029	F	43	Straw	WNL	
030	M	30	Cup	WNL	
031	F	23	Cup	WNL	
~~032~~	~~F~~	~~21~~	~~Cup~~	~~WNL~~	Incompatible hardware
033	F	51	Straw	WNL	
034	M	56	Cup	WNL	
~~035~~	~~M~~	~~60~~	~~Straw~~	~~WNL~~	Incompatible OS
036	F	33	Cup	WNL	
037	F	33	Straw	WNL	
038	M	24	Cup	WNL	
039	F	56	Straw	WNL	
040	F	46	Cup	WNL	
041	F	50	Straw	WNL	
~~042~~	~~F~~	~~61~~	~~Cup~~	~~WNL~~	Incompatible OS
043	F	65	Cup	WNL	
044	F	21	Straw	WNL	

Table 4.11: Demographic information for the entire sample

APPENDIX F: EXPERIMENTS 2 & 3 INFORMED CONSENT FORM

Research Participant Information and Consent Form

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

Study Title: Immediate Effects of Semi-Occluded Vocal Tract Exercise on Objective Measures of Voice Analysis
Researchers and Title: David S. Ford, Ph.D. Candidate, Anthony Strevet, M.A. Student, Dimitar Deliyski, Ph.D.
Department and Institution: Department of Communicative Sciences and Disorders at Michigan State University
Address and Contact Information: Oyer Speech & Hearing Bldg., 1026 Red Cedar Rd., East Lansing, MI 48824
Sponsor: Michigan State University

1. PURPOSE OF RESEARCH

You are being asked to participate in this study to help researchers gain a better understanding of the effect of a therapeutic voice protocol (semi-occluded vocal tract exercise) on metrics used to evaluate changes in a person's voice. This will assist in the understanding of the physiologic mechanisms underlying the exercise and contribute to recommendations for use in people with voice problems and as voice training for people without voice problems.

2. ELIGIBILITY CRITERIA

It is expected that you have no significant voice complaints and are in good physical and mental health.

- You must be over 18 years of age.
- No history of prior or current voice or speech problems requiring medical intervention (including voice or speech therapy).
- You may be asked about items which might affect your speech production (e.g. hearing, breathing).

3. ALTERNATIVE OPTIONS

There are no alternative procedures, but you have the option not to participate in this research study.

4. WHAT YOU WILL DO

We expect that full participation in this study will take approximately 45-60 minutes. Prior to initiating the study, you will receive a shipment containing materials needed for the experiment (e.g. microphone/hardware, USB flash drive, straw, cup). The study will require you to access a Zoom teleconferencing session, where you will be securely connected with the researcher. You will be provided a Zoom link, meeting ID, and password via e-mail. You will need to connect to Zoom using a laptop/PC running Windows or Mac operating systems. Once connected to your encrypted Zoom session, the researcher will instruct you through set up instructions, practice, and the experimental tasks. Before the experiment, you may be asked to do the following:

- Plug in the USB flash drive and microphone
- Download necessary software components and open programs from the flash drive
- Configure certain microphone settings with the help of the researcher

- Simple assembly of materials that were shipped to you (e.g. filling cup with water)
- Answer introductory questions about your past medical history and any history of voice problems or treatment

Once the experiment begins, you will be asked to record voice tasks including sustained vowel sounds (e.g. "ahh," "ooo"), as well as, reading standardized sentences and a paragraph of text. Next, you will be instructed how to perform two SOVT tasks. One task will require you to sustain a voiced sound while directing your voice through a straw. The other will require you to do the same, except while submerging the end of the straw into a cup of shallow water. You will be given the opportunity to practice each task with the researcher's assistance. You will then be asked to perform one of the two tasks 12 times (sustaining for 10 seconds each time) with 10 second breaks between each repetition. This will total two minutes of voicing through the straw and two minutes of rest. Following the SOVT task, you will be asked to perform the same voice tasks as at the beginning (e.g. sustained vowel, sentences, paragraph). You will also be asked to rate your vocal effort and voice quality following the task. There will then be a 5-minute break, in which we ask that you avoid using your voice. Following the break, you will be asked to complete the other SOVT task in the same fashion as you performed the first task. Again, you will be asked to perform the same voice tasks as at the beginning and prior to the break. In the weeks following the experiment, you may be contacted with a few, simple follow-up questions via e-mail or through brief Zoom sessions.

5. POTENTIAL BENEFITS

While the program in which you are being asked to participate may have no immediate benefit for you, it may benefit others by increasing our knowledge of factors affecting measures of speech and vocal function.

6. POTENTIAL RISKS

There is very minimal risk involved in this research program and the procedures should cause you no undue discomfort. All equipment used in the study is similar to that found in singing studios, linguistic laboratories, and speech production laboratories. They include such items as microphones, headphones, and plastic straws and cups.

This study may generate clinically significant results. The testing performed in this project is not intended to find abnormalities, the protocol does not diagnose illness and we do not refer to health care providers. Data collected do not comprise a diagnostic or clinical study. Undetected vocal abnormalities are rare, but it is possible that the investigators may perceive a vocal abnormality during the study. If this occurs, you will be advised to consult with a licensed physician to determine whether a health examination would be prudent.

7. PRIVACY AND CONFIDENTIALITY

The data for this study are being collected confidentially. Each Zoom session will be encrypted, require a password, and video of the session will not be recorded. The data for this project will be kept confidential. Data from this study will be stored in a password-protected file, in a locked cabinet in a locked room or a password protected computer in the locked laboratory. All information will be kept for at least three years after the close of the study. Only trained researchers under the jurisdiction of this project and MSU's Human Research Protection Program will have access to the data collected in the study. Information about you will be kept confidential to the maximum extent allowable by law. Although we will make every effort to keep your data confidential there are certain times, such as a court order, where we may have to disclose your data. Identifying information will not be attached to any of your individual responses or recordings when reporting results. Instead, data will only be saved using a coded ID number and a key that contains your identifying information will be kept separately and securely, as described above. The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous. By participating, you agree to allow de-identified audio recordings of your speech to be collected and shared, in this capacity. After identifiers are removed, the information could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from the subject.

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

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

9. COSTS AND COMPENSATION FOR BEING IN THE STUDY

As an incentive to participate, people who participate in this research will be offered a $30 Amazon gift card, which may be sent electronically. If you are a T.A. or affiliated with MSU in such a manner that would require course credit be awarded via the SONA system, you may choose to receive credit this way instead of the financial incentive. 1.0 SONA credits will be offered for your participation.

10. THE RIGHT TO GET HELP IF INJURED

In the unlikely event that you are injured as a result of your participation in this project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. You may contact Dr. Dimitar Deliyski at 517.884.2258 (ddd@msu.edu) with any questions or to report an injury.

11. CONTACT INFORMATION

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

- David S. Ford, Ph.D. Candidate at Michigan State Univ., forddav5@msu.edu
- Anthony Strevet, M.A. Student, Michigan State Univ., strevet1@msu.edu

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or at 4000 Collins Rd. Suite 136 Lansing, MI 48910.

12. DOCUMENTATION OF INFORMED CONSENT

Your signature below means that you voluntarily agree to participate in this research study.

____________________________________ ________________________

Signature Date

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

A signature is a required element of consent – if not included, a waiver of documentation must be applied for.

APPENDIX G: INFORMED CONSENT FORM FOR CAPE-V RATERS

Consent to Participate in a Research Study

Study Title: Immediate Effects of Semi-Occluded Vocal Tract Exercise on Objective Measures of Voice Analysis

Researchers and Title: David S. Ford, Ph.D. Candidate, Anthony Strevet, M.A. Student, Dimitar Deliyski, Ph.D.

Department and Institution: Department of Communicative Sciences and Disorders at Michigan State University

Address and Contact Information: Oyer Speech & Hearing Bldg., 1026 Red Cedar Rd., East Lansing, MI 48824

Sponsor: Michigan State University

Purpose: You are being asked to lend your expertise, by listening to de-identified audio files of voicing tasks. You will be asked to perceptually judge attributes related to vocal quality, using the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V).

Risks & Benefits: There are no risks associated with this component of the research project. There are no personal benefits expected, other than your contribution to science and clinical practice.

Privacy & Confidentiality: No personally identifiable information about you will be obtained. Your perceptual ratings (with no identifiers attached) will be kept for at least three years after the close of the study. Only trained researchers under the jurisdiction of this project and MSU's Human Research Protection Program will have access to the data collected in the study. The results of this study may be published or presented at professional meetings.

Future Use of Data Collected: By agreeing to participate in this capacity, you are agreeing that the data collected (i.e. your perceptual ratings) may be used for future projects within the Voice & Speech Lab at MSU. Additional informed consent will not be collected prior to future use.

Your Rights: Participation in this research project is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. Whether you choose to participate or not will have no impact on your relationship with the researchers at MSU. If you have any questions about this survey or participation, or to report an injury, please contact:

David S. Ford, M.S. CCC-SLP, Doctoral Candidate, Dept. of Communicative Sciences and Disorders, Michigan State University, forddav5@msu.edu

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 4000 Collins Rd, Suite 136, Lansing, MI 48910.

Your signature below means that you voluntarily agree to participate in this research study.

______________________________ ____________________

Signature | Date

REFERENCES

REFERENCES

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