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Singing Exercise Programs and Vocal Tremor: A Narrative Literature Review

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Part 1

Introduction

As a lifelong performer and professional vocal coach, I am acutely aware of the positioning, motion, and interplay of the muscles within my body while singing. As a graduate student, I have been drawn to topics that explore the relationship between health and singing. Recently, my practice has expanded to include voice lessons with health compromised individuals, and as a result, my exploration of related research and vocal technique has grown. Due to working more with the elderly, those with long COVID (see my working paper *Singing, Breathlessness and Long COVID Recovery* (Harris, 2023)), and most recently with individuals with Parkinson's disease, I am driven to broaden my understanding of singing as a form of physical therapy and source of psychological enhancement.

Research into the health benefits of singing and performing could fill the pages of many literature reviews. Indicative of this is the systematic review by Barnish and Barran on performing arts interventions and their effect on Parkinson's patients (2020). The review included 12 studies on singing interventions, which reported improved speech outcomes (phonation, eligibility and vocal intensity) in 11 of the 12 studies (Barnish and Barran, 2020).

In recent years, I have begun to work more deliberately with older adult students, some of whom have health issues that impact the quality and stability of their voice, such as essential vocal tremor, Parkinson's disease or other health conditions. Several therapeutic programs are suggested for individuals suffering from these conditions who experience vocal tremor; however, more research is needed as to their effectiveness. Preventative strategies that might slow potential vocal changes brought on by illness or aging also are absent. The goal of this literature review is to identify the different classifications of vocal tremor and their pathophysiologies, to explore how vocal tremor differs from vocal vibrato, and to review singing programs that are recommended to help manage this condition with an eye towards identifying guidelines and implications for voice teachers.

Tremor is defined as an "involuntary, rhythmic, oscillatory movement of a body part" (Saifee, 2019, p 52). It is the most common movement disorder and can occur alone or in conjunction with other medical conditions or neurological diseases (Saifee, 2019). Treatments that are available for tremor are not always as effective specifically for vocal tremor and this may be in

part because much is unknown about the etiology of vocal tremor (Xavier and Simonyan, 2022). Without understanding what causes the body, or more specifically the voice, to vibrate and what muscular systems are oscillating during vocal tremor, it can be challenging to design behavioral or exercise programs that might impact the duration or strength of the vocal tremor. Therefore, this literature review will discuss what is known about vocal tremor and potential causes as well as review therapy programs in the literature.

Vocal tremor occurs when involuntary oscillations in the muscles of the vocal tract cause modulations in the pitch or loudness of the voice (Xavier and Simonyan, 2022). Oscillations may be observed in the laryngeal muscles as well as oral structures (the velum, tongue, or jaw) and the pharyngeal and respiratory musculature (Xavier and Simonyan, 2022). Vocal tremor may appear independently or in conjunction with other neurologic disorders (Xavier and Simonyan, 2022). Tremor that occurs independently from other neurologic conditions is referred to as *essential tremor* (ET). *Essential vocal tremor* (EVT) is a symptom of ET and may occur alongside tremors experienced in other areas of the body or independently. 25-62% of ET patients experience EVT (Xavier and Simonyan, 2022). Despite its prevalence, diagnostic difficulties for vocal tremor exist and limited therapies are available (Xavier and Simonyan, 2022). There is presently no cure for vocal tremor.

Clinicians are at odds about the classification of vocal tremor with some including isolated vocal tremor as a subset of ET (Merati *et al.*, 2005) that may impact laryngeal and other phonatory muscles, and other clinicians excluding isolated vocal tremor from an ET diagnosis (Bhatia *et al.*, 2018). This can lead to complications and confusion regarding diagnosis, implications for affected muscular systems, and treatment plans. Barkmeier-Kraemer suggests that both isolated vocal tremor and vocal tremor appearing with oscillation in neighboring muscular systems should be classified as ET (Barkmeier-Kraemer, 2010). This recurring disagreement may in part explain why much of the scientific literature is focused on etiology and classification of systems and less on therapeutic treatment strategies.

Similar variance appears regarding the terminology used to define vocal tremor itself. Terminology for vocal tremor includes: tremulous voice, phonatory instability, pitch unsteadiness, and laryngeal tremor (Gillivan-Murphy and Miller, 2011; Gillivan-Murphy, Miller and Carding, 2019; Xavier and Simonyan, 2022). In a study looking at how vocal tremor is classified in medical records, researchers noted a need for consistent multidisciplinary assessment methods for vocal tremor to assess and treat the condition (Torrecillas, Dwenger

and Barkmeier-Kraemer, 2021). Researchers who mapped brain activity that accompanies vocal tremor associated with spasmodic dysphonia (discussed below) and ET noted that while different, there was sufficient overlap to consider the pathophysiology of the two conditions as not mutually exclusive (de Lima Xavier and Simonyan, 2020).

Vocal tremor can negatively disrupt an individual's daily life, causing involuntary sound modulation and compromising their communication, social interaction, and expression (Alam, Munjal and Panda, 2017; Hemmerich, Finnegan and Hoffman, 2017). A shaky voice is often associated with weakness, fear, emotion, or anxiety, exposing the speaker to misunderstanding, isolation, and potential depression (Xavier and Simonyan, 2022).

Contrary to vocal tremor, vocal vibrato is a vibration or oscillation in the singing voice that is generally desired and voluntarily used for artistic and emotional expression. (Dromey and Smith, 2008). I recently completed a research project entitled: *Understanding Vibrato: A study of definitions, perception, and instruction methods* (Harris, 2024). This study highlighted the subjective nature of vibrato use, the varied understanding of what vibrato is among singers and vocal instructors, and how to access the technique. Authors have considered the similarities and differences between vocal vibrato produced voluntarily for artistic vocal interpretation and the pathology of involuntary tremor linked to disease or aging (Ramig and Shipp, 1987; Dromey and Smith, 2008; Vieira, de C Silva and Yehia, 2011). Research has shown similarities in measurements of vocal modulations in vocal vibrato and vocal tremor, such as similar rates and extents (defined below), however the variability in measurements of vocal tremor is greater than those found in vocal vibrato (Ramig and Shipp, 1987). Considering my recent research, and voice teaching practice, vocal tremor is a subject of personal interest and a logical next topic of exploration for this literature review.

Three disorders that can appear with vocal tremor are discussed in this paper: *spasmodic dysphonia* (SD) (or laryngeal dystonia), *essential tremor* (ET) and *Parkinson's disease* (PD). Following a discussion of vocal tremor, this paper explores suggested therapeutic treatments that include singing and related voice and breathing exercises, and relevant research into these programs. It is the author's intention to better understand vocal tremor, how it differs from vocal vibrato, and the voice exercise strategies used for vocal tremor with the goal of incorporating these kinds of exercises into voice training sessions both for appropriate therapeutic purposes and potential strengthening and preventative purposes.

Aims & Objectives

Aims

- To identify vocal tremor, its different etiologies and classifications.
- To compare how vibrato and vocal tremor are discussed in the literature.
- To develop insight into singing and vocal coaching models that may be helpful for those with vocal tremor.

Objectives

- Use the hermeneutic circle while conducting a literature review.
- Gain an understanding of the Gibbs cycle as a tool for reflection.
- Critically reflect on the development of search terms and parameters when conducting a literature review.
- Identify key vocabulary used to describe vocal tremor and vocal vibrato.
- Identify gaps in knowledge.
- Identify the challenges in classifying vocal tremor.
- Identify the potential for developing vocal exercise training programs for people at risk of developing tremor.
- Become familiar with existing training protocols and their rationale to ethically incorporate aspects into my own teaching practice.

Bias and Ethical Considerations

This literature review was undertaken to provide the author with an understanding of vocal tremor and how singing and vocal exercises might be employed to improve the condition of the student with vocal tremor. I developed this topic from the biased personal perspective that singing is a whole-body experience, often employing unobservable structures within the body, and providing potential benefits that are unquantifiable and unable to be tested.

My career in health policy has caused me to work with those in the scientific and medical community and frequently dive deeply into scientific and medical research. As a voice practitioner, and not a doctor or licensed therapist, there are significant ethical considerations and constraints inherent in my work. I am constantly aware of the line between responsibly having research and continuing education programs guide my lesson strategies with voice

students, and improperly influencing their medical care. Understanding the potentially compromised health status of individuals experiencing vocal tremor and gaining increased knowledge regarding the variables defining vocal tremor and its potential causes, signs, and related treatment protocols enables me to work with these clients in a more ethical and responsible manner. To better ensure no harm is done to a student, any signs of discomfort or frustration during lessons, or reported during independent practice, will be addressed with the student and alternatives offered. Recognizing the limitations of my own training and certifications, referrals to and discussion with medical and personal caregivers will be done liberally, with the permission of the students, to best ensure both the proper care and privacy of the student.

Methodology

While post-positivist research assumes one essential truth, it also integrates additional methods of research such as surveys, interviews, or observation (O'Leary, 2004). These methods are important in any subjective singing research. However, as vocal tremor may originate from different mechanisms within the pharyngeal-laryngeal systems, be neurological in origin, or even intrinsically linked to disease, medication, or aging, one truth is unlikely regarding the cause of vocal tremor. A constructivist paradigm assumes multiple truths are possible and allows for the development of patterns and meanings from the data collected in a study itself (Creswell and Creswell, 2018). Consideration of the human experience including the view of participants is also anticipated (Mackensie and Knipe, 2006; Creswell and Creswell, 2018).

For this narrative literature review, I adopted hermeneutics as my theoretical perspective. Hermeneutics considers reality as reliant upon researcher interpretation and this interpretation as pivotal in achieving a deeper understanding (Gray, 2004). Davey describes hermeneutics not as a "specifiable theory or philosophy of understanding but primarily a mode of reflecting upon what is already at play within communicative practices and the experiences of meaning they facilitate" (Davey, 2017, p 180). When researching a question that is based on developing science, it is helpful to work within a framework that allows for contemplation of the known alongside the unknown. The science of singing as well as an understanding of the physiopathology of health conditions resulting in vocal tremor are both in development. A hermeneutic approach allowed me to interpret and learn as I engaged in my literature review, redefining my focus and expanding my search parameters as necessary (Gray, 2004). Further,

use of the hermeneutic circle aided my search, filtering, and refining process (Boell and Cecez-Kecmanovic, 2010).

I began each literature search with the online library system at University of Wales Trinity St David (UWTSD). My initial search used the terms “singing” and “vocal tremor”. Of the 15 returned documents, only 6 were related to the topic at hand. Of these 6, 4 dealt with classification of vocal tremor within the context of a specific medical condition such as SD or PD. Additional searches in this database resulted in fewer than 12 results and included “Parkinson's tremor singing”, “essential voice tremor singing”, “dysphonia tremor singing,” with many searches bringing up the same articles. I broadened my search to “therapy vocal tremor” however most results discussed surgical and pharmaceutical options, classification of tremor, or acoustic measurement of tremor. “Behavioral therapy vocal tremor singing” resulted in zero results.

I then turned to Google to help me better understand the classification of vocal tremor to expand and improve my search terms. I researched “vocal tremor classifications” which led to a list of websites representing neurological or speech language departments in hospital and medical institutions as well as conference papers on vocal tremor classification. I expanded my library search engines to include PUBMED, Science Direct, the online library at Case Western Reserve University, and Research Gate. I used the strategies of forward and backward chaining to increase my collection of relevant articles, relying heavily on citations from the few relevant articles that I had found.

Inclusion/Exclusion Criteria

Literature was limited to articles or research published from the past 15 years. An exception was made for relevant scoping reviews, as the few identified helped to expand my understanding of the history of vocal tremor research, and developments in the human neurology, etiology and physiology fields as they relate to vocal tremor. Studies that were focused on non-behavioral treatments for vocal tremor, such as injections with botulinum toxin or brain implants used for deep brain stimulation, were excluded unless they offered a discussion of protocols for assessing tremor using vocal cues.

Some articles emerged from my database searches that touched upon other observed benefits from singing in people experiencing neurological conditions affiliated with vocal tremor. For example, a peripheral benefit of singing regimens observed in people with PD is improvement in gait. Researchers found that singing while walking could serve as a successful cuing technique to lessen gait variability in PD patients (Harrison, McNeely and Earhart, 2017). Hersh et al. looked at the benefits of singing on emotional and relationship measures of PD patients and their spouses (2023). Group singing and songwriting was found to improve relationships between the couples and authors noted this benefit should be added to benefits found in previous studies including the psychological benefits of improved positivity, sense of self, social opportunities, and physical enhancements (Hersh, Kong and Smith, 2023). In a study on the effects of singing on persons with dementia, researchers found significant increases in emotional well-being and communication as well as decreases in cortisol levels, which is an indicator of stress (Dawudi *et al.*, 2024). While fascinating, and often referencing a population likely to experience vocal tremor, articles such as these were excluded as they were not related to vocal tremor directly.

I sought the advice of professionals working with tremor patients and expanded my searches to include video lectures on vocal tremor, singing protocols, or voice therapy. A Google search brought-up a variety of YouTube videos, association websites and personal voice teacher websites. To control for quality and reliability, I limited video results to only those produced in the past 3 years and targeted professional and academic sources including lectures from the Voice Study Centre (VSC) video archives, Medbridge (an online education and patient care website for healthcare professionals), hospital websites and an on-point training by my former VSC advisor, Kerrie Obert. As vocal tremor is discussed more in the medical community, a focus on health care professionals seemed appropriate. These sources also mentioned programs sponsored by Parkinson's organizations such as Power for Parkinson's, which were then reviewed (Moore, 2022a).

Critical Reflection

My practice has grown to include older adults who have physical habits or conditions that result in a tighter voice, one that sounds more pressed or gruff, or a tremorous voice. Therefore, I wanted to better understand the physical processes that happened due to aging or disease and the role singing could play in stabilizing the tremorous voice.

After Module 3 of the Voice Study Centre (VSC) program, my research into vocal vibrato began to influence my approach to lessons. I employed a greater focus on strengthening agonist/antagonist muscles within the laryngeal and pharyngeal systems (Titze *et al.*, 2002; Nix, 2013, 2014, 2023). I also instituted more stretching and strengthening work particularly with the tongue and velum, influenced greatly by the lectures housed in the VSC Video Database by Angelika Nair on the Tongue (Nair, 2022, 2023), Walt Fritz on Jaw Tension (Fritz, 2022) and the certificate program on Vocal Pedagogy by Kerrie Obert (Obert, 2023a).

For this literature review, I decided to focus on vocal tremor. Recognizing my personal tendency to choose unrealistically large topics, I believed that vocal tremor would provide a sufficient constraint on my research parameters. My research on vocal vibrato made me question how these two types of vocal vibration differed. I also was drawn to the connection between tremor and the brain, having recently completed a VSC certification on Applied Neuroscience and Voice (Moss, 2023).

I began my search by looking through two books I considered helpful in guiding my practice to date: *A Systematic Approach to Voice* by Ragan (Ragan, 2020) and *Exercises for Voice Therapy* by Behrman and Haskell (Behrman and Haskell, 2020). Surprisingly, Ragan did not address vocal tremor.

Suggested exercises for tremor in the Behrman and Haskell were limited to developing staccato or breathy speech to hide vocal tremor (Barkmeier-Kraemer, 2020) and a description of the Speak Out and Loud program for Parkinson's Disease with limited information about the rationale behind the exercises offered (Cody, 2020). The Speak Out Loud program is based on the concept of intentional learning and repetition of exercises over time, where the client is taught exercises to influence impairment of motor speech behaviors (Cody, 2020).

Similar to my research on vocal vibrato, my research goal was to understand voice teaching and singing methods used to address vocal tremor. I began with the search terms "singing" and "vocal tremor" on the UWTSD library database. Fewer than 15 results were returned, with none discussing singing programs or exercises for vocal tremor, and only a few on point that discussed the etiology or characterization of vocal tremor. I then extended my search to Google, resulting in a large body of grey research on private websites and YouTube. Having dived

deeply into this type of grey material in my vibrato study, I hesitated to do so again due to the subjective nature of the opinions expressed, often without citation or reference.

With evidence of limited on-point published research focused on singing protocols and vocal tremor and the possibility of grey literature once again coming into play in my discussion, I knew my research would quickly spiral, becoming less structured and systematic. My initial inquiries led me to rethink what I aimed to learn through this literature review. I employed a hermeneutic circle structure for my literature review suggested by Boell and Cecez-Kecmanovic (2010). The hermeneutic approach allowed me to interpret and learn as I engaged in my literature review, redefining my focus and expanding my search parameters as necessary (Gray, 2004). This strategy eased the frustration I was feeling about the potential of not reaching a final understanding of my research topic. In addition, use of the hermeneutic circle brought clarity to my literature search and its open-ended, circular nature allowed me to pursue additional lines of inquiry as I found more and more tangential information, which led me back to prior sources that I would then re-read and re-interpret (Boell and Cecez-Kecmanovic, 2010).

I determined the entry point for my circle should be review documents explaining the different types of vocal tremor. This strategy gave me a better insight into what was known about the etiology and physiology of vocal tremor and the diseases and conditions associated with its development. The first relevant underlying question for my research quickly became apparent: namely what were the types of vocal tremor, how did they differ from each other, and how did vocal tremor differ from vocal vibrato? This was the starting point for my hermeneutic circle and included summary articles defining vocal tremor and vocal tremor (Gillivan-Murphy and Miller, 2011; Saifee, 2019; Xavier and Simonyan, 2022; Carroll, 2023; Mayo Clinic, 2023).

As part of my circle process, I engaged with a number of medical practitioners working with patients with vocal tremor at George Washington University Hospital in Washington DC and Mount Sinai Hospital in New York City who recommended researching the work of Elizabeth Stegemöller, PhD in music therapy, who had presented and published papers on her work on PD patients and singing, and lectures on Medbridge, a continuing education website designed for practicing medical personnel, educators and students. I extended my focus to include lectures by Kerrie Obert, my former MA advisor in the VSC program and a licensed and experienced SLP who had worked with vocal tremor patients for over 20 years.

As my understanding of vocal tremor increased, I returned to the same search terms and re-read both articles and lists of results. Additional articles proved useful as my understanding of the topic broadened and I was able to find relevance in more documents (such as a comparison between speech and singing hinderance in PD patients) as well as eliminate studies that were of interest but outside the scope of my literature review.

Pivotal articles helped me to further refine my topic and provided useful citations that had not come up in my database searches such as *Vocal Tremor and Vibrato in the Same Person: Acoustic and Electromyographic Differences* (Dromey and Smith, 2008). Such articles highlighted the potential usefulness of publications providing background information compared with articles discussing potential protocols for people with vocal tremor. In the last section of this paper, I summarize singing related protocols identified, of which there are few. Additional studies are discussed that mention singing exercises used with vocal tremor patients without defining the programs in detail.

Reflective Model

I used the Gibbs reflective circle model to guide my research process (Gibbs, 1988). The Gibbs model requires learning through repetition. The researcher is challenged to make decisions, analyze and evaluate why those decisions were made, draw conclusions based those decisions and then reassess the underlying research action plan based on lessons learned. This process is then repeated as many times as necessary during the project with one circle informing the next until the project's completion (Gibbs, 1988; Lia, 2016).

Figure 1 – The Gibbs Reflective Model (Lia, 2016)



One example of Gibb's reflective model as it relates to my research is detailed below and is representative of multiple rounds of reflection inherent in my work.

1. Description	I looked to texts on singing exercises and speech therapy to begin my research into vocal tremor and how it was addressed therapeutically in practical literature.
2. Feelings	I expected to find specific mention of vocal tremor in books on singing pedagogy and speech language therapy. In my prior research on vibrato, the vocal qualities of tremor, defined as an involuntary vibration in the voice that is heard as a shaking in pitch or loudness, were referenced often with the terms wobble or flutter and received mention in relation to the aging singing voice. Therefore, I was confident that specific discussions about vocal tremor and relevant vocal exercises

	would be accessible in books about singing exercises and voice therapy.
3. Evaluation	I was surprised when the pedagogy books in my personal library contained little or no mention of the term tremor in either the index or table of contents. I became frustrated that my initial search in texts by trusted authors were not helpful. I became determined to understand how my search terms might be altered after I gained a better general understanding of vocal tremor, its definitions, related terms, and treatments.
4. Analysis	After some reflection, I concluded that I should have begun my research with searches regarding classification and etiology of vocal tremor, rather than in the areas of treatment of pedagogy. Redefining my initial searches to these areas helped me quickly to realize that vocal tremor was often discussed in relation to accompanying neurological conditions. I had mistakenly assumed that vocal tremor was one specific condition with one cause and suggested specific treatment plans appearing in both performance pedagogy and medical therapy books. Understanding that vocal tremor was a symptom of other accompanying conditions with differing underlying causal pathways enabled me to expand my search terms.
5. Conclusion	Switching my initial focus from treatment strategies for vocal tremor to background research expanded not only my understanding of my chosen research topic, but also my ability to further my research goals and find relevant sources. In the future, doing this background reading before settling on a research question, and thereby streamlining my research focus will help me to avoid frustration and mental paralysis at the start of my research process.

6. Action Plan	Moving forward with this project, my future search parameters will include key medical terms as well as singing such as: essential vocal tremor, dysphonia, Parkinson's, behavioral therapy, and aging.
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Final Reflection

At the conclusion of writing Part 2 of this assignment, I found myself unsatisfied with the collection of resources I had uncovered. Upon reflection, my research process brought me in and out of focus on my original research topic. I journeyed from looking specifically for studies on singing and vocal tremor, to understanding vocal tremor and its physical causes, to extrapolating from this information exercises or protocols that had been published or discussed focused on the muscular systems believed to be involved with tremor production.

While the winding path my research followed was understandably due to the minimal search results detailed above, I began to wonder if my search terms, upon reflection were the cause of my difficulty. Might it be that matching a vocational term like “singing” with a more medical term like “tremor” or “essential vocal tremor” or “Parkinson’s” was less likely to result in identified articles because authors did not tend to mix medical and layman’s terms in publications? Future literature searches using more technical voice therapy terms (such as onset, SOVT, straw phonation, phonation, slides, vocal exercises, or vocal function exercises) might yield relevant and interesting results.

To quickly test this theory, I went back to the UWSTD database and searched “vocal tremor behavioral therapy.” While once again many resulting articles included studies on treatments such as botulinum toxin injections and deep brain stimulation (as had occurred in a prior search using “vocal tremor therapy”), removing the word “singing” and adding “behavioral” brought up a literature review entitled *Behavioral Therapy for Tremor or Dystonia Affecting Voice in Speakers with Hyperkinetic Dysarthria: A Systemic Review* (Lester-Smith, Miller and Cherney, 2023). The studies discussed in this article would have been pivotal and influential had the review come-up in my initial search.

Future literature reviews on this topic might also benefit from broadening the theme of the research from tremor specifically to monikers that might be inferred to include tremor including “quality of life measures,” “voice quality,” or “listener perception.”

Lastly, to test these new ideas, I went to clinicaltrials.gov, a website run by the US National Library of Medicine to track all research globally on any medical topic. I searched for “singing” and found a plethora of studies looking at the impact of singing and singing protocols on a multitude of medical conditions. While many of the listings were studies in progress, or studies completed but not published, several relevant studies came up such as one focused on improved vocal ability in Parkinson’s patients who participated in a singing program, without mentioning tremor (Tanner, Rammage and Liu, 2016). Future literature reviews focused on medical conditions and singing might benefit from including this database in initial searches where limited research is available to develop and broaden search terms. Time and word length parameters do not allow me to include these newly found articles in Part 2, however their existence has greatly influenced my reflection on developing search terms and designing literature reviews.

Part 2

Overview

When controllable, an audible vibration in the voice is an appreciated trait known as *vocal vibrato* (VV). Comparatively, *vocal tremor* (VT), is caused by involuntary oscillations in vocal tract muscles, including those in the respiratory, laryngeal, pharyngeal and oral-pharyngeal systems, causing modulations in the pitch or loudness of the voice (Xavier and Simonyan, 2022).

In this literature review, I seek to better understand the nature of VT, including the similarities and differences between VV and VT, medical conditions that can cause VT, and assessment methods of VT as they relate to singing techniques. I then address suggested voice therapy treatment strategies for VT. My overarching goal for conducting this review is to increase my understanding of VT to supplement lesson plans with strategies that may improve the confidence, mood, muscle strength or vocal health of my students.

Comparing Vocal Vibrato and Vocal Tremor

VV is a controllable technique, audible as a slight oscillation in pitch that occurs at regular intervals. It is often used to heighten the emotive qualities of the singing voice (Seashore, 1938; Vennard, 1967; Miller, 1986; Vieira, de C Silva and Yehia, 2011). Studies have shown singers to be able to modify the rate of the VV produced (Dromey, Carter and Hopkin, 2003; Mitchell and Kenny, 2010). *Rate* represents the number of times a full oscillation occurs in a second and is measured in Hertz (Hz). How VV is produced and modified and how it might be taught is not thoroughly understood (Nix, 2013). My recent research on VV provided insight into common vibrato-related terminology used as well as teaching trends and stylistic preferences (Harris, 2024), however a background review of published literature discussing the physiological cause of VV elucidated gaps in scientific knowledge regarding the technique (Nix, 2013; Wooding and Nix, 2016; Patinka and Nix, 2020).

VT is considered an involuntary unsteadiness in pitch, amplitude, or quality of the voice, often more irregular to the ear than VV and more resistant to behavioral adjustments that may impact vocal production (Dromey and Smith, 2008). VT can be a trait of another medical condition,

causing communication difficulties, isolation, a reduced quality of life, and other health complications (Dromey, Carter and Hopkin, 2003; Dromey and Smith, 2008).

Both VV and VT are audible as fluctuations in produced vocal sound. Due to similarities in measurement of VV and VT and observations of muscles and structures engaged during their production, it is reasonable to think that the mechanisms required to produce VT and VV might be interconnected. Therefore, this author posits that the more we know about VV production, the more insight we may gain into VT and visa-versa. If singers could identify exercises to help produce and control voluntary VV, perhaps those same exercises would prove helpful in controlling VT, generally strengthening the vocal apparatus, or making VT less audible or even less likely to develop.

Similar analysis techniques are used to measure and classify VT and VV oscillations. Both frequency (FM) and amplitude modulations (AM), as well as the consistency of these modulations, are noted in studies (Dromey, Carter and Hopkin, 2003). FM analysis includes a measure of the rate and extent of the oscillation. In healthy fluid singing, typical VV rates are between 4-7 Hz (Seashore, 1931; Patinka and Nix, 2020). VT rates can often fall between 3-12 Hz (Barkmeier-Kraemer and Story, 2010; Pinto, Pérez and Garcia-Lopez, 2024). The *extent* of a modulation represents the amount of fluctuation above and below the original tone produced (Nix, 2013; Nix *et al.*, 2016). Extent is measured in cents, with 100 cents equaling a semitone, and a typical VV extent varying 50 cents above or below the intended pitch (Vieira, de C Silva and Yehia, 2011; Nix, 2013; Nix *et al.*, 2016). In contrast, VT may include a barely audible fluctuation to one that is extreme enough to halt speech altogether (Dromey and Smith, 2008).

Researchers also measure the periodicity, perturbation, or regularity of vocal modulations (Dromey and Smith, 2008). *Jitter* is the term for the regularity of change in the rate of a modulation, and *shimmer* represents the regularity of change in the extent of a modulation (Patinka and Nix, 2020; Becker and Watson, 2022). Dromey and Smith have noted that VV appears more sinusoidal, expressed with a more consistent rate and extent, whereas VT modulations can appear more haphazard (2008).

While the precise causes of VV and VT are not completely understood, both are the result of modulations of laryngeal output resulting from changes in muscle tension (Dromey and Smith, 2008). Researchers have suggested that a reflex loop that engages agonist/antagonist muscles

of the cricothyroid and thyroarytenoid muscles, which influence other laryngeal muscles, result in the oscillations of a VV (Titze *et al.*, 2002; Nix, 2013, 2014). Other research has highlighted the potential role of glottal pressure, breath control, and neurologic factors in VV production (Vennard, 1967; Iwata S and Large J, 1971; Miller, 1986; Titze *et al.*, 2002; Nix, 2014).

Individuals with VT may experience shaking due to changed neurological conditions and this shaking may arise from multiple sources including the respiratory system, laryngeal system, pharyngeal wall and the tongue, jaw or velum (Dromey and Smith, 2008). VT may be connected to a medical diagnosis of another disease or condition such as PD, or VT may be experienced without another diagnosis, in which case it is referred to as essential vocal tremor (EVT) (Dromey and Smith, 2008).

In a study by Dromey and Smith that looked at the physiological mechanisms involved in the production of VT and VV in an individual who experienced both types of modulations, researchers were able to hypothesize about how these vibrations might be produced differently (2008). VV rate measured during singing did not vary based on the amplitude (loudness) of the vowel sung. However, VT rate measured from spoken vowels, rose as the amplitude of the sound increased. Researchers speculated that with higher amplitude speech (phonation), increased laryngeal muscle activity resulted in changes in the muscle tension that caused tremor. Theoretically, with VT, the muscles “operating at a higher activity level respond more rapidly to the fluctuating levels of activation in the nerves that innervate them, and thus the modulation rate increases” (Dromey and Smith, 2008, p 543). Because the modulation rate did not change as higher vocal intensity was engaged to produce louder singing, researchers suggest that volitional vibrations seen in VV are produced in a different way that does not require the increased laryngeal muscle activity required for louder speech (Dromey and Smith, 2008). Put another way, researchers posit that the regulation of the mechanisms involved in volitional singing somehow override the influence of increased laryngeal muscle activity required for higher amplitude speech (Dromey and Smith, 2008).

Causes of Tremor

VT can occur at any age. While the etiology of VT is not definitively understood, causes may include genetics/family history, neurological conditions, trauma, and medication (Saifee, 2019). VT can impact an individual's daily life, compromising their communication, social interactions, and artistic expression (Hemmerich, Finnegan and Hoffman, 2017).

In a study of 20 individuals with VT not due to Parkinson's disease (PD), researchers determined that VT may be associated with tremorous oscillations in the muscles of the pulmonary, laryngeal, velopharyngeal, and oral systems, all of which can affect the speech mechanism (Hemmerich, Finnegan and Hoffman, 2017). Individuals with severe VT were more likely to experience oscillations in all four systems. The higher the severity of VT experienced, the higher severity of tremors in related muscular systems (Hemmerich, Finnegan and Hoffman, 2017).

Gillivan-Murphy & Miller discuss several studies in a review that sought to characterize the muscular systems engaged during VT in spasmodic dysphonia (SD), EVT, and PD (2011). In EVT the involvement of inspiratory respiratory muscles were indicated when tremor was observed at the start of exhalation on a sustained /s/, while expiratory muscles were indicated when tremor was observed at the end of exhalation (Finnegan, Hoffman and Hemmerich, 2009). Sulica & Louis found that patients with EVT had tremor that involved the vocal folds and structures in the palate and pharyngeal walls (Sulica and Louis, 2010).

Greater tremor in the laryngeal cricothyroid muscle was indicated when tremor was observed on higher pitches on a sustained /i/ (Finnegan, Hoffman and Hemmerich, 2009). In studies of tremor in patients with PD, findings of tremor in the larynx have varied, while tremor in peripheral systems such as the palate, supraglottis and pharyngeal walls were more commonly observed (Gillivan-Murphy and Miller, 2011).

A more thorough examination of findings such as these are outside of the scope of this literature review. However, a compilation of observed VT influences on specific pitches, vowels, or tones (possibly that are part of larger studies focused on broader research questions) might be helpful in mapping out subtle assessment tools that could prove useful to voice teachers, expanding our understanding of vocal health, guiding targeted and individualized singing and vocal strength exercises, and determining when students could benefit from referrals to medical specialists or trained therapists.

Vocal Tremor Etiology

Aging

Aging has been shown to decrease the stability of the vocal mechanism (Santos *et al.*, 2022). In a study comparing the young adult and geriatric larynx, researchers found a correlation between

the occurrence of presbylarynx (anatomical and functional changes in the larynx resulting from aging) and laryngeal tremor in elderly women (Pontes, Yamasaki and Behlau, 2006). Devadas et al. note that changes to laryngeal nerves and neuromuscular coordination brought about by aging may lead to tremor and vocal instability, causing the jitter and shimmer often associated with the aged voice (2022). One proposed cause of this muscle breakdown is age-related loss of myelinated fibers in laryngeal nerves in people over 60, leading to impaired laryngeal muscle tone from reduced neuromuscular transmission and coordination (Devadas *et al.*, 2022).

Neurological conditions

Below is a discussion of SD, EVT and PD: three common conditions that can be diagnosed in relation to VT. While different, they are indicative of the conditions may result in VT. While VT has no cure, treatments can help make it more manageable (Gates, Forrest and Obert, 2013). Treatments include medications, injections of botulinum toxin, deep brain stimulation, and voice therapy (Abbott, 2018).

Spasmodic Dysphonia (SD)

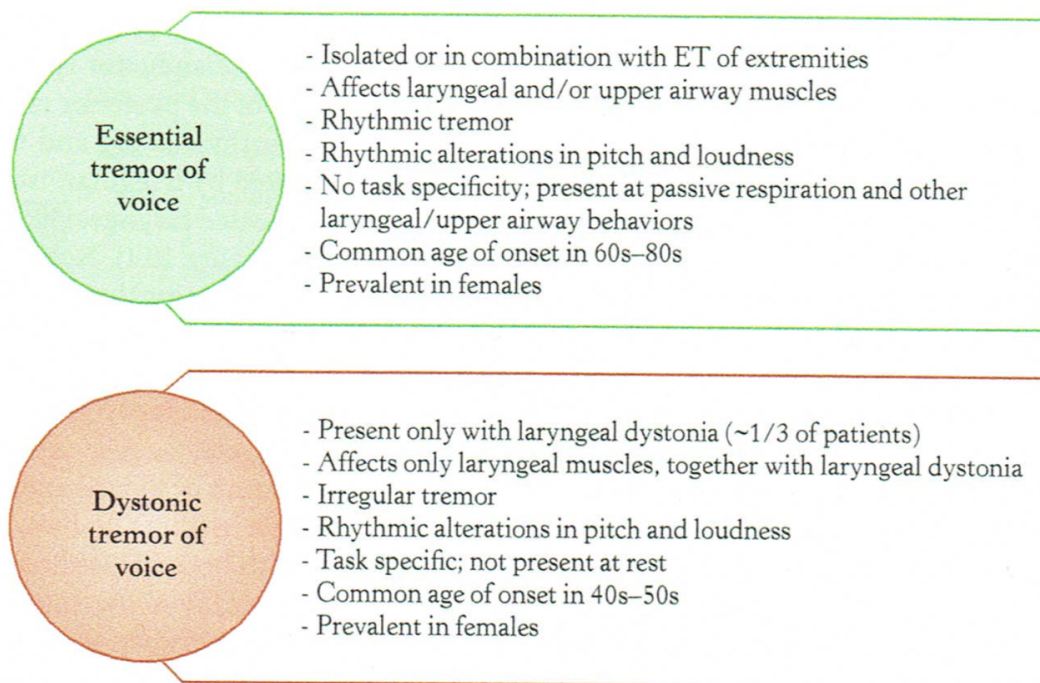
SD (or laryngeal dystonia) is a focal dystonia directly affecting the vocal cords, causing involuntary spasms and resulting in a quivering, tight or breathy sound with varying severity to the point of extreme speaking difficulty (Esper, 2023; Pinto, Pérez and Garcia-Lopez, 2024). SD is characterized by the movement of the vocal cords themselves. Voice therapy is often advised to patients with this condition in conjunction with other treatments (Esper, 2023).

Essential Vocal Tremor (EVT)

EVT is an involuntary voice disorder that can cause the voice to vibrate, resulting in a voice that is labored and unstable (Esper, 2023). EVT is a symptom of essential tremor (ET) and can appear as a stand-alone symptom or with tremors in other parts of the body (Xavier and Simonyan, 2022). EVT is a neurological condition of the nervous system that can get worse with time (Carroll, 2023; Mayo Clinic, 2023). It is more prevalent in females with a common age of onset between 60-80 (de Lima Xavier and Simonyan, 2020). Approximately half of ET cases occur in individuals with an altered gene, sometimes referred to as familial tremor, however the cause of non-familial ET is unknown (Mayo Clinic, 2023; Weill Cornell Medicine, 2024).

While SD specifically affects the vocal cords, EVT can involve muscles in neighboring pharyngeal, laryngeal, and respiratory systems such as the mouth, throat, and chest (Esper, 2023; Weill Cornell Medicine, 2024). Individuals may suffer from both conditions at the same time. Diagnosis of one condition versus another can be challenging as EVT can appear as a stand-alone condition, without accompanying tremor in other body parts (Mayo Clinic, 2023; Weill Cornell Medicine, 2024). While EVT is not caused by another medical condition, it is sometimes confused with conditions that may appear with tremor such as PD (Mayo Clinic, 2023).

Figure 2: A Comparison of EVT and SD Descriptions, reprinted from *Voice Tremor* (Xavier and Simonyan, 2022).



Parkinson's Disease (PD)

PD is a neurological disorder that appears when nerve cells in the brain produce insufficient dopamine (Abbott, 2018). Dopamine helps to control and coordinate movement in the body and lower dopamine levels associated with PD may cause symptoms of resting tremor, muscle rigidity, slouched posture, slowed movement, impaired speech, and voice intelligibility (Hersh, Kong and Smith, 2023). There are important differences between ET/EVT and PD. PD is a

degenerative disease that can shorten lifespan, while EVT alone does not (Abbott, 2018). Additionally, in ET, shaking is most noticeable when the body is in motion or engaging in muscle activity (action-tremor), whereas PD tremors are most common when the body is at rest (resting tremor) (Barkmeier-Kraemer, Lato and Wiley, 2011; Mayo Clinic, 2023).

Tremor is a common symptom of PD and unsteady voice or VT is often associated with the disease (Gillivan-Murphy, Miller and Carding, 2019; Xavier and Simonyan, 2022). PD patients can have difficulty initiating speech (Carroll, 2023). While audible on sustained vowels, studies have not shown VT in the vocal cords or laryngeal musculature in people with PD, implying that tremor may originate in nearby oral, pharyngeal, or respiratory systems (Gillivan-Murphy and Miller, 2011; Gillivan-Murphy, Carding and Miller, 2016; Xavier and Simonyan, 2022). Amplitude tremor and a slower rate of tremor have been noted with PD (Xavier and Simonyan, 2022).

Shao et al. attempted to characterize VT in individuals with PD and posited that VT was caused by vocal fold mass and tension changes and a breakdown of coordinated motor control (2010). Opinions in the literature differ as to the cause of VT in PD, and some authors have ascribed it to EVT occurring in conjunction with, rather than because of, PD, because tremor in PD happens at rest, whereas phonation is a voluntary intentional action (Deuschl *et al.*, 1998).

Amplitude instability is often a vocal symptom of PD and specific therapeutic protocols have been developed to address volume instability such as the Lee Silverman Voice Treatment program (discussed below) (Behrman and Haskell, 2020).

Vocal Tremor Assessment

In addition to a case history, familial history, imaging studies, laryngoscopy, electromyography, evaluation of mouth and pharynx, laboratory tests, respiratory tests and vocal and acoustic analysis, practitioners may receive valuable information from specific phonation exercises (Carroll, 2023). These exercises may prove useful to the voice instructor in designing singing exercises to help students with VT, or to assess the effectiveness of the exercises.

Phonation Assessment

When VT is suspected or has been diagnosed, but is not audible, certain exercises can help with VT assessment. Generally, VT is heard best during a sustained vowel such as /i/ or /a/ and

often decreases at higher pitches (Xavier and Simonyan, 2022). VT is not always audible during speech as the rate of speech (average 5 syllables per second) can mask the rate of tremor, therefore exercises that slow speech down 3 syllables per second can make VT more apparent to the listener (Barkmeier-Kraemer, Lato and Wiley, 2011).

EVT tends to be more rhythmic than VT heard in SD (Weill Cornell Medicine, 2024). Vocal changes are heard in both loudness and pitch and can appear with varying severity from minor modulations to a complete disruption in vocal production (Weill Cornell Medicine, 2024). While sound variations in EVT are always present and may be observed during respiration and phonation, vocal variations heard in SD are not usually rhythmic, are not present with breathing, and may disappear depending on the type of voicing produced, such as singing (Xavier and Simonyan, 2022; Weill Cornell Medicine, 2024).

Vocal Tremor and the Brain

The brain is thought to play a primary role in ET. VT has been linked to dysfunction in the central networks of the basal ganglia, which is also damaged in PD (Wang and Song, 2022). Researchers have also confirmed disruption in the cerebello-thalamo-cortical network in patients with ET (Nicoletti *et al.*, 2020). Activity in the cerebellum and thalamus regions have been observed to precede movement initiation, and therefore are thought to control movement timing (Dacre *et al.*, 2021). The thalamus is also credited with controlling and coordinating muscle activity (Dacre *et al.*, 2021).

Deep brain stimulation (DBS) has been found to be effective in helping to control EVT in some cases (Ravikumar *et al.*, 2016). In DBS, an electrode is surgically implanted in the thalamus and receives shocks that disrupt faulty electrical messages to the brain (Wang and Song, 2022).

PD occurs when nerve cells in the basal ganglia that produce dopamine become impaired or die as dopamine plays an important role in movement control (Nat'l Inst on Aging, 2022). DBS has also been successful in people with PD in controlling VT, albeit with less consistency (Baudouin *et al.*, 2023). Location of the electrode implanted in the brain may impact DBS effectiveness in PD patients (Baudouin *et al.*, 2023).

An in-depth review comparing research that links areas of the brain to VT and its associated neurological diseases with what is known about brain activity and speech and singing

production is outside the scope of this literature review. However, such a discussion has the potential to guide research on neuroplasticity and VT, eventually leading to the development of exercises designed to influence a compromised or aged brain, vocal production, and vocal control.

Singing and Voice Exercises as Treatments for Voice Tremor

Behavioral therapies have had varied success in the treatment of VT, and attempted methods have not been well documented (Barkmeier-Kraemer, Lato and Wiley, 2011). Even when medical intervention is effective, patients may request additional therapies for addressing voice and communication issues (Barkmeier-Kraemer, Lato and Wiley, 2011). While the results of protocols have varied, researchers have emphasized that longer protocols lasting 8-16 weeks with sessions occurring multiple times a week may be necessary for positive results (Baumgartner, Sapir and Ramig, 2001; Obert and Henny, 2024).

Diagnostics

A large body of literature discusses diagnostic challenges in the field of VT. While outside the scope of this review, it is interesting to note the focus in the medical field on characterization, evaluation, and quantification methods (Ludlow *et al.*, 2008; Gillivan-Murphy and Miller, 2011; Xavier and Simonyan, 2022). This trend is likely due to the assumption that a better understanding of the features of each type of tremor would lead to an increased understanding of causes of VT, broader ability to diagnose associated medical conditions, and development of targeted treatment plans (Xavier and Simonyan, 2022).

Familiarity with VT traits that are associated with specific sounds and characteristics of phonation can be helpful when designing singing exercises to benefit a specific student. A strained or strangled voice can result from the vocal cords spasming shut in adductor spasmodic dysphonia which often presents with phonatory breaks, hoarseness, monotonal pitch, and a strained voice quality (Carroll, 2023). In adductor dysphonia the thyroarytenoid and lateral cricoarytenoid contract irregularly (Xavier and Simonyan, 2022; Esper, 2023). A breathy or whisper sound can result from abductor spasmodic dysphonia which occurs when the vocal cords spasm open due to uncontrollable contractions of the posterior cricoarytenoid muscle. (Xavier and Simonyan, 2022; Esper, 2023). Difficulty producing voiceless consonants (/p/, /t/, /l/, /h/, /f/, /s/) is associated with abductor dysphonia (Carroll, 2023). Ragan advises for the used of respiratory coordination exercises, which coordinate airflow, air pressure and phonation, to

improve vocal fold closure (2020). Such exercises might include evenly sustaining unvoiced consonants or alternating between voiced and unvoiced consonant pairs such as s-z (Ragan, 2020).

Exercises

Several studies have looked at the effect of specific exercises on VT or voice quality, that is defined in the study to include VT. Many studies in the literature focused on people with PD. One study assessed the effect of therapeutic group singing and straw phonation (as a form of semi-occluded vocal tract (SOVT) exercises) on voice quality in persons with PD and found both to significantly improve voice quality measures after one session (Lee, Dvorak and Manternach, 2024).

Another study engaged individuals with PD in one session of group singing and found a 50% decrease in tremor (Stegemoller *et al.*, 2022). Measurements of improvement were based on sections 3.14-3.18 of the Movement Disorders Society Unified PD Rating Scale, 3.17 of which specifically observes tremor in the lips and jaw. While VT was not assessed specifically, VT accompanying PD is thought to be affected by tremor in musculature neighboring the larynx, therefore a reduction in overall tremor is noteworthy (Goetz *et al.*, 2008). Group singing sessions lasted 1 hour. Sessions included postural and diaphragmatic breathing exercises, multiple songs, and vocal exercises comprised of going from a lip trill to a sustained vowel, ascending and descending slides in intervals from a 3rd to an octave, messa de voce exercises, and articulation exercises in which multiple consonants (m, t, d, s and k) were paired with each vowel and sung following an ascending scale through the comfortable vocal range of the group (Stegemöller *et al.*, 2017; Stegemöller *et al.*, 2017; Stegemoller *et al.*, 2022).

These exercises are similar to Joseph Stemple's Voice Function Exercises (VFE) aimed at strengthening, stretching, and coordinating laryngeal muscles, increasing vocal fold adduction and coordinating respiratory muscles and the systems involved in vocal production (Behrman and Haskell, 2020).

Group and choir singing programs for PD have grown in popularity. Parkinson's UK credits such programs, which incorporate postural, breathing, vocal exercises, and singing with helping to address VT and amplitude variability experienced by people with PD (Moore, 2022b, 2022a;

Parkinson's UK, 2024). A study that provided 20 weeks of group singing therapy to people with PD saw significant improvements in singing quality and vocal range (Elefant *et al.*, 2012).

Another study compared the singing of people with and without PD to determine if singing, like speech, was affected by the disease (Harris, Leenders and de Jong, 2016). Typically, speech in PD patients has certain audible levels of dysprosody (speech lacking fluid rhythm, intonation, melody, or pattern). Researchers looked at pitch, range, pitch variability, tempo, and interval size and variability during singing and did not observe significant differences between groups (Harris, Leenders and de Jong, 2016). These results imply a dissociation of speech and singing in PD patients and suggest that singing may be helpful in improving prosody in PD patients. Research is warranted into whether singing and exercises targeted at retraining laryngeal and pharyngeal muscles may help to improve voice quality in people with PD (Harris, Leenders and de Jong, 2016).

The Lee Silverman Voice Treatment program (LSVT) was designed for people with PD to improve speech and respiratory functions (Baumgartner, Sapir and Ramig, 2001; Behrman and Haskell, 2020). The program focuses on speech volume consistency, a common symptom experienced by people with PD. Participants are instructed to produce a loud voice, sustain effort during phonation, and remain aware of the volume of their voice and the effort used to produce it (Baumgartner, Sapir and Ramig, 2001). Studies have shown improvement even after 2-years of starting the LSVT program in glottic closure, vocal fold vibration, sound pressure level, voice frequency range, voice quality, and speech intelligibility (Wang and Song, 2022). It is unclear what effect this program has specifically on vocal tremor.

A few protocols are defined in online trainings and literature to target EVT. A voice therapy protocol was designed to assist a patient with EVT who exhibited traits that elevated tremor production and/or a listener's perception of the tremor. Overall relaxation of the head and neck was encouraged using breathing, meditation, and muscle contraction and relaxation methods. Vocal exercises were aided by amplification and auditory feedback mechanisms to help the subject monitor speech production. After 9 weeks of therapy, the subject reported on the program favorably, with improved public speaking and communication ability. The remaining tremor appeared most during singing and when tired. Data collected before and after treatment showed an increased articulation rate and an increase in the number of pauses used between words and phrases (Barkmeier-Kraemer, Lato and Wiley, 2011). See Appendix 1 at page 38 for

tremor variables, vocal impacts, and corresponding exercises used in the Barkmeier-Kraemer, Lato and Wiley study.

Alam et al. looked at the impact of a similar protocol of exercises on 2 patients with VT. After an 8-week program that met twice per week, the exercise protocol resulted in improved quality of life measures in both patients and improvements in shimmer and harmonic noise to ratio measures (HRN) (Alam, Munjal and Panda, 2017). HRN is a measure indicating how efficiently air flows through the vocal mechanism without turbulence (Fernandes *et al.*, 2018). See Appendix 2 at page 40 for the VT protocol used in the Alam, Munjal and Panda study.

Voice therapist and speech-language pathologist, Kerrie Obert, in a lecture on vocal tremor, discussed a treatment plan she developed with patients that may result in a 50-80% reduction in VT when exercises are repeated 3-4 times a week for 12-16 weeks (Obert and Henny, 2024). According to Obert, when we hear a “wobble” or a vibration that is slower than it should be, it is an indication that there is insufficient muscle contraction supporting the vocal mechanism (Obert and Henny, 2024).

Obert designed a voice therapy protocol for EVT after many years of working with patients using Stemple’s VFEs. Obert’s protocol aims to strengthen vocal fold muscles themselves. It is unknown if these exercises add muscle mass to the vocal folds, or compensate for their weakness by strengthening the tongue, velum, and other muscles in the pharynx and larynx. Obert hypothesizes that by doing these exercises, the neuroplasticity of the brain is also developed, and muscles re-learn how to function with reduced tremor (Obert and Henny, 2024).

Obert further discusses her methods on a training video entitled *Strategies to Address Vocal Tremor in the Clinic and Studio Settings* (Obert, 2023b). Her protocol was developed and extensively used with EVT patients but has not been used specifically for patients with PD. A formal study testing the protocol’s results has not been published.

Repetition of the exercise program is recommended 5 times per week for 10-15 minutes for 12-16 weeks at minimum. The program focuses on three exercise strategies: using head voice, maintaining a higher tongue position in the back of the oral cavity and a firmer arch in front, and using a wide-low pharynx to reduce false vocal fold constriction (Obert, 2023b). See Appendix 3

at page 41 for the sample exercises described in Kerrie Obert's proposed therapeutic program to improve VT in patients with EVT.

Conclusion

While much has been written on the classification and measurement of vocal tremor, as well as the effect of medical and surgical interventions, few studies exist that look at stand-alone behavioral therapies such as singing on the management of VT. While incurable, VT has been diminished with singing and voice therapies. Social well-being and QOL measurement have also improved. Additional research is warranted into whether vocal training could offer long term benefits for vocal tremor patients or preventative strategies for an aging population potentially more susceptible to developing VT, just as muscle strengthening or exercise training is used as a strategy for overall body stability and health.

In the quest to develop targeted exercise protocols, researchers should strive to provide detailed, recorded, examples of exercises or singing programs employed. Often descriptions in the published literature are too vague or subjective to allow for the protocol to be repeated or built upon for either further study or treatment, potentially hindering advancement in the field. Once recorded and documented, proposed protocols should be tested for their effectiveness, both perceptually and acoustically.

As with many incompletely understood medical conditions, science looks first at what it can prove, describe, and observe. Singers and voice teachers, however, are more familiar with the concept of experimenting with behaviors and techniques based on what is felt, experienced, and heard. A multidisciplinary approach toward improving the quality of the tremulous voice is advisable to most rapidly increase an understanding of the condition while working with clients to safely develop potential behavioral options to influence their vocal condition, with one field of specialty informing the other about its work and observations, and visa-versa.

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Chart 1: Description of tremor variables, vocal impacts and corresponding exercises used in the study. (Barkmeier-Kraemer, Lato and Wiley, 2011).

Tremor Variable	Vocal Impact	Targeted Exercise
Increased tremor	More tremor during sustained phonation than conversational speech.	<i>Easy voice onset</i> used to reduce effort during vocal onset.
	Loud speech production	<i>Anterior focus on vocal production</i> to improve vocal tract resonance thereby increasing anterior vibration sensation – or singing with an “open throat”- in the anterior vocal tract to reduce pharyngeal and laryngeal tension.
Decrease tremor	High pitches and whisper	<i>Yawn-sigh</i> used to create a softer and breathier sound and increase airflow through vocal folds. <i>Easy voice onset</i> to create a softer and breathier sound and increase airflow through vocal folds.
Tremor more audible	Slower articulation rate over longer timeframes made tremor more apparent	Use <i>faster articulation rate</i> (closer to the average speech speed of 5 syllables/second). <i>Increase pauses</i> between phrases.

Increased tremor and voice breaks	Occurring at the end of utterances due to downward pitch inflection	<i>Slightly elevated pitch</i> and <i>Steady pitch level</i> encouraged at the end of phrases.
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Appendix 2

Chart 2: Voice Tremor Protocol in the Alam, Munjal and Panda study (Alam, Munjal and Panda, 2017).

Vocal Exercise	Method & Purpose
Laryngeal lowering	Using low-pitch phonation to cause vocal system relaxation and stability.
Yawn-sigh	A yawn followed by a sigh and phonation that lowers the larynx, places the tongue forward, and creates a slight opening between the vocal folds, creating a dilated pharynx.
Easy voice onset	To promote increased airflow through the vocal folds to achieve a slightly breathier and softer voice.
Anterior focus	to improve vocal tract resonance or voice projection by producing a whisper followed by lightly voiced front of mouth sounds.
Differential relaxation exercise	Relaxing and then tightening each part of the body from head to toe or toe to head.
Breathing exercises	to stabilize the diaphragm and respiratory musculature and to lower the larynx through forceful inhalation, exhalation and abdominal breathing techniques.

Chart 3: Sample exercises from Kerrie Obert's proposed therapeutic program to improve EVT (Obert, 2023b).

Exercise Name	Exercise Description	Targeted Area	Description
Kitten voice	Using a soft, quiet, and unforced head voice make a "meow" sound going down the scale for five pitches. Begin solidly in M2 working through the passagio into M1, but maintaining the soft, almost baby-like character of the voice.	Pharyngeal musculature	Head voice requires: 1. Stretched vocal folds 2. Pharyngeal narrowing 3. Cricothyroid engagement 4. stabilization of muscles used in lower range
APN (anterior to posterior narrowing) exercises	Vary between sounds that emphasize a "Y-buzz" such as "ye" and sounds that emphasize a raised velum such as imitating Billy Crystal's "Mahvelous" from Saturday night Live sketches, or Julia Child's affected speech.	Larynx, Velum, Pharyngeal musculature	APN stabilizes tongue and laryngeal muscles and requires: 1. Tongue stabilizes the larynx and connects the hyoid to the larynx 2. Tongue tip should touch the back of the lower front teeth while the back blade lowers and flattens 3. Velum stretch as

	Start from a lower pitch and progress to higher pitches,		
Widening false vocal folds (FVF)	On /i/, vary between a whine/cry and a constricted sound.	FVF, lower pharynx	Widening FVF lessens their constriction