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BMPF 7013

Module 5: Independent Study

The Impact of Using Technology in the Vocal Studio

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Part 1 – The Portfolio

Introduction and Rationale

During this study, I will examine the impact of using technology in the vocal studio, applying a two-pronged approach. The first will be a semi-systematic review of the literature on technological tools for measuring vocal output. The second will be a reflective analysis of the practical application of selected technological tools presented in the literature. Based on preliminary searches, I anticipate examining relevant literature from the fields of vocal pedagogy and speech therapy, covering topics such as acoustic measurements, biofeedback, and vocal health markers.

Two presenters of the Voice Study Centre's online short courses for singing teacher training piqued my interest in the topic and inspired the focus of this independent study (Voice Study Centre, 2021). First, Kelly Hiljeh's course *Acoustic "Tips and Tricks" for the Classical Treble Voice* in March 2021 provided a practical look at making sense of mapping vocal tract resonance visualized as a power spectrum generated by the software *VoceVista*. Her course illustrated practical applications for using *VoceVista* to monitor vibrato, legato, onset, length of consonants, etc. (Hiljeh, 2021). Her use of the software to analyze recordings particularly intrigued me, and I thought of how useful this skill could be for me in future research applications. Second, Heidi Moss Erickson's course *Biofeedback in Vocal Pedagogy* in April 2021 presented an excellent explanation of biofeedback, including how to use it to help students improve more quickly, as well as the use of mobile applications as visual feedback tools. I was particularly interested in her practical examples of using mobile applications in the teaching studio and the convenience of mobile applications compared to computer software (Erickson, 2021b).

I am an opera singer and private voice teacher based in Germany. My students range from amateurs to singers well underway in their performance careers in Musical, Opera, and

Operetta. This independent study will give me the tools to explore the use of mobile applications and software in my teaching, as well as allow me to make recommendations to students for technological tools for their independent practice. Erickson's presentation indicates that my students may benefit from the use of technological tools to "uncouple the motor action from the paradigm of judgement, correction, or criticism" (Erickson, 2021b). Using technological tools may help students to approach vocal tasks with less emotion, depersonalizing their process, which may be especially advantageous for beginners. For more established singers, using the technological tools may lend mindfulness and afford them "greater awareness of a physiological function as measured by external feedback" (Erickson, 2021b). Although the ear of a voice teacher is irreplaceable, my students may benefit from the use of technological tools as a tool for increased self-regulation. Erickson describes the advantage of "sensory distraction" in the form of biofeedback via a mobile application, especially when the singer is overthinking an aspect of vocal technique (Erickson, 2021b).

Using technology in the studio has a historic precedent. In 1855 Manuel Garcia pioneered technology in the voice studio with his invention of the laryngoscope to "view the vocal folds during singing" (Stark, 2008, pp. xxi-xxii). Since the 19th century, many pedagogues have followed in Garcia's footsteps, using a laryngoscope to scientifically analyze and illuminate the process of singing, including early adopters Emma Seiler, Lennox Brown, and Emil Behnke (Stark, 2008, pp. 78-79). Caruso's laryngologist, P. Mario Marafioti, studied tongue shape and vowel position during singing via x-ray technology in the 1940s (Marafioti, 1981, pp. 237-231). Building upon Hermann Helmholtz's (1821-1894) acoustic theory, Gunnar Fant used speech synthesis and formant synthesizers in his landmark study, that "presented a 'source-filter' theory of vowels," published in 1960 (Pearce; Stark, pp. 46-48). Fant's study gave rise to a growing body of scientific research and discoveries using spectrographic analysis, which has flourished "in the last sixty to eighty years" (Bozeman, 2013, foreword).

However, much of the technology used to study the voice "has been geared primarily toward research- and academic-oriented pursuits," and has remained the domain of researchers in laboratories full of sophisticated and expensive equipment (Erickson, 2021, p. 485). Some "robust applications and scripting languages such as *Praat* and *Matlab*" are more accessible, however, Erickson describes these as "complicated to learn and tedious to analyze" (Glasner, 2019, pp. 11-12; Erickson, 2021, p. 485). Donald Miller's work on creating the software *VoceVista* aimed to bring technology to the studio and make acoustic feedback, in

particular, more accessible (Miller, n.d.). In addition, advances in mobile application technology have made using technology in the vocal studio even more accessible. We now have the power of “acoustic visualization, involving various forms of spectrograms” in our pocket (Erickson, 2021, p. 485). Although technology use in the studio is not yet mainstream, advances in scientific equipment and an emphasis on quantitative data in voice pedagogy research have led to more adoption of technological tools for pedagogic use. There is a corresponding increase in literature on the use of technology in the voice studio.

Throughout my recent studies, I have increasingly broadened my understanding of the scientific aspects of singing, particularly in anatomy, physiology, and acoustic pedagogy. This knowledge has led to positive growth, greater confidence, and increased competence in my teaching. My aim with this literature review is to experience a similar developmental leap by becoming conversant in using technological tools for my singing practice and teaching practice. This assignment will equip me with more tools to guide my students toward vocal efficiency and self-reliance in their practice at home, and thus the freedom to explore the full expression of their artistry.

Planned Program of Study

Aims

The aims of this project are:

- To investigate the impact of using technology in the vocal studio.
- To learn to read a voice power spectrum (vocal tract resonance analysis) in real-time.
- To develop fluency with technological tools for the studio, such as spectral analysis software and mobile applications.
- To identify the practical pedagogical uses of technology.
- To integrate ideas from acoustic vocal pedagogy, biofeedback, and vocal health, “making connections between ideas, theory, and experience” to develop more effective teaching skills (Hart, 1998, p. 15).
- To develop skills related to conducting a semi-systematic literature review.
- To “acquire new intellectual abilities [I] did not have before beginning [my] research (Hart, 1998, p. 25).

Objectives

- To identify the major contributors to the topic.

- To collect, contrast, and compare literature, including primary and secondary sources.
- To identify any discrepancies between authors.
- To identify emerging themes and patterns in the literature (Snyder, 2019, p. 335).
- To keep a reflective journal to observe the use of technology in practice.
- To determine metrics for assessing technological tools for their usability in the studio.
- To identify which technological tools may be applicable for recommending to students for independent practice.
- To assess the suitability of technological tools for future research projects.
- To identify which technological tools may be practical for a voice teacher that teaches in varying spaces, vs. those which are more useful in a studio with a fixed location and equipment.
- To devise and hone teaching strategies based on the research.

Timeline

The following table illustrates the proposed timeline for the project, including a vacation period in which I blocked out work on the project.

Module 5, BMPF7013 – Independent Study	
17 – 20 July	
• Project begin • Review Module Handbook • Review exemplars • Review literature review methodology/tools	
	21 – 26 July
• Vacation	
	27 July – 17 August
• Topic choice in conjunction with tutor • Write timeline • Background Reading/Preliminary Survey • Write Project Rationale, Aims, and Objectives • Write methodological approach to Literature Review	
	18 August – 28 August
• Vacation	
	28 August – 19 September
• Submit a draft of completed sections of Part 1 (September 1) • Source, skim and organize literature • Establish inclusion and exclusion criteria	
	20 September – 9 October
• Source, read and organize literature, taking preliminary notes for Part 2	

• Refine topic if necessary • Download software and apps	
	10 – 31 October
• Write a draft of Part 2 – The Assignment (Lit Review) • Experiment with various software and apps in my singing • Experiment with selected software and apps with students • Write a draft of Part 2 – The Assignment (Reflective Analysis)	
	1 – 17 November
• Submit draft (November 1) • Write critical reflection of the learning process • Re-writes and edits	
	November 18, 2021
• Final Submission	

Independent Study Process

Methodology

“Keeping up with recent developments and recent findings can be an impossible, if not daunting process” while balancing the demanding task-loads and busy schedules of life (Rhoades, 2011, p. 61). Staying current in the literature on technology, which is a fast-moving and ever-changing landscape proves especially challenging. Hubmeta, a collaborative tool for organizing meta-analysis data, points out that “the size of research fields doubles every nine years,” progressively increasing the number of sources available for review (Hubmeta, 2021). In addition, the “fragmented and interdisciplinary” scope of research adds to the challenge of distilling knowledge via literature review and developing theories for practice (Snyder, 2019, p. 333). A pragmatic approach will allow me to shape the methodology of this semi-structured literature review to my personal development by sourcing literature to support the creation of strategies for my teaching practice. An exhaustive systematic review is outside the bounds of this study, which will be limited in scope. The pragmatic paradigm applies to a small-scale study particularly well (Morgan, 2014, p. 1051). The pragmatic paradigm’s philosophical positions acknowledge the role of the researcher’s beliefs and actions, which affect change upon each other cyclically, making this paradigm suitable for reflective analysis (Morgan, 2014, p. 1051).

For this literature review, I intend to seek out a combination of the latest journal articles on technology for the voice and sources from pedagogues using technology in their practice, ranging from books to grey literature. Approaching this project from the pragmatic paradigm will afford me the flexibility to engage with literature that mixes and matches quantitative or qualitative “data collection and analysis methods” (Mackenzie and Knipe, 2006, p. 4). I will use a hermeneutical approach to draw conclusions and identify trends from disparate sources. To synthesize findings from the literature, I will use documentary analysis to identify common themes, gather story-rich data, and triangulate data where possible (Berg, 2001, pp. 190-203; Morgan, 2014, p. 1048).

To triangulate the inferences made from the literature review, I will take a hermeneutic approach to a reflective analysis, embracing the role of an insider researcher. Instead of seeking to remove my viewpoints, these “biases and assumptions” will be integral to the “interpretive process” (Laverty, 2003, p. 28). I expect that engaging with the technology presented in the literature will create a research process that moves along the hermeneutic spiral and informs subject comprehension as a whole (Boell and Cecez-Kecmanovic, 2010, pp. 130-132). A hermeneutic manner of engaging with both data and practice in an iterative process will allow me to corroborate conclusions as much as possible. My aim is that this depth of understanding of the topic will generate fresh lines of thought for my practice and future research (Rhoades, 2011, p. 69).

Search Strategies – Literature Review

At the time of writing, I have conducted a “preliminary survey,” to familiarize myself with key authors and journals in the field (Oliver, 2012, p. 40). I expect my knowledge of leaders in the field to expand during the search process. The preliminary survey has also identified keywords within the topic, such as acoustic analysis, biofeedback, vocal health, which I expect will align with thematic coding during documentary analysis and subheadings when presenting the findings in Part 2. Besides keyword and author searches, I anticipate that “snowball, aka ancestry searching or pearl growing,” will prove to be a useful search strategy to uncover the literature specific using technology in the vocal studio (Boell & Cecez-Kecmanovic, 2010, p. 138; Steel, Beugelsdijk, & Aguinis, (2021, p. 25). Although the semi-structured review will “[cover] broad topics and different types of studies”, I will make inclusion and exclusion criteria transparent to “enables readers to assess whether the arguments for the judgments made were

reasonable” (Snyder, 2019, p. 335). I will keep a log to detail the steps I took to collect, analyze and interpret the literature (Rhoades, 2011, p. 66; Steel, Beugelsdijk, & Aguinis, 2021, p. 26).

Types of Sources – Literature Review

I expect to include 1) peer-reviewed articles and conference proceedings, 2) books, and 3) grey literature, such as blog posts, video posts, and video course material in the Voice Study Centre library. I expect to concentrate on recently published literature, particularly journal articles, especially on the topic of mobile applications, whose availability and version changes rapidly. However, based on preliminary reading on *VoceVista* I expect that some less current materials will still be of value. I do not plan to exclude literature solely according to publication date. Vocal pedagogy, like “scientific knowledge is the result of a multi-generational collaboration where we cumulatively generate and connect findings” (Steel, Beugelsdijk, & Aguinis, 2021, p. 23). This overview approach will allow me to gain a broad picture of the current trends and common knowledge in the field. At the time of writing, my search for peer-reviewed articles has included sources from journals across several scientific disciplines, such as the *Journal of Singing*, the *Journal of Speech, Language and Hearing Research*, the *International Journal of Language and Communication Disorders*, *Vox Humana*, *Psychomusicology: Music, Mind and Brain*, the *Empirical Musicology Review*, the *Journal of Voice*, and *Üben & Musizieren: Zeitschrift for Musikschule, Studium und Berufspraxis* (*Practicing and Making Music: Periodical for Music Schools, Degree Programs and Professional Practice*).

Source Organization – Literature Review

Based on preliminary searching, I expect it will be a challenge to balance limiting the literature collection enough “to make the review possible, while still broad enough to be meaningful” (Rhoades, 2011, p. 66). I have started a spreadsheet tracking attributes, from which I will develop a strategy for establishing inclusion and exclusion criteria. I will use this spreadsheet for note-taking and article summaries to facilitate categorizing the “literature into meaningful sections” as themes (or discrepancies) emerge (Oliver, 2012, p. 80).

Reflective Analysis Process

Hiljeh’s presentation included remarks on how to learn to use the software *VoceVista*. She recommended playing with it in one’s own singing practice before introducing it as a tool in

lessons. Furthermore, she warned it was possible to do more harm than good by trying to meet an arbitrary target in the software without having “calibrated” one’s eyes and voice. I plan to use reflective analysis in this independent study to explore using these tools in my own singing practice, to develop fluency in using the tools as a singer, before employing them with my students or in future research (Hiljeh, 2021).

“Reflection has been described as a process of turning experience into learning, that is, a way of exploring experience in order to learn new things from it” (Boud, 2001, p. 10). I will use a note-taking mobile application to keep a reflective journal following practice sessions and any experimentation in lessons with software or mobile applications. The journal will be a “reflection-on-action” tool to “review, describe and analyse” experiences with the technology in practice “with a few to gaining insight to improve future practice” (Finlay, 2008, p. 3). Building on Dewey and Schön, Boud recommends a model for “reflection-on-action” and specifically ties it to journal writing. *Figure 1* “[describes] the main features of the model and [discusses] the implications for journal writing of each feature in turn” (Boud, 2001, p. 11).

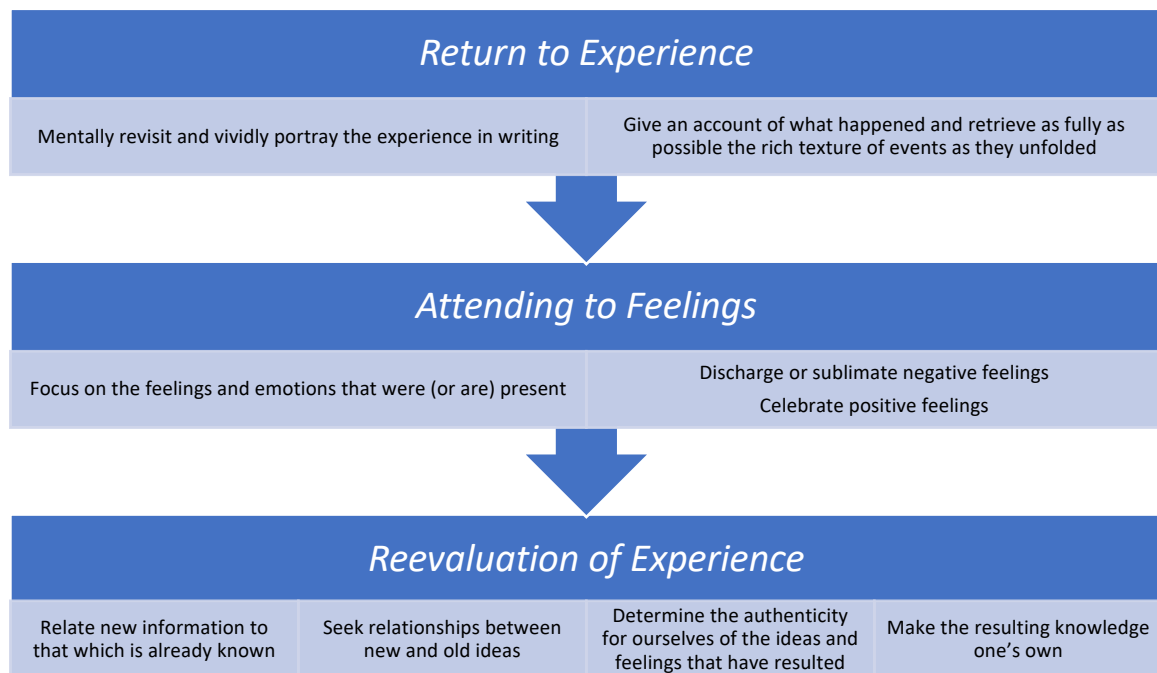


Figure 1 - Boud's Model of Reflection and its Implications for Journal Writing (Boud, 2001, pp. 13-15)

Personal Bias

Including a reflective journal to link literature review findings to professional practice, will prevent the assignment from avoiding biases completely. Following a line of inquiry “within [my] own work practice,” may magnify the impact of a researcher’s position and background on my research (Costley, Gibbs, and Elliot, 2014, p. 1). However, using the model outlined above, I hope to avoid becoming overly vested in achieving a certain outcome or become myopic (Mercer, 2007, p. 11).

Some “availability and cost biases” are likely inherent, as I will be limited to literature sources that are open access, or available via UWTSD and the Nürnberg Stadtbibliothek (Nuremberg City Library) permissions (Rhoades, 2011, p. 25-27). Sourcing software and applications for reflective analysis will also depend on my budget for investing in such tools.

Although I am open to including literature from other disciplines, the focus on literature from singing voice journals and notable pedagogues in the field will lead to some amount of “familiarity bias” (Rhoades, 2011, p. 25-27). However, this review will hopefully lay the foundations for fluency with the current landscape of technology available for voice professionals.

Based on the materials that I have sourced to date, the bulk of the material appears to be in English, which will lead to a fair amount of “language bias” (Rhoades, 2011, pp. 25-27). However, at the time of writing, I have identified at least two notable contributors to the field publishing in German. I plan to transparently record the steps I took to collect sources and to aim for “an impartial summary description of the evidence generated by each relevant and credible study” (Rhoades, 2011, p. 69). This review will serve as a snapshot of the current technological tools for measuring vocal output, “[mapping the] field of research” and “[synthesizing] the state of knowledge” (Snyder, 2019, p. 335). In addition to generating theory development for my practice, this independent study may prove to be of value for future research, in particular the following and final module in pursuit of the MA in Vocal Pedagogy.

Critical Reflection – “The Learning Process”

Following Boud’s advice to “[attend] to feelings” in reflection uncovered both negative and positive emotions, which affected the learning process (Boud, 2001, p. 13). “Reevaluating the experience” with these feelings, I identified changes I will make for future projects, as well as strategies that served me well. I was interested and motivated to start the project, and I could devote significant time to the project early in the process. I am gratified by the learning that has occurred in this module. Working with technology encountered in this study will shape my research design and impact data collection in the final module.

The greatest challenge I faced in the learning process was time management. During my summer vacation, I reviewed literature review methods, met with my tutor, searched and collected literature, and read a little along the way. While visiting my grandmother in the US on vacation, it became clear that she could no longer live alone. I cancelled other travel plans and delayed my return to my home and work in Germany multiple times. In 5 weeks, I found an Assisted Living Institution, organized medical testing resulting in an Alzheimer’s diagnosis, moved my grandmother into her new home in Assisted Living, and cleaned out her former home. Due to my husband’s work schedule and the illness of the only other living relative of my grandmother, I completed this primarily on my own, and effectively put the brakes on my own life to care for her. Thankfully, she is receiving excellent care, and I could return to Germany and manage her medical care and finances from afar with the help of the facility and her local friends. Upon returning to Germany, however, I found myself behind on more than just my studies and another couple of weeks went by before I could resume work on this independent study. I found re-starting after such a long and emotional break daunting, and I stressed over the deadline. Unlike some who flourish under deadline pressure, I find procrastination somewhat paralyzing. However, I could arrange a week extension for submission, and thankfully, because of my interest in the subject, I could recover from this unexpected time management obstacle.

Learning Strategies to Modify

Not only did I face less time than expected to complete the project, but I engaged in time-consuming processes. I chose an extensive model for keeping a reflective journal, which I found cumbersome. I kept the journal in a note-taking application, however, I often found myself pressed for time, and I augmented the written entries with voice memos to myself to speed the

process. Although the reflective journal was useful for incorporating learning into practice, I will choose a more streamlined approach in the future. I kept a spreadsheet of notes arranged thematically while reading. During the writing process, I often returned to the source from my notes and re-read. Although this hermeneutical process of zooming into detail and out to consider the whole was beneficial for identifying themes, it was time-consuming and my resulting early drafts were quite long-winded. I plan to use this thematic note-taking process in a spreadsheet in the future. However, I will simplify my processes and start the writing process with an outline rather than rambling drafts.

Learning Strategies to Continue

In the final module of this course I study, I plan to continue using two successful strategies. I will start early, using free days to put in longer stretches of work, in addition to the small, regular process accumulated on work-days. Starting early on this module set me up to cope with unexpected demands on my time and face stress as deadlines approached. In addition, I will continue to keep a logbook tracking the tasks completed, to-dos, new terms, and search strategies. Referring to my logbook helped me pick up where I had last left off and to keep search limit parameters consistent when sourcing literature.

Part 2 – The Assignment

In this independent study, I sought out literature to explore the impact of technology in the studio. In many aspects, I have been engaging with technology in my singing and teaching practice for many years, making use of various computer software, mobile applications, and online platforms. I can't imagine teaching without my students' music organized on a tablet, or mobile applications providing a foreign language dictionary, metronome, pitch pipe, or accompaniment tracks in my pocket. However, I was intrigued to discover more sophisticated technological tools for teaching, especially after reading on acoustic pedagogy in the previous module. I limited my reading to sources on technology that would be appropriate for my teaching practice, focusing on technology that was accessible, portable, and non-invasive. Literature on mobile applications introduced me to tools for ear training, solfeggio, composing, music theory, sight-reading, vocal anatomy and physiology, gender-confirming voice training, and more. I am interested in exploring many of these interesting applications further, however, for this assignment, I concentrated on technology for acoustic measurement, biofeedback, and vocal health.

Literature Review

After reading and some basic exploration of some of the technical tools readily accessible (see Reflective Analysis), I agree with the prevailing opinion that technology should complement and not supplant a voice teacher's intuition and experience (Erickson, 2021a; Mackowycz, 2021; Rollings Bigler, et al., 2021; Sataloff, 2020; Stark, 2008; Titze, 2020). Modern voice teachers must draw from both the wealth of legacy knowledge and the latest advancements in voice pedagogy and voice science research, "balancing both the science and the art of voice teaching" (Broadwater, 2021, p. 598; Rollings Bigler, et al. 2021, p. 12). The literature characterized technology as a means to yield objective assessments and measurements of singing and speaking. Technology was often described as a mechanism to address the shortfalls of subjective perception and lack of language uniformity among voice professionals (Gunjawate, Ravi & Bellur, 2018, p. 40; Jannetts, Schaeffler, Beck, et al., 2019, p. 293; Müller, 2001, p. 16; Sataloff, 2020; Titze, 2020). "Singing teachers mainly draw on their personal experience within an essentially oral culture," however, the literature refers to the long-standing historical precedent of seeking out "extra-auditory information" provided by various technologies to improve teaching and student outcomes (Broadwater, 2021; Manfredi, et al., 2015, p. 517.e1; Rollings Bigler, et al., 2021, p. 12-14). Integrating technology in the teaching studio is becoming more practical, especially considering the rise of accessible, portable, and intuitive user interfaces available in mobile applications (Erickson, 2021a, p. 485; Mackowycz, 2021, p. 40). As with any teaching method or tool, the use of technology must be adapted to the learning style and needs of individual students (Broadwater, 2020, p. 595). Meyer, Nix, and Okerlund recommend that "once introduced to this technology, students can take the lead on how much or how little they would like to use it in and/or out of the studio" (2021, p. 641).

In a short commentary on using instrumentation in the studio, Titze pointed out a disconnect between the language we typically use to talk about the singing voice in the voice community and the language which describes "acoustic properties of sound" (2020, p. 565). He succinctly connected several basic concepts in an approachable manner, which provided me with model language for discussing these concepts with students.

"Fundamental frequency correlates well with pitch, sound pressure level (SPL) correlates less well with loudness, aperiodicity correlates somewhat with roughness, and spectral features correlate moderately well with tone color and timbre." (Titze, 2020, p. 565)

Articles pointing out the connection between specific pedagogical goals and various software applications identified “where these tools can have maximum effectiveness” (Erickson, 2021a, p. 485; Mackowycz, 2021, pp. 43-44). Erickson argued that “simple vocal elements” were the best suited for training with technology, and provided examples for improving “pitch stability, onset/offset, vibrato, legato, and trills” via mobile applications (2021a, p. 490). Journal article images provided information to support linking the theory with practical application in the studio. For example, several articles included screenshots of applications illustrating the technological analysis of specific vocal tasks, which guided me in trying out the technology in the reflective analysis (Erickson, 2021a; Evans, McHenry & Averyt, 2020; Mackowycz, 2021; Müller, 2001). Figures of spectrograms illustrated how to distinguish between ambient noise and the singer’s vocal output, how to identify vocal noise, and how to identify resonances above the vowel formants, particularly in the crucial range between 2600 and 3400 Hz (Evans, McHenry, & Averyt, 2020, pp. 38-40).

Acoustic Measurements

Using software to give a spectral analysis affords the teacher or singer a visual model of the shaping of the vocal tract and the resulting resonance strategies. “Spectral analysis software typically features two important displays: the spectrogram and the spectrum”—see *Figure 2* (Meyer, Nix & Okerlund, 2021, pp. 638-639). A spectrogram, typically measured in frequency (Hz) along one axis and time along the other axis, illustrates the strength or loudness of a signal and “all the component frequencies,” or resulting harmonics or overtones that make up our vocal sound (Meyer, Nix & Okerlund, 2021, p. 638; Müller, 2001, pp. 19-20). The display indicates the relative strength or weakness of each harmonic, allowing for a much more sophisticated understanding of what may make a particular tone more or less resonant (Müller, 2001, pp. 19-20). We may describe a spectrogram as the “long-term view” (Sygyt Software, 2021). The spectrum, “an offshoot of the spectrogram, [displays] detailed information about harmonic frequency and strength at a chosen moment in time, measured in milliseconds” (Meyer, Nix & Okerlund, 2021, pp. 638-639). The spectrum zooms into a “short-term view” of the signal (Sygyt Software, 2021). Literature on acoustic pedagogy, read in the previous module, provided some consensus for which areas of the vocal tract have the most effect on specific formants. The chart in Appendix 2 may prove useful for implementing concrete pedagogic strategies for resonance tract shaping based on acoustic measurements.

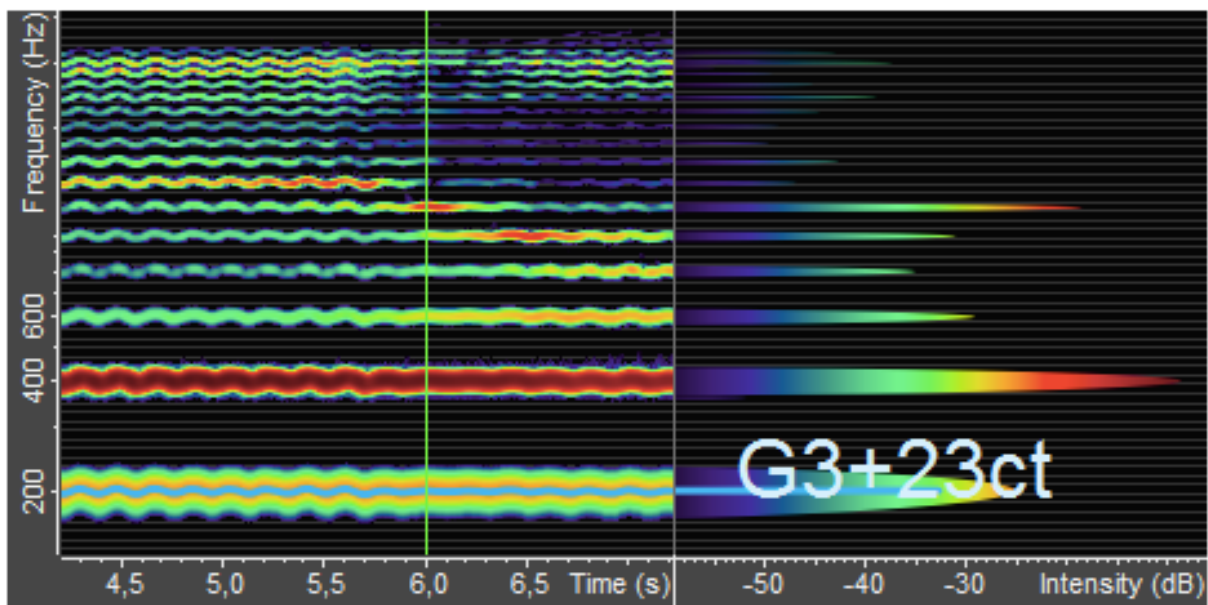


Figure 2 - Spectrogram (left) and Spectrum (right) displays side by side (Sygyt Software, 2021)

Several sources in the literature enumerate the pitfalls of comparing acoustic measurements across studies, pointing to the lack “of standardized criteria for the evaluation of singing voice” (Gunjawate, Ravi, & Bellur, 2018, pp. 40). Systematic reviews show the absence of standardized technical specifications and data collection methods, as well as the lack of homogeneity among subjects in the studies reviewed (Gunjawate, Ravi & Bellur, 2018, pp. 40 & 49; Patel, 2018, p. 888). Despite the difficulties this poses for the systematic reviewers, the diversity of populations studied offers the voice teacher instructing in different styles insight into some differences in vibrato and singer’s formant across several genres and geographical regions (Domenighini, 2021; Gunjawate, Ravi & Bellur, 2018; Malaschenko, 2020; Proutskova, 2013).

Assessing Audibility

A study by Evans, McHenry, and Averyt examined spectrographic evidence from singers in several environments, noting that the visual feedback from spectrogram software aligned with expert judges’ perceptions of singers’ ability to be heard over an orchestra. Although sound pressure levels are “very environment-sensitive,” Evans, McHenry, and Averyt noted that the “spectrographic signatures” for each singer were consistent across several types of spaces, from small rooms to large concert halls (Evans, McHenry, & Averyt, 2020, p. 37; Nix, et al., 2021, p. 511). This spectrographic consistency is notable, considering the impact of “sound

behaviors” and “reverberation times” in varying space, and the resultant effect this has on the singer’s auditory perception (Domenihini, 2021, p. 362). Evans, McHenry, and Averyt argued that technology used during the audition process assists adjudicators in “[predicting] viability in performances onstage with a full orchestra, and [helps] inform their pedagogic strategies” (2020, p. 41).

Setup and Calibration

Evans, McHenry & Averyt’s evidence offers several valuable take-aways for the private voice studio. The study used the software application Audio Analyzer, developed by Pawel Krzywdzinski. The authors noted that the application allows the user to adjust input levels, which the authors argue is “essential” (Evans, McHenry & Averyt, 2020, p. 42). In addition, the authors pointed out the importance of setup. This article prompted me to experiment with the distance between the singer and the device while exploring the software in my reflective analysis.

Maintaining an appropriate distance from the sound source is crucial when using any handheld device. Pilot work has indicated that “arm’s length,” typically used in practice rooms and studios, results in distorted input and false readings (i.e., the impression of energy in the higher harmonics when there is little or none). A distance of 12–14 feet is crucial for accurate readings. (Evans, McHenry, Averyt, 2020, p. 37).

While a teacher may have success with a setup that allows for 12-14 feet between the singer and the input microphones of the device, I am concerned that a student would need a much closer setup to respond to the visual feedback, especially on a small screen. In fact, Nix, et al. advise that the arm-length setup ensures consistency. “Singing at an arm’s length from the smartphone is a simple, repeatable method for maintaining a constant distance” (Nix, et al., 2021, 511). Jannetts, et al. offer some encouragement for yielding good results from a closer setup, suggesting that proper calibration can improve validity. In addition, a study by Grillo, et al., placed various smartphones 4 cm away from the subject’s mouth producing acoustic data, which strongly corresponded with the data captured by studio microphones in the same study. However, this study measured spoken and not sung voice. (Grillo, 2016, p. 10).

Jannetts, et al. suggested “it might be useful to develop a set of reference recordings that can be used to calibrate mobile phones for clinical use” (2019, p. 304). I find this suggestion also valuable for exploring potential new software or adjusting to the

use of familiar software on a new device. The need for proper calibration again supports the idea that using software, which allows for input or gain adjustment is important. In the studio, “research-grade measurements are not necessary,” however, the reliability of the data collected depends on consistency (Nix, et al., 2021, p. 512). To accurately compare measurements collected, the software, the settings, and the device setup must remain stable.

Singer’s Formant Cluster and the Soprano Conundrum

Evans, McHenry and Averyt’s research when applied to soprano voices surprised me and offered useful markers for measuring the acoustic output of soprano voices in the studio. The singer’s formant, or singer’s formant cluster (SFC), refers to an area of resonance in the vocal tract in which the clustering of F_3 , F_4 , and F_5 “increases the spectral energy” around 2400 to 3200 Hertz (Bozeman, 2017, p. 180; McKinney, 1982, p. 125; Manfredi, 2015, p. 517.e2; Titze, Maxfield & Walker, 2018, p. 382.e9; Vos, 2018, p. 126.e1). My reading in the previous module illustrated that this formant convergence of a few-hundred Hz is vital for male voices and less of a factor for soprano and mezzo-soprano voices (Bozeman, 2013, p. 17; Manfredi, 2015, 517.e7; McKinney, 1982, p. 133; Müller, 2001, p. 18; Müller, 2015, p. 9; Wolfe, Garnier & Smith, 2020). In fact, Bozeman argues that the SFC only plays a role for f_0 in the middle and lower ranges for treble voices, generally pitches below D_5 (2013, p. 17). Meyer, Nix, & Okerlund indicate that monitoring the harmonics in the range of the SFC is of interest to Tenors, Baritones, and Basses and does not mention SFC in conjunction with sopranos or mezzo-sopranos (2021, p. 640). Furthermore, Vos states that,

Evidence of a true singer’s formant cluster in sopranos [...] is extremely limited, and it would not necessarily provide the same acoustic benefits for low voices (2018, 126.e1).

However, Evans, McHenry, and Averyt’s analysis of soprano voices “when using the same instrumentation in live performances revealed that those with at least two enhanced frequencies near the 3000 Hz range produced the same results as singers with more clustered harmonics” (2020, p. 41). I found it particularly notable that the authors “observed that at least two, but often three, resonances near 3000 Hz must not only be present, but must have very clear blank spaces between those resonant frequencies, indicating no noise in the voice” (Evans, McHenry, & Averyt, 2020, p. 41).

Whether or not this observation corresponds to the accepted definition of singer’s formant is irrelevant to our specific, real-world purposes. The point is that the

presence of enhanced frequencies near the 3000 Hz range allows the voice to be heard (Evans, McHenry, & Averyt, 2020, p. 41).

Acoustic Measurement of Recordings

I find the prospect of using technology to conduct research on recordings especially intriguing, and I intend to include recording analysis in the research design for my final research project for this course of study. Hiljeh and Müller offered insight into how one may distinguish between the signals of the singer and the orchestra in spectral analysis of recordings. Each suggests that a certain calibration of the eye is part of the learning curve (Hiljeh, 2021; Müller, 2001, p. 22). Happily, Müller reports that this calibration occurs quickly. Around 3000 Hz and above the orchestra is no longer as intense, and the eye can identify the curve of the sung fundamental and resulting harmonics amidst the visual noise of orchestral accompaniment, which fades in comparison to the higher harmonics of the singer. The “overtone diffusion” of the musical instruments of the orchestra is weaker than that of the human singing voice in Western Classical style (Domenighini, 2021, p. 367). When the frequency of the sung fundamental is known, identifying the harmonic curve representing the singer is easier—see *Figure 3* (Müller, 2001, p. 22).

Spectrogram figures of real-time spectral analysis using VoceVista illustrate the astonishing ability to see the harmonic hallmarks that distinguish the voices of famous singers when compared singing the same phrases. Comparing the peaks in the spectral envelope of star tenors Placido Domingo and Luciano Pavarotti singing the climactic B-flat₄ (466 Hz) in the aria “*Celeste Aida*” from Verdi’s *Aida* on the vowel ‘o’ (*sole*) illustrates clear differences in the dominant harmonic – see *Figure 3*. Domingo’s sound is characterized by a dominant f_{R6} , whereas Pavarotti uses a dominant f_{R3} . Considering that the vowel formants for a closed [o] typically range from 430-780 Hz (550-820 Hz for open [o]), one would expect that one of these frequencies would dominate in the spectral analysis of a B-flat₄ ($f_{R1} = 466$ Hz; $f_{R2} = 932$ Hz). However, Müller’s figure (*Fig. 3*) illustrates that the resonance strategies of each famed tenor diverge from this expectation. Shaping their vocal tracts to adjust vowel formants, Pavarotti uses F_2 to strengthen F_{R3} , while Domingo uses the clustering of his singer’s formant to strengthen F_{R6} (Müller, 2001, p. 22). Resonance strategies play a large role in the individuality and recognizability of a singer’s voice. Using technology to analyze resonance strategies offers a fascinating objective insight into resonance strategies that I have previously only perceived via subjective aural perception.

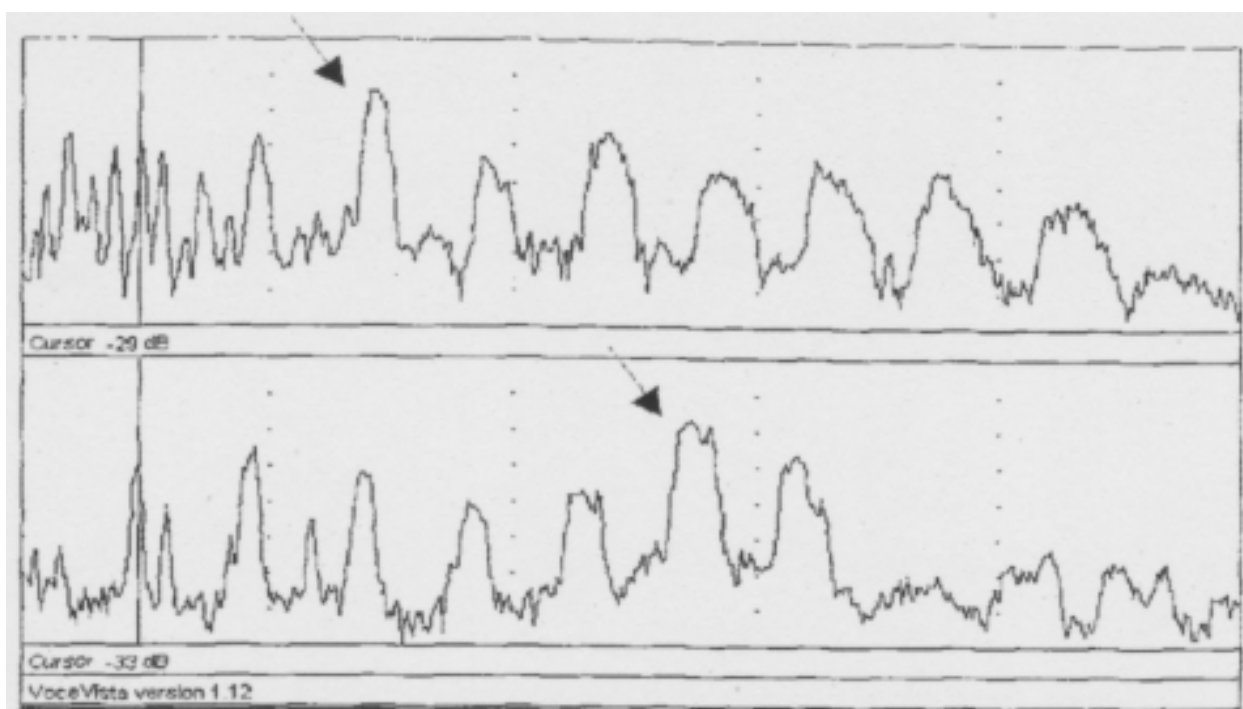


Abb. 6: Der Bildschirm ist in zwei Hälften geteilt, beide zeigen ein Echtzeitspektrum. Oben das b^1 (466 Hz) aus der Arie „Celeste Aida“ auf Vokal „o“ (sole), gesungen von Luciano Pavarotti. Unten der gleiche Ton gesungen von Placido Domingo. Die Pfeile zeigen die jeweils dominanten Harmonischen. Der Strich markiert den Grundton.

Figure 3 - Spectral Analysis Comparison of Recordings of Pavarotti (upper curve) and Domingo (lower curve) from Müller (2001, p. 21); Note that the vertical line marks f_0 and arrows indicate dominant formants, respectively.

Acoustic Measurement—Sound Pressure Level

Using a stand-alone application to measure the sound pressure level (SPL) allows the student to self-monitor loudness, especially during online lessons, when the equipment may affect the teacher's perception of loudness. However, the perception of loudness between teacher and student may differ during in-person lessons as well. "Sound pressure level (SPL) smartphone apps can help to reduce this perceptual subjectivity" (Nix, et al., 2021, p. 511). Developing targets for regulating loudness with a teacher can help the student avoid over- or under-singing.

Biofeedback

Erickson points out the complexity of the motor skills involved in singing, noting that the process requires “the coordination of more than one hundred muscles and broadly connected brain regions to coalesce into a single vocal output” (2021a, p. 486). She suggests that visual biofeedback combined with auditory, kinesthetic, and verbal feedback from a teacher can speed learning in students. The involvement of another brain region employed for visual input creates a “multisensory” learning process, which deepens learning comprehension and stimulates finer motor control and targeted acquisition of “new motor mechanism[s]” (Erickson, 2021a, pp. 485-486; 495). Seeing what one is singing increases the problem-solving capabilities of the brain, improving the efficiency of practice and motor learning (Mackowycz, 2021, p. 42; Müller, 2001, p. 18; Van Stan, et al., 2017, p. 2). Müller elegantly describes the practice of visual biofeedback when using VoceVista as “singing the curve” of the spectral envelope and emphasizes the benefits of using new cognitive patterns to improve singing (2001, p. 23). Biofeedback does not require the student to become an expert in the theory of acoustics. Instead, they simply identify which shapes, patterns, or colors of the particular technological tool that show they are on target, and the desired motor control changes will occur intuitively (Müller, 2001, p. 24). Biofeedback may promote motor learning independence and increased learning “retention of new vocal behaviors”, as the singer explores vocal tasks with minimal emphasis on auditory or perceptual feedback (Van Stan, et al., 2017, pp. 1-3).

Biofeedback for Vibrato

Several sources in the literature indicate the advantages of biofeedback for improving vibrato. An interesting study comparing vibrato acoustics across both Western Classical and jazz styles of singing, measured vibrato rate (“the number of oscillations per second”) and extent (“amplitude of the cycle” above and below f_0 , measured in cents), duration (seconds) and regularity (Manfredi, et al. 2015, pp. 517.e1-e3). Notably, the Manfredi, et al. study used software (BioVoice) that does not feature adjustable input levels, unlike other sources in the literature, which indicated that input adjustability was a strong plus when choosing software (Erickson, 2021a; Evans, McHenry, & Averyt). Tables presented in the Manfredi, et al. study offer parameters for the voice teacher to use objective guides in conjunction with their ears’ subjective feedback when seeking to train the desired rate and extent of vibrato respective to the desired style. Their research shows that vibrato rate per second does not vary widely across genders and styles, while vibrato extent shows greater disparity. When using software to measure vibrato extent for purposes of short-term biofeedback and comparison across

repetitions of the same vocal task, the following ranges (in cents) may be useful as a guide: 1.) Male classical, 81.95 ± 34.58 ; 2.) Male jazz, 66.78 ± 20.04 ; 3.) Female classical, 145.43 ± 51.57 ; 4.) Female jazz, 52.89 ± 16.71 (Manfredi, et al., 2015, p. 517.e5). Guiding students to use technology to visually compare their vibrato with recordings illustrating norms in their style of singing may affect more change in vocal habits than verbal feedback alone (Broadwater, 2021, p. 596).

Besides visual biofeedback, the use of a synthesizer to adjust the rate and extent of vibrato provides an external aural stimulus to train both teachers' and students' ears to recognize subtle changes in vibrato, as well as the effect of the relationships between harmonics and first and second vowel formants on the vibrato (Meyer, Nix & Okerlund, 2021, pp. 634-636). Meyer, Nix, and Okerlund detail procedures for this ear-training process using the Madde synthesizer or the synthesizer available in newer versions of VoceVistaPro, and include links to references, such as a YouTube video tutorial on mapping and modeling "the location and bandwidth of one's vocal tract resonances and the rate and extent of one's vibrato" and a free downloadable manual for Madde, written by Iain Howell (2021, p. 634). I am intrigued by the use of synthesizer modeling to develop my diagnostic ear, however, I found the hurdle to engage with this technology slightly higher than others encountered in the reading. Although I did not engage with synthesizer technology in the reflective analysis, I am curious to try it in the future, especially with the instructional links provided by Meyer, Nix, and Okerlund.

Biofeedback for Vowels and Resonance Tuning

Several sources indicated the usefulness of biofeedback for shaping the vocal tract in non-singing phonation processes to visualize the outside effect of very small internal adjustments (Graf, et al., 2018, pp. 343-344; Hiljeh, 2021; Müller, 2001, p. 22). Several sources point to the merits of vocal fry phonation to explore vowel formants using the software VoceVista. Comparing the spectral analysis of the vocal fry phonation with sung vowels gives insight into individual resonance strategies (Hiljeh, 2021; Meyer, Nix, & Okerlund, 2021, p. 640; Müller, 2001, p. 22). VoceVista includes a vowel chart, which allows for targeted biofeedback of vowel production. Students producing a vowel accurately will see "the first two peaks" of the vocal fry signal in alignment with the bars in the display indicating the first two resonances, or vowel formants, of the target vowel (Meyer, Nix & Okerlund, 2021, p. 640). In my teaching, I often talk about "micro-adjustments" to vocal tract shaping required by each vowel, particularly when navigating the second *passaggio* in sopranos and mezzo-sopranos. Again, the chart of

Formant Characteristics and Corresponding Articulator Adjustments for Formant Tuning in Appendix 2 provides some insight into fine-tuning vowel formation. I am intrigued by the prospect of biofeedback giving singers the chance to “see” these slight changes, instead of relying solely on feeling and hearing.

Biofeedback—Further Research

Erickson also noted the merits of biofeedback when working with “unusual populations” (2021a, p. 496). In her experience, students with limited facility in pitch-matching and students with cochlear implants showed remarkable improvement using biofeedback to visualize pitch accuracy (2021a, pp. 496-497). She points out that using technological tools to support working with “aurally-impaired” students is an area ripe for further research (2021a, p. 498).

Vocal Health

As in the teaching studio, clinical voice assessments use “perceptual analysis” to “assess voice quality” to treat vocal health disorders (Jannetts, Schaeffler, Beck, et al., 2020, p. 293). Singing and speaking phonation have several markers of vocal health in common, such as improved vocal quality, greater efficiency, and reduced fatigue. Studies demonstrating portable technology supported the retention of vocal improvements achieved in voice therapy suggest that mobile applications may also assist students in establishing vocally healthy habits more consistently in independent practice outside of lessons. The literature touted convenience and availability as being key for easy integration into regular use (Trecca, et al., 2021, p. 88; Van Stan, et al., 2017, p. 1).

Sataloff argues that turning to technology may be especially valuable for “detecting an unsuspected and treatable medical problem,” particularly in students whose singing technique presents special problems, which do not progress with a teacher’s standard methods of successful instruction (2020, pp. 432-433). Acoustic analysis may detect patterns that help to identify vocal pathologies by adding quantitative feedback “on perceptual voice quality measures, such as grade, hoarseness, and other physiological aspects of influencing the status of the vocal folds” (Gunjawate, Ravi & Bellur, 2018, p. 40). Student privacy “related to their current or past voice, physical, or mental health history” must be protected. Teachers may invite health-related disclosures to support holistic and effective teaching methods for each student, however, this should be handled sensitively and never considered compulsory (Rollings Bigler, et al., 2021, p. 21).

Determining a Baseline for Vocal Health

In a study on “the reliability of smartphone-based acoustic analysis for voice health state monitoring,” Jannetts, et al., captured acoustic measurements from studio recording equipment and several smartphones simultaneously (2020). Their work pointed out that comparing “snapshots” of acoustic measurements is unlikely to show signs of vocal health problems, as the “acoustic patterns which might identify those most at risk of developing voice disorders or signal the earliest stages of behavioral voice problems” are generally not outside the parameters of acoustic measurements for a healthy voice (Jannetts, Schaeffler, Beck et al., 2020, p. 293).

Such snapshots of vocal evaluation cannot fully capture the day-to-day effects of vocal loading (i.e., repeated vocal fold posturing or excessive tissue vibration), especially in professional voice users. (Grillo, et al., 2016, p. 9).

Grillo, et al. point to the advantages of smartphones for gathering “daily voice measures representing the effects of vocal loading within individuals” (2016, p. 9). The literature points to the importance of acoustic measurements taken over time to establish an individual baseline and identify the earliest signs of poor vocal health, such as “unusual patterns of within-speaker fluctuation” (Grillo, 2016; Jannetts, Schaeffler, Beck et al., 2020, p. 293).

Acoustic analysis of vocal shimmer, jitter, or variation of cepstral peak prominence is likely beyond both the technological tools which I would employ in the studio and my skills in data interpretation. However, more basic variations from baseline sound-pressure levels, changes in the ability to control pitch, and changes in vocal quality as seen in spectral analysis may indicate dysphonia or other vocal problems, which would spur me to recommend medical evaluation (Patel, et al., 2018, pp. 893-897). Several devices recorded sound pressure levels, measured as decibels, inaccurately, due to the differences between microphones across devices. However, a useful sound pressure level baseline may still be established over time when the setup distance and the device remain constant (Grillo, 2016, p. 13).

Reflective Analysis

Using a simple chart (see Appendix 1), I tracked mentions of computer software and mobile applications to guide me in choosing applications to try in my practice. I used the following devices, which are all registered with accounts tied to the US stores:

- Smartphone – Motorola (Moto g8 Plus); Android Version 10
- Tablet – iPad (6th generation); iOS
- Laptop – MacBook Air; macOS High Sierra Version 10.13.6

I downloaded and interacted with 7 Android mobile applications, 3 iOS mobile applications, and one software application for a computer. To date, I have spent \$12.98, however, I intend to purchase the software VoceVista Pro with the help of a student discount. Using the mobile applications Keep Notes and Voice Recorder (Android), I kept an informal reflective journal to track my interaction with the technological tools (see Appendix 3).

Metrics for choosing application technology described in the literature guided my assessment of which software applications to try or potentially recommend to students (Erickson 2021a; Evans, McHenry, & Averyt, 2020; Grillo, et al., 2016; Mackowycz, 2021; Müller, 2001; Trecca, 2021). Mobile application development has snowballed, resulting in an astonishing quantity of applications for collecting and measuring vocal output. The quality of these applications varies wildly, and most were not developed with voice teachers or voice health professionals (Trecca, 2021, p. 88). Based on the literature, I identified the following criterion for sifting through the available technology:

- cost,
- availability,
- portability,
- usability,
- accuracy of information provided,
- input sensitivity,
- gain controls,
- touch-screen capability,
- record/playback feature, and
- neutrality of feedback.

Few sources addressed security or privacy concerns, however, Trecca, et al., noted that “many apps reduce security risks by not allowing users to export data” (2021, p. 88). However, this

would limit the ability to save and share graphs and recordings between teacher and student, a potentially useful feature of an application.

Keeping a reflective journal following Boud's model for reflection via journal writing exposed the importance of the emotional response to engaging with technology for the studio (see Appendix 3.) At times, I found the process of "attending to feelings" in the reflective journal cumbersome, however, examining the emotional reactions to using an application, especially concerning usability, expedited the process of winnowing out the most effective tools for my practice (Boud, 2001, p. 11). The software applications, which I found the most intuitive also allowed me to link the "new information to that which is already known," connecting previous modules' acquired knowledge to this independent study in a hermeneutic manner (Boell and Cecez-Kecmanovic, 2010, pp. 130-132; Boud, 2001, p. 11).

Before I felt confident introducing the technology to my students, I wanted to gain a certain level of proficiency with the various software applications. Thus, most of the reflective analysis occurred in my own practice sessions. I chose specific examples of pedagogic strategies in the literature and sought to reproduce them. Although I could not always reproduce display graphs exactly as presented in the literature, the process allowed me to discover my preferred applications and explore corresponding strategies. In my experience, some technology was worth a steeper learning curve. VoceVista was my favorite tool of the study, although the cost factor does not make this software suitable for recommending to students for home use. However, several simpler tools, which are more suitable for students to use outside of lessons, could prove useful. I preferred the mobile applications Audio Analyzer (iOS) and SPL Meter (Android version), and I plan to continue exploring implementation with students. Since I registered my devices with the US stores and I teach in Germany, I searched for the availability for both applications in the German stores, where it appears students could download each of these applications if interested.

VoceVista Computer Software

I found VoceVista simple to install. The software requires little disk space, although saved recordings could quickly increase required storage space. I enjoyed observing the display change as I experimented with vibrato and onsets/offsets. This software application seemed most accurate in capturing pressed, breathy and flow phonation, showing distinctively identifiable patterns in the display graph.

Comparing vocal tract shaping between vocal fry phonation and singing in my own singing practice served as a foundation for introducing VoceVista in a lesson with a professional opera singer (Baritone, 34 years old). He has habitually struggled to produce a pure [u] vowel in Italian and German texts, which I felt was dampening his resonance throughout the vocal range when compared to other vowels. I had described his impure [u] vowel as having “tongue pollution,” which also affected source function. Exercises out of [ng] sounds and other vowels with which he had more success would produce better results, but he had trouble retaining the improved vowel position and perceiving it well on his own. I used VoceVista in the vowel chart view, selecting his more successful vowels to illustrate how the peaks in the display of his sound signal corresponded with the vowel formant frequency bars on the chart. Upon trying an [u] vowel, the visual display indicated his voice signal vowel formant resonances were not matching the target. He reacted quickly and intuitively to the biofeedback on the screen and quickly began producing pure [u] vowels, which I perceived as having more resonance and carrying power.

Audio Analyzer iOS Mobile Application

Downloading Audio Analyzer was simple, and I found the function to be worth the cost of \$9.99. I had experienced some frustration with the usability of other applications, and I found the application was fun and interesting to use. I ran Audio Analyzer on my tablet, on which I also have organized PDF files of my students' music in ForScore. It is not possible to run both applications simultaneously, meaning that with my current setup, I use Audio Analyzer primarily during the technical/warm-up portion of the lesson and less in the second part of the lesson, focused on repertoire. In my singing practice, I enjoyed experimenting with observing vibrato and onsets/offsets. Although the measurements do not seem as accurate as those captured by VoceVista, I envision AudioAnalyzer being a convenient and informative biofeedback tool in lessons for exploring vibrato vibrancy, pitch, and the relationship between healthy vibrato and effective onsets and offsets. I also enjoyed watching the acoustic analysis change, as I compared opened and closed vocal tract shaping throughout my range. I think that this application has potential for exploring resonance tuning strategies with students, however, I plan to explore this further independently until I improve my proficiency with the application.

I discovered two practical applications for using Audio Analyzer, which I did not see mentioned in the literature, 1.) *messa di voce* and 2.) *portamento*. Working with Audio Analyzer in my practice session on *messa di voce*, I observed a steady, even *crescendo*, followed by an

uneven *decrescendo* with a step-pattern drop off leaving the climax of the phrase, instead of the desired gradual downward slant. Biofeedback from the application proved more useful than my auditory perception to correct and train the *decrescendo* portion of the exercise more accurately and effectively. Based on my aural perception in lessons, I find students working on *portamento* often lose connection and legato when transitioning between pitches. This “drop” in legato typically occurs just as the singer is ending or beginning the *portamento*. Again, experimenting with Audio Analyzer, I found the application captured and illustrated the “drops” accurately. I think this will be an effective tool for biofeedback the next time I approach uneven *portamento* with a student.

SPL Meter Android Mobile Application

SPL Meter is a low-tech simple application with a streamlined, “less potentially distracting” display suitable for running in the background during a lesson (Nix, et al., 2021, p. 521). As Covid-19 infection rates rise in Germany, I anticipate that in-person teaching may again be affected. The possibility of setting loudness benchmarks with SPL Meter in person may be useful for online teaching in the future.

Further Development

I plan to continue to explore using these technological tools independently and introducing them to students from time to time. I plan to explore YouTube resources for working with VoceVista to continue to develop my proficiency with the software. After developing some confidence with these tools, I am inspired to test using Madde synthesizer via conversion software to enable use on my Mac. I am curious to play with vibrato modeling and plan to revisit Bozeman’s examples of acoustic registration, which he modeled with Madde in the online course on acoustic pedagogy.

Conclusion

“Science is not only for an exclusive cohort of specialist-trained teachers.

Science is for all of us.” (Meyer, Nix & Okerlund, 2021, p. 633).

Technology in the studio has several benefits. It allows a teacher to link perception with the mechanics of vocal production, complementing the subjective experience with objective measurements (Titze, 2020, pp. 565-566). However, for those objective measures to be useful

for the teacher and students, I must take care choosing which technology to use and learning to assess the data output accurately.

In addition to the implementation strategies outlined in the reflective analysis above, I plan to use technology in the future to track progress. Titze points out that our perceptual memory “is not robust over time” and suggests that technology allows for long-term tracking of some changes and improvements (2020, p. 566). I am inspired to audio record my students periodically to remind myself and them how much change has occurred, thus using basic and proven technology to augment my “auditory memory” (Sataloff, 2020, p. 433).

Additionally, technology offers another tool to support my development as a teacher via reflective practice. My aim when teaching is to focus squarely on the development of my student at that moment, however, I am aware of bias from my own vocal technique challenges and journey, training, genetics, and upbringing. Linear feedback from technological tools over time may provide insight into my own habits and preferences. Titze points out that “our perceptual systems have evolved to be highly complex and nonlinear” while “acoustic and biomechanical instrumentation often begins (in design) with linear system components, giving all detail in the sound or movement equal weighting” (2020, p. 565). Comparing technological feedback across different students may uncover patterns that enable me to identify my own strengths and weaknesses as a teacher (Sataloff, 2020, pp. 435-436). Furthermore, technology affords me the opportunity to develop my diagnostic facility by sharpening my analytical ear (Müller, 2001, p. 24; Rollings Bigler, et al., 2021, p. 19-20).

Clearly, there are a number of positive ways in which the rise of easily accessible, non-invasive technology may prove useful to the voice community. I look forward to developing more fluency with the software and applications, particularly VoceVista, AudioAnalyzer, and SingScope for use in the studio and future research.

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Appendix 1 – Software Encountered in the Literature

Highlighted software applications indicate technological tools explored in reflective analysis.

Software	Cost/Platform/Availability	Functions	Mentions
Audioanalyzer Pawel Krzywdzinski (Mobile App)	\$9.99 iOS US Store	acoustic analysis	• Erickson • Evans, McHenry, & Averyt • Mackowycz
BioVoice (Computer Software)	A freely available release of BioVoice is in preparation. Runs over MatLab software; Beta version for Windows, runs without MatLab.	acoustic analysis	• Manfredi, et al.
Decibel X (Mobile App)	\$3.99 monthly subscription; 3-day trial available Android US Store	sound pressure level	• Nix, et al.
Fitvoice (Mobile App)	Free iOS UK Store	mobile voice health monitoring	• Jannetts, Schaeffler, & Beck, et al.
Madde (Computer Software)	Freeware PC Only; however, conversion software can help to run it on Mac	synthesizer tool for voice source and filter modeling	• Meyer, Nix, Okerlund
Nail the Pitch (Mobile App)	Free; Pro-version available iOS & Android	pitch monitor	• Mackowycz
PitchLab (Mobile App)	\$0.99 No longer in Android or iOS US stores		• Erickson

Praat (Computer Software)	Freeware Available for PC and Mac	acoustic analysis	• Grillo, et al.
Singscope (Mobile App)	Free iOS US Store	pitch monitor	• Erickson • Mackowycz
Spectrogram Pro Dominick Seibold (Mobile App)	\$2.99 iOS US Store	acoustic analysis	• Erickson
SPL Meter (Mobile App)	Free iOS and Android US Store	sound pressure level	• Nix, et al.
VoceVista Video Pro (Software Application)	Free Trial Version \$399; Student Discounts Available Available for PC and Mac	acoustic analysis	• Erickson • Manfredi • Meyer, Nix & Okerlund • Müller

Appendix 2 - Formant Characteristics and Corresponding Articulator

Adjustments for Formant Tuning

Note: The material in Appendix 2 is excerpted from my module 4 paper, BMPF 7013 Module 4: Independent Study, “An Overview of Acoustic Vocal Pedagogy and its Implications for the Female Voice,” submitted on June 27, 2021.

In order to engage with the literature on resonance tuning, I found it useful to create a chart to summarize the relationship between each formant and the corresponding articulator primarily responsible for raising or lowering each formant frequency (see Figure 4). The higher formants such as F_4 and F_5 are generally less mobile, and less tunable than the lower formants (Sundberg, 1987, p. 23).

All Formants	The longer the vocal tract (low larynx and rounded lips), the lower the formant frequencies.
F_1 (very mobile)	• Lies between C4 and C6; Most often in contact with treble clef (D4-G5) • Most responsive to adjustments to <u>vowel height (vertical vowel position)</u> • The higher or <u>closer</u> the vowel (e.g. /i/, /u/), the <u>lower</u> the F_1 frequency • The lower or more <u>open</u> the vowel (e.g. /ɛ/, /ɔ/, /a/), the <u>higher</u> the F_1 frequency
F_2 (very mobile)	• Lies approximately between A5 and D7; vowel spans generally an octave in a given voice • Most responsible for <u>vowel clarity</u> • Most responsive to adjustments to <u>horizontal vowel position (front/back)</u> • The more <u>forward</u> the vowel (e.g. /i/), the <u>higher</u> the F_2 frequency • The farther <u>back</u> the vowel (e.g. /u/), the <u>lower</u> the F_2 frequency
	• Most responsive to adjustments to <u>tongue shape</u> • Tongue constriction in the <u>anterior</u> region of the mouth <u>raises</u> the F_2 frequency maximally • Tongue constriction in the <u>velar</u> region of the mouth <u>lowers</u> the F_2 frequency maximally • Tongue constriction in the <u>pharynx</u> <u>lowers</u> the F_2 frequency to a lesser degree

Therefore:	
• Forward internal narrowing near the lips (anterior mouth region), <u>lowers</u> F_1 and <u>raises</u> F_2 • Back internal narrowing (near the pharynx), <u>raises</u> F_1 and <u>lowers</u> F_2	
F_3 (less mobile)	• Most responsive to <u>tongue tip</u> position • The <u>larger the cavity</u> immediately behind the incisors, the <u>lower</u> the F_3 frequency tends to be • Also responsive to lip rounding
F_4 (less mobile)	• Most responsive to <u>laryngeal position</u> • The <u>lower</u> the larynx, the <u>lower</u> the frequency

When formants are near one another, they reinforce one another, increasing loudness. For example, lowering the second formant energizes the first formant, “boosting the low frequency components of the timbre and creating a ‘back’ vowel” (Bozeman, p. 16, 2013). Raising the second formant on the other hand bolsters the singer’s formant cluster (see below) and “[boosts] the treble components of the timbre, creating a ‘front’ vowel” (Bozeman, p. 16, 2013).

Appendix 3 – Reflective Journal

Reflective Journal includes notes made in the mobile application Keep Notes and remarks transcribed from the mobile application Voice Recorder.

Boud Reflective Model Notes for Reflective Journal

Experience – what happened; describe in rich texture

Feelings – which were present

Reevaluate – relate new info to old; determine authenticity of resulting ideas and feelings; make knowledge one's own

20.10.21

Using phone to try to download apps

PitchLab – no longer available in Android store; work around seems available via Amazon app store, but process of downloading seems cumbersome; unsure if trustworthy; abandoned download attempt

SingScope – not available for Android; try later with iPad

Interesting to see the other apps the Google Play store recommends. Will have to explore.

25.10.21

Downloaded VocalPitchMonitor – free; Android

Easy process; simple app; but not much of a value add? Perhaps useful for pitch matching troubles, but not sophisticated enough for what I need? Possible to adjust input volume, color scheme, horizontal and vertical zooming; Also possible to calibrate to non-standard (A440) tuning

Wave form in display does not seem to be sensitive enough to register phonation modes well.

Sensitivity to changes in vibrato also not particularly visible; even between singing same pitch in belt/hoot acoustic registration

Can see legato drops in portamento, but still not detailed enough

Potential Use – would be good for tuning instruments for old music or European tuning

Although not likely to keep this app installed on my phone

25.10.21

Experimented with apps recommended by the Google Play Store

Downloaded AspectPro – free; Android

Possible to analyze existing files in WAV or MP3, 192 Kbit/sec

Not for real-time analysis;

Can select spectrum for short-term view, however the frequencies are not labeled in that view?

Seems to require an in-app purchase for scanning a file?

Found unintuitive, which was annoying. Also, not thrilled about lack of real time analysis option, and the subscription model. Due to annoyance did not spend too much time trying to learn how this app works. Will uninstall.

Downloaded Phonetic Spectrogram – free; Android

Wideband spectrogram for vowel-formant plotting

Easy to start using, but not sophisticated or sensitive enough to bother using; should have probably ascertained that from the screenshots in the GooglePlayStore

Will uninstall; Noticed on uninstall that there are not reviews. Why did I even download this app?

Striking out on Android, which is frustrating; must remember iPad tomorrow

29.10.21

Downloaded AudioAnalyzer - \$9.99; iOS

intuitive; could start playing immediately; so far best use seems to be finding legato through consonants and seeing lazy offsets; recognizing when vibrancy does not start immediately
I could envision using this with my students.

Downloaded Vocal Tools – free; Android

Has modes to monitor pitch as wave form display, pitch in Hz, decibel meter, statistics,

Seems geared toward working on speaking voice; does not have recording ability beyond 30sec

Potentially useful to monitor vocal health? Try analyzing spoken voice passage in statistic mode to see average pitch changes. Probably excellent to support work with a speech therapist. Might

be interesting to measure average pitch after a lesson, after talking in a noisy bar, after teaching several lessons in a row. I often notice my students are more “functional” in their speaking at the end of a lesson.

Potentially useful if ever coaching a transgender student to find healthy, yet gender-affirming spoken voice? Statistics measuring femininity and masculinity potentially problematic? Not neutral enough?

A bit “sticky.” Often have to close out of app completely to switch between modes.

I might play with this app in the future, but it is not as useful as AudioAnalyzer appears to be.

02.11.21

Downloaded SingScope

Appears to have robust help menu; Intuitive, easy to start using

Graphs Pitch over time; records up to 5 minutes; stores files up to 1GB; has capability to combine with lead sheet programs for learning music and transposing;

Tried to recreate onset/offset, vibrato, & trill exercises from Erickson, Mackowycz; I can definitely see the usefulness for trilling

I would potentially use this with a student to visualize trilling. Good for training trill regularity and making sure the trill actually covers two pitches instead of just a wide vibrato.

05.11.21

Downloaded Nail the Pitch – free; Android; pro version available to unlock recording availability

Can adjust input

Not very robust; not sure I am the intended audience for this app

Tried deliberately pressed, airy and flow onsets; hard to tell the difference, although pressing appears like scooping in the graph display; don’t see right away an easy use

Will probably not keep on my phone.

Potential future use for working with a student that has difficulty matching pitch.

06.11.21

After reading Nix article

Downloaded DecibelX and SPL Meter; both free both Android

DecibelX – also includes spectrum analyzer, but not enough labeling and detail to extrapolate

Can record and playback; exports WAV, CSV and HTML files; interacts with camera to make

overlays for social media posts; could be a fun, kind of one-off use

adjustable themes

Upon trying to play with this app I was prompted to subscribe at \$3.99 a month. Nope.

Will uninstall this from my phone.

SPL Meter

Allows for calibration against a known SPL; interesting!

Practiced leaving this running in the same position; was kind of fun to see the meter running while singing.

I would like to try this with students on their phones, especially since it is free and compare in-person to on-line lessons.

07.11.21

Played with setup for iPad and AudioAnalyzer

Highest harmonics not as robust (yellow) when at 12-14 ft (Evans, McHenry & Averyt Article),

however not a huge change in the display with my voice. I would be curious to try to play with

this in different spaces to see the environmental effect on the spectral analysis. The largest

change is indeed around 3000 Hz as the article suggested, although lower harmonics appear just as robust? Color intensity

Interesting to note the difference between the complexity of the piano signal and the voice signal. Makes me think that discerning orchestra from voice will be possible.

Fun to have AudioAnalyzer running while practicing, just watching the effects of different ranges and vowels. Fun to sing pop and classical style back to back and pause display. Will keep letting this run while practicing to calibrate my eye.

comparing the first phrase of summertime, inspired by literature, singing in a “pop” setup and a classical set up. Definitely more intensity of overtones in classical setup, as well greater vibrato extent; In classical setup vibrato starts more immediately at the beginning of the tone, instead of building on each note. Nothing surprising here, but it is interesting to “see” it.

comparing staccato and legato patterns – beginning to think there is some validity in an armlength setup

09.11.21

Downloaded VoceVista – why did I wait so long? Surprised that it is possible to jump right in and play without extensive tutorials

I found myself less likely to download computer software than the mobile apps. Seemed like a more daunting process, and, of course, I don’t always have my computer with me when teaching or practicing in the opera house. Somehow it seems like apps are an easier “try out” and an easier delete. The hurdle emotionally was larger for VoceVista. But, now I am loving it.

Vowel chart on VoceVista fun, intuitive

difference between phonation types for onset (pressed, airy, flow) is really visible. really, really good.

Finding journaling useful; but the reflective model is a bit time-consuming; Not a good method for making shorter remarks for remembering later, especially when using an App on the phone. Not as bad, since AudioAnalyzer on iPad and now VoceVista seem to be the most useful, but why did I choose such a detailed journal model. A logbook would be easier. Maybe I am tending that way anyway?

15.11.21

Had only played with VoceVista during a few warm-ups and did not record, however I had my computer and decided to try it with KHM in lesson for vowel targets. He was open to it. He was surprised by the way his [U] vowel did not line up with the bars on the vowel chart display. But, he corrected quickly with less feedback from me. We both found it fun. I was nervous to pull out “the technology,” when I feel I am still learning it myself, but it was a success!

16.11.21

Downloaded Dominick Seibold app - \$2.99; iOS

Erickson presented this as a less robust, more cost effective alternative to Audio Analyzer, and I tend to agree.

Trials with deliberate pressed, airy and flow onsets showed up, but doesn't seem to have as much data as AudioAnalyzer and VoceVista.

Airy phonation not visually distinguishable enough from flow phonation for me to feel confident recommending this to a student. I wonder about it actually being useful for gamifying onsets. Feel a bit doubtful.

17.11.21

VoceVista

Playing with Lin layout vs Log layout seems to have some interesting information on vibrato vibrancy (more robust than AudioAnalyzer); However this is cost prohibitive to recommend for students to use on their own. Likely to play with this more on my own and potentially utilize as Biofeedback for lessons in the future

18.11.21

VoceVista

Playing with vowel changes in the range; Interesting to “see” the rich harmonic context in that small “voce chiusa” position that feel mosquito-y and small; great tool to show how we can not trust our own aural perception

22.11.21

VoceVista

experimented with top of range; just watching, calibrating eye

23.11.21

Tried running Trov Endproben files through VoceVista and AudioAnalyzer

Bit more a learning curve, but this is interesting. I am curious to compare my singing of the aria phrases with Price and Callas just for grins.