

MAPPING FIRST AND SECOND FORMANTS IN ITALIAN OPERA: CLASSIFICATION
OF VOWEL PHONEMES SUNG BY 20TH CENTURY ITALIAN TENORS ON MIDDLE C

By

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(Under the Direction of Frederick Burchinal)

ABSTRACT

One of the core principles of Italian *bel canto* is pronouncing vowels well, yet scientists and voice teachers have noted the lack of specific definition of vowel quality related to singing. This study analyzes vowels sung by Italian tenors of the 20th Century on Middle C in Italian operatic arias. The first and second formant frequencies of the vowels were measured and used to create a vowel chart specific to Middle C. The vowel chart reveals sixteen groupings which enable the definition of vowels specific to Middle C. The vowel groupings demonstrate patterns of formant tuning that align resonances of the vocal tract with the overtone series and display leveraging of nonlinear source-filter dynamics¹ by the tenors. The findings provide specific information for singers who wish to tune their vowels for acoustic efficiency and aesthetics in the style of 20th century Italian opera singers. The findings also clarify various opinions and directives related to vowel quality encountered in the historic vocal pedagogy literature.

INDEX WORDS: Italian Tenors, Formant Tuning, Vowel Quality, Historic Vocal Pedagogy, Nonlinear Source Filter Theory, Italian Opera, Vowel Chart, Middle C

¹ Nonlinear source-filter theory describes how the tuning of the vocal tract can have a positive influence on the vibration of the vocal folds and help coordinate the dynamic equilibrium of singing.

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DEDICATION

I dedicate my thesis to the following family and friends that inspired and guided me through my vocal journey and have helped me to reach this milestone. Lisette Ellis, my loving wife who has supported me through every moment of my graduate studies. Lucianna Ellis, my darling daughter who is the light and joy of our family. Mark and Diane Ellis, my dear parents who raised me in faith and instilled in me a love of music. Herb Hofer, my dear grandfather who introduced me to opera singing and taught me that a great voice can come from anywhere. Wilson Nascimento, who gave me my first voice lessons and emphasized the natural quality of my voice. Adelaide Trombetta, who believed in me and encouraged me to study everything I could about singing. Joseph Shore, who taught me that singing isn't magic but is a craft that can be developed. Wayne Kompelien, who knew I loved singing before I did and taught me that singing should always be beautiful. Jack Li Vigni, who taught me to love the Italian tradition of singing and introduced me to the science of acoustics. David Ehrman, my piano teacher, mentor, and friend who has been a constant source of prayer, wisdom, and guidance. Rockwell Blake, who taught me what it means to be an artist and introduced me to Garcia and pure vowels. Frederick Burchinal, who believed in me, entrusted me with the opportunity of a lifetime at UGA, and taught me the importance of singing on the breath. Kathryn Wright, my coach and diction teacher who always lifted my singing and pronunciation to a higher standard. Justin Petersen, my kindred spirit in singing, voice science, and historic vocal pedagogy. And finally, Alexander Kariotis, who helped fine-tune my vowels and connected me to the traditions of Coffin, Pola, and Pavarotti.

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CHAPTER 1

INTRODUCTION: THE QUESTION OF VOWEL QUALITY IN SINGING

Statement of Problem

The Italians of the last five hundred years developed a unique method of singing that became known as *bel canto* and was used by opera singers throughout Europe. This method of singing was documented by the European writers of vocal treatises of the 18th and 19th centuries. In most of the major treatises, clarity of pronunciation and the quality of sung vowels were emphasized as important aspects of the *bel canto* method.² So important were these aspects of *bel canto* that they were codified as rules of singing in the Italian school.³ Voice teachers developed a special appreciation for the Italian language as the mother tongue of singing.⁴ Nicola Vaccai (1790-1848), one of the influential composers and pedagogues of the *bel canto* school, wrote that “Anyone who wishes to sing really well should begin by learning how to sing in Italian, not only because the Italian school of vocalization is acknowledged to be superior to all others, but also on account of the language itself, where the pure and sonorous tone of its many vowel sounds will assist the singer in acquiring a fine voice-production and a clear and distinct enunciation in any language he may have to sing.”⁵

² Pier Francesco Tosi, *Observations on the Florid Song*, translated by John Ernest Galliard (London: J. Wilcox, 1743), 25; Giambattista Mancini, *Practical Reflections on the Figurative Art of Singing*, translated by Pietro Buzzi (Boston: The Gorham Press, 1912), 170; Francesco Lamperti, *Guida Teorico-Pratica-Elementare Per Lo Studio Del Canto* (Milano: Ricordi, 1864), 1; Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, translated by Donald Paschke (New York: Da Capo Press, 1984), 1.

³ Giusto Ferdinando Tenducci. *Instruction of Mr. Tenducci to his scholars* (London: Longman & Broderip, 1785), 1.

⁴ Mancini, *Practical Reflections on the Figurative Art of Singing*, 170-171.

⁵ Nicola Vaccai, *Metodo Pratico di Canto*, Critical and technical revision by Elio Battaglia, translated by Stephen Hastings (Milan: Ricordi, 1990), 1.

This quote from Vaccai's popular *Practical Method of Italian Singing* is a likely source for the circulation of the term "pure vowels" as it relates to singing. In 2013, John Nix included the term "pure vowels" as one of the "statements commonly used by vocal educators in choral rehearsals and applied lessons" as part of "pedagogic fundamentalism" in singing.⁶ Nix wondered if widespread agreement regarding pure vowels exists and questioned "what a singer using pure vowels would sound like."⁷ He also suggested that "clarification seems needed regarding this terminology."⁸ Stephen Austin, in his 2011 article "Canaries in the Coal Mine: The Pure Vowel,"⁹ also raised questions about what the Italian masters meant when they urged their singers to pronounce their vowels distinctly. He wrote, "There is an aural definition of vowel quality in the collective consciousness of good teachers and singers everywhere. ... The existence of a universal defined vowel quality may be "pie in the sky," but [it] is fundamental to what we do as voice teachers."¹⁰

The concept of pure vowels may be present in the "collective consciousness" of singers and teachers; however, there is little consensus on its definition. In the author's experience, voice teachers seem to have their own ideas about how pure vowels should sound and how to achieve them. One teacher may ask for a smiling embouchure to produce bright and clear vowels, while another may ask for an oval embouchure to produce round and full vowels. A third teacher is skeptical of the pure vowel concept all together. Each teacher regards his vowel targets and strategies to be the true *bel canto* standard. These examples are not hypothetical; each of the three teachers mentioned was instructed by masterful voice teachers and operatic coaches from Italy.

⁶ John Nix, "'You Want Me To Do What?': Twenty-First-Century Voice Pedagogy Encounters Pedagogical Fundamentalism," in *The Choral Journal*, Vol. 53, No. 10 (May 2013): 43.

⁷ Ibid, 50.

⁸ Ibid.

⁹ Stephen Austin, "Canaries in the Coal Mine: The Pure Vowel," in *Journal of Singing*, Vol. 68, Iss. 1, (Sep/Oct 2011): 84.

¹⁰ Ibid.

Each also launched a successful international performing career and a thriving voice studio. Herein lies the problem: although pronunciation of vowel sounds is of utmost importance in the vocal treatises that documented the *bel canto* tradition, modern-day voice pedagogues demonstrate that there is a lack of consensus on the specific definition of “pure vowels in singing.”

During the same time period that vocal treatises were being written, the systematic use of the scientific method was leading to developments in the fields of acoustics, voice science, and phonetics. Scientists observed the patterns of sound and speech generated by the voice. Voice scientists created the source-filter theory to describe the voice’s process of sound creation. Linear source-filter theory can be summarized by saying that the air pressure from the lungs vibrates the adducted vocal folds resulting in a fundamental frequency (the perceived pitch) and its overtones which are then filtered and resonated by the vocal tract. In parallel, the International Phonetic Alphabet was created to identify the sounds of language created by the voice. Vowels in IPA were identified with unique symbols placed on a two-dimensional chart. Their relation to one another on the chart was based on the position of the articulators (jaw, tongue, lips, etc.). This chart was later adapted to represent perceived vowel quality, given the acoustic characteristics of vowel sound.¹¹ Vowels came to be defined based on the frequency of distinctive spectral peaks, formants,¹² present in the sound spectrum of the voice.¹³ There are five to seven spectral peaks generated by the resonance of the vocal tract, but scientists use the first two, called vowel formants, to define vowels within the two-dimensional space of a vowel chart.¹⁴

¹¹ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production* (Oxford: Oxford University Press, 1994), 1.3.4.

¹² Formants is a vocal term which is commonly used to mean a resonance of the vocal tract.

¹³ “Formant: What Is a Formant?”, www.phys.unsw.edu.au, accessed March 1, 2023, <https://www.phys.unsw.edu.au/jw/formant.html>.

¹⁴ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production*, 1.3.4.

Phoneticians create vowel charts by studying the frequency of the vowel formants spoken by a focus group. A focus group is a small number of individuals of a predefined demographic who are studied to shed light on a topic of interest.¹⁵ As an example, the Peterson and Barney study published in 1952 measured vowel formant frequencies of American English vowels spoken by American men, women, and children.¹⁶ The subjects of that study read lists of words whose vowels were analyzed for their formant frequencies.¹⁷ In other speech studies the subjects read a standard paragraph of text that will be analyzed in the same way.¹⁸ The data gathered from the vowels in the readings are plotted and averaged to define standard formant frequency patterns for each particular vowel.¹⁹ The individual measurements come together in the aggregate to indicate patterns of vowel formation used to better understand and perceive the nature of speech. These kinds of studies define the vowel formant frequencies of spoken vowels in their respective languages. However, this technique has never been used to create a chart mapping the vowels sung by peak performance opera singers on a single pitch for any language.

There is practical value in measuring the specific vowel formant frequencies of singers related to pitch. Linear source filter theory is an incomplete model that sees the vocal tract as merely a resonator and a filter that does not influence the vibration of the vocal folds. Using the linear model, some have theorized that vowels are like colors of paint that can be indiscriminately applied to any sung tone.²⁰ Due to the nonlinear source filter theory, voice

¹⁵ Tegan George, "What Is a Focus Group?" (Scribbr, December 10, 2021), <https://www.scribbr.com/methodology/focus-group/>.

¹⁶ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production*, 1.4.2

¹⁷ Gordon E. Peterson and Harold L. Barney, "Control Methods used in a Study of the Vowels," in *The Journal of the Acoustical Society of America*, Vol. 24, No. 2, (March 1952): 175.

¹⁸ Pier Marco Bertinetto and Michele Loporcaro, "The Sound pattern of Standard Italian, as compared with the varieties spoken in Florence, Milan, and Rome," in *Journal of the International Phonetic Association*, Vol. 35, No. 2 (December 2005): 144.

¹⁹ Peterson and Barney, "Control Methods used in a Study of the Vowels", 183.

²⁰ Berton Coffin, *Overtone of Bel Canto*, Metuchen, New Jersey: Scarecrow Press, 1980, 28.

scientists in the last century have come to a more complete understanding. The acoustics of the vocal tract have a profound influence on the function of the vocal folds.

According to the nonlinear source filter theory, acoustic energy resonating in the vocal tract influences the vibration of the vocal folds.²¹ This dynamic, when tuned in particular ways, can either reinforce or interfere with the vibration of the vocal folds.²² If the vowels are shaped so that the resonances of the vocal tract align with the partials of the overtone series, this benefits the singer.²³ This tuning not only generates standing waves which boost the energy levels of the sound,²⁴ but the interaction of the resonance and overtone series generates acoustic pressure which influences the nature of the vibration at the vocal fold level.²⁵

This coordination helps to stabilize the vocal folds which vibrate because of the flow of compressed air coming from the lungs. As acoustic energy increases, the vocal folds are able to withstand the air pressure needed for high intensity operatic singing. The scenario described creates a positive feedback loop of healthy vocal function. In contrast, if vowels are poorly shaped, the resulting resonance or lack thereof can interfere with the vibration of the vocal folds and the dynamic equilibrium. The resulting destabilization leads to muscular interference as an attempt to continue phonation. If the singer persists, a negative feedback loop of vocal disfunction and muscular rigidity occurs, hindering the musical tones²⁶ of *bel canto*. In summary, singing with well-tuned vowels helps a singer produce acoustic energy in the vocal tract which

²¹ Joe Wolfe, "Vocal tract resonances in speech, singing, and playing musical instruments," in *HFSP Journal*, Vol. 3, No. 1, (February 2009), 8.

²² Ingo Titze, "The Concept of Impedance," in *The Journal of Singing*, Vol. 77, No. 3, (January/February 2021), 380.

²³ Kenneth Bozeman, *Practical Vocal Acoustics*, Hillsdale, NY: Pendragon Press, 2013, 43-44.

²⁴ Coffin, *Overtones of Bel Canto*, 11.

²⁵ Wolfe, "Vocal tract resonances in speech, singing, and playing musical instruments", 13.

²⁶ "Musical Sound," 2019, in *Encyclopædia Britannica*, <https://www.britannica.com/science/musical-sound>.

influences the vibration of the vocal folds and balances the dynamic equilibrium of air pressure. Understanding and applying this important phenomenon would benefit students and teachers.

Many voice scientists of the last century have studied nonlinear source filter dynamics, desiring to tune formants to coordinate the voice. Berton Coffin created a chromatic vowel chart to encourage optimal tuning of the first formant through vowel choice. He did not create a pitch specific vowel chart. Formant tuning studies are becoming ever more present in academic literature yet to date there is no map to systematic formant tuning based on pitch. Having such a map would be useful on a theoretical and a practical level. Some studies have explored the formant tuning of certain vowels sung on specific pitches, but they often rely on focus groups made up of anonymous professional and/or graduate level singers. In addition, those studies often measure vowels sung outside the context of sung repertoire. Understanding of vowels in speech may be benefited through study of patterns collected from the average person, whereas the aesthetics of song are more concerned with the standards set by peak performance practitioners in the context of repertoire.

Breakthroughs in digital media, the internet, and voice analysis technology enable today's researchers and voice scientists to conveniently access and analyze recordings performed by peak performing artists of the past. The recordings of an aria can be compared to the standard text that is read by a focus group in a vowel study. The vowel formant measurements sung on a single pitch within the context of repertoire gathered from recordings can be used to build a vowel chart. This chart would indicate a much clearer picture of vowel quality in singing and may offer answers behind the *bel canto* orientation to "sing pure vowels." Creating such a vowel chart is the objective of this thesis.

Definition of Terms

Vowel. Evelina Colorni writes that “vowels may be roughly defined as continuous voiced speech sounds produced without constriction or obstruction in the pharynx and mouth ... every vowel is the result of a particular position of the tongue and lips and phoneticians have found it pertinent to classify vowel sounds according to the position of the tongue.”²⁷ J.B. Rosner and B.S. Pickering have noted that phoneticians have “traditionally used a two-dimensional graph, the vowel quadrilateral” to represent the physical characteristics of the vowel where the “horizontal dimension ... represents tongue advancement, while the vertical dimension indicates tongue height.”²⁸ The two-dimensional graph has also been used to represent the acoustic characteristics of the vowel. Generally, the acoustic chart has a different orientation where the horizontal dimension represents the first formant tuning and the vertical dimension represents the second formant tuning. The acoustic orientation is the one used in this thesis. In summary, vowels can be defined based either on the position of the physical articulators (tongue, lips, jaw) or the perception of the acoustic characteristics controlled by the frequency of the vowel formants tuned by the vocal tract.²⁹

Phoneme. Collinsdictionary.com defines a phoneme as “the smallest unit of significant sound in a language.”³⁰ Phonemes can be vowels or consonants. In this thesis the term phoneme will be used to refer to the unique vowel shapes produced by the formant tuning patterns of the Italian tenors on the middle C vowel chart and not the Italian vowels of spoken and written language.

²⁷ Evelina Colorni, *Singer's Italian: A Manual of Diction and Phonetics*, New York: Wadsworth Publishing, 1996, 3.

²⁸ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production*, 1.3.4

²⁹ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production*, 1.2

³⁰ “Definition of ‘phoneme’”, Collinsdictionary.com, <https://www.collinsdictionary.com/us/dictionary/english/phoneme>.

Formant. Gunnar Fant defined formants in 1960 as “the spectral peaks of the sound spectrum.”³¹ In layman’s terms this means that on a spectrograph readout as seen in a program like VoceVistaVideo, the highest peaks or the most intense coloring of the spectrograph are indicators of the effect of a resonance of the vocal tract. Voice scientists call these spectral peaks formants. In the common language of voice science, the definition of a formant is simply “a resonance of the vocal tract.” The term formant is often used interchangeably with the term resonance.

Partials, Fundamental Tones, Overtones, and the Harmonic Series. OnMusic Dictionary provides the following description for the term partial: “When we hear the sound from a vibrating object (such as a musical instrument) we hear a complex sound that contains many different frequencies or pitches called partials. This collection of frequencies, pitches or partials is called the harmonic series or overtone series. This series is based on a fundamental frequency or pitch (first partial) with the series of harmonics or overtones comprising the remaining frequencies or partials. The fundamental is usually the strongest frequency to the ear and defines the pitch of that sound. The intensity (or volume) of the overtones or remaining partials provide the “tone color” or “timbre” of the sound which explains why a middle C on a trumpet sounds different from a middle C on a trombone or tuba. Many factors enter into the strengths and weaknesses (intensity or volume) of the partials.”³²

Vocal tract. *Dictionary.com* defines the vocal tract as “the passages above the larynx through which air passes in the production of speech, including the buccal, oral, nasal, and pharyngeal cavities.” In layman’s terms the vocal tract is the tube of air above the vocal folds that is made up of all the potential resonating cavities including the throat, mouth, and nose.

³¹ “Formant: What Is a Formant?”, [Www.phys.unsw.edu.au](https://www.phys.unsw.edu.au/jw/formant.html), <https://www.phys.unsw.edu.au/jw/formant.html>.

³² “OnMusic Dictionary - Term”, [Dictionary.onmusic.org](https://dictionary.onmusic.org/terms/2484-partial), <https://dictionary.onmusic.org/terms/2484-partial>.

Linear source filter theory. Ingo Titze writes that, “The acoustic features of all vowel productions ... have generally been described by a linear source-filter theory. This linear theory is based on the assumption that the source of sound for vowels ... is independent of the filter. ... The output of any and all input frequencies can at most be an amplitude and phase changed version of these input frequencies. The filter cannot influence the source to produce new frequencies or change the overall energy level of the source.”³³ In layman’s terms this description implies that the sound of the human voice is created by vibration of the vocal folds (the source of the sound) whose sound is filtered and amplified by the vocal tract (the filter) and that the vocal folds are independent of the influence of the filter. The shaping of the vocal tract and its resonance properties does not influence the source vibration of the vocal folds. This is a simplified and incomplete model of the functioning of the human voice.

Nonlinear source filter theory. In contrast to the linear source-filter theory, nonlinear source-filter theory states that the source vibration of the vocal folds is influenced by the shaping of the vocal tract and its resultant acoustic properties. Ingo Titze describes the phenomenon of nonlinear source-filter coupling like this: “For nonlinear-source filter coupling, the glottal impedance is adjusted to be comparable to the vocal tract input impedance, making the glottal flow highly dependent on acoustic pressures in the vocal tracts (above and below the glottis).³⁴ In layman’s terms, this means that the acoustic shaping of the vocal tract when tuned appropriately creates a favorable environment for vocal fold vibration. In contrast, other tunings of the vocal tract can create an environment that hinders vocal fold vibration. Thus, in nonlinear theory the shaping of the vocal tract has a direct impact on the ability of the singer to continue the necessary

³³ Ingo Titze, “Nonlinear source-filter coupling in phonation: Theory,” in *The Journal of the Acoustical Society of America*, Vol. 123, No. 5 (May 2008), 2733.

³⁴ *Ibid*, 2734.

source vibration for singing. Kenneth Bozeman succinctly writes that, “In certain circumstances acoustic energy passing through the filter can be productively reflected back onto the source, assisting the efficiency and power of the voice source/vibrator.”³⁵

Vowel chart. A vowel chart is a schematic arrangement of the vowels of a language. A traditional vowel chart can be obtained by plotting the vowel formants in a graph where the horizontal axis relates to Formant 1, and the vertical axis relates to Formant 2.

Pure vowel. In the world of phonetics, a pure vowel is one that is pronounced with more or less unvarying quality without any glide; a monophthong.³⁶ In other words, a pure vowel is one whose formants are not changing frequency for the length of the vowel’s duration. However, this definition is not sufficient to explain the pure vowel concept discussed in the literature of vocal pedagogy. Cornelius Reid in his discussion of the pure vowel concept says that it “represents a condition of agreement between our mental concepts of quality and the laws of physics.”³⁷ Reid continues by writing that “the constant striving of the early masters of singing toward the goal of ‘vowel purity,’ therefore, was in effect an effort guided by instinct whose purpose was to duplicate a favorable acoustic condition. To form a “pure” vowel is to set the vocal organs in a favorable adjustment, and this adjustment then awakens a desirable harmonic response increasing the beauty and purity of the tone quality.”³⁸ This description neatly marries the concepts of vowel perception with the musical and vocal need for acoustic equilibrium that is generated by nonlinear source-filter dynamics. The goal of this thesis is to observe performance practice by the focus group with the expectation that they will demonstrate formant tuning

³⁵ Kenneth Bozeman, *Practical Vocal Acoustics*, 10.

³⁶ “Definition of ‘pure vowel’”, Collinsdictionary.com, <https://www.collinsdictionary.com/us/dictionary/english/pure-vowel>.

³⁷ Cornelius L. Reid, *Bel Canto: Principles and Practices*, New York: Coleman-Ross Company, Inc., 1950, 38.

³⁸ *Ibid*, 38.

resulting in acoustic efficiency while giving the perception of clear and distinct vowel pronunciation on pitch. Documenting the tenors' formant tuning patterns will give specific definition to the pure vowels of singing on middle C.

Bel Canto. Translated from Italian, *bel canto* means “beautiful singing.” It is a term that may refer to a technique of singing originating in Italy, as well as a subgenre of Italian operatic music composed in the 19th century by composers like Rossini, Donizetti, and Bellini. In this thesis, the term *bel canto* will be used to refer to the school and technique of singing which developed in Italy that accompanied the creation of opera at the beginning of the 17th century. This style and technique of singing was disseminated throughout Europe and eventually the world.

Articulators. *Encyclopedia Britannica* says that articulation, in phonetics, is a configuration of the vocal tract resulting from the positioning of the mobile organs of the vocal tract relative to the parts of the vocal tract that are rigid.³⁹ In other words the moveable parts of the vocal tract which include the tongue, lips, jaw, velum and glottis are the agents responsible to articulate sound emitted by the human voice.

Vowel Formants, First Formant, Second Formant. Bozeman writes that the first two formants of the vocal tract are “the most responsive to changes in vocal tract shape and are therefore tunable to differentiate and define vowels. They are therefore referred to as vowel formants.”⁴⁰ Bozeman continues by writing that the “first formant determines depth or fullness of timbre, and the openness-closeness dimension of vowels.”⁴¹ He writes that the second formant,

³⁹ “Articulation | Speech | Britannica”, 2020, In *Encyclopædia Britannica*, <https://www.britannica.com/topic/articulation-speech>.

⁴⁰ Kenneth Bozeman, *Practical Vocal Acoustics*, 12

⁴¹ *Ibid*, 13.

“plays a role in clarity of vowel definition” and that it “is perceptually more responsible for clarity of definition.”⁴²

Delimitations of Study

This thesis is a scientific study of vowels sung by peak performance singers on historical audio recordings. There is a wide world of styles, nationalities, and languages in singing, so limitations needed to be set. This study focused on gathering vowel samples on a single pitch, middle C / C4. The “standard text” that was read was limited to seven Italian arias composed by Italian composers. The seven vowels of the Italian language [a, e, ε, i, o, ɔ, u] sung on middle C were measured for their first and second formant frequencies. The focus group of the “readers” was limited to twenty prolific, Italian-born tenors of the 20th century. The combination of selected arias and tenors produced ~4,000 vowel samples on middle C which were used to create a vowel chart for that pitch.

Hypotheses

The hypothesis of the thesis is that distinct patterns will occur in the formant tuning of the focus group. The data patterns represented on a vowel chart from a speech study are often quite dispersed.⁴³ In this study, the limitations of pitch and the Italian language should result in more concentrated groupings. Each grouping on the vowel chart will be defined with an IPA symbol based on perceived vowel quality. The patterns of vowel tuning sung by the tenors should demonstrate the interaction of formants and overtones predicted by nonlinear source filter theory. Among the vowel groupings gathered from the focus group, preferences for certain vowel shapes will be observed.⁴⁴

⁴² Ibid, 15.

⁴³ Peterson and Barney, “Control Methods used in a Study of the Vowels”, 182.

⁴⁴ Kurt Adler, *Phonetics and Diction in Singing: Italian, French, Spanish, and German*, Minneapolis: University of Minnesota Press, 1974, 14-15.

Significance of Study

This study will bring clarity to the question of vowel quality related to pitch and shed light on the pure vowel concept in singing. The vowel groupings from the study will indicate optimal formant tuning to take advantage of nonlinear source filter dynamics when singing on middle C. The directive in *bel canto* treatises to sing pure vowels is likely designed to prompt nonlinear source-filter dynamics. The vowel chart will demonstrate nonlinear source-filter theory and bring clarity to the directions found in historic literature related to vowel shaping.

The vowel chart for middle C documents vowels sung by peak performance practitioners of the Italian singing tradition. The chart will offer a significant and specific guide for singers who desire to shape their vowels in the tradition of Italian tenors. Programs like VoceVistaVideo and spectrograph apps make formant tuning an increasingly viable and accessible strategy for students and teachers. The middle C vowel chart will serve as a guide for formant tuning on Middle C which can then serve as a guide for discovering effective vowel shapes on other pitches.

CHAPTER 2

LITERATURE REVIEW: THE HISTORY OF VOWELS IN SINGING

The literature review component of the study will encompass three primary areas. First is the development of a uniquely Italianate tradition of singing which was then disseminated throughout Europe and documented by vocal writers of the 17th, 18th, and 19th centuries. Second is the birth of the science of voice acoustics and phonetics in the 19th century and its work to describe and define the phenomena of human vocal sounds. Third is the use and continued development of the theories of vocal training by voice teachers from 1967 to present. A survey of these three areas will help to establish that there is a school of Italian singing and that the school is concerned with the quality of the vowels used in singing. This literature review will also trace the way scientists have come to think about the voice, the vowel sounds of the voice, and how to categorize those sounds. The nonlinear source filter theory in particular figures prominently in the writings of voice teachers from 1967 on, and is an important component of this thesis. The thesis will demonstrate that vowel quality is an essential component in the search for equilibrium in singing. Therefore, studying the vowel shapes of great singers will meaningfully contribute to the body of knowledge in the field of singing.

Background of the Italian School

Research and publications of the last decades have done much to illuminate the development of the Italian school of operatic singing. The earliest documents and treatises have become much more accessible, and scholars and voice teachers have written commentary both towards the end of the 20th century and now in the beginning of the 21st century. Cornelius Reid in *Bel Canto: Principles*

and Practices and Edgar Herbert-Caesari in *Tradition and Gigli*, did significant work to survey the earliest voice treatises, do research on the beginnings of Italian singing in the *schola cantorum*, and the Florentine *camerata*'s contributions to the new art form of opera.⁴⁵ William Henderson, with his book *Early History of Singing* also contributed to this survey of the history of singing as it led up to and contributed to Italian *bel canto*. It becomes clear that, with the Renaissance and the birth of opera, many factors contributed to the establishment of the Italian school of singing including philosophy, architecture, the education system, and economics. Nicholas Baragwanath, with *The Solfeggio Tradition*, has shed light on the Italian music trade which used *solfeggio* as a cornerstone of its education system. The right tone quality and correct pronunciation was coached from the first lessons on all the Italian vowels using *solfeggio*.⁴⁶ John Rosselli's work *Singers of Italian Opera: The History of a Profession* examines the history of opera singers in Italy, and how economics and geography influenced the proliferation of theatres and singing schools. Lastly, Berton Coffin, in his appendices to the *Historical Vocal Pedagogy Classics*, explores how the acoustics and architecture of Italian theatres which were being built in the 1600s contributed to cultivation of the *bel canto* sound that was most effective at communicating language and drama over an orchestra. These resources together point to a specific moment of time (the Renaissance) in which musicians and voice teachers were exploring a new art form (opera) in a specific language with particular attributes (Italian) which was to be performed in specific acoustic spaces (Italian box theatres).

Primary Sources of the *Castrati* School

Pier Francesco Tosi was the first to write extensively on *castrati* singing with his *Observations on the Florid Song*, published in 1723. The most thorough examination of vocal art followed in Giovanni Mancini's book *Practical Reflections on the Figurative Art of Singing* in

⁴⁵ Edgar F. Herbert-Caesari, *Tradition and Gigli 1600-1955: a panegyric*, London: Robert Hale Limited, 1963, 26.

⁴⁶ Nicholas Baragwanath, *The Solfeggio Tradition*, New York: Oxford University Press, 2020, 131.

1774.⁴⁷ These two books form an eyewitness account of the style, values, and technique of singing in Italian opera during its development and high-water mark with the *castrati*. Among the *castrati* school priorities was clear and distinct pronunciation and the positioning of the mouth for the vowels which was in the shape of a smile for EE, EH, and AH, and with rounded lips for OH and OO.⁴⁸ Many writers of the time, Giusto Tenducci for example, referred to the “rules of bel canto.” Those rules always included the importance of clear pronunciation and the use of pronunciation to express the words of the lyrics.⁴⁹ Italian singers and music teachers were one of Italy’s great exports, but foreigners also made pilgrimages into Italy to study singing. Johann Friedrich Agricola documented what he learned in *Introduction to the Art of Singing* and Manuel Garcia I published his *Exercises for the Voice* for use by his students. These two books are among the many that communicated the principles of *bel canto* singing developed in Italy to the wider world.

Documentation of the Italian School in the 1800s

Tosi and Mancini were riding the beginning wave of the scientific revolution in the 1700s. However, in the 1800s, there was a deeper desire to understand and document the workings of the voice both anatomically, as well as acoustically. More complete descriptions of the workings of the voice, including the methods and techniques of developing the voice, were being published. Probably the most influential was the *Treatise on Singing* in two parts published by Manuel Garcia II in the 1840s. Garcia created a watershed moment in vocal history through the combination of tradition passed down from his father, with the newest advancements in scientific discovery.⁵⁰ He focused significant attention on the shaping of vowels, the anatomy of

⁴⁷ Cornelius L. Reid, *Bel Canto: Principles and Practices*, 15.

⁴⁸ Mancini, *Practical Reflections on the Figurative Art of Singing*, 93-94

⁴⁹ Giusto Ferdinando Tenducci. *Instruction of Mr. Tenducci to his scholars*, 2.

⁵⁰ Matthew Hoch, “Historical Landmarks in Singing Voice Pedagogy”, *Voice and Speech Review*, Vol. 13, No. 1 (2019), 48.

the voice, and he developed a theory of clear and somber timbres to describe the various qualities of sound produced by the human voice. Francesco Lamperti published his *Guida Teorico-Pratica-Elementare per lo Studio Del Canto* in 1864 as a thorough technical instruction on the development and exercise of the voice. He noted decadence in the singing world and believed that a return to the practice of *solfeggio* and careful attention to the pronunciation of the vowels in singing would help rectify that problem.⁵¹ Nicola Vaccai made a significant contribution to the discussion with the introduction to his *Practical Vocal Method of Italian Singing*, wherein he wrote of the importance of singing in Italian with its pure and sonorous vowels.

One area of note from this period of time is the popularization and greater awareness of the *voix sombre*. Gregory Bloch in his article, *The Pathological Voice of Gilbert Louise Duprez*, documents the writings of two French scientists, Diday and Petrequin. They analyzed what they called a new species of singing voice found in the singing of Duprez. Their article introduced the world to the concept of clear colored singing and dark colored singing and prompted quite the exchange with Manuel Garcia II, who said that the somber timbre was not new at all.⁵² Garcia's writing on vowels and timbres explored a calculated departure from singing Italian vowels for the purpose of vocal coloring and expression by using French vowels.⁵³ Duprez himself commented on the vowels of singing and *voix sombre* in his book *The Art of Singing*, published in 1846.

Primary Sources of Vocal Pedagogy on Vowels in the 1900s

In the wake of Garcia's writing and the proliferation of Duprez's style of singing, two camps emerged in vocal pedagogy. The first camp was exemplified by Oscar Saenger (teacher of

⁵¹ Francesco Lamperti, *Guida Teorico-Pratica-Elementare Per Lo Studio Del Canto*, 16.

⁵² Gregory W. Bloch, "The Pathological Voice of Gilbert-Louis Duprez", *Cambridge Opera Journal* 19, no. 1 (2007), 17-18.

⁵³ Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 4-9.

Paul Althouse, the teacher of Richard Tucker) who taught in his *Oscar Saenger Phono-vocal Method* to sing the pure Italian vowels as the basis of vocalization. The other camp included the likes of D.A. Clippinger. In Clippinger's *Class-Method of Voice Culture*, he described the use of timbres and desired for the standard function of the voice to achieve a homogenization of the vowel sounds. This approach would make the brighter vowels like EE and EH to be rounded and more gathered, and the darker vowels like OH and OO to be more open and resonant. Aureliano Pertile, leading tenor at *La Scala* in the early 1900s, described his method in Domenico Silvestrini's book *Aureliano Pertile e il suo metodo di canto*. He described his vowels as all being influenced by the OH.⁵⁴ Kurt Adler, in *Phonetics and Diction in Singing*, confirmed Pertile's approach by noting that while in provincial theatres pure Italian vowels were acceptable, the standard observed at La Scala was to color and round vowels towards OH. A third camp was also beginning to be established, as shown in Herbert Witherspoon's *Singing; a Treatise for Teachers and Students*, published in 1925. Witherspoon was exploring the perceptions of vowels related to pitch, based on the laws of acoustics.

Surveys of Vocal Pedagogic Literature

The above sources highlight some of the important and pertinent documents related to the history of singing which reference pronunciation. Further research in this thesis was accomplished by referencing the survey works *The Art of Singing*, by Brent Monahan which looked at literature in singing from 1777 to 1927, *Training the Singing Voice*, by Victor Alexander Fields which looked at literature in singing from 1928 to 1942, and *Teaching Singing*, by John Carroll Burgin which looked at literature in singing from 1941 to 1971. Also consulted was Berton Coffin's *Historical Vocal Pedagogy Classics*, which gave summaries and

⁵⁴ Domenico Silvestrini, *Aureliano Pertile E Il Suo Metodo Di Canto*, Bologna: Tipografia Adlina, 1932, 56-57.

commentary on important vocal pedagogy literature. Stark's *Bel Canto: A History of Vocal Pedagogy* is a great contemporary survey of historical vocal pedagogy literature. The general trend of these surveys acknowledged that pronunciation was extremely important for the development of the singing voice. Physical descriptions of the articulators for pronunciation abound, and references to the qualities of the Italian language which contribute to good singing are numerous. The connection between pronunciation and good tone quality was noted, however the field began shifting its attention towards the development of resonance and anatomical physical descriptions for tone shaping.

References on Acoustics, Phonetics, and Diction

Hermann Helmholtz published his work *On the Sensations of Tone* in 1863, which presented a quantum leap forward in the understanding of the acoustical phenomena of sound, the human voice, vowels, and human hearing. It was finally possible to give vowels definition based on the frequency of the overtones which were prominent in the different vowels. The phenomenon of overtones and harmonics in music had been observed earlier, as surveyed in Olivier Darrigol's article, "The Acoustic Origins of Harmonic Analysis." Helmholtz was the one to connect the overtones to the voice, which facilitated the definition of vowels. Labeling of language sounds with a phonetic alphabet had been explored as early as 1845 by Pitman and Ellis, and the International Phonetic Alphabet was established in 1888.⁵⁵ However, an acoustic definition of the vowel sounds was still developing. Rosner and Pickering's book *Vowel Perception and Production* explores in depth, the current understanding and application of acoustics and anatomy in the perception, documentation, and categorization of vowel sounds. Rosner and Pickering's book was a thorough reference for the concepts of vowel charts, vowel formants, and the perception and definition of

⁵⁵ Kurt Adler, *Phonetics and Diction in Singing*, Page 4

vowel sounds. Colorni, in her book *Singer's Italian: A Manual of Diction and Phonetics* and Kurt Adler, in his book *Phonetics and Diction in Singing* describe in detail the physical articulation of the vowel sounds in Italian. Colorni described natural Italian vowels and Adler made allowance for the adjustments necessary for coloring in singing. The actual acoustic descriptions of Italian vowels gained from formant measurement were documented in "The Sound Patterns of Standard Italian" by Bertinetto and Loporcaro.

Synthesis of Voice Pedagogy and Voice Science

Matthew Hoch in his article "Historical Landmarks in Singing Voice Pedagogy" identifies 1967 as the inauguration of the fact-based era in singing, thanks to the publication of Appelman's *The Science of Voice Pedagogy* and Vennard's *Singing: The Mechanism and the Technic*. Both books sought to find a synthesis between the traditions of voice training for singing and the proliferation of scientific knowledge on the anatomy and acoustics of singing. Appelman was keen to explore the connection between the quality of the vowel and the generation of good singing tone. He published in-depth physical descriptions and vowel charts on the different vowels of IPA. Johan Sundberg also contributed significantly to the field with his article "The Acoustics of the Singing Voice" and his book *The Science of the Singing Voice*.

The works of Berton Coffin were particularly influential on this thesis, including *The Sounds of Singing*, *Overtones of Bel Canto*, and the chromatic vowel chart. Coffin wrote in practical terms on nonlinear source-filter dynamics and sought to find ways to tune the voice to take advantage of that phenomenon. Coffin also connected the scientific discoveries in voice and acoustics of his time to the traditions of historical voice pedagogy.

Other references of note include Ingo Titze and his book *Principles of Voice Production*, his articles "Resurrection from the Coffin", "Another Incremental Step in Reviving and Revising

Coffin's Favorable Vowel Chart", and "Nonlinear Source-filter Coupling in Phonation: Theory." These sources help to specifically identify the dynamics involved in the voice and vowels with nonlinear-source filter theory. This literature review would not be complete without also mentioning Richard Miller's book *Structure of Singing*, which acknowledges the dynamic of vowels and their contribution to singing.

Contemporary Discussion of Diction and Acoustics in Singing

In the 21st century world of formant tuning and acoustic analysis, there continues to be discussion related to pure vowels of singing. Stephen Austin in his article "Canaries in the Coal Mine", and John Nix in "You Want Me to Do What?" and "Pedagogic Fundamentalism" indicated that there is little consensus on the concept of pure vowels in singing. Kenneth Bozeman has made significant contributions towards the practical use of acoustics in the voice studio with his books *Practical Vocal Acoustics* and *Kinesthetic Voice Pedagogy*. Fleisher's article "Formant frequencies and bandwidths of the vocal tract" as well as Joe Wolfe's "Vocal Tract Resonances in Speech, Singing, and Playing Musical Instruments" were helpful in summarizing contemporary understanding of the vocal instrument and the interaction between breath, vocal folds, and resonators. The VoiceScienceWorks website was useful for ideas on filtered listening and a clearer understanding of the practical effects of the vowel on the vocal folds.

The acoustic analysis of historical recordings has been used by Miller and Schutte in their article "Resonance Strategies Revealed in Recorded Tenor High Notes", as well in Troy Castle's dissertation "Shifting Gears: Formant Tuning Strategies of Elite Operatic Baritones." Analysis of historical singer performances, both in audio and on video, was carried out in Titze, Worley, and Story's article "Source-vocal Tract Interaction in Female Operatic Singing and Theater Belting." There is significant precedent for the kind of acoustic study of recordings found in this thesis.

Professional Testimonials on the Importance of Vowels in Singing

Testimonials by important singers on their training were also influential on this study. Luciano Pavarotti, in his book *My World*, Richard Tucker in the interview “The First Step is... Honesty”, and Frank Sinatra in *Tips on Popular Singing*, all reported that attention was focused on their pronunciation and vowel quality at the very beginning of their formal vocal training. Lastly, personal interaction with several career singers by the author of this thesis affirm the importance of pronunciation in voice training. Metropolitan Opera Rossini tenor Rockwell Blake studied with Renata Booth, a native Italian voice teacher, and reported the importance of singing pure vowels in his training. He also taught pure Italian vowels in his voice studio. Metropolitan opera Verdi baritone Frederick Burchinal reported drills in Italian pronunciation by his Italian voice coaches. He also emphasized the importance of singing pure vowels in his voice studio. Rock Opera Orchestra tenor Alexander Kariotis, who studied with Dan Marek, Arrigo Pola, and Gianni Raimondi, emphasized the absolute importance of the correct shaping of the vowels for the purpose of achieving *bel canto* singing quality in the Italian school.

Implications for this Thesis

This literature review demonstrates the uniqueness of the Italian school of singing called *bel canto* which came into being alongside the invention of the operatic art form. *Bel canto* included clear and distinct pronunciation of vowel sounds as one of its foundational principles. Correct formation of pure vowels for singing was a consistent theme throughout the literature. The Italian school valued particular qualities of sound and tone quality in singing. Nevertheless, aside from the guidance of the vowels of language to serve as a reference, there was no set definition of what the pure vowels of singing were. Even today there is little consensus on what the vowels of singing should be, how to define them, or what it even means to “sing a pure

vowel.” D.A. Clippinger noted that it is impossible to put down on the page the tonal characteristics of good singing, but that it is something that has to be experienced with the ear.⁵⁶

At first, vowels were understood in a general way based on the pronunciation of vowel sounds in different languages. The perception of vowel quality in speech was later differentiated with IPA symbols and speech-based vowel charts. These vowel charts were created based on positioning of the tongue, lips, and jaw. With the development of the field of acoustics, it became possible to give specific definition to vowels based on the locations of the vowel formants. There is significant precedent for creating vowel charts from the formant frequency data of focus groups. Attempts have been made by voice researchers, including Coffin and Appelman, to bring greater definition to the formant tuning of singing. However, their studies were broad in scope, and attempted to address the general tuning strategies of many voice types across the entirety of the singer’s range. The information was useful, however not specific enough for clear and direct application.

No vowel chart has ever been created for a single pitch based on the formant tuning of historic-level singers in the context of singing. In recent years, more and more studies have been done based on acoustic data found in historical recordings. There is precedent for using historical recordings to carry out acoustic analysis. The creation of a vowel chart based on the performance practice of a national school of singing would be a valuable contribution to the field of singing. It would be valuable both for pedagogical guidance, and for clarification of directions on vowels found in the historic pedagogical literature.

⁵⁶ David Alva Clippinger, *The Clippinger Class-Method of Voice Culture*, Bryn Mawr, Pennsylvania: Oliver Ditson Company, 1932, 12.

CHAPTER 3

METHODOLOGY: THE SCIENCE OF CREATING A VOWEL CHART

This chapter will explain in detail the delimitations of the study which will analyze the first and second formant frequencies of vowels sung on middle C by Italian tenors of the 20th century. This chapter will also explain the process of selecting the tenors which make up the focus group and the arias which they sang. The process of collecting and organizing the vowel formant frequencies to create the vowel chart will also be explained.

Delimitations

The first limitation of the study was to focus on a single pitch: middle C / C = 256Hz. Middle C is a note that sits in the middle range of the tenor voice and is frequently encountered in the operatic literature. Middle C is convenient for formant tuning analysis because the overtone series is not overly spread out, which happens in tenor high notes or overly condensed which happens in tenor low notes. In the case of higher pitches, the resonances of the vocal tract can get lost between harmonics, which makes them difficult if not impossible to accurately measure. In the case of lower pitches, the density of the overtones creates an untold number of formant tuning possibilities. Middle C also for the most part avoids the polemic *passaggio*. All these reasons make middle C an ideal pitch with which to study the formant tuning strategies of tenors.

The second limitation was to restrict the study to the tenor voice category. Restricting to a single voice category is significant because the relative size of the instrument (larynx, pharynx, and other resonators) has a significant impact on the overall tuning of the formants of a singing

voice.⁵⁷ As a practical example, the formant tuning strategies used to sing what is perceived to be an Italian /a/ may be different between different voice categories.

The third limitation was of language and nationality. Italian was selected because it is the language of *bel canto* and it has a rich canon of operatic repertoire. The decision was also made that all repertoire selections would be made up of operatic arias with lyrics written by Italians with music composed by Italians. The arias would come from the standard repertoire, are often recorded, and have a rich tradition of performance. The tenors selected for analysis also needed to be native born Italians.

Another limitation was to analyze audio recordings from a specific period of history. Audio recording began in the late 19th century but reached a rudimentary maturity at the beginning of the 20th century.⁵⁸ The thesis will analyze recordings from the 20th century, divided into the time period before and after World War 2. Tenors whose primary recording and stage career was made before WW2 were selected for the first group, while tenors whose primary recording and stage career was made after WW2 were selected for the second group. The post-World War 2 tenors who were born after 1940 were not selected due to their current ongoing careers and because most of their recordings were produced in the digital era of the 21st century.

Selection of Tenors and Arias

The selection of the tenors required a process to include a variety of prominent tenors with a specific criterion that would merit them being included in the analysis and who were the best representatives of Italian voice culture. One standard formulated by which to judge which tenors are exemplary representatives of the culture was to look at the history of recordings and

⁵⁷Dmitriev L. and Kiselev A., “Relationship between the Formant Structure of different types of singing voices and the dimensions of supraglottic cavities”, *Folia Phoniatr*, Vol. 31, No. 4 (1979): 238.

⁵⁸ Roger Beardsley and Daniel Leech-Wilkinson, 2020, “A Brief History of Recording to Ca. 1950”, Rhul.ac.uk. May 2, 2020, https://www.charm.rhul.ac.uk/history/p20_4_1.html.

investigate who was the most prolific. The more the tenor was appreciated by the recording industry and the record-buying public, the better the indication of the tenor's place as a representative of the aesthetic values of the culture. The tenors that were the best sellers would have had the most opportunity to make recordings, and their legacy would be carried on through re-issues and "best of" albums. Simply put, those tenors who produced the most recordings were judged to be the best representatives of the Italian operatic culture.

The website www.historicaltenors.net was used as a reference when developing a list of Italian tenors who have made recordings. The website features an impressive listing of opera singers of all sorts, including a listing of 310 Italian tenors.⁵⁹ The recording legacy of these Italian tenors was researched using the websites www.discogs.com, www.allmusic.com, and www.worldcat.org. The name of each Italian tenor was searched in the three databases. The number of search results from each tenor within the category of releases on Discogs.com was counted. The number of search results for each tenor within his artist page on Allmusic.com was counted. Lastly, the number of search results for each tenor within the music category of Worldcat.org was counted. The three numbers were then averaged and sorted to calculate a ranking for each tenor from most prolific to least prolific.

Twenty tenors were selected, including the top ten from the Pre-WW2 era and the top ten from the Post-WW2 era, with tenors being born after 1940 being left out entirely. There were three tenors born before 1940 that were found to be unsuitable for the study and replaced with substitutes. The three included Fernando De Lucia, Francesco Albanese, and Nicola Monti. Fernando De Lucia recorded the arias in keys different from the ones in which the music was originally composed, which made his recordings unusable for the study. He was substituted by

⁵⁹ "Italian Tenors Index", [Www.historicaltenors.net](http://www.historicaltenors.net), <http://www.historicaltenors.net/italian/indexitalian.html>.

Francesco Merli to round out the Pre-War ten. Francesco Albanese was a popular leading tenor who sang often with Maria Callas and recorded many Neapolitan songs. However, he did not record a single one of the arias selected for analysis. He was replaced by Franco Bonisolli.

Nicola Monti ranked higher than Bonisolli among the Post-War tenors, however his recording and stage career was largely built on singing *comprimario* roles. The final list of tenors included in the study are found in Table 1 with their name, overall ranking, the number of search results averaged from the three websites, and their life dates.

	PreWW2 Tenors. Born late 1800s, primary recording career pre-1945.	PostWW2 Tenors. Born early 1900s-1940, primary recording career post-1945.
1	Caruso, Enrico (#2, 3115.33) - 1873-1921	Pavarotti, Luciano (#1, 3,701.33) - 1935-2007
2	Gigli, Beniamino (#3, 2,285.33) - 1890-1957	DiStefano, Giuseppe (#4, 1,754.67) - 1921-2008
3	Schipa, Tito (#5, 1,210.67) - 1889-1965	Del Monaco, Mario (#6, 1,183.00) - 1915-1982
4	Martinelli, Giovanni (#9, 616.00) - 1885-1969	Bergonzi, Carlo (#7, 1,121.00) - 1924-2014
5	Pertile, Aureliano (#11, 537.67) - 1885-1952	Corelli, Franco (#8, 989.33) - 1921-2003
6	Lauri Volpi, Giacomo (#13, 406.67) - 1892-1979	Tagliavini, Ferruccio (#10, 574.33) - 1913-1995
7	Zenatello, Giovanni (#15, 315.00) - 1876-1949	Valletti, Cesare (#16, 311.33) - 1922-2000
8	Bonci, Alessandro (#17, 283.67) - 1870-1940	Poggi, Gianni (#20, 223.33) - 1921-1989
9	Anselmi, Giuseppe (#18, 275.33) - 1876-1929	Raimondi, Gianni (#21, 218.00) - 1923-2008
10	Merli, Francesco (#19, 234.33) - 1887-1976	Bonisolli, Franco (#26, 191.33) - 1938-2003

Seven arias were selected for the study from the canon of Italian operatic repertoire. The selection of the seven arias included the criteria that each needed to have a sizeable number of notes sung on middle C. Between the arias, it was preferred that there be a reasonable distribution of the Italian vowels so that there would be a similar number of samples for each vowel. The only exception was the Italian vowel /u/, which is relatively rare. The arias were selected from famous operas which have a rich history of performance tradition. Table two lists

the selected arias, the operas from which they were taken, and the composers of the operas. Also listed are the number of tenors from the twenty that recorded the aria.

TABLE 2, Listing of Italian Arias	
Aria, Opera, and Composer:	# of tenors who recorded each aria:
Lunge da lei ... De miei bollenti spiriti, <i>La Traviata</i> , Giuseppe Verdi	15
Che gelida manina, <i>La Boheme</i> , Giacomo Puccini	14
Una furtiva lagrima, <i>L'elisir d'amore</i> , Gaetano Donizetti	14
Giunto sul passo estremo, <i>Mefistofele</i> , Arrigo Boito	15
Recondita armonia, <i>Tosca</i> , Giacomo Puccini	18
Se quell guerriero fossi ... Celeste aida, <i>Aida</i> , Giuseppe Verdi	15

The combination of tenors and arias resulted in 106 historical recordings for the study with 97 recordings accessed through www.youtube.com, four through www.spotify.com, three through www.enricocaruso.dk, and one each through adp.library.ucsb.edu and www.classicalarchives.com. A full listing of recordings used for the study is included in the discography section of the References chapter. In some cases, a tenor had recorded multiple versions of the aria. In those situations, the decision was made to select one of the recordings based on its quality for the purpose of collecting the clearest vowel formant analysis.

Target of Analysis and a Disclaimer

The first and second formant frequencies of vowels sung on Middle C are the target data to be collected from each recording. The formant data was collected from the recordings using VoceVistaVideo (hereafter referred to as VVV), a program “designed for scientists and artists alike [which can] help them to visualize the musical interpretation of the sound, and to

understand the role of harmonic overtones, especially in the voice.”⁶⁰ The software is designed for use by singers, singing teachers, and speech language pathologists, and allows one to view and interact with the spectrogram readout of an audio file.

When a resonance of the vocal tract falls between two overtones, there is greater difficulty in ascertaining the frequency of the formant. Formants are revealed through the interaction of vocal tract resonances with the overtone series of the sung pitch. If a resonance is close to or in conjunction with a harmonic of the overtone series, that overtone will sound with greater intensity. The spectral peak visible on the spectrogram indicates the frequency of the formant. When a vowel needs to be analyzed whose formants are between the overtones, the frequency of the formant is documented based on two criteria. First, the formant is analyzed based on the way the resonance influences and amplifies the surrounding overtones. If one of the overtones has a higher intensity or dB level as indicated by a brighter color picture on the spectrogram, this indicates the proximity of the formant. Second, the formant is based on a match between the sound of the vowel from the recording and the sound of an artificial vowel generated by the VVV vowel chart tool. The VVV vowel chart tool generates an artificial two-formant vowel whose formants can be adjusted by clicking and dragging the cursor around the two-dimensional space of the vowel chart. If the artificial vowel’s formants are placed so that the artificial sound matches the singer’s vowel from the recording, this serves as a good secondary indication of the formant frequencies. Measuring formant frequencies is not an exact science and user error is a factor in the data collection. In addition, this study is the first of its kind which seeks to map a pitch specific vowel chart based on historical recordings. Results may not be precisely accurate to the level desired by many voice scientists. However, the patterns of formant

⁶⁰ “VoceVista: Science of Singing”, VoceVista: Science of Singing, Accessed March 1, 2023, <https://www.vocevista.com/>.

tuning which are revealed in the aggregate are a significant indicator of Italian tenor vowel-shaping strategies which makes a compelling argument for the value of this study.

Collection and Organization of Data

The process of collecting the vowel formant frequencies and organizing the data for analysis will be explained in this section. The first step was to document every vowel sung on middle C in the repertoire selections. Every vowel, in order, from each aria was given a unique label. For example, the first vowel on middle C from *Recondita Armonia* was labeled “Rec_1.” The total number of vowel samples to be analyzed in the study was counted. Between the number of vowels on middle C per aria, and the number of tenors from the twenty which had recorded that aria, the study would analyze 4,242 vowel samples. Each individual sample was given a unique number code from 0001 to 4242. The sample was documented with reference to the tenor who sang the vowel, the tenor’s generation, the tenor’s voice category, and the tenor’s birth region of Italy. The sample was also documented with the name of the aria, the name of the composer, and the unique aria-vowel code. Lastly, the Italian vowel (a,e,i,o,u) and the IPA symbol (i,e,ɛ,a,o,ɔ,u) for the sample were recorded.

The acoustic data documented included the first and second formant frequency, as well as the number of the harmonic with which the formant was aligned. In most cases, the formant was measured as tracking with a specific harmonic: the first, second, third, or fourth harmonic of the overtone series, etc. However, nearly twenty-five percent of the vowels measured demonstrated a formant tracking between harmonics. In those cases, the number was given a 0.5 in addition to the number, following Berton Coffin’s practice.⁶¹ Thus, if a formant tracked with the 2nd harmonic,

⁶¹ Coffin, *Overtones of Bel Canto*, 96

that formant would be documented with a “2.” If the formant was tracking between the 2nd and 3rd harmonic, the formant would be documented with a “2.5.”

Each recording to be analyzed was loaded into VVV. An example from the aria *Recondita Armonia* from *Tosca* by Puccini will be used to demonstrate the process of formant analysis. In the aria there is a phrase, “Tosca ha l’occhio nero!”. The word to analyze is *nero*, which contains two syllables sung on Middle C. The spectrogram readout of that phrase sung by Luciano Pavarotti, the same one analyzed in the study, is pictured in Figure 1.

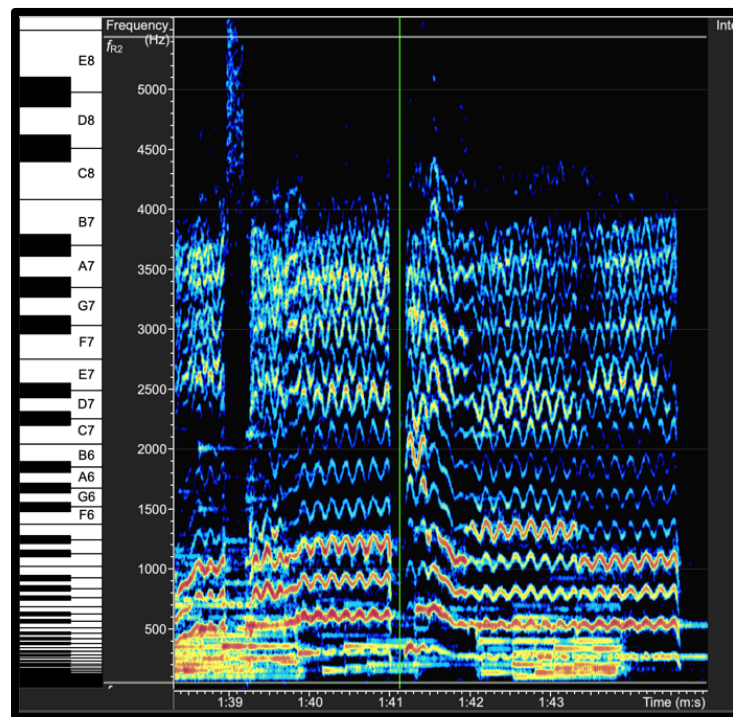


Figure 1, *Tosca Spectrogram #1 “Tosca ha l’occhio nero!”*

In Figure 1, one can see a linear frequency scale of the acoustic spectrum for the phrase. The following paragraphs will describe the acoustic phenomena relevant to the study by examining the “o” in the word *nero*, which is isolated in Figure 2. First, the overtone series is made up of a series of oscillating lines. The scientific term for one of the lines is a harmonic or partial, which is defined as a component frequency of an oscillation or wave. To be clear, the waves visible in the sample are the result of vibrato, the oscillation of the fundamental pitch and

its overtones, which is a separate oscillation. There are 15 harmonics visible in the example, the first of which is the fundamental frequency called the “first harmonic.” The second line is the 2nd harmonic, which is the first overtone. The fundamental is the first line around 262hz, the first overtone is the second line around 524hz, the second overtone is the third line around 786hz, and the third overtone is the fourth line around 1048hz. The overtone series continues indefinitely. However, in the example the overtone series diminishes in acoustic energy significantly at around 4000hz. There are 14 lines visible, indicating a fundamental pitch and 13 overtones for a total of 14 harmonics. The frequencies visualized are produced by the human voice, and observations on the lines which portray the overtones make up the analysis.

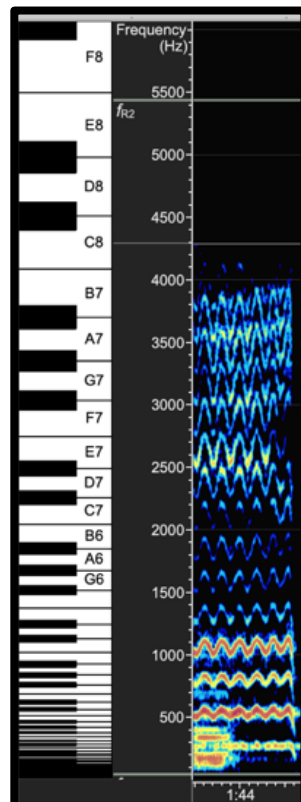


Figure 2, Tosca Spectrograph #2 “Nero”

The harmonics are lit up in different colors. The color indicates the relative loudness or intensity. Black indicates silence, whereas the sounds range from blue (fewer decibels) to bright red (more decibels). Most of the harmonics in the example are lower in decibels and colored blue.

There are a few harmonics that are predominately yellow, and there are two that are bright red. The agents responsible for the variety of sound intensity through the range of the harmonic series are the resonances of the vocal tract. Each resonance will amplify the frequencies which lie within its bandwidth. A resonance does not typically influence a single frequency but generates an acoustic bandwidth of influence wherein frequencies on the edges of the bandwidth will receive a slight boost. The frequencies at the center of the bandwidth will receive the strongest boost.⁶² If a harmonic is close to the resonance, then that harmonic will be higher in amplitude than those harmonics which are not as close to the resonance. If a resonance is tuned to line up precisely with a harmonic, that harmonic's decibels will be maximally resonated. If the resonance is positioned between two harmonics, then the resonance's boosting capability will be significantly diminished, if not lost entirely, on the harmonics around it. The implication is that the color of the harmonics on the spectrograph are an indication of formant tuning. More vivid color is an indication that a formant is tracking with the harmonic. Less intense color is an indication that a formant is not aligned with the harmonic but may nevertheless be close enough to have influence on it.

In Figure 2, the second harmonic and the fourth harmonic are bright red. The intensity indicates that the resonance is well-tuned to those harmonics. The color yellow is lighting up harmonics nine and ten near 2,500hz. In the example, the shading of yellow on the top of the vibrato of the ninth harmonic, and the tinging of yellow on the bottom of the vibrato of the tenth harmonic, give an indication that the formant is in between the overtones. The bandwidth of the formant has an influence on these harmonics. Because the resonance is not aligned with the harmonics, it will not produce the same intensity as the spectral peak generated by the first and

⁶² Kenneth Bozeman, *Practical Vocal Acoustics*, 9.

second resonances in the example. For clarity, see Figure 3, where red boxes indicate location of the vocal tract resonances, with the label for each formant in white text to the left of the red boxes.

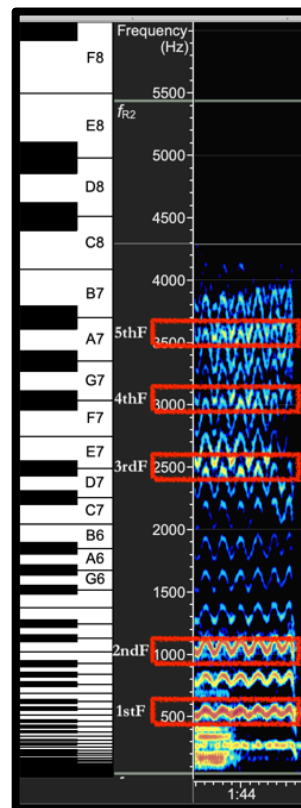


Figure 3, *Tosca Spectrograph #3 Formants*

The first and second formants are known as the “vowel formants.”⁶³ The vowel formants are the primary focus of the study and are recognized and studied by speech and voice scientists as the basis for the makeup of vowels in linguistics.⁶⁴ The third, fourth, and fifth formants make up what voice scientists call the “singer’s formant cluster.”⁶⁵ The tuning of the singer’s formant cluster creates additional carrying power and influences overall timbre to the extent of altering the perception of the vowel itself. This further explains why the study is focused on a single voice category. The longer vocal tract of a bass, for example, can so significantly alter the

⁶³ Kenneth Bozeman, *Practical Vocal Acoustics*, 12.

⁶⁴ B. S. Rosner and J. B. Pickering, *Vowel Perception and Production*, 1.2

⁶⁵ Sang-Hyuk Lee, Hee-Jun Kwon, Hyun-Jin Choi, Nam-Hun Lee, Sung-Jin Lee, and Sung-Min Jin, “The Singer’s Formant and Speaker’s Ring Resonance: A Long-Term Average Spectrum Analysis”, in *Clin Exp Otorhinolaryngol*, Jun 2008, 1(2), 92.

frequencies of the singer's formant cluster and the overall timbre of the vowel, that even with the same vowel formant tuning as a tenor, the perception of the vowel will be different.

The measurement of the first and second formant frequencies are taken using the VVV vowel chart tool. The vowel chart tool allows one to click and drag the first and second formants around an X-Y axis, which at the same time drags transparent grey reference bars on the spectrograph. The vowel chart generates a vowel sound created by the frequencies of the computer generated first and second formants. The use of these tools is visible in Figure 4.

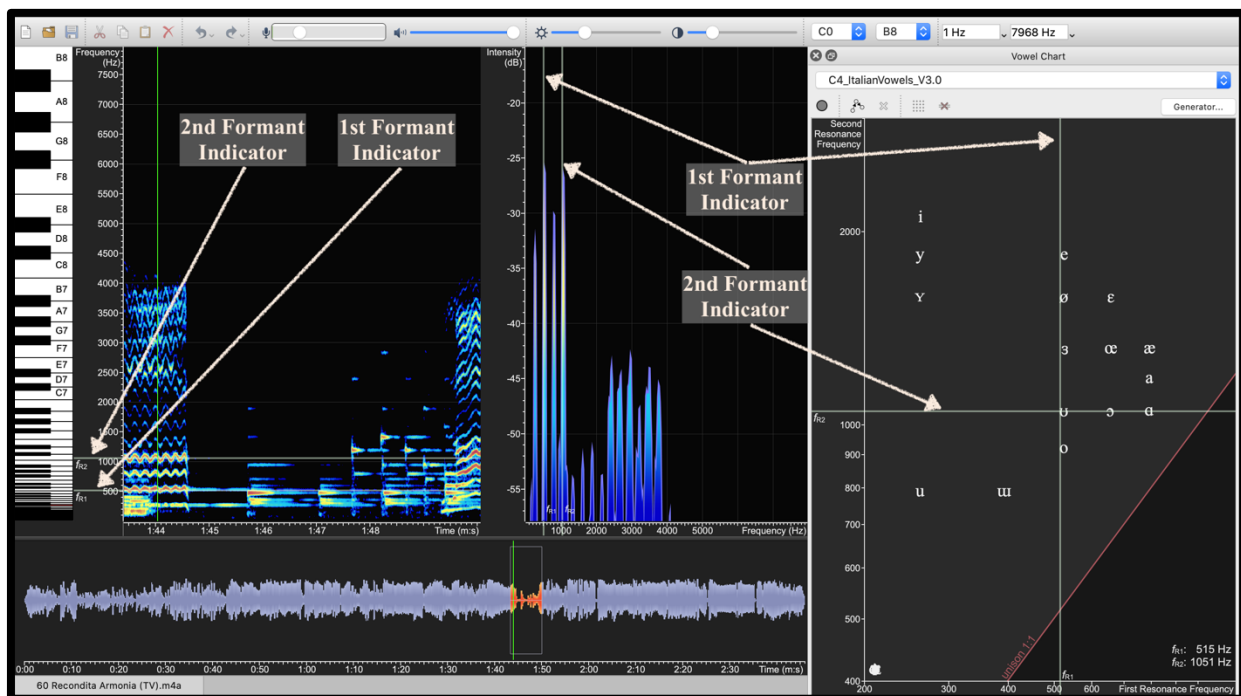


Figure 4, VoceVistaVideo Vowel Chart Tool

The first formant is positioned at 515hz, and the second formant is positioned at 1051hz. The digital vowel generated by the vowel chart is also compared and fine-tuned to achieve the closest match to the sound of the vowel being sung by the singer. The combination of formant positioning through the visual indication of the decibels of the harmonics, combined with the aural indication of the digital vowel from the vowel chart, gives a solid indication of the location of the vowel formants. The process described has identified the first formant frequency of 515hz,

and the second formant frequency of 1051hz. The process can be repeated again for the vowel “e” for *nero*. In that case, the first formant is tuned to 528hz, and the second formant is tuned to 1325hz. The process is repeated for every single vowel sample in the study. The data for all the samples was documented in Excel, using the format displayed in Figure 5.

Sample unique ID	Tenor	Generation	Region of Italy	Fach	Aria	Composer	Aria-Letter-Code	Letter	IPA	F1 hz	F2 hz	F1-Harm.	F2-Harm.
0001	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec1	e	ɛ	510	1589	2	6
0002	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec2	a	a	791	1298	3	5
0003	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec3	a	a	781	1115	3	4
0004	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec4	a	a	777	1083	3	4
0005	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec5	o	o	516	1051	2	4
0006	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec6	a	a	764	1253	3	5
0007	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec7	o	o	528	1051	2	4
0008	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec8	a	a	794	1064	3	4
0009	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec9	i	i	238	2106	1	8
0010	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec10	a	a	794	1073	3	4
0011	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec11	e	e	519	1321	2	5
0012	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec12	o	o	532	1058	2	4
0013	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec13	o	o	523	1036	2	4
0014	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec14	e	e	516	1575	2	6
0015	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec15	i	i	247	2161	1	8
0016	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec16	o	o	768	1067	3	4
0017	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec17	e	e	761	1357	3	5
0018	Pavarotti	PostWar	Emilia-Romagna	Lyric	Recondita Armonia	Puccini	Rec18	u	u	367	796	1.5	3
0019	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec1	e	ɛ	532	1333	2	5
0020	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec2	a	a	782	1212	3	4.5
0021	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec3	a	a	684	1075	2.5	4
0022	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec4	a	a	764	1043	3	4
0023	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec5	o	o	534	1021	2	4
0024	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec6	a	a	776	1069	3	4
0025	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec7	o	o	520	1040	2	4
0026	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec8	a	a	-	-	-	-
0027	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec9	i	i	-	-	-	-
0028	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec10	a	a	794	1072	3	4
0029	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec11	e	e	547	1346	2	5
0030	DiStefano	PostWar	Sicily	Lyric	Recondita Armonia	Puccini	Rec12	o	o	528	1033	2	4

Figure 5, MS Excel Documentation of Vowel Samples

CHAPTER 4

RESULTS OF THE STUDY: THE MIDDLE C VOWEL CHART REVEALED

Scatter Plot Graph of All Vowels

The thesis has studied vowel formant frequencies of 3,923 vowels from 106 recordings sung by twenty individual tenors. A scatter plot chart was created from the vowel formant frequencies sung on middle C. Figure 6 is the vowel chart representing the middle C formant tuning of the 20th century Italian tenors.

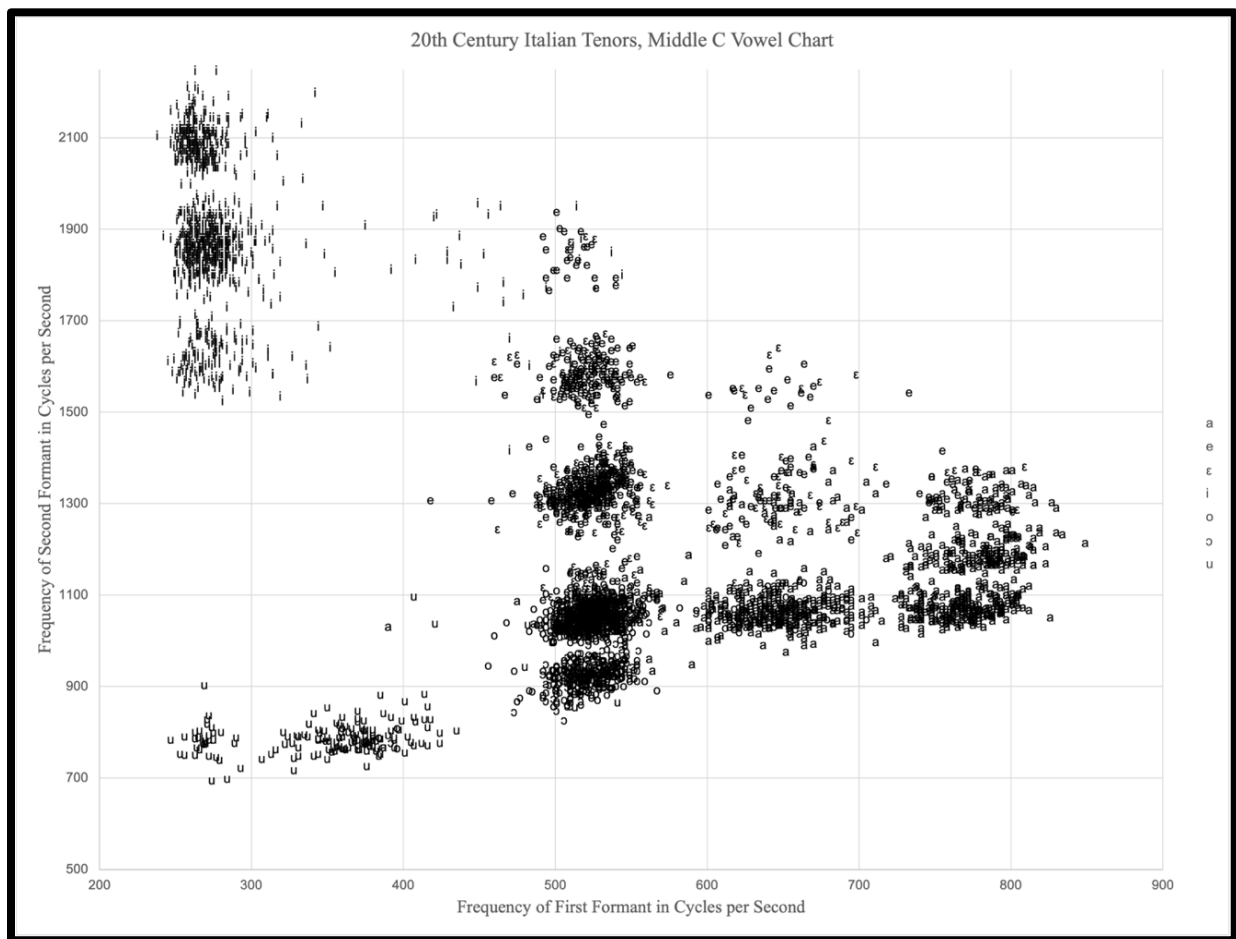


Figure 6, Middle C Vowel Chart

The middle C vowel chart (Figure 6) can be compared to the vowel chart from the Peterson and Barney study⁶⁶ (Figure 7). The first observation is the contrast between the wide range of vowels in the speech study (Figure 7) and the concentrated groupings of the singing study (Figure 6). The second observation is that while there is relatively little overlap between the vowels of the speech chart, there is significant overlap in the sung vowels chart. These two observations will be explored further.

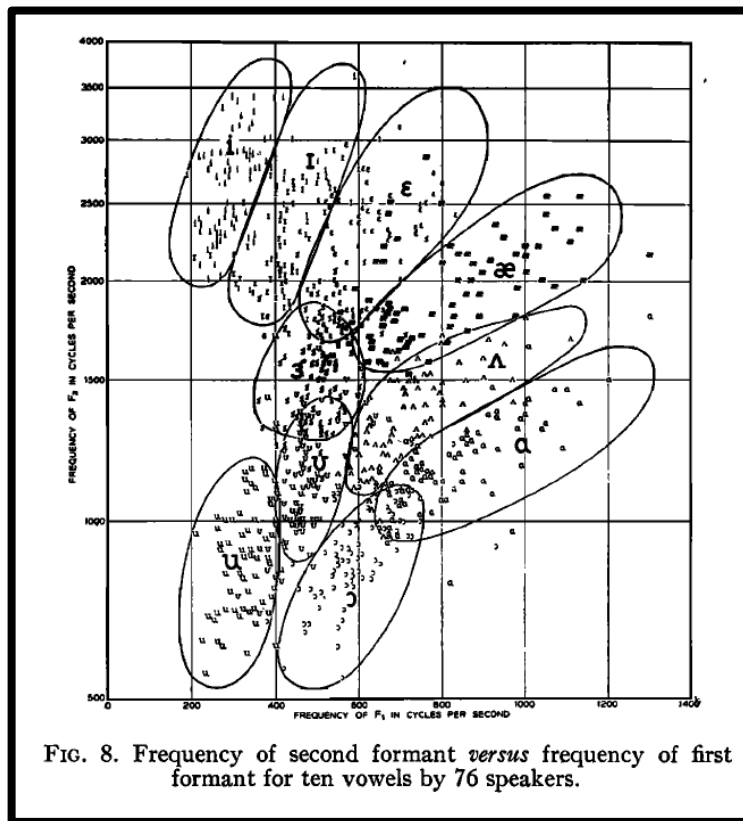


Figure 7, Peterson and Barney American English Speech Vowel Chart

16 Concentrated Groupings

The vowel samples were found to produce clusters which could be sorted into sixteen groupings, which have been circled in Figure 8. The vowel sound of each grouping is distinct from the vowel sound of the other groupings.

⁶⁶ Peterson and Barney, “Control Methods used in a Study of the Vowels”, 183.

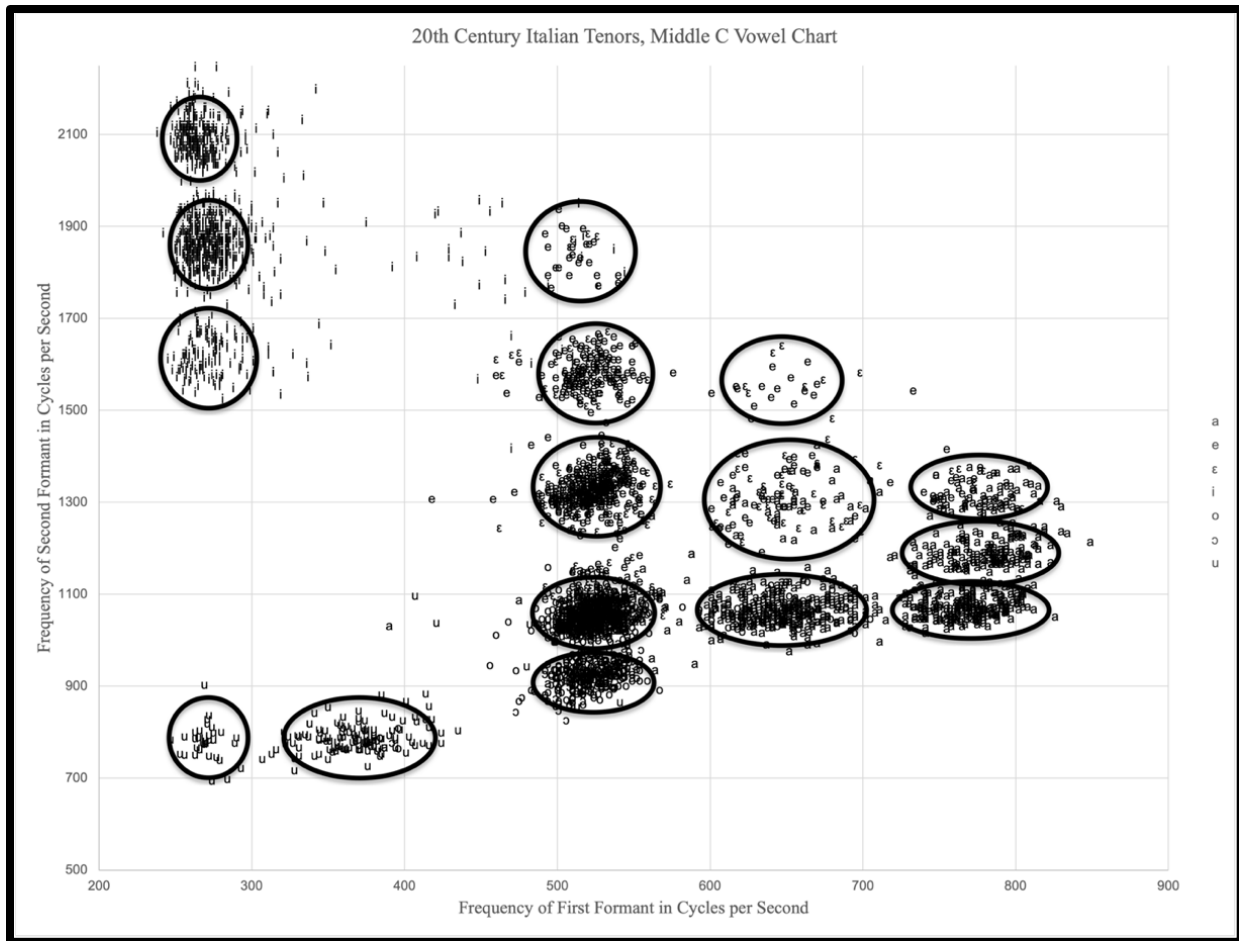


Figure 8, Middle C Vowel Chart 16 Groupings

There is a relationship between the formant tuning of the concentrated groupings and the overtone series. In every case, there is an overlap between the frequency of the overtone series and the groupings. See Figure 9, where the dark grey bars indicate the location of the harmonics of the overtone series for Middle C. Ten of the sixteen groupings (circled in black) demonstrate tuning where both formants align with a harmonic of the overtone series. The light grey bars indicate the halfway point between harmonics, following Berton Coffin’s method. The light grey bars help to give definition to six of the sixteen groupings (circled in light grey) where only one of the first and second formants are aligned with a harmonic.

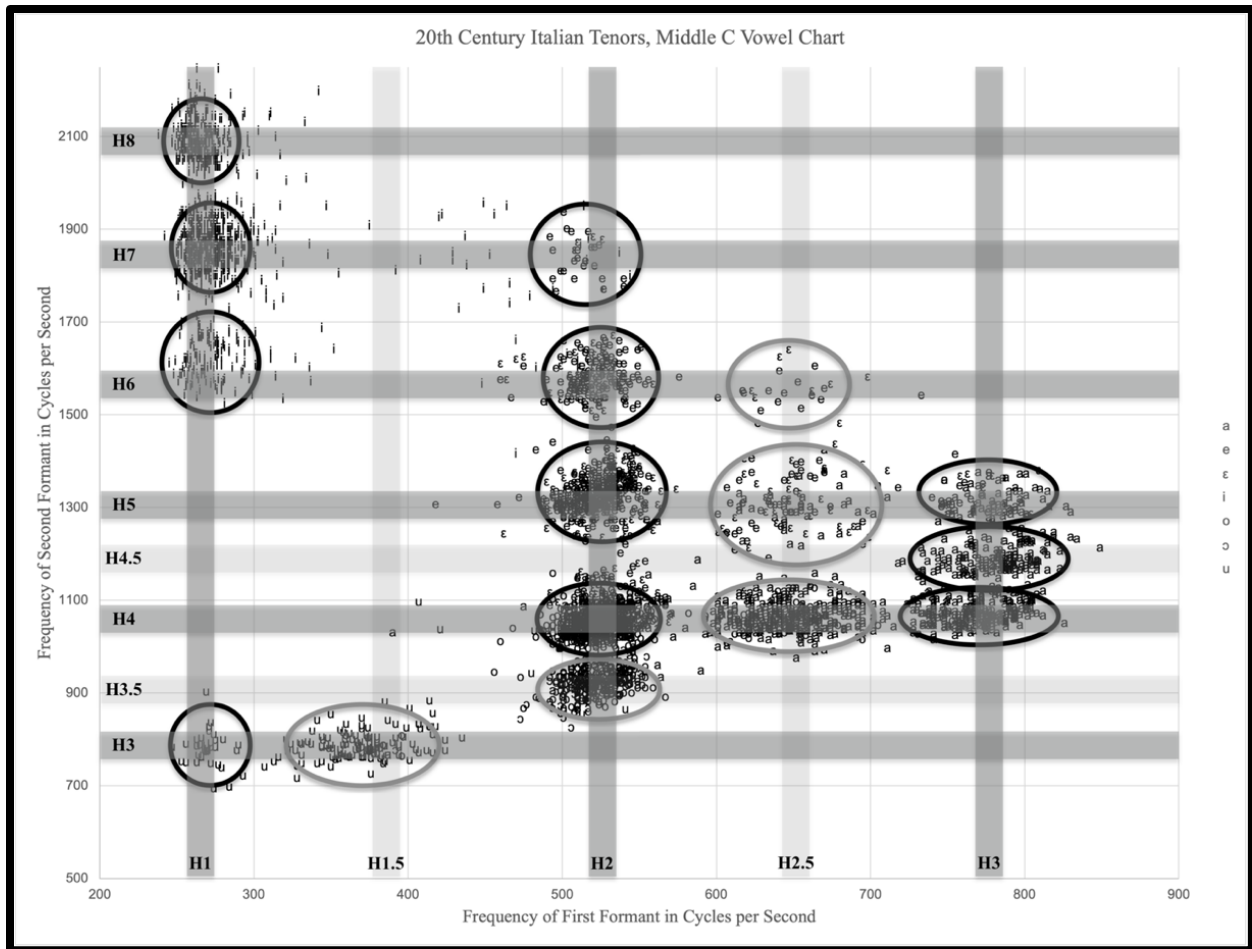


Figure 9, Middle C Vowel Chart Overtone Series

The sixteen groupings discovered by the study will be called middle C phonemes. The term “phoneme,” which means any perceptually distinct unit of sound, will help to distinguish the vowel shapes of the chart from the regular Italian vowels used in speech or writing. The groupings in general do not correspond to the articulator positioning or formant tuning of spoken vowels as defined in speech studies. However, in perception of human hearing, there is a relationship between the speech level vowels and the phonemes sung on middle C.

This phenomenon deserves further explanation. Bozeman has demonstrated using the Madde program how static formant tuning results in the perception of different vowel sounds

when the fundamental pitch is changed.⁶⁷ Even though the formant tuning is static, the change in fundamental pitch and its accompanying overtone series results in different vowel sounds. In the video demonstration, the lowest pitch sounds like [a]. However, as Bozeman changes the fundamental to higher pitches, the sound modulates to sound like [ɔ], then [o], and finally [u] on the highest note. If a person desired to sing a vowel sound that gives the listener the perception of being an [a] vowel with ascending pitch, the singer would have to modify the formant tuning to maintain the illusion that they are singing the same vowel.

The frequencies of the vowel formant tuning patterns on middle C discovered in this thesis do not match the frequencies of the formant tuning patterns recorded in speech studies. But thanks to the higher fundamental pitch, the middle C formant tuning patterns sound like clear and distinct speech level vowels. The phonemes of middle C sound like clear and distinct pure vowels of spoken language despite the height of the fundamental pitch. Thanks to the power of perception, each phoneme can be given an IPA symbol as its representative marker because it sounds the most like that IPA symbol in the context of the other middle C phonemes. In Figure 10, each IPA symbol is placed at the intersection of harmonics from the overtone series for its grouping.

⁶⁷ Kenneth Bozeman, “acoustic register demonstration by Ken Bozeman,” March 1, 2023, educational video, <https://www.youtube.com/watch?v=fFHUSVmyPXQ>.



Figure 10, Middle C Vowel Chart IPA Symbols

The Italian tenors did not restrict themselves to singing the phonemes of middle C which sound the most like their spoken language counterparts. Instead of limiting themselves to seven phonemes, the tenors sang sixteen. The sixteen patterns are not widely dispersed, but neatly grouped along the lines of the overtone series. The hypothesis of this study is that the Italian tenors are using formant tuning to take advantage of nonlinear source filter dynamics to maximize equilibrium of the vocal instrument. Each of the sixteen phonemes is acoustically efficient, thanks to at least one vowel formant tracking with a harmonic of the overtone series. Together, the middle C phonemes offer a much greater variety of musically expressive colors or timbres while being acoustically efficient. The observation on timbres will be explored in greater depth in chapter five.

Definition of Middle C Phonemes

The above analysis shows that the tenors had specific strategies of formant tuning which they used to express the Italian vowels. The groupings are concentrated in such a way that they enable the definition of phonemes. The phonemes in relation to one another give the perception of sounding like IPA vowels, which is one method of categorization (Table 3, Column 1). The groupings can also be defined based on first and second formant relationships to the overtone series of middle C (Table 3, Column 2). Lastly, the phonemes can be defined by where the frequency of formant one and formant two cross as seen in Figure 9. The frequency numbers (Table 3, Column 3 and 4) are the frequencies of the overtone series of middle C, given that the groupings are aligned in relation to the overtone series.

Table 3, Middle C Vowel Phonemes			
IPA Symbol	1st Formant Harmonic x 2nd Formant Harmonic	1st Formant Frequency	2nd Formant Frequency
i	1x8	261	2093.008
y	1x7	261	1831.382
Y	1x6	261	1569.756
u	1x3	261	784.878
uu	1.5x3	392.939	784.878
e	2x7	523.252	1831.382
ø	2x6	523.252	1569.756
ɜ	2x5	523.252	1308.13
o	2x4	523.252	1046.504
o	2x3.5	523.252	916.191
ɛ	2.5x6	654.565	1569.756
o	2.5x4	654.565	1046.504
œ	2.5x5	654.565	1308.13
æ	3x5	784.878	1308.13
a	3x4.5	784.878	1,177.82
ɑ	3x4	784.878	1046.504

The YouTube links below give a visual and aural representation of the middle C vowel phonemes as sung by Luciano Pavarotti and Franco Corelli.

Link 1, Pavarotti: https://youtu.be/y7p_O-Wa8Qw

Link 2, Corelli: <https://youtu.be/T4z3LoQ3z4A>

Vowel Overlap and Phoneme Paradigms

The tenors used many phonemes from the vowel chart to express each Italian vowel. For example, the tenors used the Italian vowel /a/ on seven different phonemes. To complicate the matter, in eleven of the sixteen groupings, more than one Italian vowel is present. For example, the /o/ phoneme grouping includes examples from six of the seven Italian vowels. See Figure 11, where all the samples of each Italian vowel are circled to show the range and overlap of the Italian vowels in relation to the groupings which the Italian tenors used in performance.

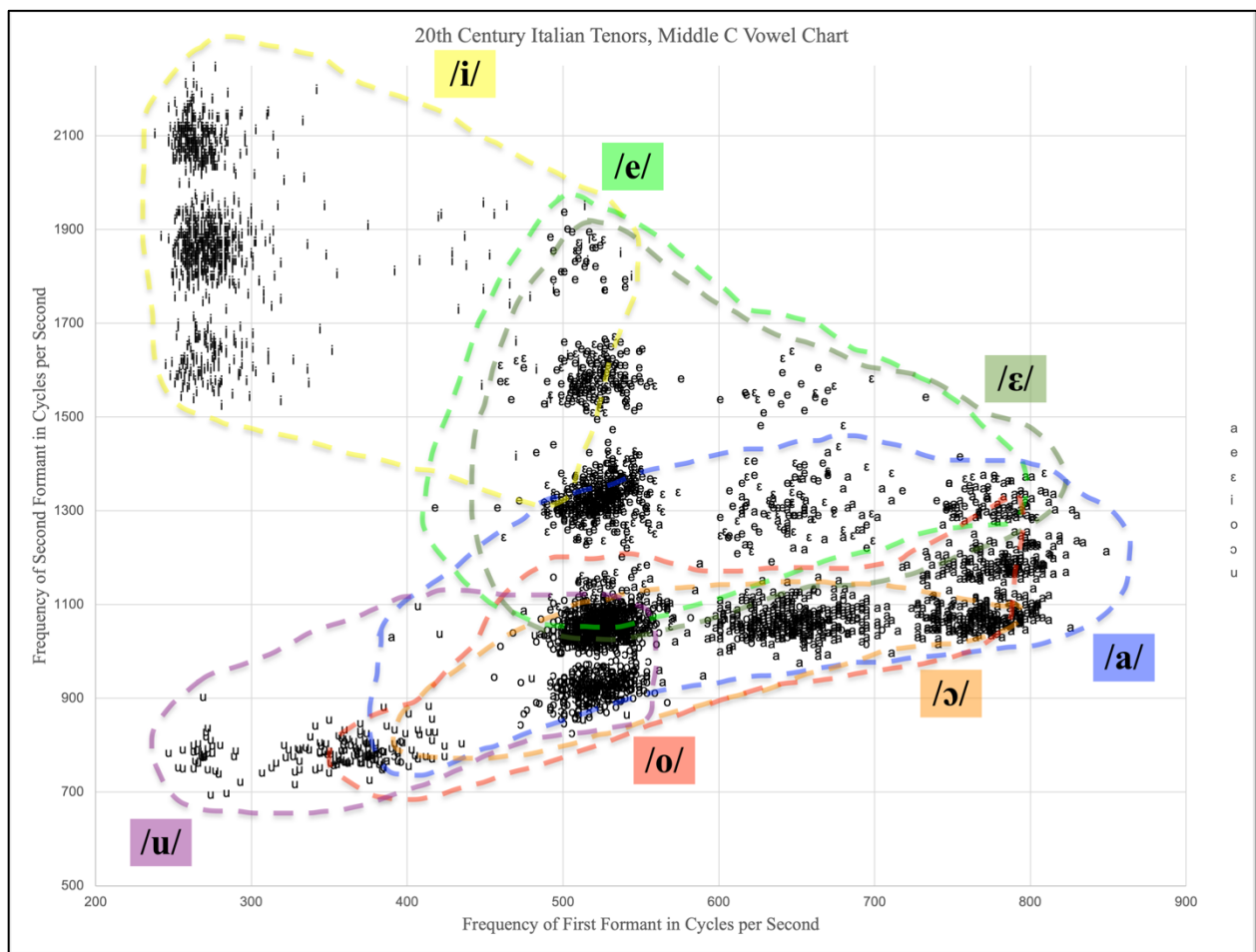


Figure 11, Middle C Vowel Chart Italian Vowel Overlap

The middle C vowel chart indicates that there are a variety of vocal colors or timbres that are viable. In performance, within the context of the music, the phonemes can still be understood

as the vowel in question. The context of the sung phoneme creates the illusion for the audience that they are hearing the vowel they associate with the lyrics. This “sleight of hand” allows singers to color their voices for expressive purposes while still being understood. They are understood even though they may sing a phoneme with a sound which in isolation sounds different from the written vowel. Out of context, an /i/ vowel sung with the first formant tuned to ~500hz and the second formant tuned to ~1,900hz will sound much more like /e/, as it aligns with the /e/ phoneme. An /a/ vowel, sung with the first formant tuned to ~550hz and the second formant tuned to ~1000hz will sound like /u/, as it aligns with the /u/ phoneme. A numbering system was developed to track this phenomenon. Every time one of the seven Italian vowels was sung in the vicinity of one of the sixteen middle C phonemes, it was labeled with a unique paradigm code. See the following tables which document this relationship between the Italian vowels and the vowel chart phonemes.

Table 4, Italian Vowel /i/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
i	I1	i	1x8
	I2	y	1x7
	I3	Y	1x6
	I4	e	2x7
	I5	ø	2x6
	I6	ɜ	2x5

Table 5, Italian Vowel /e/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
e	E1	e	2x7
	E2	ø	2x6
	E3	ɜ	2x5
	E4	æ	3x5
	E5	u	2x4
	E6	ɛ	2.5x6
	E7	œ	2.5x5
	E8	ɔ	2.5x4

Table 6, Italian Vowel /ε/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
ε	E1	e	2x7
	E2	ø	2x6
	E3	ɜ	2x5
	E4	æ	3x5
	E5	ɔ	2x4
	E6	ε	2.5x6
	E7	œ	2.5x5
	E8	ɔ	2.5x4

Table 7, Italian Vowel /a/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
a	A1	æ	3x5
	A2	a	3x4.5
	A3	ɑ	3x4
	A4	ɔ	2.5x4
	A5	ɔ	2x4
	A6	œ	2.5x5
	A7	o	2x3.5

Table 8, Italian Vowel /o/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
o	O1	ɑ	3x4
	O2	ɔ	2.5x4
	O3	ɔ	2x4
	O4	o	2x3.5
	O5	u	1.5x3

Table 9, Italian Vowel /ɔ/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
ɔ	O1	ɑ	3x4
	O2	ɔ	2.5x4
	O3	ɔ	2x4
	O4	o	2x3.5
	O5	u	1.5x3

Table 10, Italian Vowel /u/ Paradigms			
Italian Vowel:	Paradigm:	IPA:	F1HxF2H
u	U1	ɔ	2x4
	U2	o	2x3.5
	U3	u	1.5x3
	U4	u	1x3

Middle C Phoneme Distribution by Italian Vowel

The Italian tenors sang several phoneme possibilities for each Italian vowel. However, the occurrence of these tuning relationships does not demonstrate the tenor's preferences. The last section of this chapter presents the percentage of time that the Italian tenors used a particular phoneme to sing an Italian vowel. The distribution charts below (Figures 12 through 18) indicate the preferences of the tenors using the categorization system of phonemes and paradigms.

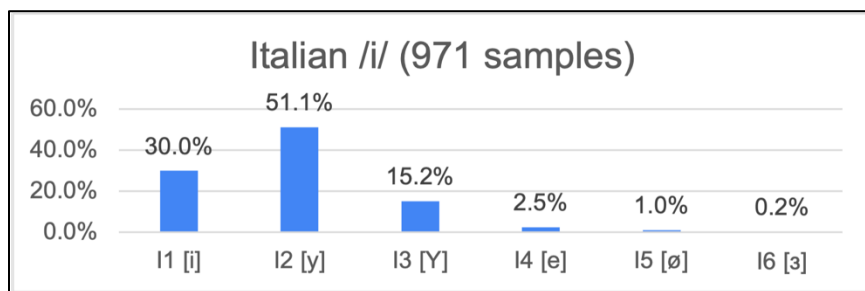


Figure 12, Italian vowel /i/ Distribution

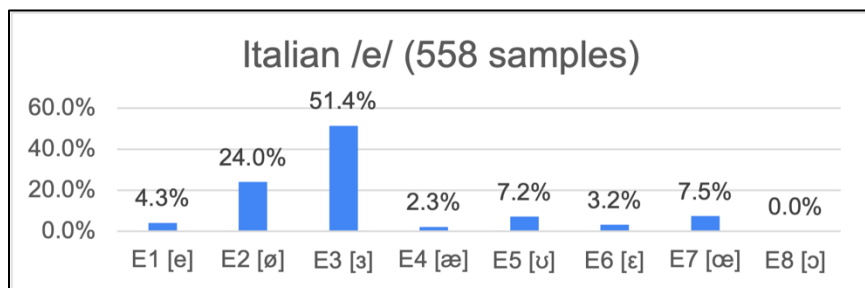


Figure 13, Italian vowel /e/ Distribution

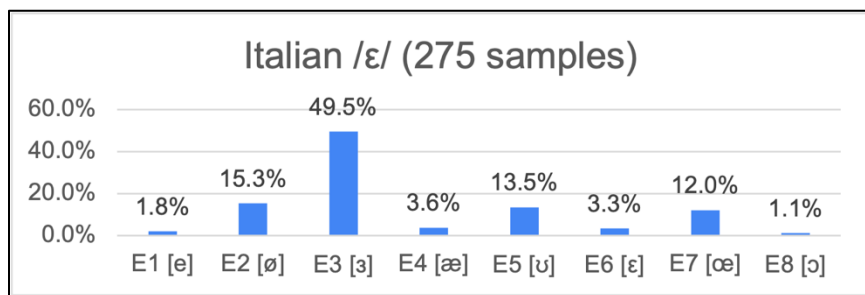


Figure 14, Italian vowel /ɛ/ Distribution

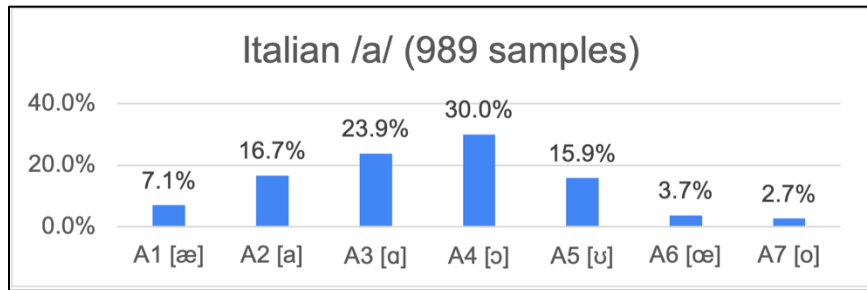


Figure 15, Italian vowel /a/ Distribution

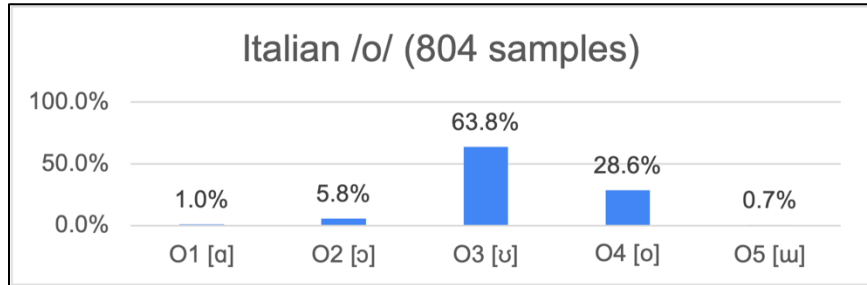


Figure 16, Italian vowel /o/ Distribution

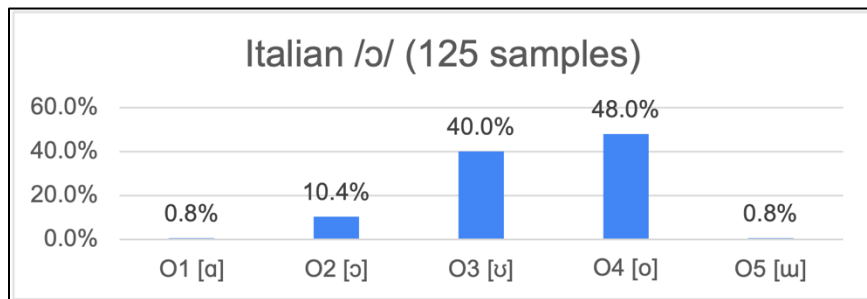


Figure 17, Italian vowel /ɔ/ Distribution

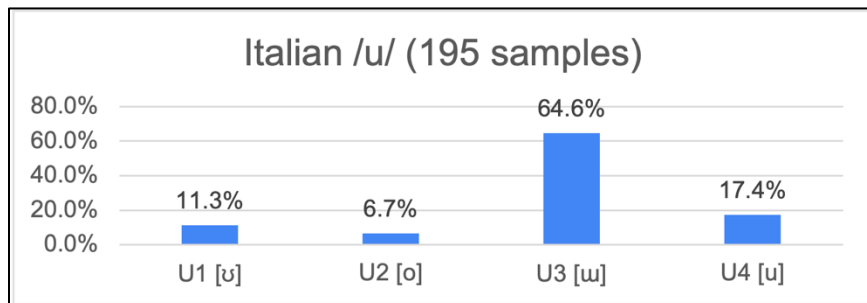


Figure 18, Italian vowel /u/ Distribution

The above charts demonstrate that there is a unique relationship between certain Italian vowels and certain phonemes. There are combinations which are used so infrequently as to be

considered flukes and outliers. Other combinations are used so frequently, they can be considered standard performance practice by the 20th Century Italian tenors.

This study has discovered significant patterns of formant tuning related to pitch. These patterns demonstrate leveraging of source-filter dynamics by the tenors and have enabled the definition of phonemes specific to middle C. The use of the phonemes by the tenors for the expression and performance of Italian vowels has also been demonstrated. There are many connections to be made between the data of the vowel chart and the writings of historic vocal pedagogy, as well as possibilities for application in pedagogy today. These topics will be explored further in chapter five.

CHAPTER 5

DISCUSSION

The middle C vowel chart with its sixteen phonemes contributes to the body of knowledge in the field of singing in a variety of ways. Three of those will be discussed and explored in this chapter. First, the vowel chart is a tool which can be used to interpret the writings on vowels found in historic vocal pedagogy literature. The vowel chart will be used to make sense out of the varied and seemingly contradictory directions related to vowels for singing found in the vocal literature. Second, the vowel chart is a practical tool which can guide formant tuning to coordinate and condition the voice. Using the vowel chart to precisely cultivate nonlinear source-filter dynamics through formant tuning will be discussed in this chapter. Third, the vowel chart, its data, and its methodology have potential to be used for future studies which can further contribute to the field of singing.

Middle C Vowel Chart Clarifies Historic Vocal Pedagogy

The writings of pedagogues and singers throughout history communicate varied and at times contradictory directions on vowel shapes for singing. As a first example, Tosi, Mancini, and other representatives of the *castrati* school often wrote of shaping the mouth into the position of a smile and encouraged the use of the bright Italian ah.⁶⁸ They permitted the use of the lips for the /o/ and /u/, however the old Italian school often discouraged vocalization on vowels other than /a/ and /ε/. They were also critical of the sound that would be emitted when vocalizing on /i/, /o/, or /u/.

⁶⁸ Berton Coffin, *Sounds of Singing*, Lanham, Maryland: Scarecrow Press, 2002, 83-84.

Nevertheless, they emphasized clear and distinct pronunciation as one of the rules of *bel canto*. These directions seem to conflict with each other and require explanation.

According to Garcia certain vowel sounds like /i/ and /e/ if unmodulated would become pinched and metallic.⁶⁹ More closed and rounded vowels like /u/ and /o/ if unmodulated will become choked or smothered.⁷⁰ Garcia’s observation explains the early orientation by the *castrati* school to vocalize on /a/ and /ε/, and to avoid /i/, /o/, and /u/. If one compares the spoken Italian vowel shapes from Bertinetto⁷¹ to the sung shapes of the Middle C vowel chart as done in Figure 19, one will observe that there is little overlap.

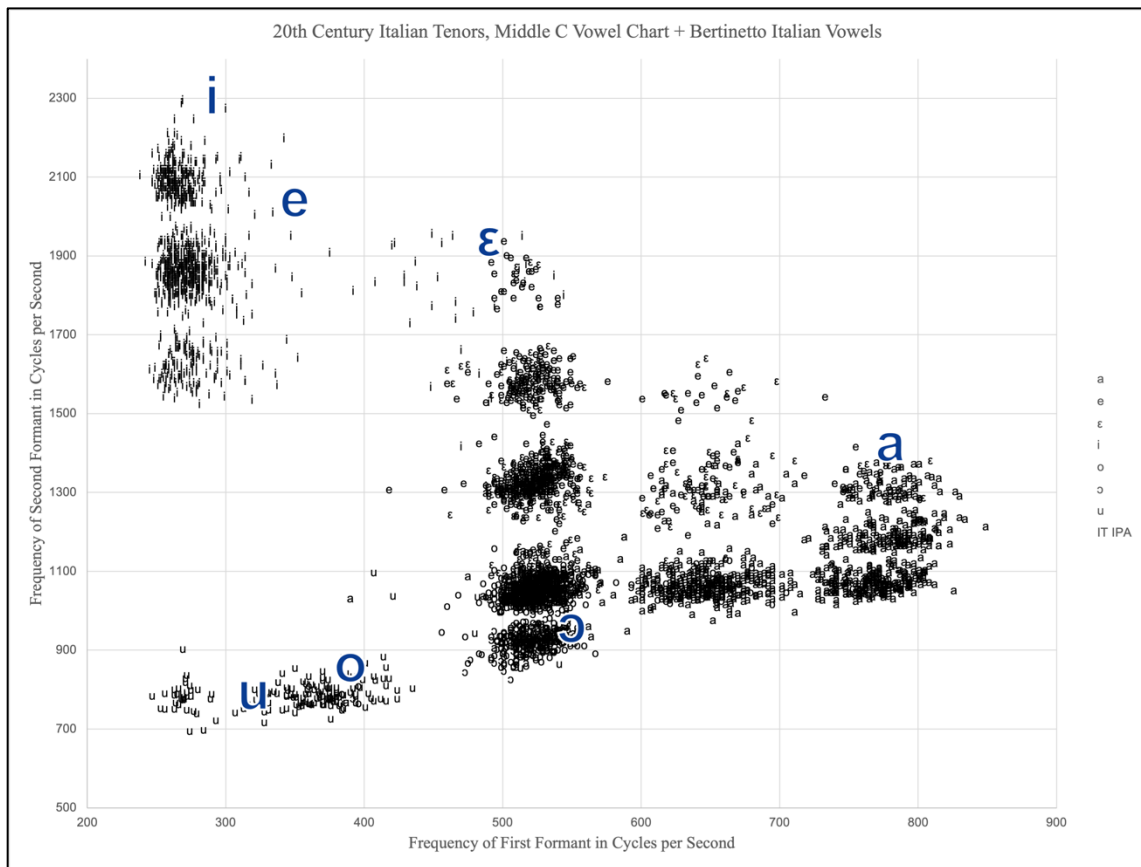


Figure 19, Middle C Vowel Chart with Italian Spoken IPA Vowels

⁶⁹ Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 8.

⁷⁰ *Ibid*, 8.

⁷¹ Pier Marco Bertinetto and Michele Loporcaro, “The Sound pattern of Standard Italian, as compared with the varieties spoken in Florence, Milan, and Rome”, 136.

The Bertinetto vowels sit beyond the outer edge of the middle C phoneme groupings. They are also frequently mismatched, with certain speech vowel shapes sitting close to phoneme shapes that on middle C no longer give the perception of sounding like the spoken vowel. The Bertinetto vowel /e/ is closer to the vowel chart phonemes associated with /i/. The spoken /ε/ is on the fringe of the /e/ phoneme. The spoken /o/ and /u/ vowels sit on either side of the /u/ phoneme. The only spoken vowel that is aligned so that the first formant tracks with the same harmonic of a middle C phoneme is the vowel /a/. This observation may explain why the Italians valued the /a/ vowel for singing above any others as at least in this case it is closer to the first formant tuning necessary for singing than any of the other Italian spoken vowels. The /i/, /e/, and /ε/ vowels pronounced with spoken tuning on middle C would indeed sound pinched, metallic, and they would lack acoustics efficiency. The /o/ and /u/ vowels would sound muffled or choked, as they also lack the requisite formant tuning.

These observations account for the challenge beginners have when seeking to produce a resonant tone since their throat is not habitually accustomed to shaping the sounds of singing. The speech vowel will be just enough out of tune with the overtone series that the tuning will interfere with source-filter dynamics. Also, at a higher pitch like middle C unless one is singing /a/ the perception of the spoken vowel tuning will be mismatched with the tuning necessary to sing the efficient and recognizable phonemes. When the beginner sings on pitch with the spoken vowel shape that they are accustomed to, it will sound like they are mispronouncing or at the very least constricting or muffling the voice. The *castrati* school recognized the tendency of the spoken vowels to override the tuning of ideal sung vowels, and they recognized something in the quality of the /a/ and /ε/ that was more conducive to good singing. Their directions were practically speaking an attempt to get students to experience nonlinear source-filter dynamics. These dynamics could

then be carried over to the other shapes that would give the perception of clear and distinct Italian vowels. While a bit dogmatic, their directions may have been an early technique of formant tuning.

Manuel Garcia II also emphasized the smile shape of the mouth for singing,⁷² however he included some additional information. Garcia encouraged singers to study their vocal exercises beginning with /a/, followed by /ε/,⁷³ and only then adding the rest of the Italian vowels. He wrote that the singer should eventually be able to sing all the exercises of his treatise with the seven Italian vowels.⁷⁴ He wrote that the singers would need to modulate the shapes of their mouths to give the vowel the right quality of sound both in descending and ascending in range. Vaccai and Lamperti do not go into the depth of anatomical description that Garcia did, but they also encouraged singers to sing pure Italian vowels. From what is understood today about vowels in singing, Garcia, Lamperti, and Vaccai were indicating the challenge of creating the perception of singing pure Italian vowels. That skill can be briefly described as positioning the articulators and formant tuning to sing an efficient resonant tone that sounds like the Italian vowel in question on pitch. Their method was based on vocalizing and coordinating the voice with a variety of scales while maintaining the perception of a consistent pure Italian vowel. This was done even as the articulators are in a state of adaptation to enable the formant tuning which makes the illusion possible. Garcia and the teachers of his day were likely indirectly seeking ways to help the student experience nonlinear source-filter dynamics.

Based on their writings, Garcia and others of the *castrati* school would have probably appreciated the phonemes on the Middle C vowel chart that carry the symbols of the Italian IPA vowels when referring to pure Italian vowels. Those phonemes have the ideal combination of

⁷² Garcia II, Manuel. *A Complete Treatise on the Art of Singing Part One: Complete and Unabridged*. Translated by Donald Paschke. Plattsburgh, NY: Rodeti Enterprises Inc., 2016, 39-40..

⁷³ Garcia II, Manuel. *New Treatise on the Art of Singing*. Boston: Oliver Ditson Company, 1857, 12.

⁷⁴ Garcia II, Manuel. *New Treatise on the Art of Singing*. Boston: Oliver Ditson Company, 1857, 28.

acoustic efficiency with Italian vowel perception. The vowels (except for /o/ and /u/) are facilitated by having a mouth position more in the shape of a smile, and they are bright and penetrating. This matches the descriptions of the *castrati* school literature.

In contrast to the ideals of the *castrati* school, vocal aesthetics in the Romantic period began to shift. Tenors like Domenico Donzelli (Bellini's first Pollione in *Norma*) and Gilbert Duprez (famous interpreter of Arnold in Rossini's *Guillaume Tell* and Donizetti's first Edgardo in *Lucia di Lammermoor*) championed a new style of singing that used the *voix sombre*. Diday and Petrequin were two doctors who wrote an evaluation of Duprez' singing. Gregory Bloch in reviewing their work writes that, "the new species Duprez represents lies outside the system of vocal registers, of head and chest, altogether. The phrase "ut de poitrine" never appears in their [Diday and Petrequin] essay. Rather the authors call what Duprez produced the *voix sombre*. The voice is "darkened," Diday and Petrequin claim, by lowering of the larynx, visible as a forward tilted head and a lowered Adam's apple. They describe repeatedly and at length the difference between this "darkened voiced" and the "ordinary, older style," which they call *voix blanche*: The darkening gives the singing more energy, but takes away much of its agility; the *voix blanche* has less force, but it gains the advantage whenever vivacity becomes indispensable."⁷⁵

Aureliano Pertile, whose life overlapped with Garcia and Duprez, was a favorite tenor of conductor Toscanini and star of La Scala. He wrote in 1922 that for his day's operatic aesthetic all the Italian vowels should be sung, with the addition of the OH color.⁷⁶ /a/ becomes /ɔ/, /ɛ/ becomes /ø/, /i/ becomes /y/, /u/ becomes /ʊ/. Around the same time American authors were encouraging their singers to adjust their vowels for singing along similar lines. D.A. Clippinger's

⁷⁵ Gregory W. Bloch, "The Pathological Voice of Gilbert-Louis Duprez", 14-15.

⁷⁶ Domenico Silvestrini, *Aureliano Pertile E Il Suo Metodo Di Canto*, 56-57.

comments demonstrate how to his ear the brighter vowels need to be rounded and opened slightly more, while the darker more closed vowels need to be brightened and opened.⁷⁷

Renowned vocal coach Kurt Adler observed the same phenomenon from his observations at La Scala. He noted that while metallic and penetrating performance of pure vowels like /i/, /e/, and /ε/ were still encountered in provincial theatres, the standard at La Scala was to sing /y/ or /e/ in substitution of /i/,⁷⁸ and /ø/ or /œ/ in substitution of /e/ and /ε/.⁷⁹ Adler also noted that great singers modulate the shape of their vowels for best resonance and to make expressive interpretations.⁸⁰

Garcia was one of the first to make a thorough description of the *voix sombre* in his treatise, and his writing carried tremendous influence in the world of singing. What is clear is that the pure Italian vowels were becoming less and less the default for singing, and they were being replaced by vowels with a more somber timbre. Instead of the smile, the embouchure of the mouth began to take on the shape of an oval with lips more or less rounded. When one looks at the middle C vowel chart, one can see exactly this phenomenon. The Middle C vowel chart distinctly shows the preferences for 20th century Italian singers to do exactly what Pertile encourages. The preferred vowel choice is not the pure Italian variant, but an option that matches the vowel shapes that Garcia recommends when counseling singers to sing with somber timbre.

The arc of vowel aesthetic throughout history is becoming more clear. At the beginning Tosi was teaching against those who would distort efficient and beautiful vocal sounds by adhering too closely to speech values. The Italian school observed that “natural” singers shaped

⁷⁷ David Alva Clippinger, *The Clippinger Class-Method of Voice Culture*, 12.

⁷⁸ Kurt Adler, *Phonetics and Diction in Singing: Italian, French, Spanish, and German*, 14-15.

⁷⁹ *Ibid*, 13-14.

⁸⁰ *Ibid*, 16.

their vowels in particular ways for the most efficient and aesthetically pleasing vocal sounds.⁸¹ They found ways to produce sound that was efficient, aesthetically valuable, and perceived as being a pure Italian vowel. The tonal values of the Italian school were communicated to Manuel Garcia I by Ansani who was trained by the *castrati*.⁸²

Garcia II documented this practice and encouraged his singers to vocalize with the pure Italian vowels, as did Vaccai.⁸³ However, Garcia opened the door to sing with a variety of vocal colors through his theory of vocal timbres.⁸⁴ By using so-called French vowels, Garcia codified that the voice could be produced with a darker timbre for variety of coloring and expressivity. Duprez was an exponent of the *voix sombre* which took advantage of the somber timbred vowels.⁸⁵ The change in vocal aesthetic may very well have been a driving influence behind the stylistic compositional changes of Verdi and the *Verismo* school. Most tenors adopted this new aesthetic, perhaps none more famously than Enrico Caruso. His recordings demonstrate a shading of his tenor instrument with more and more baritone coloring as his career progressed.⁸⁶ In the past Garcia and the *castrati* would have defaulted to the clear timbre vowels. 20th century Italian tenors defaulted to the somber timbre vowels.

The middle C vowel chart accurately maps and explains these trends of vowel shaping that are encountered in the pedagogic literature. From the end of the 19th century through the 20th century the classical operatic sound gradually tended to lean more towards the darker timbre and singers tended to sing the pure Italian vowels less. However, the great Italian tenors of the 20th century do not demonstrate a monochromatic dark sound – they sing a variety of vowel shapes

⁸¹ Edgar F. Herbert-Caesari, *Tradition and Gigli 1600-1955: a panegyric*, 55-56.

⁸² Coffin, *Historical Vocal Pedagogy Classics*, page 12-14

⁸³ Nicola Vaccai, *Metodo Pratico di Canto*, 1.

⁸⁴ Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 7-9

⁸⁵ Gregory W. Bloch, “The Pathological Voice of Gilbert-Louis Duprez”, 14.

⁸⁶ Frederick Husler and Yvonne Rodd-Marling, *Singing: The Physical Nature of the Vocal Organ; a Guide to the Unlocking of the Singing Voice*, New York: October House, 1965, 129-130.

for the purpose of varied expression. These shapes include phonemes that sound like the Italian vowels, and they also include phonemes that sound like French vowels. The Italian tenors exemplify Garcia's values of a kaleidoscope of sound for dramatic and artistic effect, albeit while favoring the somber timbre.

Practical Example: Manuel Garcia's Timbre Exercise

One specific and practical example has been chosen from the writings of Garcia to demonstrate the explanatory power of the middle C vowel chart. In his magnum opus, Garcia describes the phenomenon of "vocal timbre." He says that the timbre of the voice is inseparably linked from the quality of the vowel and the shaping of the vocal tract.⁸⁷ He generally categorized the sounds of the human voice into three categories along this spectrum, from clear to round to somber.⁸⁸ Garcia developed a vocal exercise to explore this spectrum of sound. He writes, "The need to master all the colors of the voice has caused us to improvise the following exercise; we consider it one of the most useful with our experience has suggested to us. On a single note and with a single breath, pass gradually through all the timbres from the most clear to the most somber, and then with another breath pass from the somber timbre to the clear timbre. The sound must keep a uniform degree of force during the whole operation. This study is really effective only in the chest register and between the tones a and F#1; aided by the exercise which unifies the registers, it teaches the mastery of all the movements of the throat and the production at will of all the sounds of diverse natures."⁸⁹ Garcia wrote out the following guide to help singers in their exploration of timbres, from the first edition in French.⁹⁰

⁸⁷ Garcia II, Manuel. *A Complete Treatise on the Art of Singing Part One: Complete and Unabridged*, 1-li.

⁸⁸ *Ibid*, llvii-lxii.

⁸⁹ Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 8-9.

⁹⁰ Manuel Garcia II, *Ecole de Garcia Seconde Partie*, Paris: Troupenas, 1847, 2.

Table 11 – Garcia’s Timbre Exercise in French	
<i>L’A s’approche de l’O ouvert;</i>	(The French “AH” sound approaches the French open “OH” sound)
<i>L’È ouvert s’approche de l’É, puis de l’EU;</i>	(The French open “EH” sound approaches the French closed “EH” sound, and then the French “EU” sound)
<i>L’I s’approche de l’U, sans le secours des lèvres;</i>	(The French “EE” sound approaches the French “U” sound, without the aid of the lips)
<i>L’O s’approche de l’OU.</i>	(The French “OH” sound approaches the French “OO” sound)

The Italian edition communicates the same information like this:⁹¹

Table 12 – Garcia’s Timbre Exercise in Italian	
<i>L’A s’avvicinia all’O larga;</i>	(The Italian “AH” sound approaches the broad/open Italian “OH” sound)
<i>L’E larga s’avvicina all’E stretta, poi all’ EU francese;</i>	(The broad/open Italian “EH” sound approaches the narrow/closed Italian “EH” sound, and then the French “EU” sound)
<i>L’I s’avvicina all’U francese, senza il soccorso delle labbra;</i>	(The Italian “EE” sound approaches the French “U” sound, without the help of the lips)
<i>L’O s’avvicina all’U italiana.</i>	(The Italian “OH” sound” approaches the Italian “OO” sound.)

The goal is to make sense of Garcia’s directions within the context of the Middle C Vowel chart. Garcia is asking for four maneuvers by using the descriptions of language which will accomplish formant tuning configurations. First, he is asking for an open Italian or French “ah” sound (which is brighter than the standard American “ah”), that will migrate towards an open and broad “oh” sound. Second, he asks for an open and broad “eh” sound which first approaches the closed or tight “eh” sound and then rounds toward the French “eu” sound which today is represented by a /ø/ symbol. Third Garcia asks for a bright “ee” sound which approaches the French “u” sound, which today is represented by a /y/ symbol. Garcia recommends that the

⁹¹ Manuel Garcia II, *Scuola di Garcia Parte Seconda*, translated by Renato Borromeo, Milano: Ricordi, 4.

singer not use the lips for this last maneuver, but the sound will become rounder and darker as the exercise progresses. Lastly, Garcia suggests traveling from the “oh” sound towards the Italian “oo” sound. Using these descriptions, vowel migration tracks have been placed on the Middle C Vowel chart as interpretations of Garcia’s writing.

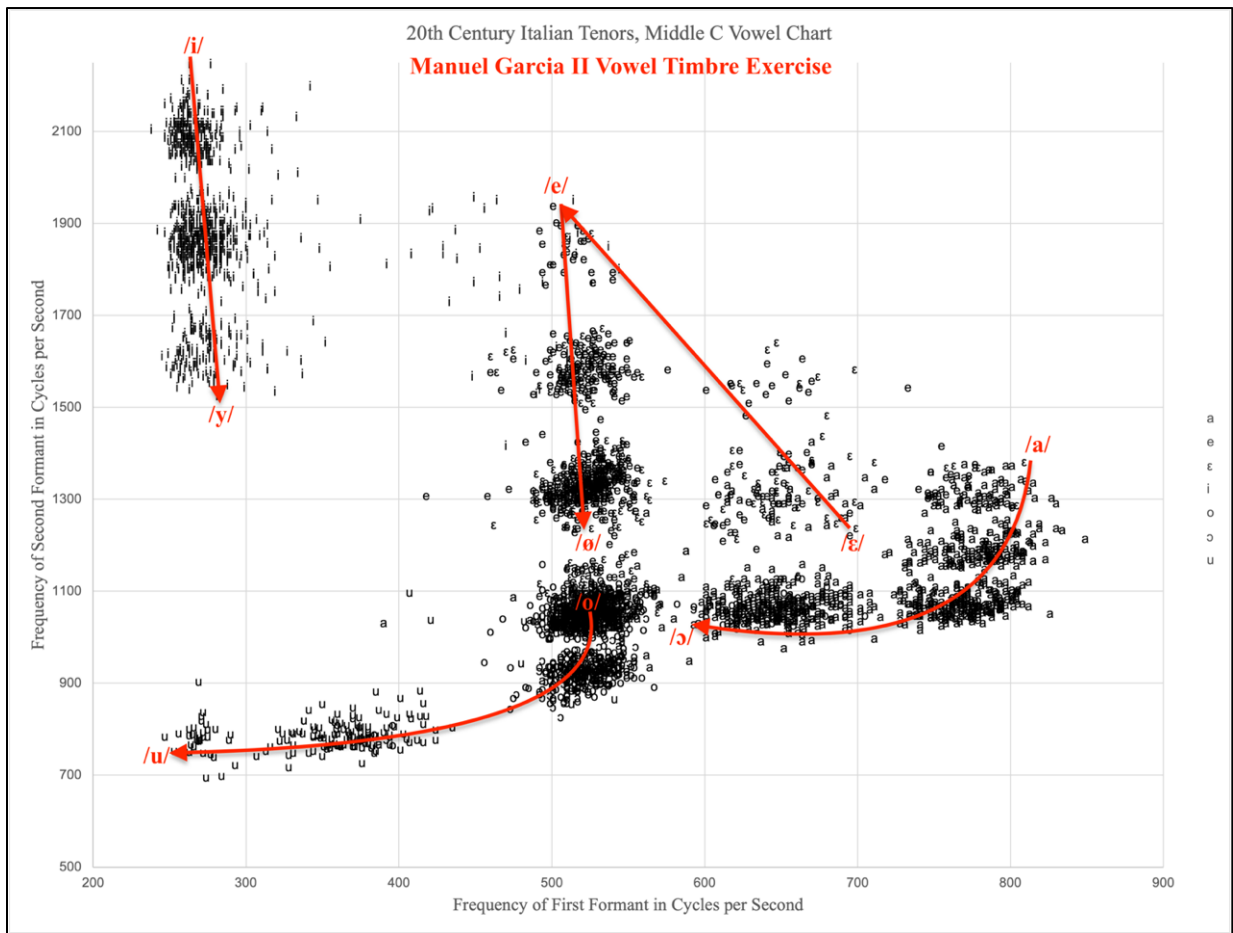


Figure 20, Middle C Vowel Chart with Garcia Vowel Timbre Exercise

These guides show distinctly that Garcia’s suggestions cover every phoneme grouping on the chart. The “ah” journey begins at the brightest most open paradigm, /æ/, and travels through /a/, and /ɑ/, before arriving at /ɔ/. It could continue into /ʊ/, as demonstrated by the tenors, which would be the darkest timbre possibility. The “eh” journey starts at the most open phoneme /œ/. Instead of going directly towards a more closed and more rounded possibility, /ɜ/, which would

leave out several phonemes, Garcia suggests closing the vowel first. The vowel moves through /ɛ/ towards the most bright and closed paradigm, /e/, before steadily rounding itself off as it travels through /ø/ and arriving at /ɜ/. Again, the track could continue into /ʊ/, as demonstrated by the tenors, which would be the darkest timbre possibility. The “ee” route is the most one directional, starting with a bright and metallic /i/ which then steadily rounds itself so as to travel through /y/ towards /Y/. Lastly the “oh” and “oo” route are one maneuver. The journey begins at the /ʊ/ phoneme, and steadily closes and rounds from /o/ to /u/ before arriving at /u/. Given the possibilities for formant tuning demonstrated by the 20th century Italian tenors, Garcia’s advice that following the timbre exercise will introduce one to “all the sounds of diverse natures”⁹² bears itself true. Garcia may have not known about formant tuning, but he certainly understood the relationships of sound and how to navigate them in a comprehensive manner.

There is one comment in Garcia’s directions on the timbre exercise that is worth exploring further. Garcia wrote that “The sound must keep a uniform degree of force during the whole operation.” Regardless of which dynamic the singer begins the exercise, what is most important is that the timbral exploration from clear to somber timbre will not affect the “degree of force” with which the singer is singing. There is an implication that while the singer is shading the vowel in a darker direction, he or she is not supposed to allow the voice to fall backward in placement or change significantly in its intensity because of the adjustment. This direction was not idly included by Garcia, and it brings up one of the observations that was gleaned from the recordings of the twenty Italian tenors studied for this thesis. Virtually all of the tenors analyzed in the recordings maintained a consistent vocal production. The vowels and dynamics of the singers were variable, but the manner in which they produced the voice was not. The Italian tenors never allowed the

⁹² Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 9.

voice to fall back in placement or become swallowed. The vowel, no matter its timbre, does not interfere with the consistent production of the voice, or in Garcia's words, the ability to produce the voice with a uniform degree of force. Those singers that would explore the vowel timbre exercise as designed by Garcia and described in this thesis would be wise to not allow the voice to change intensity or production while exploring the vowel phonemes. The exercise is not a *messa di voce*, which is the proper exercise to explore variation in intensity and force in vocal technique.

The mapping of the vowel timbre exercise is a practical example of how the middle C vowel chart has explanatory power to specifically interpret and explain the directions of historical vocal pedagogy. Directions on vowel formation shift throughout history. When the directions seem to contradict themselves, they are merely describing the method by which to achieve different phonemes which belong to a different aesthetic. The thesis, contrary to the predictions of Clippinger,⁹³ is quantifying and demonstrating in a scientific and repeatable manner the empirical observations of voice teachers and opera performers throughout the centuries. The 20th century Italian tenors demonstrated distinctive preferences for the *voix sombre* in their vowel choices. They also demonstrated that vocal mastery and artistic greatness make use of many different vowel phonemes – they do not dogmatically restrict the voice to exclusively dark or clear timbre.

Practical Applications of the Middle C Vowel Chart

The thesis will now examine practical applications of the 20th century Italian tenor vowel chart. The thesis has demonstrated that the great tenors of the Italian tradition use 16 vowel phonemes on middle C. They do not limit themselves to only seven vowel shapes of the Italian vowels, and they do not limit themselves to the phonemes of the *voix sombre* or the *voix blanche*. Berton Coffin has noted that singing exclusively back vowels or front vowels in vocalization has

⁹³ David Alva Clippinger, *The Clippinger Class-Method of Voice Culture*, 12.

an adverse effect on the voice and that vocalizing exclusively on one kind of vowel shape for a prolonged period of time can unbalance the voice.⁹⁴ Coffin suggests a rotation of vowels in exercise to coordinate, stretch, and condition the voice for performance. Garcia in the same vein suggests exercising the voice on a single note with an equal force, or intensity, of the sound while moving from one timbre of vowel to another. He wrote that it is one of the most effective exercises he knows for coordinating and mastering the movements of the vocal instrument. The middle C vowel chart created by this study is an ideal guide for exercising and coordinating the voice for singing classical art music. The author is a witness that exercising the phonemes demonstrated by the Italian tenors in the vowel chart helps to coordinate, stretch, and condition the voice. Perhaps not all the phonemes fit within one's tonal ideals or aesthetic preferences. However, exploration of the phonemes and the ability to coordinate them is good for the balance of strength and flexibility in the voice. Lastly, exercising the vowel shapes heeds Garcia's advice that a thorough exploration of the timbres, combined with mastery over the various levels of glottal closure, introduces the singer to all the diverse sounds of vocal production.⁹⁵

Clippinger noted, as do many, that training for singing is primarily training of the mind and ear.⁹⁶ Pavarotti said that a singer should think the pitch and tone the moment before singing it, and that if a singer can "hear like Caruso" they will "sing like Caruso."⁹⁷ Listening to the sounds of the vowels of the Italian tenors on middle C is an excellent guide to specific vowel colors that must be integrated in the ear and mind before they can be performed. Once that step is accomplished, exercising the vowel shapes will make one intimately aware of the physical coordination, ear

⁹⁴ Berton Coffin, *Overtones of Bel Canto*, 12.

⁹⁵ Manuel Garcia II, *A Complete Treatise on the Art of Singing Part Two: Complete and Unabridged*, 9.

⁹⁶ David Alva Clippinger, *The Clippinger Class-Method of Voice Culture*, 1.

⁹⁷ Luciano Pavarotti, "Pavarotti, Horne, Sutherland - How to sing bel canto 1", March 1, 2023, educational video, 1:50 to 2:08, <https://www.youtube.com/watch?v=JvdtNkbu3gI>.

training, and sensation awareness of the formant tuning necessary to sing all the different phonemes accurately. Switching back and forth on the same pitch between different vowels will help to free the instrument from stiffness and imbalance, and help the voice find the groove of the resonance of the vowel formants. The exercise will aid the singer in mapping their own individual sensations of resonance and placement that have been explored by Bozeman,⁹⁸ Herbert-Caesari,⁹⁹ Lehman,¹⁰⁰ and others. Exercising on a single pitch will show the way to carry out the same exploration on other pitches. If there are challenging pitches in the singer's range that line up with the formant tuning of the middle C phonemes, then the middle C phonemes may offer a guide of sensation and coordination to help coordinate the other pitches.

Formant tuning has been on the map of vocal pedagogy for decades and traces its lineage all the way back to Appelman and Coffin.¹⁰¹ However, to date, no systematic map of formant tuning possibilities has been published. Formant tuning presents a tool to the singers and teachers of the world, but the tool doesn't come with an instruction manual. The middle C vowel chart is the first systematic mapping of viable, acoustically efficient vowel tuning possibilities for achieving an Italian operatic aesthetic. The middle C vowel chart is the map that can guide singers in a practical exploration of formant tuning on a single pitch. Formant tuning need no longer be a buzz word that bears no fruit but can be a powerful tool that can be put to good use with the right guide. No map has been made like the middle C vowel chart before, which guides and instructs singers on the formant tuning of a single pitch. The vowel chart has the potential to be useful in the studio to guide students and teachers in their coordination and awareness of the possibilities of their instrument.

⁹⁸ Kenneth Bozeman, *Practical Vocal Acoustics*, 64-65.

⁹⁹ Edgard F. Herbert-Caesari, *The Science and Sensations of Vocal Tone*, London: J.M. Dent and Sons Ltd, 1968, 62,63, 67.

¹⁰⁰ Maria Popova, "How To Sing: A 1902 Illustrated Guide from the Great German Opera Singer Lilli Lehmann," *The Marginalian*, October 14, 2022, <https://www.themarginalian.org/2012/12/04/how-to-sing-lilli-lehmann-1902/>.

¹⁰¹ Matthew Hoch, "Historical Landmarks in Singing Voice Pedagogy", 50-51..

Future Research Possibilities of Thesis Data and Middle C Vowel Chart

The study has only touched the surface in its interpretation of the patterns shown in the data of the Italian tenor middle C vowels. There are many possibilities for application of the vowel data. The formant tuning patterns of individual tenors could be explored. The formant tuning strategies of a lyric tenor like Pavarotti can be compared to the choices of a dramatic tenor like Del Monaco. The thesis facilitates that exploration. The formant tuning strategies for different repertoire can be explored. Do Italian tenors sing the same phonemes when they express a reflective melancholic aria like *Una Furtiva Lagrime* as they do when they sing an extroverted optimistic romantic expression like *Che Gelida Manina*? The study facilitates that kind of exploration which would verify whether or not the tenors follow Garcia's advice to modulate their timbre in relation to the repertoire for expression.

Going beyond the data found in the thesis, one hypothetical study would have student and professional tenors sing the vowel chart phonemes in a voice lab to connect the projections of historic recordings to state-of-the-art high-definition acoustic measurement. A study like the one described would explore articulator positioning, glottal vibration, and air pressure dynamics that happen when singers exercise the formant tuning strategies. The methodology of the thesis points a way forward to greater investigation of historic recordings. Valuable scientific data exists to be studied which holds specific direction for performance and style. The scientific data gained from the thesis can help to explain traditions of performance practice. Those traditions and formant tuning strategies may very well be different for other voice categories or other nationalities. Vowel formant tuning patterns may be remarkably similar, but the preferences indicated by the choices of other voice categories or national traditions could be revelatory. The methodology of the study could be carried out for other voice types, other nationalities, other repertoire, and other pitches.

CHAPTER 6

CONCLUSION

This project was born from curiosity about pure vowels in singing. Not only was there little consensus on what pure vowels were in the singing community, there was no specific definition that provided formant tuning frequencies for sung vowels of the *bel canto* tradition in relation to pitch. Because of this project, a vowel chart has been created based on the singing of peak performance Italian operatic tenors of the 20th century. The middle C vowel chart sheds light on the pure vowel concept in singing and the directions on vowels and pronunciation in historical vocal pedagogy literature. The Italian tenors demonstrate that vowels for singing rely on tuning of the vowel formants with the overtone series to generate nonlinear source filter dynamics. The perception of the formant tuning patterns demonstrated by the tenors in context of the vowel chart reveals that certain vowels sound like pure Italian vowels and others sound like pure French vowels. The Italian tenors also demonstrated that they used the variety of formant tuning patterns in their performances for the purpose of aesthetic and interpretive expression of the musical and dramatic context of the piece. This description and definition match the theory of vowel timbre written by Manuel Garcia II. This thesis contributes to the field of singing by providing scientific data on the written page to back up Garcia's empirical observations.

The process of researching this thesis and building the study methodology was a personally transformative experience. Familiarity with the history of *bel canto* singing, the pedagogical writings, and the recorded legacy of Italian tenors was enlightening and educational. In addition to the vowel chart, the ear training that developed from listening to and analyzing the

recordings was an education in perception and listening comprehension. Matching the formant tuning of the tenors in vocal exercises led to setting free the nonlinear source-filter dynamics which resulted in increased clarity combined with depth of color and presence of resonance. What started out as an intellectual and scientific exercise resulted in a life changing practical reformation of mind, ears, and voice. The observations and knowledge encapsulated in this thesis have the potential to breathe new life into an individual's experience of singing. If a singer is willing to trust the tradition demonstrated by the Italian tenors, matching the middle C phonemes will help them to discover nonlinear source-filter dynamics which will go a long way to helping them find equilibrium in their singing.

This thesis serves as a pilot study for using acoustic analysis of historical recordings to find patterns of performance practice. There are limitations to acoustic analysis of recordings, but with large enough of a data set significant patterns begin to emerge that shed light on the traditions of singing. These patterns do not provide the kind of high-definition specificity of a conventional scientific study in a laboratory, but the data indicates patterns with enough specificity to be useful for application in the studio and on stage. The data set collected from this study will hopefully be the source of more observations related to individual tenors, tenor sub-categories, and repertoire. The way that singers vary the vocal colors at their disposal while maintaining acoustic efficiency will offer tangible orientation to singers that desire to sing in a historically informed manner while maximizing their vocal potential. The author hopes that other studies will examine other voice types, and other national traditions of singing. The more that one can take the guess work out of singing, and make conscious decisions about technique, and the application of that technique in interpretation, the better for the art form. The knowledge collected from the study is hoped to be practical for singers in the exercise of their voices.

Hopefully the discoveries may take some of the mystery away from vowels in singing and formant tuning, and lead to a transformation in how voice teachers guide their students. Using data of this specificity may open the doorway for more practical and innovative teaching methods, pedagogical materials, and even mobile applications or computer programs that can help singers achieve the results they desire. Progress on the operatic front will also open doors for the same exercise and study to be done in other genres and styles.

The thesis has shed light on the concept of pure vowels in singing as found in the historic vocal pedagogic literature. It also has drawn up a guide for formant tuning in the form of a middle C vowel chart that can be used by singers as they build their voices. Both of these areas were undefined portions of the knowledge base in classical singing. This thesis provides further argument for the validity of nonlinear source-filter theory and the importance of vowel tuning for equilibrium in singing. Greater understanding of vowel tuning by great singers indicates standards of tonal quality that will encourage great singing and help preserve the *bel canto* tradition in the present and future.

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Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Gianni Raimondi, tenor. With Symphony Orchestra, Benedetto Ghiglia, cond. Recorded 1962. Philips AL3442. Youtube video, 4:25, <https://www.youtube.com/watch?v=eEyW80fgIVE>.

Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Giovanni Martinelli, tenor. Recorded 1926. Fonotipia D.B. 979. Youtube video, 4:26, <https://www.youtube.com/watch?v=odXcku8bH3A>.

Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Giovanni Zenatello, tenor. Recorded 1908. HMV XX 74105. Youtube video, 4:08, <https://www.youtube.com/watch?v=s7QJllsZ43s>.

Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Giuseppe Di Stefano, tenor. With San Francisco Association Orchestra, Gaetano Merola, cond. Recorded 1950. Myto MCD00069. Youtube video, 15:19, <https://www.youtube.com/watch?v=XxmSNxrn7Wo>.

- Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Luciano Pavarotti, tenor. With Nello Santi, cond. Recorded 1965. Youtube video, 5:21, <https://www.youtube.com/watch?v=mEptCT9rf-o>.
- Puccini, Giacomo. *Che Gelida Manina* from *La Boheme*. Mario Del Monaco, tenor. With Franco Ghione, cond. Recorded 1954. Decca 45-71061. Youtube video, 4:22, <https://www.youtube.com/watch?v=je7-EVId2xs&t=184s>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Alessandro Bonci, tenor. With Franco Ghione, cond. Recorded 1913. Columbia 38596. Youtube video, 2:49, <https://www.youtube.com/watch?v=r4NmdWRTn4U>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Aureliano Pertile, tenor. Recorded 1927. Fonotipia 120056. Youtube video, 2:19, <https://www.youtube.com/watch?v=le7-gekKtiw>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Beniamino Gigli, tenor. With Josef Pasternack, cond. Recorded 1921. Victor 64944. Youtube video, 2:59, <https://www.youtube.com/watch?v=plISPDNGNUU>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Carlo Bergonzi, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Gianandrea Gavazzeni, cond. Recorded 1957. Decca SXL 2048. Youtube video, 2:48, <https://www.youtube.com/watch?v=sAgJGjE2h90&t=315s>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Enrico Caruso, tenor. Recorded 1904. Victor B-999. Youtube video, 2:35, <https://www.youtube.com/watch?v=GGIgYzHRqLw>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Ferruccio Tagliavini, tenor. With Orchestra Sinfonica Dell'Eiar, Ugo Tansini, cond. Recorded 1950. HMV D.B. 21134. Youtube video, 3:16, <https://www.youtube.com/watch?v=Kv1MsUn9nn0>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Franco Bonisolli, tenor. With Orchestre National de France, Mstislav Rostropovich, cond. Recorded 1976. Deutsche Grammophon 2707 087. Youtube video, 5:32, <https://www.youtube.com/watch?v=bOZsn-DDYyo>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Franco Corelli, tenor. With Philharmonia Orchestra, Franco Ferraris, cond. Recorded 1962. EMI 7243 5 66533 2 0. Youtube video, 3:00, <https://www.youtube.com/watch?v=csuxsEO3Xw8>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Giacomo Lauri Volpi, tenor. Recorded 1922. Odeon 152012. Youtube video, 2:53, https://www.youtube.com/watch?v=efl_WMqoAq8.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Gianni Poggi, tenor. With Orchestra Del Teatro San Carlo di Napoli, Tullio Serafin, cond. Recorded 1957. Preiser Records B002VURJJW. Spotify audio, 4:11, <https://open.spotify.com/track/64OjRRNP13vWzqzjth6oOL?si=1776c1d6e2644f1b>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Gianni Raimondi, tenor. With Symphony Orchestra, Benedetto Ghiglia, cond. Recorded 1962. Philips AL3442. YouTube video, 2:46, <https://www.youtube.com/watch?v=cRjawu0Uc10>.

Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Giovanni Martinelli, tenor. Recorded 1914. Victor B-14276. Youtube video, 2:27, <https://www.youtube.com/watch?v=3XCcqZ5UHe0>.

- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Giovanni Zenatello, tenor. Recorded 1909. Fonotipia X 92209. Youtube video, 2:54, <https://www.youtube.com/watch?v=AjjsLaaikfo>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Giuseppe Anselmi, tenor. Recorded 1907. Fonotipia X 62185. Youtube video, 2:15, <https://www.youtube.com/watch?v=0y7t-JuWn8A>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Giuseppe Di Stefano, tenor. With Orchestra Del Teatro Alla Scala, Victor de Sabata, cond. Recorded 1953. EMI Classics 7243 5 67756 2 6. Youtube video, 3:45, <https://www.youtube.com/watch?v=5DemTdHmg3w>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Luciano Pavarotti, tenor. With Rolando Nicolosi, pianist; Recorded 1979. Domenica In RAI Uno. Youtube video, 3:29, <https://www.youtube.com/watch?v=N86DLLTBn1A>.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Mario Del Monaco, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Alberto Erede, cond. Recorded 1952. Decca. Youtube video, 2:44, https://www.youtube.com/watch?v=O5v_4EUXcJA.
- Puccini, Giacomo. *Recondita Armonia* from *Tosca*. Tito Schipa, tenor. With Carlo Sabajno, cond. Recorded 1913. HMV 252133. Youtube video, 2:49, <https://www.youtube.com/watch?v=e4KP04EX5gY>.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Alessandro Bonci, tenor. Recorded 1907. Fonotipia X 39695. Youtube video, 3:18, <https://www.youtube.com/watch?v=L27ktRDtnfE>.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Aureliano Pertile, tenor. Recorded 1927. Fonotipia 120048 xxPh 5969. Youtube video, 4:06, <https://www.youtube.com/watch?v=fCjdct7keB4>.

- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Beniamino Gigli, tenor. With Walter Goehr, cond. Recorded 1937. HMV DB 3225. Youtube video, 4:28, https://www.youtube.com/watch?v=_A4ZDpxu6qk.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Carlo Bergonzi, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Gianandrea Gavazzeni, cond. Recorded 1957. Decca SXL 2048. Youtube video, 5:04, <https://www.youtube.com/watch?v=sAgJGjE2h90&t=315s>.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Enrico Caruso, tenor. Recorded 1904. Victor C-997. EnricoCaruso.dk audio clip, 3:45, <https://www.enricocaruso.dk/musicdetails.php?mid=192>.
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- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Gianni Poggi, tenor. With Orchestra Del Teatro San Carlo di Napoli, Francesco Molinari-Pradelli, cond. Recorded 1957. Philips P 13531 R. Spotify audio, 4:07, <https://open.spotify.com/track/55DhwN58cpYIxDyvOdYt49?si=42218dba1fed445f>.
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- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Giovanni Zenatello, tenor. Recorded 1909. Fonotipia X 92609. YouTube video, 3:46, <https://www.youtube.com/watch?v=57gKov5ac1g>.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Giuseppe Anselmi, tenor. Recorded 1910. Fonotipia X 62561. YouTube video, 3:50, <https://www.youtube.com/watch?v=lTuY64VqmH8>.
- Verdi, Giuseppe. *Celeste Aida* from *Aida*. Giuseppe Di Stefano, tenor. With Orchestra Del Teatro Alla Scala, Antonino Votto, cond. Recorded 1956. International Music of Italy DMV-01. YouTube video, 4:25, <https://youtu.be/oBneqHZmrLo>.
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- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Alessandro Bonci, tenor. Recorded 1906. Fonotipia X 62130. YouTube video, 2:06, <https://www.youtube.com/watch?v=c-wiAdtz7gw>.
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- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Beniamino Gigli, tenor. With Rosario Bourdon, cond. Recorded 1928. Victor 6876. YouTube video, 4:25, <https://www.youtube.com/watch?v=V07APrpOpx4>.

- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Carlo Bergonzi, tenor. With Maggio Musicale Fiorentino Orchestra, John Pritchard, cond. Recorded 1962. Decca SET 249-51. YouTube video, 7:46, <https://www.youtube.com/watch?v=CxLTyz7MA0g>.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Cesare Valletti, tenor. With Orchestra del Teatro dell'Opera di Roma, Pierre Monteux, cond. Recorded 1956. RCA Victor LM 2 044. YouTube video, 4:04, https://www.youtube.com/watch?v=_cPnrYWwN3k.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Ferruccio Tagliavini, tenor. With Metropolitan Opera Orchestra, Alberto Erede cond. Recorded 1950. Bongiovanni. YouTube video, 3:23, <https://www.youtube.com/watch?v=lwYGnOucPY0>.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Franco Bonisoli, tenor. With Staatskapelle Berlin, Lamberto Gardelli, cond. Recorded 1973. Acanta JB 21.644. YouTube video, 6:07, <https://www.youtube.com/watch?v=WHxkVCgh9lo>.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Gianni Raimondi, tenor. With Symphony Orchestra, Benedetto Ghiglia, cond. Recorded 1962. Philips AL3442. YouTube video, 3:50, <https://www.youtube.com/watch?v=pf0eGRqpgiM>.
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- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Giovanni Zenatello, tenor. Recorded 1906. Fonotipia X 39663. YouTube video, 3:10, <https://www.youtube.com/watch?v=KkRaJI9OPRg>.

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- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Giuseppe Di Stefano, tenor. With London Symphony Orchestra, Alberto Erede, cond. Recorded 1947. HMV OXLP.7638. YouTube video, 3:47, <https://www.youtube.com/watch?v=Qn1pek6n7RQ>.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Luciano Pavarotti, tenor. With Leone Magiera, pianist; Recorded 1976. HMV OXLP.7638. YouTube video, 5:20, https://www.youtube.com/watch?v=35IAkXi9_FQ&t=1s.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Mario Del Monaco, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Alberto Erede, cond. Recorded 1952. Decca. YouTube video, 3:24, <https://www.youtube.com/watch?v=zlgYkpfmDFE>.
- Verdi, Giuseppe. *Lunge Da Lei* from *La Traviata*. Tito Schipa, tenor. Recorded 1921. Pathe. YouTube video, 3:49, <https://www.youtube.com/watch?v=OOx1DBtiXvc>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Alessandro Bonci, tenor. Recorded 1906. Fonotipia X 39691. YouTube video, 5:22, <https://www.youtube.com/watch?v=iNSdMj7Ftv8>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Aureliano Pertile, tenor. With Teatro Alla Scala Milano Orchestra, Carlo Sabajno, cond. Recorded 1927. HMV DB111 (2-052354). YouTube video, 3:36, <https://www.youtube.com/watch?v=n4eBB83KDwE>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Carlo Bergonzi, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Gianandrea Gavazzeni, cond.

- Recorded 1958. Decca SXL 2048. YouTube video, 5:06,
<https://www.youtube.com/watch?v=sAgJGjE2h90>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Cesare Valletti, tenor, tenor.
With Orchestra Sinfonica di Torino della Rai, Mario Fighera, cond. Recorded 1951. Fonit
Cetra LMR 5012. YouTube video, 5:12, <https://www.youtube.com/watch?v=--vzXGRiF18>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Ferruccio Tagliavini, tenor.
With Grande Orchestra Sinfonica Della Radio Italiana, Mario Rossi, cond. Recorded
1948. Fonit Cetra BB 25230. YouTube video, 3:41,
<https://www.youtube.com/watch?v=19krhgvyYZ4>.
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Wiener Staatsoper Orchestra, Alberto Erede, cond. Recorded 1974. YouTube video,
11:19, <https://www.youtube.com/watch?v=4Q5fAJSdMYw>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Franco Corelli, tenor. With New
Philharmonia Orchestra, Franco Ferraris, cond. Recorded 1967. EMI 7243 5 62699 2 7.
YouTube video, 5:14, <https://www.youtube.com/watch?v=L9L4Hoh5ogs>.
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With Orchestra del Teatro dell'Opera di Roma, Roberto Arduini, cond. Recorded 1943.
La voce del padrone DB5449. YouTube video, 3:27,
<https://www.youtube.com/watch?v=rA7vfQqYBCs>.
- Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Gianni Poggi, tenor. With
L'Accademia di Santa Cecilia, Alberto Erede, cond. Recorded 1954. London Records LL

1381. YouTube video, 1:19:45,

<https://www.youtube.com/watch?v=4LkOR7FP2NU&t=112s>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Gianni Raimondi, tenor. With Symphony Orchestra, Benedetto Ghiglia, cond. Recorded 1962. Philips AL3442.

YouTube video, 4:34, <https://www.youtube.com/watch?v=KDLKkR0N3d4>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Giuseppe Anselmi, tenor. Recorded 1907. Fonotipia X 62166. YouTube video, 3:49,

<https://www.youtube.com/watch?v=2kXPmIdLuqk>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Giuseppe Di Stefano, tenor. Recorded 1962. YouTube video, 5:00,

<https://www.youtube.com/watch?v=NHuHogdDa88>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Luciano Pavarotti, tenor. With Wiener Opernorchester, Sir Edward Downes, cond. Recorded 1968. Decca SXL 6377.

YouTube video, 5:42, <https://www.youtube.com/watch?v=DcZp4UCVco4>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Mario Del Monaco, tenor. With Orchestra dell'Accademia Nazionale di Santa Cecilia, Alberto Erede, cond. Recorded 1955. Decca SXL 6377. Spotify audio, 4:44,

<https://open.spotify.com/track/2OvOdb30A1xzpfidfrq8lQ?si=5aa34da3c50744ee>.

Verdi, Giuseppe. *Quando Le Sere Al Placido* from *Luisa Miller*. Tito Schipa, tenor. Recorded 1928. Gramophone DB-1372. YouTube video, 3:37,

<https://www.youtube.com/watch?v=0hGPdEqrGDs>.