Nicola Vicentino and the Enharmonic Diesis: An Analytical and Empirical Study

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ABSTRACT

Nicola Vicentino is recognized as a sixteenth-century musical revolutionary; a wealth of scholarly work has been devoted to his theories and philosophies. Attempts to analyze Vicentino's compositions are limited in number, however, and empirical studies of the perception of his music are non-existent. In his treatise, *Ancient Music Adapted to Modern Practice,* Vicentino illustrates the practical application of his theories with compositional examples that employ the microtonal interval of the minor enharmonic diesis, and novel 31-tone tuning system that he developed himself. The first two chapters of this thesis review Vicentino's theories and philosophies of music, and undertake an analytical survey of the extant enharmonic compositions. This analysis explores the possibilities available in Vicentino's tuning system, and characterizes the voice-leading and harmonic patterns found in Vicentino's enharmonic compositions in terms of the use of the microtonal interval, the minor enharmonic diesis. I show that Vicentino uses only a handful of possibilities at his disposal, and that the voice-leading and harmonic patterns involving the minor enharmonic diesis are used in systematic ways depending on the musical context.

The final two chapters of this thesis develop and test the hypothesis that trained musicians can hear the nuances of Vicentino's music when the enharmonic diesis is involved (as Vicentino claims). This hypothesis was experimentally tested in a discrimination study in which trained musicians had to discriminate between short musical excerpts in Vicentino's 31-tone equal temperament and the standard 12-tone equal temperament. The results of the empirical study show that listeners are able to reliably discriminate between the two systems, and that harmonic and voice-leading contexts affect discrimination ability.

RÉSUMÉ

Nicola Vicentino est reconnu en tant que révolutionnaire de la pensée musicale du seizième siècle; plusieurs ouvrages académiques sont dévoués à ses théories et philosophies. Par contre, des analyses des compositions de Vicentino sont peu nombreuses, et des études empiriques sur la perception de sa musique sont inexistantes. Dans son traité, *L'antica musica ridotta alla moderna prattica,* Vicentino explique les applications pratiques de ses théories en se servant d'exemples musicaux qui emploient l'intervalle microtonal d'un cinquième ($^1/_5$) d'un ton ainsi qu'un système novateur de tempérament égal à 31 tons basé sur cet intervalle. Les deux premiers chapitres de cette thèse révisent les théories et philosophies musicales de Vicentino et entreprennent un survol analytique de ses compositions qui survivent jusqu'à aujourd'hui. Cette analyse explore les possibilités du système d'accord tempéré de Vicentino et présente les principes de la conduite des voix et des séquences harmoniques retrouvées dans le contexte de l'intervalle d'un cinquième d'un ton. Je démontre que Vicentino utilise seulement quelques-unes des possibilités à sa disposition, et que la conduite des voix et des séquences harmoniques impliquant l'intervalle d'un cinquième d'un ton sont utilisées de façon systématique, dépendant du contexte musical.

Les deux derniers chapitres de la thèse développent l'hypothèse que des musiciens formés sont capables d'entendre les nuances intervallaires de la musique de Vicentino quand l'intervalle d'un cinquième d'un ton est utilisé (comme Vicentino le réclamait). Cette hypothèse est testée par une expérience discriminatoire où des musiciens formés ont eu à différencier entre de cours extraits musicaux, certains provenant du système de Vicentino du tempérament égal à 31 tons et d'autres de l'accord tempéré égal conventionnel à douze tons. Les résultats de cette étude empirique démontrent que les auditeurs sont capables de discriminer entre les deux systèmes de façon fiable, mais que les contextes spécifiques harmoniques et de la conduite des voix peuvent affecter la fiabilité de ces habiletés.

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INTRODUCTION

The musical philosophies and theories of Nicola Vicentino (ca. 1511-1576) are often cited as the pinnacle of the avant-garde in sixteenth-century Italy.[1] The compositions of Vicentino, however, have fallen into obscurity. Though these compositions may not be considered as musically sophisticated as those of his contemporaries, they nonetheless demonstrate Vicentino's revolutionary musical ideas and novel 31-tone tuning system. Vicentino claims in his 1555 treatise, *Ancient Music Adapted to Modern Practice,* that the microtonal inflections of his tuning system are subtle yet perceptible, and that the nuances of his system are capable of moving the affections of listeners. Recently, Professors Jonathan Wild and Peter Schubert have rendered recordings of Vicentino's music in the precise tuning system prescribed in Vicentino's treatise.[2] These recordings have allowed listeners to hear (perhaps for the first time in centuries) the microtonal music as Vicentino envisioned. The present project provides musical analyses characterizing Vicentino's employment of the microtonal intervals of his system, and uses the recordings made by Professors Wild and Schubert to investigate whether these various interval sizes are as effective and perceptible as Vicentino claims.

In the first chapter, I review Vicentino's biographical information and the philosophical, theoretical, and practical ideas found in Vicentino's treatise. This review will include a discussion of Vicentino's listener-oriented approach to music and his

[1] Claude V. Palisca, foreword to *Ancient Music Adapted to Modern Practice,* by Nicola Vicentino, trans. Maria Rika Maniates, ed. Claude V. Palisca (New Haven: Yale University Press, 1996), vii; see also Timothy McKinney, *Adrian Willaert and the Theory of Interval Affect: the* Musica Nova *Madrigals and the Novel Theories of Zarlino and Vicentino* (Burlington, VT: Ashgate, 2009), 8.

[2] The Vicentino recordings were part of a larger project about historical tuning systems. See Jonathan Wild, and Peter Schubert, "Historically Informed Retuning of Polyphonic Vocal Performance," *Journal of Interdisciplinary Music Studies* 2, no. 1 (2008): 121-139.

determination to revive the miraculous emotional effects of music as reported in ancient sources. I will then discuss Vicentino's adaptation of the Greek genera, his theory of interval affect, and the features of his 31-tone tuning system. The discussion will focus on Vicentino's advocacy for the use of microtonal step of the minor enharmonic diesis as a means of affective expression.

Chapter Two explores the harmonic and voice-leading possibilities of Vicentino's system of 31-tone equal temperament (31-TET). I develop a system of categorizing harmonic relations in terms of the intervals traversed in smooth voice-leading; this is inspired by Vicentino's definition of pure diatonic, chromatic, and enharmonic writing, which only uses the intervals available in a specific genus. I demonstrate that only certain progressions have the potential to produce the step of the enharmonic diesis. In Vicentino's music, I suggest that the use of the step of the enharmonic diesis is always signaled by his notational convention for raising notes by a fifth of a tone. I analyze the harmonic content of Vicentino's four extant enharmonic compositions (*Dolce mio ben*, *Madonna, il poco dolce*, *Soav'e dolc'ardore,* and *Musica prisca caput*) to illustrate the key differences in the various contexts in which Vicentino involves the minor enharmonic diesis. I analyze thirty excerpts from the four enharmonic compositions listed above in terms of the voice-leading features found in various contexts in Vicentino's enharmonic music.

In Chapter Three, I develop a hypothesis concerning the ability of trained musicians to detect the differences between Vicentino's tuning system and the standard 12-tone equal temperament (12-TET). This chapter provides a review of the relevant psychological research regarding the perception and discrimination of pitches, musical intervals, and tuning systems. I also include a discussion of the perception of voice-leading distance and perceptual validity of voice-leading metrics.

Chapter Four reports the results of two experiments that test the hypothesis developed in chapter three. The goal of the first experiment is to determine if musically trained listeners can discriminate between short musical examples in 12-TET and 31-TET; the second experiment investigates the effect of the experimental paradigm on the discrimination task. The stimuli for the experiments consist of recordings of the thirty excerpts analyzed in Chapter Two, tuned to correspond to either 12-TET or 31-TET. The results of the empirical investigation provide evidence that musically trained listeners can reliably tell the difference between 31-TET and 12-TET versions of Vicentino's music, but that certain harmonic and voice-leading parameters encourage greater discrimination ability.

CHAPTER ONE: A Review of Nicola Vicentino's Life and Works

This chapter provides information about the life and works of Nicola Vicentino. I begin with a biographical outline to contextualize Vicentino's position in sixteenth-century Italian musical life, to uncover the principal influences and sources available to Vicentino in developing his theoretical ideas, and to explore the impact of his career. A discussion of his works will include a brief overview of his extant compositions and writings, and an examination of the theoretical ideas found in his treatise, *Ancient Music Adapted to Modern Practice*. The discussion of the treatise will include information concerning Vicentino's musical philosophy, an account of his theory of interval affect and the genera, and a synopsis of the tuning system devised by Vicentino. I will demonstrate in this chapter that Vicentino's approach to music privileges the listener's perceptions and emotions, and that the ensuing empirical study of the perception of his music is not contradictory to his philosophy.

Biographical Information

The Renaissance musicologist Edward E. Lowinsky acknowledges the innovation found in Vicentino's works, referring to Vicentino as "the greatest revolutionary of the sixteenth century."[3] In the foreword to the translation of Vicentino's treatise *Ancient Music Adapted to Modern Practice*, Claude V. Palisca describes Vicentino's position in the music-theoretic environment of mid-sixteenth century Italy as follows: "While Gioseffo Zarlino's *Le istitutioni harmoniche* of 1558 stood for the status quo, Vicentino

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[3] Edward E. Lowinsky, "The Musical Avant-Garde of the Renaissance," in *Art, Science and History in the Renaissance* (Baltimore: Johns Hopkins Press, 1967), 133.

led the avant garde."[4] Although both Zarlino and Vicentino were students of the composer Adrian Willaert, Vicentino (the older of the two pupils), was far more progressive in his musical thinking. Timothy McKinney echoes Palisca's observation, describing Zarlino as the codifier of tradition and Vicentino as a pioneer of experimental music.[5] The mid-sixteenth century in Italy was, therefore, defined by two opposing camps that stemmed from the same tradition. Zarlino was situated on one side, defending and elevating the traditional style of polyphonic writing. On the other side was Vicentino, who was forging a radical path toward the "new music," which had begun with Willaert and reached maturity in the music of Monteverdi.[6] As Karol Berger puts it in *Theories of Chromatic and Enharmonic Music in Late 16th-Century Italy*, Vicentino was concerned with music as it could and should be, not with music as it was.[7]

The novelty of Vicentino's ideas extends beyond his theoretical treatment of the rules of counterpoint and voice-leading, the adaptation of ancient Greek genera to modern composition, and his 31-tone tuning system that can accommodate versions of the Greek diatonic, chromatic, and enharmonic genera. His philosophy emphasized the expressive and emotional powers of music, and made the case that sense and reason were equally important in the reception of music.[8] The ultimate judges of the value of composition, according to Vicentino, were the ears of the listeners, who possessed greatly different artistic and natural faculties.[9] The success of a composition was due to

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[4] Palisca, vii.
[5] McKinney, 8.
[6] *Ibid.*, 1-15.
[7] Karol Berger, "Nicola Vicentino and Ghiselin Danckerts," in *Theories of Chromatic and Enharmonic Music in Late 16th Century Italy,* ed. George Buelow, Studies in Musicology, no. 10 (Ann Arbor: UMI Research Press, 1980), 41.
[8] Nicola Vicentino, *Ancient Music Adapted to Modern Practice,* trans. Maria Rika Maniates, ed. Claude V. Palisca (New Haven: Yale University Press, 1996), 6.
[9] *Ibid.*, 21-22.

appropriate treatment of the musical subject, and its ability to arouse a variety of emotions in a diverse audience.[10] Palisca describes Vicentino as "an early champion" of this mid-sixteenth century focus on "moving the affections" of listeners.[11]

The influence of Vicentino on musical thinking is well documented, but the details of his early life are scattered and incomplete. Vicentino was born in Vicenza in 1511. He received his musical education in Venice as a student of the composer Adrian Willaert, probably in the early 1530s.[12] Willaert, a renowned master of counterpoint and composition, was also interested in the affective qualities of intervals, issues of tuning, performance practice, and the enharmonic and chromatic genera.[13] The theory of the three genera (diatonic, chromatic, and enharmonic), which define the relative positions of the two moveable notes within a tetrachord, was not one of aspects of ancient Greek music theory that was popularly revived during the Renaissance. Willaert's interest in the enharmonic and chromatic genera dates from a correspondence between Willaert, Giovanni Spataro, and Giovanni del Lago some 19 years before Vicentino's treatise was published. In these letters, the three musicians seem to reach a conclusion that agrees with Vicentino's view that modern music is a mixture of the genera.[14] Vicentino's own interest in non-diatonic music was likely influenced by his teacher and began early in his

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[10] *Ibid.*, 67-68; 203.
[11] Claude V. Palisca, *Music and Music and Ideas in the Sixteenth and Seventeenth Centuries,* In *Studies in the History of Music Theory and Literature,* vol. 1, ed. Thomas J. Mathiesen (Chicago: University of Illinois Press, 2006), 179.
[12]No solid evidence of Vicentino's relationship to Willaert exists, except for Vicentino's claim to be a disciple of Willaert and Vicentino's obvious familiarity with Willaert's method. See McKinney, 8.
[13] For a chronology of the life Adrian Willaert, see David M. Kidger, *Adrian Willaert: A Guide to Research* (New York: Routledge, 2005), http://lib.myilibrary.com?ID=20440. (4 September 2010), 5-6. For a discussion of Willaert's influence on Vicentino, see McKinney, 225-242; see also Lowinsky, 131.
[14] See McKinney, 10; for a translation of the letter see Bonnie J. Blackburn, Edward E. Lowinsky, Clement A. Miller, eds., *A Correspondence of Renaissance Musicians* (New York : Oxford University Press, 1991), letter 46, 548-554. In his commentary, Lowinsky notes the similarity between Spataro's wording on the subject and Vicentino's position. Willaert, Spataro, and del Lago do not condone the use of the enharmonic genera in modern composition, however.

musical career, around the same time as the correspondence between Willaert, Spataro, and del Lago. By 1534, Vicentino was already experimenting with non-diatonic music and researching the theory and practice of ancient Greek music.[15]

Willaert's influence on Vicentino, whether direct or by proxy, is apparent; Vicentino's first book of madrigals (1546) is dedicated to his teacher and the "new manner" of composition he attributes to Willaert.[16] During the 1540's, Willaert was implicitly developing a theory of interval affect, harmonic chord quality, and chord stability that would define a new style of musical composition that privileged the expression of text.[17] Willaert's new style of composition is embodied in his *Musica Nova* madrigals, which were not published until 1559. Vicentino's system of interval affect from 1555 predates Willaert's *Musica Nova,* but was nonetheless heavily influenced by the earlier methods of his teacher.

Although interested in the humanistic ideas of the sixteenth century, Vicentino was not a humanist scholar. This term is traditionally reserved for those scholars who edited, translated, or interpreted ancient texts. Vicentino was unable to read Greek, and his Latin was poor. He had contact with the several humanist scholars early in his career in Ferrara and Vicenza, of whom Gian Giorgio Trissino, Giambattista Giraldi Cintio, Francesco Patrizi, and Lilio Gregorio Giraldi were probably most influential.[18] Vicentino more appropriately belongs to the wave of "musical humanism" discussed by Walker,

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[15] Maria Rika Maniates, introduction to *Ancient Music Adapted to Modern Practice*, by Nicola Vicentino, trans. Maria Rika Maniates, ed. Claude V. Palisca (New Haven: Yale University Press, 1996), xii. This was reported by Ghiselin Danckerts, who, in 1549, claimed that Vicentino had been experimenting in the non-diatonic genera for 15 years. This places his first dealings with the chromatic and enharmonic genera in 1534. See also Henry William Kaufmann, *The Life and Works of Nicola Vicentino (1511-c.1576)*, Musical Studies and Documents, vol. 11 ([n.p.]: American Institute of Musicology, 1966), 18.
[16] Kaufmann, 52-53.
[17] See McKinney, 73; 290.
[18] Maniates, xxvii-xxxi.

Lowinsky, Palisca, and others.[19] This term describes a movement whose members were familiar with ancient texts, but were more interested in reviving the alleged powers of music to affect the ethical and emotional state of listeners than the actual practice of ancient music.[20]

Vicentino secured a position as a household musician in Rome under the Cardinal Ippolito II d'Este of Ferrara in the late 1540s. Sometime before his appointment with the cardinal, he was ordained as a priest.[21] The dates of Vicentino's employment with the Cardinal (from approximately 1549 to 1563) correspond to an era of political and religious prominence in for Ippolito II. As a result, Vicentino travelled frequently with his employer, spending time in Siena, Rome, and Ferrara.

In his early musical career, Vicentino did not have many students. Although Vicentino's position with the Cardinal was not officially part of the court of the Duke Ercole II, who was the brother of Ippolito II, Vicentino did instruct the Duke's son, Prince Alfonso, in the theory and performance of the chromatic and enharmonic genera. Vicentino was also approached in 1549 by musicians of Niccolò Cardinal Ridolfi, who sought instruction in the performance of his enharmonic and chromatic music. Vicentino initially refused the offer, supposedly for fear that his ideas would be stolen and he would no longer be able to use his work to leverage a position in the papal choir. In October of 1549, a contract was drawn up, stipulating that Vicentino would teach his music to only a handful of singers, who, under penalty, could not reveal his methods for a period of ten years. This period of silence was set to allow Vicentino time to finish and publish his

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[19] See D.P. Walker, "Musical Humanism in the 16th and Early 17th Centuries," *Music Review* 2 (1941): 1-11; Lowinsky, 130-139; Palisca, *Music and Ideas,* 13-28; 71-98.
[20] See Walker, 1-11, Berger 38-41; Maniates, xxxviii-xl.
[21] See Maniates, xi. In footnote (4) , there is list the documents that provide evidence of Vicentino's vocation as a priest.

treatise before his secrets were divulged. This contract was never broken by any of the singers, perhaps because Vicentino's method was too difficult to teach, or because, as an adversary of Vicentino's work conjectured, the secret was worthless.[22]

In 1551, after attending a private musical performance, Vicentino became involved in a dispute concerning the true genus of the plainchant *Regina coeli.* His opponent in the matter was the Portuguese composer Vicente Lusitano. Vicentino asserted that contemporary composers were unaware of the true genus in which they were composing, and that they employed a "mixed" style defined by the use of melodic major and minor thirds, which rightfully belonged to the enharmonic and chromatic genera, respectively.[23] It should be noted that Vicentino was thinking of the genera in strictly melodic terms; his compositions otherwise adhere to sixteenth-century polyphonic style and triadic vertical sonorities.[24] Lusitano viewed contemporary music as essentially diatonic, with chromatic accidentals added only when necessary. The presence of major and minor thirds, or any interval larger than a semitone for that matter, was the cumulative effect of traversing multiple diatonic steps. Both Lusitano and Vicentino cited the same passages from Boethius's *De institutione musica* as support for their arguments, but each interpreted the passages differently. Kaufmann notes that Lusitano conveniently omitted the last part of one of the passages, in which Boethius speaks of mixing the different genera—a passage that would have contradicted Lusitano's

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[22] Ghiselin Danckerts, one of the judges in the debate between Vicentino and Lusitano (discussed later in this chapter) and one of Vicentino's main adversaries made this comment. For information concerning Danckerts' opinions of Vicentino, see Maniates, xv-xvi.

[23] In *Book III on Music Practice*, Vicentino explains his reasoning behind the belief that music is not purely diatonic. See Vicentino, 152.

[24] Alexander Silbiger, *Introduction to Four Enharmonic Madrigals*, *by Nicola Vicentino*, ed. Alexander Silbiger (Houten: Diapason, 1990), 7.

argument that music is essentially diatonic.[25] Vicentino claimed that his opponent eventually adopted the view that contemporary music mixed the genera in his treatise in 1553. However, Vicentino based this claim on a passage that summarized the same Boethian theories that Lusitano presented in his original argument. This evidence cited by Vicentino does not necessarily imply that Lusitano changed his position. And, as Kaufmann suggests, Vicentino probably would not have gone to such great length in 1555 in his treatise to attack Lusitano's argument and defend his own position had he truly believed Lusitano was converted.[26]

The verdict for the debate was delivered by two singers in the Papal choir, Bartolemeo Escobedo and Ghiselin Danckerts (who would later become Vicentino's greatest opponent on the matter) in Lusitano's favor in June of 1551. However, the circumstances surrounding the decision are subject to skepticism. The deciding vote was cast by Danckerts days after the debate, as he was not present for the initial oral debate. He requested that Lusitano and Vicentino submit their arguments in writing, and that he would read them before casting his vote. Danckerts also admitted to being angry with Vicentino at the time, allegedly because Vicentino had previously remarked that the singers of the papal choir were regrettable performers.[27] In any event, Vicentino lost the debate and would not have a chance to publicly defend his ideas until he returned to Rome in 1555 and published his treatise.

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[25] See Kaufmann, 26-28. Lusitano omits the following passage: "[…] the explanation of these modes [e.g. the Lydian] is not now under consideration. In order, however, for the mixed description to run through the three genera and for the proper number of figures to be applied in every place for the maintenance, namely, of proportions, a number is devised for the tones and dieses which can satisfy all this […]"
[26] *Ibid.*, 28.
[27] *Ibid.*, 22; Maniates, xx.

Vicentino left Rome with the Cardinal and moved to Siena soon after the verdict was decided. During his absence from Rome, Vicentino completed his treatise. *L'antica musica ridotta all moderna prattica* was published on May 22, 1555, shortly after Vicentino returned to Rome. In late 1555 and early 1556, there is evidence that Vicentino used the publication of his treatise to seek other employment. He had contact with the Mantuan court and sent examples of his chromatic and enharmonic music. They were not well received, and Vicentino remained in the service of the Cardinal. A second printing of his treatise in Rome in 1557 did little to bolster Vicentino's career.

By 1561, Vicentino had built both his *archicembalo* and *archiorgano* (although the former was completed before the 1555 publication date of his treatise), and was able to teach his enharmonic and chromatic music to singers.[28] Vicentino circulated a broadsheet detailing the construction of his *archicembalo* to advertise his availability for new employment.[29] Unable to secure a new major post, Vicentino relied on fervent self-promotion to promulgate his music and theories. During the 1560s, he traveled with a group of singers and gave public concerts of his music in major Italian cities. McKinney suggests that these performances influenced other progressive composers of the latter-half of the sixteenth century, namely Luzzasco Luzzaschi and Carlo Gesualdo.[30]

Vincenzo Galilei, father of the famous physicist and astronomer Galileo Galilei, reports that Vicentino did have many pupils of his music in the 1560s and that he actively sought the public performance of his compositions.[31] These performances were not well

[28] Kaufmann., 35.
[29] McKinney, 9.
[30] *Ibid.*, 9.
[31] Kaufmann., 36.

received according to Galilei, who had little faith that Vicentino's work would survive beyond the death of its composer. Galilei writes:

> I doubt if the enharmonic music pleased even Don Nicola himself. I think what happened to him was that which occurs to many other people: and this is that inadvertently, because of their simplicity, they abuse what deserves praise and praise what merits to be abused, and afterward, ashamed to contradict themselves, they remain obstinate; others because of their ambitions boast of being capable of things beyond their powers, and badly as they succeed in their ventures, always wish to sustain them as well done.[32]

After many prolonged absences of his patron, Vicentino left the service of the Cardinal and assumed the position of chapel master at the Cathedral of Vicenza in 1563. Apparently dissatisfied with the position, Vicentino left the chapel after only two years of service. He then moved to Milan, where he remained until his death around 1576.

Compositional Output

Vicentino's first book of madrigals was published in Venice in 1546. The book was dedicated to his teacher, Adrian Willaert. It consists of 19 madrigals, based on texts by mostly little-known authors. The music itself is also unexceptional, which has prompted Maria Rika Maniates to suggest that Vicentino's "comments about his new or rediscovered styles of composing, allegedly influenced by Willaert, are little more than the customary platitudes."[33] Henry Kaufmann, in contrast, devotes a large portion of his chapter about Vicentino's music to defining exactly what this new style of composing might entail.[34] Regardless of the differing opinions about the compositional value of

[32] For translation of Galilei, see Kaufmann, 106. This translation originally appeared in Claude V. Palisca's unpublished dissertation, "The Beginnings of Baroque Music: Its Roots in Sixteenth-Century Theory and Polemics," Harvard University, 1953.
[33] Maniates, xi.
[34] See Kaufmann, 53-72. The main feature of the "new manner" is freedom in formal structure for the sake of expression the text.

these early madrigals, the book does offer a view into the musical life of the young Vicentino. They represent Vicentino's progressive attitude, even though he lacked compositional prowess.

There is then a large gap in the extant compositions; the only other surviving works attributed to Vicentino were published in the 1560s or later (excluding those compositions that appear as didactic examples in *Book III on Music Practice* of his treatise in 1555). These extant compositions include another book of madrigals published in 1572, a few isolated works that exist in manuscript form or concordant sources, and a part-book from a lost book of motets. The only extant examples of his enharmonic compositions are found in *Book III on Music Practice* of the treatise, and in two short fragments in Ercole Bottrigari's *Il Melone secondo.*[35] The three-decade span of time covered by these remaining compositions allows for a juxtaposition of Vicentino as a young and mature composer.[36]

The Treatise

Sources

Vicentino's source for the music-theoretical aspects of his treatise was primarily Boethius's *De institutione musica*. Modern texts by Gaffurio and Lusitano and the medieval texts of Guido of Arezzo and Jehan de Murs were the primary sources for the practical aspects of his treatise such as contrapuntal practice, notation, and solmization. Lodovico Fogliano was his source for ancient tuning theory and modern temperament.[37] A Latin translation of Ptolemy's *Harmonics* was printed in 1499, but there is little

[35] Silbiger, 5.
[36] Kaufmann, 49
[37] Maniates, xxvii.

evidence Vicentino read it—even though aspects of his theory align with Ptolemy's diatonic syntonic system that contains two sizes of whole tones.[38] The ancient sources known to Vicentino include works by Aristotle (both in translation and paraphrase in Trissino's *La Poetica*), Plato, and Plutarch; but his exposure to Ptolemy and Aristoxenus was limited to overviews and references found in the treatises of Vitruvius and Fogliano.[39] These last sources offer accounts of the ancient belief in the miraculous effects of music. It is from these sources that Vicentino derives his philosophy of music.

Musical Philosophy

Vicentino's interest in the music of antiquity was the same as many of his contemporaries: to revive the marvelous ethical and emotional effects of ancient music. Walker and others have termed this movement "musical humanism," and Vicentino stood near the front of it.[40] Vicentino's sources on the subject, chiefly Aristotle, claimed that poetry and music were one and the same.[41] These sources also cited the power of different modes to affect moods and emotions, and the proper usage of the genera and modes in different styles of music.[42] The diatonic genus was cheerful and harsh and meant for public forums and common people; the chromatic and enharmonic genera were

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[38] *Ibid.*, xxxii.
[39] *Ibid.*, xxv-xxvi.
[40] Walker., 8-9.
[41] For a translation of Aristotle's *Poetics,* see Thomas Twining, *Aristotle's Treatise on Poetry, Translated: With Notes on the Translation, and on the Original; and Two Dissertations, on Poetical, and Musical Imitation* [Originally published in 1789] (Westmead, Farnborough, Hants, England: Gregg International Publishers Limited, 1972), 69-74. See also Twining's "Dissertation II" in the same volume, 44-61.
[42] See Aristotle's *Politics* for references to the power of music to move listeners. Relevant excerpts can be found in Aristotle, "2. Aristotle: From the *Politics*," in *Source Readings in Music History from Classical Antiquity Through the Romantic Era,* ed. W. Oliver Strunk (New York: Norton, 1950), 13-24. See also Boethuis, "Boethius: From the *De Institutione Musica*," in *Source Readings in Music History from Classical Antiquity Through the Romantic Era,* ed. W. Oliver Strunk (New York: Norton, 1950), 82. Here, Boethius retells the story of the youth Taormina, who upon hearing the music in the Phyrigian mode had been riled to set fire to a rival's home. A change of mode calmed the youth's rage.

much sweeter and nobler and intended for learned ears and private audiences.[43] For Vicentino, music had aesthetic and social values: that which was common or dated was popular and simple; and that which was novel and new was demanding and nuanced.[44]

Throughout his treatise, Vicentino articulates the belief that music has affective and expressive power, and that these powers are drawn out through compositional choices.[45] This belief originates in antiquity, and is the most important aspect of ancient music theory for Vicentino. As Berger suggests, "[w]hat was meant by the programmatic title of the treatise, *The Ancient Music Restored to Modern Practice,* was the restoration of the miraculous effects of the ancient music, not of its style or compositional resources."[46] Berger is only one of the many scholars who support this view: nearly all writers on the subject agree that Vicentino had no interest in literally reviving the music of the past. His interest in the enharmonic and chromatic genera was to adapt them to modern writing in hopes of resuscitating some of the affective powers of music as reported by the writers of antiquity.

To elucidate the moving powers in practice, Vicentino relaxed and revised some of the strict rules of counterpoint for the sake of expressing the text. [47] In this respect, he anticipated ideas of Vincenzo Galilei and Claudio Monteverdi.[48] D.P. Walker has suggested that the preoccupation with the connection between words and music in the sixteenth century was due to the inseparable treatment of poetry and music in ancient

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[43] Vicentino, 33.
[44] Maniates, xxiii.
[45] Vicentino, 149-150.
[46] Berger, 40.
[47] See Vicentino, 22; 86; 99-100; 195. Most of Vicentino's references to the importance of text in musical setting are found in *Books II and III on Music Practice* in the treatise.
[48] Palisca, introduction to *Ancient Music Adapted to Modern Practice,* vii.

texts.[49] In the sixteenth century, it was believed that music gave spiritual pleasure to the listener, and that poetry possessed a "powerful ethical and emotional force, producing almost miraculous effects on the body and soul of the listener."[50] Thus, the treatment of the text was the most important factor in recreating the marvelous emotional effects of music reported in ancient sources.

In vocal music, the purpose is above all to express the text. Leeman Perkins has categorized the levels of musical expression in the Renaissance as rhetorical, mimetic, and affective.[51] The rhetorical level of expression emphasizes significant words by the manner of presentation. For example, a poignant word might be emphasized by strong metric placement or long note-value duration. Mimetic expression is subdivided into two types: either sonorous or cognitive. Sonorous mimesis is iconic in the semiotic sense; the musical elements imitate the textual elements. Cognitive mimesis is indexical in the semiotic sense; the musical elements establish a link with the textual elements.[52] Text-painting is an example of the mimetic level of expression: hunting horn calls and bird calls are sonorous mimesis, whereas the use of quickly moving notes to convey a sense of hurry is cognitive mimesis. Affective expression is harder to pinpoint: it is the emotional representation of the text.

Music, according to Vicentino, should not merely express or represent sentiments of the text (the mimetic and affective levels of expression of Perkins' theory), but it

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[49]Walker, 8-9.
[50] *Ibid*., 8-9.
[51] Leeman Perkins, "Towards a Theory of Text-Music Relations in the Music of the Renaissance," in *Binchois Studies*, ed. Andrew Kirkman and Dennis Slavin (New York: Oxford University Press, 2000), 313-329. McKinney discusses some of the implications of these categories; see McKinney 15-16.
[52] For a discussion of indexical and iconic references, see Raymond Monelle, "The Search for Topics," in *The Sense of Music: Semiotic Essays* (Princeton: Princeton University Press, 2000), 14-40.

should also arouse emotions and passions within the listener.[53] According to Vicentino, the probing emotional effects of music can only be experienced if the textual subject is first suitably musically represented. Vicentino believed that one must make any concessions to voice-leading rules or formal standards for the sake of articulating and expressing the text. Musical form need not coincide with the poetic form, but the text must be properly dictated and intelligible. Effectively combining the text with music meant enhancing the emotional powers of the poetry with pleasantness of melody, harmony, and rhythm. Vicentino believed that if a composer could capture the essence of the text and reproduce it in musical terms, then the resulting composition should have the power to evoke an emotional response in the listener. Vicentino's concern for the emotional state aroused in the listener and the appropriateness of the music for the audience and the venue of performance are always at the forefront of his discussion. His musical philosophy, therefore, is novel in its primacy of the listener's relationship to the music.[54]

Musical Intervals and Affect

The proper expression of text, Vicentino claims, is achieved with the colorings and inflections found through the employment of various sizes of intervals, modes, harmonies, contours, tempi, tone-color, and ranges.[55] An affect is assigned to almost

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[53] Vicentino, 52. In this passage, Vicentino speaks of exciting or weakening the souls of the listeners with the different genera.
[54] Maniates, xxxvii-xxxviii.
[55] *Ibid.*, 203. Here, Vicentino discusses the pleasure found in the variety of intervals of his system. For genus affects, see Vicentino, 11-12; 43-48. For interval affects, see Vicentino, 58-83; diatonic mode affects 143-145; for harmonic chord quality, tempo, and range affects; 254-256. Quicker tempi, higher ranges, and major harmonies are associated with excitement and cheer. Slower tempi, minor harmonies, and lower ranges are associated with sadness. Tempo, or motion, should always be appropriate to the

every musical parameter Vicentino describes in the treatise; and these inherent musical affects should be utilized by the composer to express the text.[56] Vicentino provides an extensive description of the affects of intervals in the treatise. This list is incomplete, however, as Vicentino does not describe all of the intervals available in his tuning system. Vicentino's focus on intervals is not unique to his writings; as Berger suggests, "the sixteenth-century tonal system should be described in terms of intervallic material available to a composer and its pre-compositional organization."[57] Theoretical discussions prior to Vicentino and Zarlino were concerned with intervals as the building blocks of musical structure. The modal quality of intervals in earlier treatises was only considered in conjunction with quantitative interval size—not with qualitative interval affect.[58] Vicentino's treatise contains the first appearance in print of a theory of qualitative interval affect. For Vicentino, intervals are more than building blocks; they are vehicles for expression that can excite or weaken the souls of the listeners.[59]

Vicentino's interest in the chromatic and enharmonic genera can also be explained on these grounds; the enharmonic and chromatic genera offer more interval sizes than the diatonic genus alone. These other genera provide the composer with a greater variety of intervals, and thus greater nuance in expression of the text. The diatonic genus consists only of whole tones and major semitones; whereas the chromatic genus consists of two sizes of semitone and a minor third, and the enharmonic genus consists of enharmonic dieses and the major third. If the ancients were able to move

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subject, 135. The major/minor, cheerful/sad dichotomy is discussed by D.P. Walker in *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, 1978), 63-80. See also Kaufmann, 55-56.

[56] Maniates, xxxviii.

[57] Berger, 3.

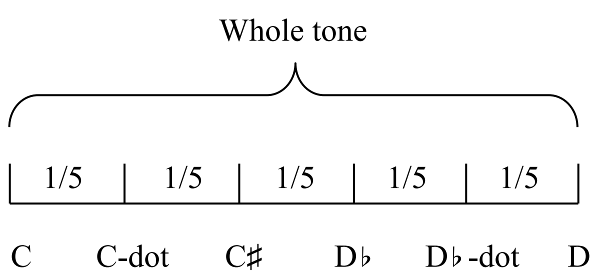
[58] McKinney, 12.

[59] Vicentino, 52.

listeners with music, Vicentino assumes it was due to their use of the different genera. Vicentino adopts the notion of genera, and the variety interval sizes contained within each, in hopes of reviving some of the ancient powers of music.

To accommodate the numerous intervals found in the three genera, Vicentino develops a 31-tone tuning system and a system of notation that accounts for all 31 tones. Each octave in the tuning system consists of 31 minor enharmonic dieses (the smallest interval found in all three genera) so that enharmonic steps can occur in any key at any point in the scale. The five whole tones of the diatonic scale each contain five minor enharmonic dieses (5 × 5 = 25 discrete pitches), and the two semitones are major semitones of three minor enharmonic dieses (3 × 2 = 6 discrete pitches). This implies a system of 31-tone equal temperament (25 + 6 = 31), with two sizes of semitone (the minor semitone consists of two enharmonic dieses). All of the intervals in Vicentino's system can be constructed as composite intervals of multiple enharmonic dieses. Vicentino devises a system of notation to indicate the intervals of the genera as shown in Figure 1-1; a sharp raises a note by the minor semitone (or two enharmonic dieses), and a flat lowers a note by the minor semitone.

Figure 1-1. Vicentino's division of the whole tone and associated notation



Thus, C♯ and D♭ are different pitches: C♯ is a minor semitone above C and D♭ is a major semitone above C (D♭ is a minor semitone below D, thus the difference from D♭ down to C is a major semitone). Vicentino places a dot above a note to indicate that that note should be raised by one fifth of a tone, or the minor enharmonic diesis. C-dot is one enharmonic diesis above C, and D♭-dot is one enharmonic diesis above C♯. The enharmonic relationships in 31-TET are different from those in 12-TET: in 31-TET, D𝄫 is equivalent to C-dot (two minor semitones below D), C♯-dot is equivalent to D♭, C𝄪 is equivalent to D♭-dot, etc. Figure 1-1 displays the divisions of the whole tone.

The melodic characteristics of the intervals are extensively enumerated in Vicentino's treatise in chapters 14-42 of *Book I on Music Practice*; the description of the affect of each interval merits its own brief chapter. The table below lists the intervals discussed by Vicentino in the treatise (Table 1-1). The list begins with the smallest interval of the system, the minor enharmonic diesis, and proceeds in increments of one minor enharmonic diesis to the largest interval described, the proximate fifth (Vicentino does not mention the augmented third). Vicentino refers to an interval as "proximate" if it is widened by the minor enharmonic diesis, or one-fifth of a whole tone. Always included with the affect is the associated directionality.

Table 1-1. Vicentino's interval affects

Interval Name	Size (in cents)	Characterization of Affect
Minor Enharmonic Diesis	*38.71*	*sweet, smooth; slack in ascent and descent*
Major Enharmonic Diesis	*77.42*	*sweet, smooth; melancholic when fast*
Minor Semitone	*77.42*	*tense/cheerful in ascent, slack/sad in descent*
Major Semitone	*116.13*	*slack/sad in ascent, tense/cheerful in descent*
Minor Whole Tone	*154.83*	*slack, but somewhat tense in both ascent and descent*
Natural Whole Tone	*193.54*	*tense in ascent, slack in descent*
Major Whole Tone	*232.25*	*more tense in ascent, more slack in descent than natural WT*
Minimal Third	*270.96*	*slack in ascent, tense in descent*
Natural Minor Third	*309.67*	*slack in ascent, tense in descent*
Proximate Minor Third	*348.38*	*tense in ascent, sad/slack in descent*
Natural Major Third	*387.09*	*tense/imperious in ascent, slack in descent, opposite of minor third*
Proximate Major Third	*425.80*	*extremely tense in ascent, extremely slack sad and slack in descent*
Natural Fourth	*503.21*	*tense in ascent, slack in descent*
Proximate Fourth	*541.92*	*lively and tense in ascent, sad and slack in descent*
Natural Tritone	*580.62*	*vivacious/forceful in ascent, funeral/sad in descent*
Imperfect Fifth	*619.34*	*slack in ascent, tense or slack in descent*
Proximate Imperfect Fifth	*658.05*	*shared slackness and tenseness in ascent and descent*
Natural Fifth	*696.76*	*Very tense in ascent, very slack in descent*
Proximate Fifth	*735.47*	*lively and tense in ascent, slack in descent*

Vicentino does not describe any interval larger than a proximate fifth, except to say that any larger intervals are just the cumulative effect of the leap of a fifth plus a step. We must recall that in Vicentino's genera-based system, *steps* include the minor enharmonic diesis, major enharmonic diesis/minor semitone, major semitone, whole tone, minor third, and major third.[60] The neglect of large intervals is an odd omission on Vicentino's part. Vicentino does not even consider harmonic octave compounds to be the same intervals or have the same affect in *Book II on Music Practice*; it seems contradictory, then, that large melodic intervals are not considered as their own entities.

[60] Vicentino, 81-82.

No one writing about polyphonic practice systematized interval affect before the 1550's.[61] Timothy McKinney suggests that Vicentino and Zarlino were the first theorists to develop "a systematic means of explaining music's expressive power based upon the melodic and harmonic intervals from which it is constructed," but the idea of interval affect originates with their teacher, Adrian Willaert.[62] Vicentino's theory of interval affect differs from those of Zarlino or Willaert in two principal ways. Firstly, Vicentino's system contained the various chromatic and enharmonic intervals available in his 31-tone tuning system. Neither Zarlino nor Willaert contemplated such a tuning system for practical use. Secondly, Vicentino considered the direction of the interval and the speed at which it is performed the most important factors in determining affect.[63] Zarlino and Willaert privileged interval quality over directionality and speed.[64] For Vicentino, a single interval could convey a vastly different affect depending on its direction.

Vicentino's Tuning System

Vicentino describes tuning systems (or at least aspects of tuning systems) in both the *Book on Music Theory* and the *Books on Music Practice* in his treatise. In fact, Vicentino at different points describes all of the "Big Four" tuning systems: Pythagorean, just intonation, meantone, and equal temperament.[65] The interval ratios described in the

[61] *Ibid.*, 12.
[62] McKinney, 1.
[63] See Vicentino, *Book I on Music Practice*, chapters 14-42. Here, Vicentino describes the affects of various intervals in terms of their directionality and quality. However, the direction of an interval can easily change the affect. The affect is, therefore, not inherent in the quality of the interval alone.
[64] McKinney, 51-54.
[65] J. Murray Barbour, *Tuning and Temperament: A Historical Survey* (East Lansing: Michigan State College Press, 1951), 10. Vicentino discusses Pythagorean ratios in the *Book on Music Theory*, 7-14; A system of just intonation is described in *Book I on Music Practice*, 45-50; Vicentino refers to the "customary" tuning of his day, which was a system of meantone temperament, 331-333; Vicentino's equal

Book on Music Theory are Pythagorean and derived from Boethius's *De institutione musica*; but they are only discussed in connection with tetrachord divisions. The systems described in the *Books on Music Practice* are inconsistent, and differ from those described in the *Book on Music Theory*. In *Book I on Music Practice* Vicentino describes a syntonic diatonic division of the tetrachord (though he never refers to it by this Ptolemaic name) that is identical to Ptolemy's and hence suggests a system of just intonation.[66] He almost immediately dismisses the syntonic diatonic division and admits that temperament of fourths and fifths is a practical necessity. He then describes divisions of whole tones as equal divisions (five minor enharmonic dieses per whole tone). Vicentino later claims there are two different sizes of whole tones in his system (as are found in just intonation), but each of these whole tones incompatibly contains five minor enharmonic dieses. In yet another passage, Vicentino points out (perhaps for the first time in history) that fretted instruments are equally tempered, and are never in tune with keyboard instruments.[67] This suggests that he advocates the equal-tempered system as a practical necessity if fretted instruments and keyboard instruments are playing together. The tuning described for his *archicembalo* in *Book V on Music Practice* resembles the quarter-comma meantone system.[68] With all of these different descriptions, it is difficult to deduce which of these systems Vicentino had in mind for the realization of his chromatic and enharmonic music.

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division of the whole tone into five enharmonic dieses and the major semitone into 3 enharmonic dieses implies a system of equal temperament, 53-55.

[66] Vicentino, 44-45.

[67] Barbour, 11. See Vicentino, chapter 66 in *Book V on Music Practice,* 443.

[68] Vicentino, 109; 331-333. Vicentino states that the fifths of his *archicembalo* should be tempered "according to the custom of ordinary tuning for all keyboard instruments—that is, organs, spinets, monochords, and the like." Vicentino refers to blunting fifths as done by the "good masters." Pietro Aaron developed the most widely used keyboard temperament in the sixteenth century, quarter-comma meantone. See Aaron, Pietro, *Toscanello in Music,* trans. Peter Burgquist (Colorado Springs: Colorado College Music Press, 1970), 10-11.

Vicentino's reasons for describing multiple tuning systems multiple times in multiple ways may be attributed to the fact that he wanted his interval sizes to correspond to those in his historical sources (Boethius's monochord divisions); he hoped to develop a system that supported the intervals necessary for his theory of the enharmonic and chromatic genera; and he had to describe the construction and the practical tuning of his keyboard instrument, the *archicembalo*. Some of the contradictions may also be attributed to errors on the part of Vicentino.

The opening of the *Book on Music Theory* demonstrates Vicentino's confounding views within the context of the ancient sources known to him. He writes:

> Aristoxenus, who depended solely on sense, denied reason, whereas the Pythagoreans, in contrast, governed themselves solely by reason, not sense. Ptolemy more sanely embraced both sense and reason, and his opinion has satisfied many people up to now.[69]

It seems, as I will describe below, that for his *Book on Music Theory*, Vicentino adopts a Pythagorean view (as learned from Boethius) of tetrachord divisions. This discussion occurs in the *Book on Music Theory*, and is regarded as the scientific and mathematical basis for the musical intervals; it is solely reason. In *Book I on Music Practice,* Vicentino dismisses the Pythagorean divisions and describes divisions that are more closely related to Ptolemy's syntonic diatonic tuning system, although he never cites Ptolemy. This would imply a system of just intonation, with a [10:9] whole tone and a [9:8] whole tone, and a [16:15] semitone. The just intonation system embraces reason because it uses only superparticular ratios, but embodies sensory experience because the differing sizes of whole tones and semitones are not disruptive or offensive to the ear. Yet Vicentino also describes temperament of fourths and fifths in *Book I on Music Practice*, which belongs

[69] *Ibid.*, 6.

to the Aristoxenian tradition where the musician's ear is the guiding principle in the construction of intervals and scales.[70] I will examine the different suggestions of interval sizes that Vicentino provides and show that, ultimately, Vicentino aligns himself most closely with the Aristoxenian philosophy in the *Books on Music Practice*.

Tuning in the Book on Music Theory

Vicentino uses the Pythagorean whole tone interval ratio [9:8], which is the difference between the pure fourth [4:3] and the pure fifth [3:2], to describe the divisions of the diatonic tetrachord in the *Book on Music Theory*. His semitone is therefore the Pythagorean limma [256:243], or the difference between two whole tones and the pure fourth. In describing the chromatic divisions of the tetrachord, Vicentino suggests that one of the [9:8] whole tones be divided exactly in half (which yields an irrational interval size) and added to the other whole tone to create the incomposite trihemitone. Thus the semitones of the chromatic tetrachord are of two different sizes: one is the Pythagorean limma and the other is half of the [9:8] whole tone, and is slightly larger. The enharmonic division of the tetrachord involves adding the two whole steps together to form a single Pythagorean ditone [81:64], an extremely wide major 3rd, and the Pythagorean limma (or minor semitone, as Vicentino refers to it in this chapter),[71] is divided in half to yield two enharmonic dieses of equal size. These divisions are later abandoned by Vicentino, and appear in the *Book on Music Theory* merely to pay lip-service to ancient theories. For the purely theoretical discussion, Vicentino adopts a

[70] In Book II of *Harmonic Elements*, Aristoxenus discusses the importance of sense-perception and the musician's ear to making musical judgments. For a translation, see Aristoxenus, "Book II." In *The Harmonics of Aristoxenus*, ed. Henry S. Macran (Oxford: Clarendon Press, 1902), 187-208.

[71] Vicentino, 10-11.

Pythagorean (or perhaps more correctly, a Boethian) stance. A chart of the divisions of the tetrachords and the affects associated with each as described in the *Book on Music Theory* appears below (Table 1-2).[72]

Table 1-2. Vicentino's genera divisions in the *Book on Music Theory* (Boethian)

Genus	Sequence of Steps	Affect
Diatonic	*whole tone-whole tone-semitone*	*harsh*
Chromatic	*trihemitone-semitone-semitone*	*sweet*
Enharmonic	*ditone-enharmonic diesis-enharmonic diesis*	*sweeter and smoother*

Tuning in the Books on Music Practice

Vicentino claims to adopt the Ptolemaic approach to practical issues of tuning in the *Books on Music Practice* (which outweigh the *Book on Music Theory* by nearly 400 pages). As discussed above, it is unlikely that Vicentino had read Ptolemy's *Harmonics*, but he was attracted to the compromise of two different sizes of whole tones in order to achieve better consonances; namely, the major and minor thirds and sixths. The Pythagorean system produced extremely wide major thirds, practically unusable because of their harshness. His reasons for accepting the different sizes of whole tones are explained in *Book I on Music Practice*:

[72] Vicentino, 11-12.

> Students are advised that the diatonic genus we use is not exactly the same as the one of which Boethius wrote, for Boethius' diatonic genus is composed of a minor semitone and two sesquioctaval [9:8] whole tones. You must realize that in contemporary practice we form the diatonic genus out of one major semitone, one sesquinonal [10:9] whole tone, and one sesquioctaval whole tone. The inequality of tones affords us the advantage of being able to use the consonances of the third and sixth, both major and minor. Readers should know that in Boethius' division, no third or sixth can be accommodated in practice. Moreover, the fourths and fifths of Boethius are perfect, whereas ours are a little blunted and shortened in the tuning of instruments.[73]

Vicentino immediately admits that the divisions mentioned in the *Book on Music Theory* are not the ones used in practice. If these divisions describing the diatonic genus are used to create scales and imply a tuning system, then Vicentino is confounding tuning practices. The tempering of fourths and fifths of a system would in turn temper all of the intervals in the system by some amount. Thus, the intervals of such a system would not be the ratios he first describes as part of "contemporary practice." The sesquioctaval and sesquinonal whole steps could theoretically fit into a tempered fourth, but the remaining semitone produced by such a division would be irrational. The compromise of two different sizes of whole tones offers the advantage of just intonation; that all the intervals in the tetrachord division can have superparticular, pure ratios. If the fourth itself is tempered, this advantage is nullified. Vicentino confounds the principles of just intonation and temperament, and the result is an impossible diatonic division of the tetrachord.

Vicentino then goes on to explain that when Boethius described the diatonic genus, he described it as the progression of two consecutive whole tones and a semitone. Vicentino argues that the exact ratios of these whole tones and semitones are not

[73] Vicentino, 44-45.

important in characterizing the genus; it is the sequence of the intervals that is important.[74] He writes:

> Therefore, every time you see a fourth made up of two sesquioctaval whole tones [and a minor semitone], or of one sesquioctaval and one sesquinonal whole tone plus a major semitone, or of two tones and a semitone of whatever ratios proceeding through the consecutive steps of two whole tones and a semitone, then this fourth is called diatonic on account of the whole tones and semitones, not on account of their ratios.[75]

Here, Vicentino is adopting a categorical view of musical intervals. The theory of categorical perception of musical intervals states that the infinite continuum of frequency ratios is divided into only a handful of distinct categories, and that each category has a window of belongingness.[76] Thus, two whole tones can have slightly different interval ratios, but still both be perceived as whole tones. Although the theory of categorical perception originates in linguistic studies of the twentieth-century, this is an Aristoxenian stance regarding the divisions of the genera and intervals. Aristoxenus develops the notion of "shadings" of the genera based on small deviations in the interval sizes. Vicentino also loosely interprets the genera as having characteristic interval patterns, not specific interval sizes. This leniency in defining intervals differs from Vicentino's contemporaries. Karol Berger suggests that in the sixteenth century, a "genus is defined by the sizes of consecutive intervals and their relative positions."[77]

Note also, that Vicentino does not require that the fourth be a perfect fourth; it may be tempered as he concedes in the passage quoted above. At this point in his treatise, it cannot be deduced what sort of tuning system he has in mind (either meantone

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[74] *Ibid*., 46.
[75] *Ibid*., 46.
[76] For a discussion of categorical perception and musical intervals, see Edward M. Burns W. Dixon Ward, "Categorical perception—phenomenon or epiphenomenon: Evidence from experiments in the perception of melodic musical intervals," *Journal of the Acoustical Society of America* 63, no. 2 (Feb. 1978): 456.
[77] Berger, 4.

or equal temperament) because he does not reveal the amount of tempering. It is clear, however, that for practical purposes, Vicentino does not adopt the Ptolemaic philosophy and his system is not one of just intonation. Vicentino may merely be presenting just intonation as a theoretical ideal, but admits that temperament is a practical necessity.

A similar argument is presented for the divisions of the chromatic genus in contemporary practice. Vicentino diverges once again from the divisions of Boethius that he reported in the *Book on Music Theory*. Boethius, according to Vicentino, divided one sesquioctaval whole tone in half to create the larger of his two semitones, and the minor semitone (the Pythagorean limma) came first in the series.[78] Vicentino illustrates his division, which places the major semitone first from B to C (an interval that is comprised of a major enharmonic diesis and a minor enharmonic diesis, or three minor enharmonic dieses), followed by the minor semitone from C to C♯ (an interval that is two minor enharmonic dieses wide), and the trihemitone from C♯ to E.[79] He states that even though his divisions are not the chromatic divisions described by the ancients, it is "nonetheless a chromatic genus insofar as the difference between Boethius' division and mine is a small one."[80] Vicentino is referring to the reversed order of semitones and the small difference in interval sizes. Again, we do not know the exact sizes of these intervals because we do not know the amount of tempering Vicentino had in mind.

The enharmonic genus in Vicentino's *Book I on Music Practice* similarly contradicts that of Boethius and that mentioned in the *Book on Music Theory*. Whereas

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[78] Boethius's chromatic division actually consisted of a minor semitone [256:243], a major semitone [81:76], and a wide minor third [19:16]. Though not superparticular, these ratios add up to a [4:3] perfect fourth. See Boethius, *Fundamentals of Music*, trans. Calvin M. Bower, ed. Claude V. Palisca (New Haven: Yale University Press, 1989), 134.
[79] Vicentino, 48.
[80] *Ibid*., 47

Boethius' enharmonic genus, according to Vicentino, consists of a ditone that spans the distance of two sesquioctaval whole tones, and the limma was split exactly in half to create to identical enharmonic dieses, Vicentino's genus consists of a ditone with unequal whole steps (the sesquioctaval and sesquinonal combine into one incomposite step), and the major semitone [16:15] is divided unequally into the major enharmonic diesis (which is the same as the minor semitone) and minor enharmonic diesis. The minor enharmonic diesis is one-half the size of the minor semitone, or the difference between the major and minor semitones. There are three minor enharmonic dieses in a major semitone, and two in the minor semitone. Therefore, there are five enharmonic dieses in the whole tone comprised of a major and minor semitone. These enharmonic divisions, however, are contradicted by Vicentino's statement that there are two different sizes of whole tones, and by his affirmation of the tempering of fourths and fifths. The chart below displays the genera that Vicentino describes in *Book I on Music Practice* (Table 1-3).

Table 1-3. Vicentino's genera as described in *Book I on Music Practice*

Genus	Sequence of Steps
Diatonic	*whole tone-whole tone-semitone*
Chromatic	*major semitone-minor semitone-minor third*
Enharmonic	*minor enharmonic diesis-major enharmonic diesis-major 3rd*

Later, in chapter 53, Vicentino describes a system of solmization with the enharmonic genus. This is the first time that we see the *whole tone* (not the semitones) divided into four enharmonic dieses: three of these enharmonic dieses are minor and one is major (further corroboration of the fact that a whole consists of 5 minor enharmonic dieses, as the major enharmonic diesis is twice the size of its minor counterpart).[81] However, Vicentino decides that his whole tone will be the minor whole tone of the Ptolemaic syntonon, or [10:9], and not the major whole tone [9:8] that he first described in the *Book on Music Theory* as one of the two whole tone sizes.

Vicentino later admits in his *Books on Musical Practice* that he accepts temperament of pure intervals because the small adjustments, though irrational, are imperceptible and inoffensive to the ear. This acceptance of tempered intervals is Aristoxenian at heart. Temperament, therefore, allowed modern music to include more consonances (namely thirds and sixths) than did the tuning systems of the ancients, but is also imperceptible and harmless.[82] Vicentino writes that temperament is necessary:

> […] to be able to have more consonances as well as to make many steps, we do not find it inconvenient to blunt a fifth and enlarge a fourth […] This blunting […] does not shock the sense of hearing because the quantity removed is so tiny in itself and because these particles are distributed here and there wherever they are needed. Practitioners of this tuning describe such fifths and fourths as tempered.[83]

Thus, the system of dividing the different genera described in the *Book on Music Theory* is dismissed entirely and not the same as that described for the practical purposes of the tuning system Vicentino develops. The remainder of the treatise speaks of tempered, not pure, intervals.

Vicentino confounds a number of tuning traditions in his treatise, and the result is unclear at best. For theoretical endeavors, he favors the mathematical rationality of the pure intervals; for practical purposes, he favors the irrational compromise of the geometric intervals of temperament. He even states in *Book III on Music Practice* that

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[81] *Ibid*., 53-54
[82] *Ibid*., 109
[83] *Ibid*., 45.

his enharmonic diesis is irrational and disproportioned, but that singers should be able to execute and accompany any size of interval to produce harmony.[84] He does not, regrettably, entirely dispense with pure interval ratios in favor of temperament, and these systems are irreconcilable. The question arises as to which system of temperament Vicentino had in mind for his compositions.

J. Murray Barbour proposes that because Vicentino describes the amount of temperament for the fifths of his system as being the same as that used for all keyboard instruments at the time, Vicentino must have tempered his fifths by one quarter of the syntonic comma.[85] The syntonic comma is the difference between a Pythagorean major third [80:64] and a pure major third [5:4], and is approximately 21.5 cents. In quarter-comma meantone, the major thirds are pure and the fifths are tempered by a quarter of the syntonic comma. However, when extended to twelve tones, the final fifth of the chain of twelve consecutive fifths that produce the pitches of the scale is too wide (737.6 cents). The unusable fifth is known as the "wolf" because of the frequency beating that occurs due to its severe deviation from a pure fifth. Vicentino cleverly extended the quarter-comma meantone system to a gamut of thirty-one pitch-classes, practically forming a closed system. Vicentino's extension of quarter-comma meantone to a scale of thirty-one tones removes the "wolf" associated with 12-tone quarter-comma meantone temperament and makes possible modulation to any key area. Vicentino observes this feature of his system in *Book V on Musical Practice* when he states that all seven octave species can be

[84] *Ibid.*, 207.
[85] Barbour, 117-118. See also Maniates's footnote 71 in *Ancient Music Adapted to Modern Practice*, 58. Maniates states that the "customary" system of tuning alluded to by Vicentino is probably the meantone system developed by Pietro Aaron in *Toscanello in musica* (Venice, 1529).

formed beginning on any note of his *archicembalo*.[86] His system of thirty-one tempered fifths produces thirds that are pure and fifths that are only slightly tempered. And as the 17th-century Dutch mathematician Christian Huygens has shown, a 31-tone equal division of the octave does not differ perceptibly from the quarter-comma meantone temperament. Huygens noted that the quarter-comma meantone fifth is narrower than the fifth of 31-tone equal temperament by less than 0.20 cents.[87] The fourths of quarter-comma meantone are larger than the fourths of 31-tone equal temperament by the same amount; the minor thirds of quarter-comma meantone are approximately 0.59 cents wider than 31-tone equal temperament, and the major sixths are smaller by the same amount; the major thirds of quarter-comma meantone are approximately 0.78 cents smaller than those of 31-tone equal temperament, and the minor sixths are wider by the same amount. The difference between the analogous diatonic steps of the 31-tone equal temperament scale and the scale steps of the quarter-comma meantone temperament never differ by more than a cent.[88]

Although Vicentino did not conceive of it in this way, his tuning system has been described by Rudolf Rasch and others as an equal-tempered system, because all of the fifths are tempered by the same amount.[89] Rasch conjectures that multiple divisions of the octave are devised for one of two reasons: to offer intonational improvements over

[86] Vicentino, 316-317.

[87] Huyghens expressed the difference in logarithms: the difference between the logarithm of the quarter-comma meantone fifth and the logarithm of the fifth of 31-TET is 0.0000491089, approximately 1/110 of the logarithm of the syntonic comma. Working backwards from logarithms to frequency ratios and converting to cents, this difference is approximately 0.20 cents. See Christian Huygens, *Le cycle harmonique (Rotterdam 1691); Novus cyclus harmonicus (Leiden 1724) / Christiaan Huygens; with Dutch and English translations*, ed. and trans. Rudolf Rasch (Utrecht: Diapason Press, 1986) 145-152.

[88] Silbiger, 6.

[89] Rudolf Rasch, "Relations between Multiple Divisions of the Octave and the Traditional Twelve tone system," *Journal of New Music Research* 14, no. 1 & 14, no. 2 (1985): 75-108.

12-TET; or to explore the "finer distinctions of interval sizes that are possible."[90] Vicentino was obviously interested in the latter, and the former was a perk of his system that solved practical problems associated with the intonation of fixed pitch instruments.

Conclusion

I demonstrate in this chapter that Vicentino's preoccupation with the affective qualities of music is Aristotelian at heart, but is in synch with the "musical humanist" movement of the sixteenth century. His theoretical ideas most closely align with Aristoxenus because they give primacy to the ear of the listener in making musical judgments. Whether or not we accept Vicentino's argument that compositions of his day were written in a mixed style (as he conceived of it), his enharmonic music is unique. Many other examples can be found of chromatic polyphonic writing from the sixteenth century, but Vicentino's enharmonic endeavors and novel 31-tone tuning system were revolutionary. The following chapter provides analyses of those points in Vicentino's enharmonic music that specifically involve the enharmonic diesis; an interval that was uncommon to the compositional practice and practical tuning systems in the sixteenth century.

[90] *Ibid.*, 76.

CHAPTER TWO: Analysis of the Extant Enharmonic Compositions of Nicola Vicentino

Although Henry W. Kaufmann suggests that "no purely technical analysis of Vicentino's manner of composing is really possible without a textual frame of reference,"[91] the analyses offered below concentrate on aspects of harmony and voice-leading in Vicentino's 31-tone tuning system, with minimal consideration of the text. I will begin with an overview of the compositions found in *Book III on Music Practice* in his treatise *Ancient Music Adapted to Modern Practice*, followed by a summary of previously discussed features of Vicentino's compositional style. I will then provide a comprehensive analysis of the diatonic, chromatic, and enharmonic harmonic relationships available in Vicentino's 31-tone tuning system, and compare these findings to the features of the system that are actually used by Vicentino. Finally, I will provide analyses of thirty excerpts from Vicentino's four enharmonic compositions (*Soav'e dolc'ardore*, *Dolce mio ben*, *Madonna, il poco dolce*, and *Musica prisca caput*). The excerpts are analyzed using theories of voice-leading distance and Neo-Riemannian transformations. The goal of these analyses is to uncover typical voice-leading patterns used by Vicentino when transitioning into and out of the enharmonic genus via the minor enharmonic diesis, and the implications of his notation. For sake of comparison, a number of excerpts that are non-enharmonic are included as well. I will return to these music analyses in Chapter Four for the discussion of the empirical study data.

[91] Kaufmann, 58.

Compositions in *Ancient Music Adapted to Modern Practice*

The examples of diatonic, chromatic, and enharmonic compositions in *Book III on Music Practice* of *Ancient Music Adapted to Modern Practice* vary greatly in their style and employment of the different genera. Vicentino offers examples of pure, or "completely" diatonic, chromatic, and enharmonic music.[92] Vicentino takes care to differentiate between examples of pure diatonic, chromatic, or enharmonic writing and examples of mixed writing because this was a source of confusion in his debate with Lusitano. In Vicentino's written argument, he does not specify the difference between "pure" and "mixed" writing. In the former, only the steps found within a specific genus are admissible; in "mixed" writing, the intervals found within all three genera are admissible. Ghiselin Danckerts reports that in the original documents, Vicentino never used the phrase "pure diatonic," but in later documents he corrects himself.[93] Thus, when Vicentino wrote "diatonic" he was almost certainly referring to the pure diatonic genera, and not to the category of diatonic writing of his day.

The examples of pure writing in *Book III on Music Practice* include an untitled, contrapuntal diatonic work without text for four voices[94]; two chromatic sacred motets, *Alleluia. Haec dies*[95] and *Hierusalem, Hierusalem*[96]; and the first fourteen measures of the secular madrigal *Soav'e dolc'ardore*,[97] an example of pure enharmonic writing. The untitled diatonic composition truly employs a single genus in Vicentino's sense: each voice moves exclusively by melodic major semitones and whole tones. Vicentino notes

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[92] For Vicentino's descriptions of his musical examples, see *Book III on Music Practice,* 164-228.
[93] Maniates, xxi.
[94] Vicentino, 165-166.
[95] *Ibid*., 196-197
[96] *Ibid*., 223-225.
[97] *Ibid*., 209-210.

in his treatise that the insertion of rests in the diatonic composition "nullifies the step of a major or minor third," and the music retains its diatonic nature.[98] We can therefore safely assume that rests in other pieces have a similar effect on determining the genus of the music. The chromatic composition *Alleliua.Haec dies* wavers in regards to purity of writing; excluding the non-chromatic intervals broken up by rests, the composition still contains a few major thirds, which belong to the enharmonic genus. Maniates attributes this deviation to the fact that it is a joyous Easter text and the minor third is a sad and somber interval to Vicentino's ears.[99] *Soav'e dolc'ardore* also contains melodic intervals foreign to the enharmonic genus (namely the minor third, major semitone, and whole tone), but these are attributed to the difficulties encountered by Vicentino in purely enharmonic contrapuntal writing. Restricting melodic motion to only the intervals in the enharmonic genus makes it impossible to always produce vertical triadic sonorities.[100]

Vicentino also demonstrates how to properly mix the genera with the first halves of two madrigals, *Dolce mio ben* and *Madonna, il poco dolce*. Vicentino adds that these two partial madrigals can be performed in different ways by observing various levels of the notation: diatonic (ignore all accidentals and dots), chromatic (ignore only the dots, but observe other accidentals), or enharmonic (observe all levels of notation).[101] On these different modes of performance, Vicentino writes:

[98] *Ibid*., 165.
[99] Maniates, lii. Vicentino himself says he purposely changed the intervals to accommodate the "intensity of the words." See Vicentino, 195.
[100] Maniates., lii.
[101] Vicentino claims there are five modes of performance in the treatise; diatonic, chromatic, chromatic and enharmonic, diatonic and chromatic, and diatonic, chromatic and enharmonic. However, Vicentino only describes the three levels I have written about above. See Maniates liii-liv; Kaufmann 78.

> Students are advised that wonderful secrets are found in such compositions, for every work based on this method can be sung in three ways. To make the comparison and to permit the composition to improve and make better listening, you begin by singing it without any accidentals—that is, without flats, naturals, sharps, or enharmonic dots. The results will be music without much harmonic sweetness because of the diatonic mixture. The second time, the composition is sung with the flats, naturals and sharps but without enharmonic dots. The entire composition will become sweetly chromatic. And the third time, when sung with all the accidentals as written, the composition will become mixed chromatic and enharmonic, both sweet and gentle.[102]

In the passage quoted above, Vicentino encourages both composers and listeners to compare the various effects of diatonic, chromatic, and enharmonic writing. These mixed-genera compositions contain a wealth of interval sizes and melodic patterns that contribute to the overall affect of the piece. For Vicentino, the chromatic and enharmonic inflections improve not only the quality of the composition, but also the quality of the musical experience of the listener. The comparison of essentially the same music sung in three different ways allows the listener to perceive the subtle affective differences between the genera. Again, we see Vicentino encouraging a listening-oriented view of music composition.

As a final composition, Vicentino includes *Musica prisca caput,* a complete secular motet praising his patron, Cardinal Ippolito II d'Este. This motet can be divided into three sections, and each section is purportedly written in the purely diatonic, chromatic, or enharmonic genus. Thus the composition is globally in the mixed style, but the local sections employ pure writing. Each section, then, appropriately expresses a different sentiment in the text. The first section, written in the diatonic genus, details the revival of the ancient music. The second section is chromatic, and mentions the sweetness of music that can be achieved. The first appearance of the word *dulcibus*

[102] Vicentino, 211.

(sweetness) occurs with the first appearance of a chromatic minor semitone. In the final section, Vicentino expresses the graciousness of his patron, and this section is written in the subtle, sweet, and noble enharmonic genus.[103] The first mention of Ippolito's name (*Hyppolite* in Latin) is accompanied by the first step of the enharmonic diesis.

Examples of enharmonic writing in *Ancient Music Adapted to Modern Practice*, then, appear only in *Soav'e dolc'ardore, Dolce mio ben, Madonna, il poco dolce,* and *Musica prisca caput.* Indeed, these are the only surviving examples of enharmonic composition by Vicentino (with the exception of a few short fragments reproduced in Bottrigari's treatise *Il melone secondo*). Of these four compositions, only *Musica prisca caput* is complete. It is these four compositions (or portions thereof) that I will examine and analyze for their use of the enharmonic genus and particularly the enharmonic dieses, and from which the stimuli for the empirical investigation originate.

Previously Discussed Descriptions of Vicentino's Style

Kaufmann describes the musical style of Vicentino as "polyphonically animated homophony."[104] This description suggests that the music is essentially triadic in its organization, with the bass voice as the harmonic support. Each voice, however, retains its individuality and melodiousness.[105] Vicentino's writes in his treatise:

> Readers are advised that the bass is the governing part. It endows all the parts with a gracefully refined unfolding and varied harmony, not only when approaching the cadences but also when moving to other passages.[106]

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[103] *Ibid.*,12; 33.
[104] Kaufmann, 70. This term is borrowed from Alfred Einstein, who uses the phrase to describe the music of the "first madrigalists," Verdelot, Festa, and Arcadelt. His description, however, is fitting for Vicentino's music as well; like Vicentino's compositions, the music of these first madrigalists "submits to no constraint and honors the poetic text by treating it with the utmost freedom." See Einstein, *The Italian Madrigal*, vol. 1 (Princeton: Princeton University Press, 1949), 153.
[105] Kaufmann, 60-61.
[106] Vicentino, 175.

Thus, Vicentino privileged the bass voice as the source of the harmony. Triadic sonorities with the root of the chord present in the bass voice are not rare moments in Vicentino's compositions; rather, such instances are exemplary of Vicentino's writing style and treatment of polyphonic voices. As I will demonstrate in the analysis below, even inverted triads are scarce in Vicentino's music. In his treatise, Vicentino writes that the vertical consonances are the most important compositional resources, and these must always include the third and fifth, the fifth and the tenth, or the tenth and the twelfth.[107] In other words, they must be triadic and in root position because adding the third and the fifth (or their octave compounds) above the bass completes a triad in root position. Melodic intervals are important considerations for Vicentino, but it is the triadic consonances that endow the music with full harmony.[108] Vicentino substantiates the primacy of consonances from a perceptual standpoint, stating that it is "the ear that feeds on consonances," and without harmony the ear is left unsatisfied by melody alone.[109]

Vicentino's compositional organization has been described by Lowinsky as "floating tonality" or "triadic atonality."[110] Though the music is triadic, Vicentino's penchant for root motion by semitone or whole tone produces unexpected tonal motions.[111] Lowinsky surmises that the melodic restrictions of certain genera produce the startling and atypical progression of harmonic major and minor triads. McKinney suggests that because Vicentino privileged harmonic chord quality over melodic interval quality, the strange progressions that arise are a consequence of the expressive demands

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[107] *Ibid*, 254.
[108] *Ibid.*, 254.
[109] *Ibid.*, 254.
[110] Lowinsky, 133.
[111] Kaufmann, 78.

of the text.[112] Whereas Lowinsky attributes the strange chord progressions to the restrictions of the genera, McKinney attributes it to the demands of the text. Therefore, both authors propose the same conclusion, but from different perspectives. Vicentino himself advocated using the different genera to express the nuances of the text, so both Lowinsky's and McKinney's theories are reasonable. Though their explanations differ, Lowinsky, McKinney, and Kaufmann all share the assessment of Vicentino's musical writing as residing somewhere between traditional polyphony and an emerging homophony. The bold chromatic progressions defy the expectations of today's tonally attuned ears; and the enharmonic progressions are as foreign today as they were in the sixteenth century.

Voice-leading and Harmonic features of Vicentino's Tuning System

The analysis of major and minor triadic sonorities and the progressions among them will be the focus of this chapter. I will consider the melodic motions found in each of the polyphonic voices (soprano, alto, tenor, and bass) and the harmonic relationships of the vertical triads that these voices produce. The thirty excerpts subjected to analysis in this chapter and used as stimuli for the empirical investigation were not selected solely due to their resemblance of models of triadic voice-leading; they are excerpts that embody the defining characteristics of Vicentino's writing. The ensuing sections define the characteristics of Vicentino's enharmonic style more precisely by examining the possibilities of his novel tuning system, and by uncovering features of that system that he typically exploits.

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[112] McKinney, 54;73.

In his treatise, Vicentino refers to "completely" (or pure) enharmonic, diatonic, and chromatic writing.[113] For Vicentino, pure writing entails using only the melodic intervals available in a specific genus, plus the intervals of the fourth, fifth, and octave. These latter intervals are included as a result of the modal system Vicentino devised in *Book III on Music Practice*. To build the different modes, Vicentino follows the well-established music-theoretical tradition of first defining species of fourths, fifths, and octaves.[114] The species are the cyclic permutations of the sequence of intervals found within each of the genus divisions. The first species of fourth differ from the tetrachord divisions described in *Book I on Music Practice* in that they place the largest interval of each genus in the middle of the fourth rather than at the upper end (i.e., the diatonic tetrachord division is *semitone-whole tone-whole tone*, and the first species of diatonic fourth is *whole tone-semitone-whole tone*). Thus, the first species of chromatic fourth has the sequence of intervals *major semitone-minor third-minor semitone*, and the first species of enharmonic fourth has the sequence of intervals *minor enharmonic diesis-major third-major enharmonic diesis*.[115] These interval sequences are then cyclically permuted to form three species of fourth for each genus. Vicentino similarly rotates the intervals in the species of fifths, and there are four species of fifth for each genus. Octave species are formed by the concatenation of a species of fourth and species of fifth, and there are seven usable octave species in each genus.[116] From the different octave species, Vicentino develops a system of modes.[117] Vicentino assigns one mode to each of six of

[113] See Vicentino, 165; 195; 209.
[114] Kaufman, 131.
[115] Vicentino, 198.
[116] *Ibid.*, 136; 185-186.
[117] Vicentino follows the methods of his erroneous predecessors; Greek theory did not develop modes from the octave species, because the octave species were not associated with particular pitches or finals. See Kaufmann, 130-131.

the octave species, and two modes share the sequence of intervals found in the seventh octave species. Vicentino does not include all possible combinations of species of fourths and fifths, however, and there are only 32 modes in his system: eight diatonic modes, eight chromatic modes, eight enharmonic modes, and eight mixed modes of tempered music in.[118] Therefore, the intervals of the fourth, fifth, and octave are shared between enharmonic, chromatic, and diatonic writing because they are the "stationary steps" in all three genera.[119] In other words, the fourth and fifths are the framing intervals, and the moveable steps found within these boundaries define the different genera.

Vicentino's examples of pure writing, however, often contain intervals other than the fourth, fifth, octave, and those intervals inherent to a particular genus. In order to maintain triadic vertical sonorities and some semblance of mode, it is simply not feasible to restrict each voice to the intervals of a specific genus. For instance, if every voice in an F-major triad proceeded by common tone, whole-step, or semitone to form the next sonority, not every plausible triad is reachable. Those that are reachable (e.g., G♭-major), are far-removed from the diatonic modal system. Accidentals such as G♭ and D♭ appeared in sixteenth-century polyphony as *musica ficta*, or notes that are flattened to avoid the leaps or outlines of melodic tritones.[120] Although Vicentino takes great liberty with this convention of accidentals for sake of textual expression, he generally chooses triads that can be built with the given steps of a mode.

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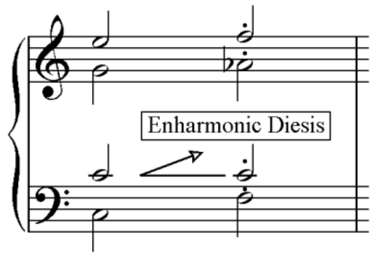
[118] Vicentino, 185.
[119] *Ibid.*, 225-228.
[120] For detailed account of the practice of *musica ficta* in the Renaissance, see Margaret Bent, *Counterpoint, Composition, and* Musica Ficta (New York: Routledge, 2002), 130.

It is possible, however, to devise a system of harmonic relationships based on the enharmonic, chromatic, and diatonic melodic voice-leading. Given that certain intervals occur in each of the genera, the progressions between triads can be categorized in terms of the intervals the individual voices must travel. Each possible chord progression can be considered abstractly as a motion between two triads of three distinct pitches, in which each voice maps to one other voice and the voices will always move smoothly along the path of least resistance to produce the smallest possible total displacement.[121] The smallest melodic interval produced by a smooth progression will define the type of progression. Any motion that produces the step of the minor enharmonic diesis is undeniably an enharmonic progression, as this interval is only available in the enharmonic genus. If two chords are related enharmonically, at least one voice will move by enharmonic diesis; the other voices will move by a minor enharmonic diesis, a minor semitone (or major enharmonic diesis, 2 minor enharmonic dieses in size), a major semitone (3 minor enharmonic dieses in size), a minor whole tone (4 minor enharmonic dieses in size), or major whole tone (6 minor enharmonic dieses in size). Figure 2-1 illustrates the enharmonic progression from C-major to F-dot-major. Enharmonically related chords will *never* have common tones because all pitches in a dotted chord are raised by the enharmonic diesis and will be a fifth of a tone higher than the undotted version of a pitch. Enharmonically related chords are designated with an 'E.'

[121] Richard Cohn, "Maximally Smooth Cycles, Hexatonic Systems, and the Analysis of Late-Romantic Triadic Progressions," *Music Analysis* 15, no. 1 (1996): 9-40; Joseph Straus, "Uniformity, Balance, and Smoothness in Atonal Voice Leading." *Music Theory Spectrum* 25, no. 2 (2003): 305-352.

Figure 2-1: Enharmonic progression between C-major and F-dot-major triads



A progression that contains only common tones, major semitones, and natural whole tones (0, 3 and 5 minor enharmonic dieses in size, respectively) must be categorized as a diatonic progression because the major semitone is the smallest interval available in the diatonic genus and the whole tone is the largest. Vicentino's qualifications incorporate more possible progressions than traditional diatonic relations found in tonal harmony. For example, the progression from a C-major triad to a D-major triad is diatonic because it contains only whole tones when the voice-leading is parsimonious; the progression from a C major triad to a D♭-major triad is also diatonic because it contains only major semitones when the voice-leading is parsimonious. Diatonic progressions are designated with a 'D.'

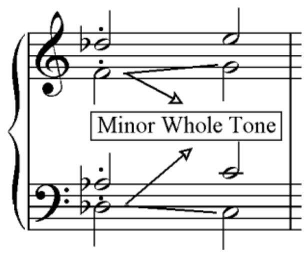
Progressions that contain a minor semitone (which is equivalent in size to the major enharmonic diesis of the enharmonic genus) as the smallest interval will be considered a chromatic progression. Chromatic progressions may also contain common tones, major semitones (3 enharmonic dieses in size), a whole tone (5 enharmonic dieses in size), or a minor third (7 enharmonic dieses in size). Chromatic progressions are designated with a 'C.'

These three definitions do not cover all of the possible relations, however. There are eight progressions out of the possible 61 two-chord progressions that are root-related by minor whole tone (four enharmonic dieses in size) or major whole tone (six enharmonic dieses in size). Such progressions arise between chords whose 12-tone versions are root-related by a whole tone, but the inclusion of a dot on one of the chords has narrowed or widened the whole tone by an enharmonic diesis. Half of the chord progressions in which the roots of the chords are four or six enharmonic dieses apart produce steps that do not belong to any of the genera. The other half produce a step of two enharmonic dieses, which can be considered a major enharmonic diesis of the enharmonic genus, or the minor semitone of the chromatic genus. Although the minor and major whole tones do not belong to any of the genera, Vicentino states that these intervals are only found in enharmonic writing as a consequence of raising some pitches by a fifth of a tone.[122] For example, a parsimonious progression from D♭-dot-minor to C-major produces displacements of 2 or 4 enharmonic dieses. An interval of two enharmonic dieses is equivalent to a minor semitone, so by the above definition this would be considered chromatic. But a progression from D♭-dot-major to C-major produces displacements of minor whole tones (4 enharmonic dieses). These relationships will be referred to as diatonic-enharmonic relationships (designated with 'DE') to illustrate that the name of a whole tone implies a diatonic step, but the inclusion of a dot widens or narrows these intervals by the enharmonic dieses (see Figure 2-2). This type of relation is only found twice (less than 1% of the time) in the four enharmonic compositions in *Book III on Music Practice*; once in *Soav'e dolc'ardore* and once in

[122] Vicentino, 209.

Madonna, il poco dolce.[123] In both cases it arises as a result of preserving imitation between voices.

Figure 2-2: Example of a diatonic enharmonic progression



There are also three relations containing major semitones, whose other intervals are major or minor thirds. Because the smallest interval in these progressions also belongs to the chromatic genus, and the other interval is not a whole tone, I consider these chromatic progressions. These three relations are C-major to D♭-minor, C-major to G♭-minor, and C-major to B♭-minor. These progressions, however, never appear in Vicentino's surviving enharmonic compositions.

The table below (Table 2-1) summarizes the type of interval relationships, voice-leading patterns, and whether the chord progression appears in Vicentino's music using a C-major triad as a point of departure. The voice-leading distances are reported as the displacements measured in minor enharmonic dieses and direction travelled by each voice to produce a progression with the lowest possible total displacement. Progressions beginning on a minor triad would be inversions of the progressions from a major triad and produce the same end results, and thus are not illustrated separately here.

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[123] In *Soav'e dolc'ardore*, the diatonic-enharmonic progression occurs in mm. 7-8. In *Madonna, il poco dolce*, it occurs in m. 29. See appendix for scores.

Table 2-1 below illustrates that not all of the possible enharmonically-related progressions occur between undotted and dotted chords, nor are all of the progressions between undotted and dotted chords capable of producing the step of the enharmonic diesis. It is, therefore, not sufficient to alternate between dotted and undotted roots to produce a step of an enharmonic diesis in at least one voice. Nor can it be assumed that if there are no dots above the notes of two chords that the progression does not contain an enharmonic diesis. Vicentino's music does not contain any enharmonic progressions between two undotted or two dotted chords; all enharmonic progressions, in other words, are between one dotted chord and one undotted chord. Not all progressions between undotted and dotted chords in Vicentino's music are enharmonically related. The dots do, however, indicate that the intervals found within each voice are either widened or narrowed by the enharmonic diesis, and are thus not found in diatonic or chromatic systems. The above-mentioned analyses of the possible enharmonic progressions prove that only progressions involving specific chords can produce the step of an enharmonic diesis and these are not always signaled by alternating dotted and undotted chords. The step of the enharmonic diesis step may also not be realized in the score.

Table 2-1. Possible target chords of two-chord progressions from C-major in 31-TET

Chord	Voice-Leading Displacement	Type of Relation	Used by Vicentino	Chord	Voice-Leading Displacement	Type of Relation	Used by Vicentino
Cm	(0,0,-2)	C	Y	G♭M	(-2,-5,-7)	C	N
C-dotM	(+1,+1,+1)	E	Y	G♭m	(+3,+6,+6)	C	N
C-dotm	(-1,+1+,1)	E	Y	G♭-dotM	(-1,-4,-6)	E	N
C♯M	(+2+,2,+2)	C	Y	G♭-dotm	(-1,-6,-6)	E	N
C♯m	(0,+2,+2)	C	Y	GM	(0,-3,-5)	D	Y
D♭M	(+3,+3+,3)	D	Y	Gm	(0,-5,-5)	D	Y
D♭m	(+1,+3,+3)	E	N	G-dotM	(+1,-2,-4)	E	Y
D♭-dotM	(+4,+4,+4)	DE	N	G-dotm	(+1,-4-,4)	E	Y
Db-dotm	(+2+,4,+4)	C	N	G♯M	(-1,+2,-3)	E	N
DM	(+5,+5,+5)	D	Y	G♯m	(+2,-3,-3)	C	N
Dm	(+3,+5,+5)	D	Y	A♭M	(0,-2,+3)	C	Y
D-dotM	(-2,-4,-7)	C	Y	A♭m	(-2,-2,+3)	C	N
D-dotm	(-4,-4,-7)	DE	N	A♭-dotM	(-1,+1,+4)	E	N
D♯M	(-1,-3,-6)	E	N	A♭-dotm	(-1,-1,+4)	E	N
D♯m	(-3,-3,-6)	C	N	AM	(0,+2,+5)	D	Y
E♭M	(0,-2,-5)	C	Y	Am	(0,0,+5)	D	Y
E♭m	(-2-,2,-5)	C	N	A-dotM	(+1,+3,+6)	E	Y
E♭-dotM	(-1,+1,-4)	E	Y	A-dotm	(+1,+1,+6)	E	Y
E♭-dotm	(-1,-1,-4,)	E	N	A♯M	(+2,+4,+7)	C	N
EM	(0,+2,-3)	C	Y	A♯m	(+2,+2,+7)	C	N
Em	(0,0,-3)	D	Y	B♭M	(-5,-5,-5)	D	Y
E-dotM	(+1,-2,+3)	E	N	B♭m	(+3,+3,+8)	C	N
E-dotm	(+1,+1,-2)	E	N	B♭-dotM	(-4,-4,-4)	DE	N
E♯M	(-1,+2,+4)	E	N	B♭-dotm	(-4,-4,-6)	DE	N
E♯m	(-1,+2+,2)	E	N	BM	(-3,-3,-3)	D	Y
FM	(0,+3,+5)	D	Y	Bm	(-3,-3,-5)	D	Y
Fm	(0,+3,+3)	D	Y	B-dotM	(-2,-2,-2)	C	N
F-dotM	(+1,+4,+6)	E	Y	B-dotm	(-2,-2,-4)	C	N
F-dotm	(+1,+4,+4)	E	Y	B♯M	(-1,-1,-1)	E	N
F♯M	(+2,+5,+7)	C	N	B♯m	(-1,-1,-3)	E	N
F♯m	(+2,+5,+5)	C	N				

There are sixty-two possible major or minor triads in Vicentino's tuning system. From any one of these triads it is possible to move to any other triad. Thus, from any given major or minor triad there are sixty-one progressions to another major or minor triad. This makes a total of 3,782 available distinct two-chord progressions. I do not consider static harmony a progression (e.g., from G-major to G-major), but merely a re-articulation of the same chord. Of these sixty-one possible progressions, only twenty-three can potentially produce a step of the minor enharmonic diesis (although this step might not be realized in Vicentino's music). Of those twenty-three progressions that produce a step of the enharmonic diesis, four are root-related by a minor enharmonic diesis, four are root-related by proximate fifth or its 31-TET inversion of a fourth narrowed by one enharmonic diesis; four are root-related by proximate fourth or its 31-TET inversions of a fifth narrowed by one enharmonic diesis; four are root-related by proximate minor third, three are root-related by proximate major third, three are root-related by minimal third, and one is root-related by major semitone. Root-relations by third (proximate major third, proximate minor third, and minimal third) make up the largest group of relations that produce the step of the enharmonic diesis (10 out of 23). After third relations, fourth/fifth relations make up the next largest group (8 out of 23), and enharmonic diesis relations are the next after that (4 out of 23). The major semitone relation is the smallest group with only one member. There are sixty-six enharmonic chord progressions in the four enharmonic compositions *Soav'e dolc'ardore*, *Dolce mio ben*, *Madonna, il poco dolce*, and *Musica prisca caput.*

It stands to reason that the groups of relations with the highest memberships should be most prevalent in the music if Vicentino is truly using all aspects of his tuning system; third relations should be found more frequently than fourth/fifth relationships, and both should be found more frequently than root-relations by a minor enharmonic diesis or a major semitone. This is not the case, however, for the sixty-six enharmonic chord progressions in the four enharmonic compositions. The distributions for the expected proportion and observed proportion of each root-relation found in enharmonic music appear in the table below (Table 2-2).

Table 2-2. Expected and observed proportions of enharmonically-related chords

Interval	**Size (in Enharmonic Dieses)**	**Expected Proportion**	**Observed Proportion**
Enharmonic Diesis	*1*	*17.4%*	*34.8%*
Major Semitone	*3*	*4.3%*	*0.0%*
Minimal Third	*7*	*13.0%*	*9.1%*
Proximate Minor Third	*9*	*17.4%*	*7.6%*
Proximate Major Third	*11*	*13.0%*	*1.5%*
Proximate 5th	*12*	*17.4%*	*42.4%*
Proximate 4th	*14*	*17.4%*	*4.5%*

The table of expected and observed proportions shows that an overwhelming proportion of the progressions in the four enharmonic compositions that produce the step of the enharmonic diesis are between chords related by proximate fifth or by enharmonic diesis. Third relations are sparse; while they make up over 43.5% of the twenty-three progressions that have the potential to produce the enharmonic diesis, only 18.2% of the enharmonically-related chord progressions in the music are third-related. The differences between the observed and expected proportions of the different enharmonically related chords are significantly different.[124] Vicentino, thus, significantly favors root progressions by enharmonic diesis or proximate fifth.

[124] $\chi^2(6, 66) = 38.059$, $p<0.005$. These proportions were first converted to frequencies to perform the statistical test.

Vicentino only uses progressions whose root-motion outlines an interval described in *Book I on Music Practice*. For example, the proximate fifth is the only interval 12 minor enharmonic dieses in size that Vicentino uses to produce a step of the minor enharmonic dieses; the augmented third is never used. Only those root-motion intervals that are used by Vicentino appear in Table 2-2 Vicentino's music rarely contains two-chord progressions that do not relate by one of the intervals in Table 1-1 in the previous chapter. The only cases I found in the music where the root-motion interval was not described by Vicentino in *Book I on Music Practice* involve 31-TET enharmonic re-spellings.[125] This is true for diatonic, chromatic, and enharmonic relations.

In the four enharmonic compositions found in *Book III on Music Practice* there are 273 chords and 269 two-chord progressions (once reduced and embellishing tones were removed). Only 22 out of 273 chords are inverted (8.1%); the remaining chords are root positions triads. There are 36 undotted-to-dotted chord progressions, and 35 dotted-to-undotted chord progressions (the portion of *Dolce mio ben* that is included in the treatise ends on a dotted sonority, so the number of transitions between undotted-to-dotted and dotted-to-undotted is not the same). Thirty-five of the undotted-to-dotted excerpts (97.2%) occur between chords that are enharmonically related. Only one of those thirty-five enharmonically-related, undotted-to-dotted chord progressions does not realize the step of the enharmonic diesis in the score. Thus, 34 out of 36 (94.4%) undotted-to-dotted progressions contain the step of the enharmonic diesis. A lower percentage of the dotted-to-undotted progressions (88.6%, or 31 out of 35) appear

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[125] For example, in mm. 40-41 of *Madonna, il poco dolce*, there is a progression from B-dot-minor to E♭-major. E♭-major is a 31-TET enharmonic re-spelling of D♭-dot major. The alteration of dotted and undotted notes here, therefore, does not indicate motion by an interval not described by Vicentino: B-dot to E♭ is a natural major third.

between enharmonically-related chords. Of the 31 chord progressions that have the potential to produce the step of the enharmonic diesis, only 18 realize it in the score (58.1%). This implies that only slightly more than half of the dotted-to-undotted progressions (51.4%, or 18 out of 35) contain the step of the enharmonic diesis.

Given that my analysis has examined the entire set of chord progressions in the four enharmonic compositions and not just a sample, the differences between undotted-to-dotted and dotted-to-undotted progressions are significant. I can therefore conclude that undotted-to-dotted progressions occur more frequently between enharmonically-related chords, and almost always realize the step of the enharmonic diesis in the score. Dotted-to-undotted progressions occur less frequently between enharmonically-related chords, and even less frequently realize the step of the enharmonic diesis. Transitions from undotted to dotted triads and transitions from dotted to undotted triads do not display similar harmonic or voice-leading patterns. Vicentino, therefore, not only wrote fewer enharmonically-related chord progressions in the dotted-to-undotted cases, but also constructed the voice-leading in these cases so as to avoid the step of the enharmonic diesis.

Table 2-3 summarizes the frequencies of the enharmonically-related chord progressions in Vicentino's four enharmonic compositions by category: undotted-to-dotted (UD) and dotted-to-undotted (DU). The two most frequent root progressions (by enharmonic diesis and by proximate fifth) make up 71.8% of all the progressions between undotted and dotted chords. The distribution of these frequent enharmonic progressions between the UD and DU categories is unbalanced: 91.3% of the root-progressions by enharmonic diesis occur in UD situations; 85.7% of the root-progressions by proximate fifth occur in the DU cases. Minimal third and proximate major third relations occur overwhelmingly in UD progressions, whereas proximate minor third progressions occur primarily in DU situations.

Table 2-3. Frequencies of root-relations of enharmonically-related progressions

Interval	UD	DU	Total
Enharmonic Diesis	*21*	*2*	*23*
Major Semitone	*0*	*0*	*0*
Minimal Third	*6*	*0*	*6*
Proximate Minor Third	*1*	*4*	*5*
Proximate Major Third	*1*	*0*	*1*
Proximate 5th	*4*	*24*	*28*
Proximate 4th	*2*	*1*	*3*
Total	*35*	*31*	*66*

The question arises as to whether these results are biased by voice-leading restrictions in Vicentino's 31-tone tuning system or whether it was solely a matter of compositional choice. As I have stated above, any major or minor triad in Vicentino's system can move to 23 other triads to produce the step of an enharmonic diesis. These voice-leading patterns are symmetric; a motion from chord *a* to chord *b* is considered identical to motion from chord *b* back to chord *a.* As shown in the table above, there are instances of progressions in both cases (with the exception of the minimal third and the proximate major third for the DU cases). There are no voice-leading restrictions that prevent these motions; root-motions by enharmonic diesis could occur just as easily in dotted-to-undotted situations (and they do, but less frequently), and root-motions by proximate fifth would be just as plausible in undotted-to-dotted situations. It is therefore a bias produced by Vicentino, and I conjecture it is due to the expressive demands of the text. The analysis of *Dolce, mio ben* (see appendix) supports this hypothesis since the only enharmonic progressions that occur in the composition are UD progressions by enharmonic diesis and DU progressions by proximate fifth. Every time this occurs in succession, the text is either *dolci lumi* or *dolcemente* ("sweet lights" or "sweetly"). 'Sweet' is the adjective used by Vicentino to describe the sound of his enharmonic writing. Further analysis of text/music relations is needed to substantiate this claim, but is beyond the scope of this chapter.

Analysis of Excerpts

The analyses offered below concentrate on aspects of voice-leading in a smaller sample of two-chord progressions from Vicentino's enharmonic compositions. They primarily consist of tabulated measures of voice-leading distance using several metrics. The excerpts are marked on the full scores that appear in the appendix. The goal of the analyses was to find voice-leading patterns inherent to Vicentino's enharmonic writing.

Thirty excerpts were selected for detailed analysis from the four enharmonic compositions discussed thus far. These excerpts were chosen on the basis of their membership in one of three categories: UD ("undotted-to-dotted"), DU ("dotted-to-undotted"), or NE ("neither," where neither vertical sonority of the excerpt involved pitches raised by the enharmonic diesis). They are numbered from 1 to 10 within each of these categories (e.g., DU_06 is the sixth excerpt in the DU category). In the UD excerpts, the pitches of the second vertical sonority of the excerpt are all raised by an enharmonic diesis above the diatonic versions of the pitches with the same name; in the DU excerpts, the pitches of the first vertical sonority are all raised by the enharmonic diesis above the diatonic pitches with the same name. The NE excerpts are either diatonic or chromatic, but do not involve the steps of an enharmonic diesis or intervals widened or narrowed by the enharmonic diesis. These excerpts have a much more even distribution of harmonic root-motions: two are by whole-tone, three by semitone, two by fourth/fifth, and three by third.

All of the excerpts are progressions between three-voice or four-voice vertical sonorities, without embellishing tones. All but one of these vertical sonorities is a major or minor triad.[126] As was mentioned previously, root position triadic sonorities are exemplary of Vicentino's compositional writing. These excerpts, therefore, are not rare exceptions plucked from the music for sake of analytic convenience; rather, they are emblematic of Vicentino's compositional style. Both vertical sonorities of each progression are also of the same cardinality (i.e., no voice dropped out or entered over the course of the excerpt). These criteria were set because the analysis of voice-leading with the existing metrics and methods are most robust for triadic sonorities in which no voices "split" or "fuse" between successive sonorities.[127]

The sample of excerpts chosen for the experiment is representative of the entire extant body of Vicentino's enharmonic compositions. The aforementioned analysis demonstrated that 94.4% of all undotted-to-dotted progressions produced the step of the enharmonic diesis, and only 51.4% of all dotted-to-undotted progressions produced the step of the enharmonic diesis. All of the selected undotted-to-dotted excerpts contain a step of the enharmonic diesis (100%), and half of the dotted-to-undotted excerpts contain the step of the enharmonic diesis (50%). These samples are not significantly different

[126] One excerpt (NE_09) contains a suspension that resolves in the chord after the second chord. The second triad has an augmented quality initially.
[127] See Straus, 305-352.

from the entire set of chord progressions and are thus representative of the corpus as a whole.[128]

In the sample of 10 undotted-to-dotted progressions extracted for the empirical study, five are root-progression by enharmonic diesis (50%), three are root-progressions by third (30%), and two are root-progressions by fourth/fifth (20%). This is representative of the distribution of root-motions (see Table 2-3). For the dotted-to-undotted excerpts, eight out of ten occur between chords that have the potential to produce the step of the enharmonic diesis. This is representative of the entire body of Vicentino's enharmonic writing; 88.6% of all dotted-to-undotted progressions and 80% of the sampled dotted-to-undotted progressions are between enharmonically-related chords. Of the eight enharmonically-related dotted-to-undotted excerpts, only five realized the step of an enharmonic diesis. This sample is not significantly different from the set of all the dotted-to-undotted progressions in Vicentino's four enharmonic compositions; 50% of the sample realizes the step of the enharmonic diesis, and 51.4% of all dotted-to-undotted progressions realize the step of the enharmonic diesis.[129] The distribution of root-motions for the enharmonically-related chord progression is slightly less representative of the entire body of enharmonic compositions. For the dotted-to-undotted excerpts, seven are root-progressions by proximate fifth (70%), one is a root-progression by third (10%), one is a non-enharmonic root-progression by major whole tone (10%), and one is a non-enharmonic root progression by diminished fourth (10%). The root-progression by major whole tone, the root-progression by diminished fourth, and three of the root-progressions by fourth/fifth do not contain a step of an enharmonic

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[128] χ^2 (1, 20) = 0.037, p=0.85. Again, these proportions were converted to frequencies in order to perform the test.
[129] χ^2 (1, 20)= 7.879, p<0.005.

diesis. Three of the excerpts that could support a step of an enharmonic diesis do not realize it in the score (DU_01, DU_07 and DU_08). Cross-relations between the voices prevent the enharmonic diesis from being realized (see appendix for scores). It seems that when transitioning from dotted to undotted notes, Vicentino does not write as "enharmonically," perhaps to smooth the transition into the next genus.

Because no system of calculating voice-leading similarity or distance exists for a tonal system with 31 tones per octave, and because Vicentino's system does not use all thirty-one tones continuously, the analyses below are conducted by observing only the diatonic and chromatic levels of notation. I have analyzed, effectively, only the 12-TET versions of each excerpt. This allows for a direct comparison between the patterns found in the diatonic and chromatic sections of Vicentino's writing with the enharmonic sections; by ignoring the enharmonic level of notation, all of the excerpts are placed in a 12-tone system. However, the voice-leading and harmonic patterns will be different as a result of the melodic and harmonic restrictions of certain genera, as discussed earlier in this chapter. Excerpts intended to be diatonic should be categorized by tones and semitones; chromatic excerpts should contain minor semitones and minor thirds, and the enharmonic excerpts should be categorized by static motion (if the enharmonic diesis is ignored). Leaps of perfect fourth, fifths, and octaves are found in every genus as these are the interval species that are common to each genus. So even though the systems of analysis used here were not intended for Vicentino's enharmonic music, the melodic and harmonic differences between the genera are mostly accounted for in the different sizes of steps found in each type of progression.

Voice-leading displacement was calculated using the "taxi cab" metric, in which each semitone displacement contributes one unit of displacement. The taxi cab metric has been adopted by Joseph Straus in his theory of uniformity and balance in atonal voice-leading, and by Neo-Riemannian theorists such as Richard Cohn in theories of parsimonious voice-leading.[130] Although this metric has been criticized by music theorist Clifton Callender because it does not properly emphasize common-tone retention or harmonic implications, a more comprehensive metric has not been systematically proposed and implemented.[131] The "taxi cab" metric is used in my analysis to calculate the total displacement of all the voices in moving from the first sonority to the second sonority. The displacement (in semitones) of each voice in moving from the first chord to the second chord of the excerpt was recorded. The individual voice displacements were then added together to determine the total voice-leading displacement. Maximum displacement was also tabulated as the maximum distance travelled by a single voice in moving from one sonority to the next.

Common-tone retention is another important voice-leading distance metric.[132] I calculated the number of pitches (not pitch-classes) the two chords had in common. If a pitch is retained in the second chord but moved to a different voice, it is still considered a common tone. The maximum number of common tones is 4 (all four pitches are retained, but have switched positions within the voices), and the minimum is 0 (no pitches are held in common between the two chords of the excerpt). In the UD and DU excerpts, common-tone retention is also an indicator of enharmonically related chords; in

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[130] Straus, 305-352; Cohn, 9-40.

[131] Clifton Callender and Nancy Rogers, "Judgments of Distance Between Trichords," paper presented at the 9th Annual Conference on Music Perception and Cognition. Alma Mater Studiorum University of Bologna (Aug 22-26, 2006), 1691.

[132] Callender and Rogers, 1687-88.

UD excerpts the common tone is raised by an enharmonic diesis in the second chord; in DU excerpts the common tone is lowered by an enharmonic diesis in the second chord. In the NE excerpts, the common tones are the exact same pitch within each tuning system (12-TET or 31-TET), but differ slightly between the two tuning systems.

The harmonic distance between the two sonorities of each excerpt was determined using the Neo-Riemannian transformations P (Parallel, which transforms triad into its parallel), R (Relative, which transforms a triad into its relative triad), and L (Leading-tone exchange, which transforms a triad by moving its root to the leading tone of triad).[133] This distance was calculated by totaling the minimum number of edge-flips on the 12-TET *Tonnetz*, as well as on a 31-TET *Tonnetz* where G♯ and A♭ are different pitches, G♯-dot is equivalent to A♭, and G-dot is equivalent to A𝄫 (Figure 2-3 below).

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[133] See Richard Cohn, "Introduction to Neo-Riemannian Theory: A Survey and a Historical Perspective," *Music Theory Spectrum* 42, no. 2 (Autumn 1998): 167-80.

Figure 2-3. The 31-TET *Tonnetz*

B♯ F𝄪 C𝄪 G𝄪 D𝄪 A𝄪 E𝄪

D♯ A♯ E♯ B♯ F𝄪 C𝄪 G𝄪

F♯ C♯ G♯ D♯ A♯ E♯ B♯

A E B F♯ C♯ G♯ D♯

C G D A E B F♯

E♭ B♭ F C G D A

G♭ D♭ A♭ E♭ B♭ F C

B𝄫 F♭ C♭ G♭ D♭ A♭ E♭

Fewer transformations implies more common tones: a single transformation guarantees two common tones and a displacement of only one or two semitones if the voices move as smoothly as possible; two transformations guarantees one common tone and a total displacement of two or three semitones if each voice moves as smoothly as possible. The more edge flips required to move from one triad to another on the *Tonnetz*, the more likely the two triads do not have common tones and the total displacement is very high. These tabulations are summarized in Table 2-4.

Table 2-4. Voice-leading characteristics of the 30 excerpts

Excerpt	Total Displacement	Maximum Displacement	Common Tones in 12-TET Version	Harmonic Distance on Tonnetz (12TET)	Harmonic Distance on Tonnetz (31TET)	Realizes Step of Enharmonic Diesis
DU_01	*14*	*5*	*1*	*2*	*8*	*N*
DU_02	*6*	*3*	*1*	*2*	*8*	*Y*
DU_03	*6*	*3*	*0*	*4*	*6*	*N*
DU_04	*7*	*5*	*1*	*3*	*5*	*Y*
DU_05	*7*	*4*	*0*	*3*	*3*	*N*
DU_06	*11*	*7*	*1*	*2*	*6*	*Y*
DU_07	*16*	*7*	*0*	*2*	*6*	*N*
DU_08	*10*	*4*	*0*	*2*	*6*	*N*
DU_09	*8*	*5*	*1*	*2*	*6*	*Y*
DU_10	*7*	*5*	*1*	*3*	*5*	*Y*
NE_01	*9*	*3*	*0*	*3*	*3*	*N*
NE_02	*6*	*2*	*0*	*3*	*3*	*N*
NE_03	*8*	*5*	*1*	*2*	*2*	*N*
NE_04	*8*	*3*	*0*	*3*	*3*	*N*
NE_05	*8*	*4*	*1*	*3*	*3*	*N*
NE_06	*5*	*3*	*1*	*2*	*2*	*N*
NE_07	*5*	*4*	*2*	*1*	*1*	*N*
NE_08	*6*	*3*	*1*	*2*	*2*	*N*
NE_09	*6*	*4*	*1*	*2*	*2*	*N*
NE_10	*15*	*7*	*1*	*2*	*2*	*N*
UD_01	*7*	*5*	*1*	*3*	*5*	*Y*
UD_02	*6*	*3*	*1*	*2*	*6*	*Y*
UD_03	*10*	*7*	*1*	*3*	*5*	*Y*
UD_04	*6*	*3*	*1*	*2*	*8*	*Y*
UD_05	*10*	*5*	*4*	*0*	*6*	*Y*
UD_06	*10*	*5*	*2*	*0*	*6*	*Y*
UD_07	*8*	*5*	*2*	*0*	*6*	*Y*
UD_08	*5*	*3*	*2*	*1*	*7*	*Y*
UD_09	*12*	*12*	*3*	*0*	*6*	*Y*
UD_10	*11*	*5*	*3*	*1*	*7*	*Y*

In Table 2-5, we can see that the 12-TET versions of the DU excerpts have the greatest mean total displacement, followed by 12-TET versions of UD excerpts and the

NE excerpts. The 12-TET versions of DU excerpts also have the lowest mean for common tones, preceded by the NE excerpts. The 12-TET versions of UD excerpts have the highest mean for common tone retention, but the greatest variability (2.0 pitches retained, standard deviation of 1.1). The UD excerpts also have the lowest mean harmonic distance followed by NE excerpts and DU excerpts. Thus the sample of excerpts exhibit different characteristics in terms of the voice-leading.

Table 2-5. Mean values of voice-leading parameters by excerpt group

Voice-Leading Parameter	UD	DU	NE
Total Displacement in semitones	*8.5*	*9.2*	*7.2*
Common-Tones (12-TET)	*2.0*	*0.6*	*0.8*
Harmonic Distance in edge-flips on the Tonnetze	*1.2*	*2.5*	*2.3*

Conclusion

The analyses in this chapter characterize the features of Vicentino's compositional style and enharmonic writing. In Vicentino's 31-tone tuning system, there are sixty-one possible chord progressions from any given major or minor triad. Only twenty-three of these possible progressions have the potential to produce the step of an enharmonic diesis; I have called this type of progression an enharmonic progression. Not all of the possible twenty-three progressions are between dotted notes and undotted notes, but in Vicentino's music enharmonic relations always occur between dotted and undotted chords. Vicentino also only writes progressions between chords whose roots are related by one of the intervals described in *Book I on Music Practice.* Vicentino heavily favors the enharmonic root-progression by enharmonic diesis in undotted-to-dotted cases; but in the dotted-to-undotted cases he favors root-motion by proximate fifth.

The thirty excerpts analyzed in this chapter are instances of undotted-to-dotted progressions (all enharmonic), dotted-to-undotted progressions (8 out of 10 are enharmonic), or neither (progressions in which neither chord has dotted pitches and they chords are not enharmonically related). It was shown that these 30 excerpts are representative of Vicentino's enharmonic oeuvre. These thirty excerpts were then analyzed in terms of their voice-leading distance and harmonic relations between the two chords. The results illustrated slight differences in voice-leading and harmonic patterns between the excerpts groups (UD, DU, and NE).

These musical analyses (Table 2-4, in particular) will be recalled in Chapter Four, which reports the results of an empirical study investigating the ability of trained musicians to discriminate between versions of Vicentino's music performed in 12-TET and 31-TET. The music analyses from this chapter determine characteristics of Vicentino's music that will be treated as factors that may have an effect on discrimination ability.

CHAPTER THREE: Developing a Hypothesis for the Perception of Vicentino's Tuning System

In his chapter entitled "Intervals, Scales and Tuning" in *The Psychology of Music*, Edward Burns concludes controversially that

> […] the small number of discrete pitch relationships in music is probably dictated by inherent limitations on the processing of high-information-load stimuli by human sensory systems. Quarter-tone music might be theoretically feasible given sufficient exposure, but the 12-interval Western scale is probably a practical limit. Any division of the octave into intervals smaller than quarter tones is perceptually irrelevant for melodic information.[134]

While Burns does concede that some world music employs microtonal scales with more than twelve divisions per octave, he suggests that these microtones are not played contiguously, but as alternative versions of other scale steps.[135] Burns implies that microtonal scale steps are "perceptually irrelevant" because they convey no different melodic information. Although microtones may be perceptible, they are simply mistuned versions of other more relevant scale steps in Burns' view.

Burns seems to be confounding perceptual relevance with perceptibility—if listeners are able to hear these microtones falling between the cracks of the 12-interval scale, then they are hearing something differently. Whether or not these microtones cognitively represent inflections or mistuned versions of other scale steps, they are carrying different sensory information, and are thus relevant from a phenomenological standpoint. Microtonal scales have existed for centuries and are culturally significant, and therefore potentially worthy of study. Vicentino valued microtones and slight

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[134] Edward M. Burns, "Intervals, Scales, and Tuning," in *The Psychology of Music*, ed. Diana Deutsch, 2nd ed. (San Diego: Academic Press, 1999), 257.

[135] *Ibid*., 218.

variations in interval size as necessary vehicles to express and evoke the variety of nuanced emotions in music.[136] If quarter-tones in music are only "theoretically feasible" in Burns' view, where does that leave the fifths of tones found in Vicentino's music? Are fifths of tones perceptually irrelevant? Are they even perceptible?

This chapter will investigate possible answers to these questions reviewing the relevant literature in pitch discrimination, musical interval perception, categorical perception, the perception of tuning systems, and the perception of voice-leading distance. A hypothesis will then be developed for the perception of Vicentino's 31-tone equal-tempered tuning system (31-TET), and how listeners might discriminate between it and the standard 12-tone equal-tempered tuning system (12-TET).

Pitch Perception

Tuning systems detail the arrangement and spacing of the members of a gamut of pitches. These relationships form the intervals of the tuning system. Absolute relationships also exist between the frequencies of the discrete pitches of a scale, particularly for fixed-pitch instruments. A given tuning system thus implies a set of relative and absolute relationships among its pitches. Studies in pitch discrimination investigate the participants' ability to detect changes in the absolute relationships between pitches, whereas studies in musical interval perception examine the ability of humans to hear relative relationships between pitches, regardless of the absolute frequencies of the stimuli. Therefore, pitch discrimination and musical interval perception are both linked to the perception of musical tuning systems.

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[136] Vicentino, 22.

The mechanics of pitch perception are complicated auditory phenomena. Pitch, as perceived by humans, is a subjective quality of sound events and cannot be measured directly. As Richard Parncutt states in *Harmony: A Psychoacoustical Approach*, a sound can have pitch but it cannot be pitch.[137] Assigning pitch to a sound is understood to mean "specifying the frequency of a pure tone having the same subjective pitch as the sound."[138] As most real-world sounds are complex tones, the process of pitch perception is complicated by the presence of frequencies other than the fundamental frequency of the pure tone. Several theories explaining the phenomena of pitch perception exist, but it is generally accepted that a sound stimulus is analyzed by the basilar membrane, and the different components of the waveforms excite different regions along the membrane.[139] Some researchers believe that the stimulus then creates a distinctive pattern of excitation along the basilar membrane (this is the *tonotopic,* or place theory of pitch perception). More recent evidence has suggested a temporal theory of pitch perception: a stimulus creates a periodic sequence of neuron firings related to the structure of the sound. Neuron firings tend to occur at a certain phase of the waveform, thus different wavelengths produce different sequences and timings of neuron activity.[140] Moore (1982) and van Noorden (1982) independently proposed models of pitch perception that combine the temporal periodicity theory with tonotopic theory.[141]

Pitch perception is also multi-dimensional. Dowling and Harwood have noted that pitches may be judged as similar not only according to the proximity of their

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[137] Richard Parncutt, *Harmony: A Psychoacoustical Approach* (New York: Springer, 1989), 33.
[138] Brian C.J. Moore, "Pitch Perception," in *An Introduction to the Psychology of Hearing*, 2nd ed. (New York: Academic Press, 1982), 115.
[139] Moore, 115-116.
[140] *Ibid*., 115-116.
[141] Moore, 138-144; Leon van Noorden, "Two Channel Pitch Perception," in *Music, Mind, and Brain: The Neuropsychology of Music*, ed. Manfred Clynes (New York: Plenum Press, 1982), 251-270.

absolute frequencies (referred to as *pitch height*), but also in terms of positions they occupy within their respective octaves (*pitch chroma*).[142] Two pitches close in proximity (such as C4 and C♯4) would be judged as similar. Two pitches with the same *chroma* (such as C4 and C5) would also be judged as similar. This chapter will focus on the perception of differences in pitch height.

Listeners can perceive at least 1,400 different frequencies under laboratory conditions.[143] Over the range of frequencies used in music (approximately C0 to B8), listeners are able to discriminate more than a thousand different frequencies.[144] Pitch discrimination ability is most acute between 500 and 2,000 Hz (approximately B4 to B6) and is very finely tuned; differences of the magnitude of a few cents are easily perceptible. The ear, however, has limited frequency resolution: simultaneous pure tone components must differ in frequency by a certain minimum amount before they can be resolved (or discriminated). The minimum amount necessary to resolve frequency differences is known as the discrimination threshold. The discrimination threshold is dependent on the fundamental frequencies of the pitches; it is not constant across the continuum of frequencies.[145]

Pitch discrimination thresholds are often reported as the *just noticeable difference* (JND), or difference limen (DL), which is "the smallest perceptible distance between two values of a stimulus that still seem different *in immediate succession.*"[146] In *Music and Memory: An Introduction,* Bob Snyder suggests that discrimination tasks of this type use

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[142]W. Jay Dowling and Dane L. Harwood, "Musical Scales," in *Music Cognition* (San Diego: Academic Press, 1986), 107-108.
[143] Stephen Handel, "Phonemes: Notes and Intervals," in *Listening: An introduction to the Perception of Auditory Events* (Cambridge, MA: MIT Press, 1989), 286.
[144] Burns, 218.
[145] Parncutt, 27.
[146] Bob Snyder, *Music and Memory: An Introduction* (Cambridge, MA: The MIT Press, 2000), 127.

only "echoic memory, which for a very short amount of time can maintain a high-resolution representation of the two pitch events."[147] Many of these discrimination studies involve a two-alternative forced-choice task (2AFC), where listeners must determine whether or not two stimuli are the same in terms of frequency. For pitch discrimination, the JND or DL is measured in cents or as a percentage of the frequency. The JND or DL is a statistical quantity that is determined through repeated trials. Typically, it represents the difference that is detectable by a subject at least 75% of the time, but more stringent proportions are often used. Wier, Jesteadt, and Green have shown that DL's for musical-interval size can be estimated from the standard deviation of repeated measurements, because any deviation in the stimuli smaller than the standard deviation would not be detected.[148]

In a 2003 study, Brian C.J. Moore and Geoffrey A. Moore investigated the pitch discrimination ability of normal-hearing subjects.[149] The study estimated difference limens for complex tones (DLCs) for each of three fundamental frequencies: 100 Hz, 200 Hz, and 400 Hz. These fundamental frequencies approximately correspond to the musical pitches G2, G3, and G4, respectively.[150] Each fundamental frequency also had three conditions for the resolution of the upper harmonics: resolved, (RES), which had a low spectral center between harmonics 5 and 8; intermediate (INT), which had a higher spectral center around the 11th harmonic; and unresolved (UNRES), which had yet a

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[147] *Ibid*., 127.
[148] C. C. Wier, W. Jesteadt, and David M. Green, "Comparison of method of adjustment and forced-choice procedures in frequency discriminations," *Journal of the Acoustical Society of America* 57 (1975): S27(A). In this study, the authors obtained DLs from the standard deviation of adjustments, the adaptive tracking method in a 2AFC, and the 76% cutoff for correct responses in a 2AFC task. The two 2AFC tasks yielded similar DLs, whereas the standard-deviation method yielded lower DLs.
[149] Brian C.J. Moore and Geoffrey A. Moore. "Discrimination of the fundamental frequency of complex tones with fixed and shifting spectral envelopes by normally hearing and hearing-impaired subjects," *Hearing Research* 182, 153-163.
[150] This is approximately the same pitch range found in the vocal music of Vicentino.

higher spectral center around the 16th harmonic. Each of the nine conditions (3 fundamental frequencies × 3 resolution conditions) also had two conditions for spectral envelope: fixed (does not change over time) and shifting (changes over time). The tones were presented sequentially.

For the RES condition, which most closely resembles the spectral structure of the human voice, the range of DLCs for fixed harmonic stimuli was between 4.3 cents for 400 Hz and 7.8 cents for 100 Hz. The shaped stimuli had DLCs between 9.5 cents for 400 Hz and 20.8 cents for 100 Hz. The DLCs were greatest for the lowest frequency (100 Hz) and smallest for the highest frequency (400 Hz) for the RES condition. DLCs were also greater for tones with shifting spectral envelopes than for those with fixed spectral envelopes in the RES condition. Thus, pitch discrimination ability for complex tones with resolved harmonics improves as frequency increases from 100 and 400 Hz, and is better for tones with fixed spectral envelopes than for those with shifting spectral envelopes.[151] These findings suggest that differences in absolute frequency of approximately a fifth of a semitone (20 cents) in the range between G2 and G4 are perceptible by normal-hearing listeners under laboratory conditions with complex stimuli. The differences in pitch height between the pitches in 12-TET and the dotted (raised by a fifth of a tone) pitches of 31-TET, incidentally, are never less than 22 cents.

Musical Interval and Categorical Perception

Studies in musical interval perception involve the relative relationships between pitches. Researchers in musical interval perception are interested not only in difference limens, but also in the ability of subjects to identify, label, and reproduce intervals

[151] Moore and Moore, 157.

according to their magnitudes. Interval specifications are typically those that correspond to Western 12-tone chromatic scales (i.e., minor second, major second, minor third, etc.), but some studies have tried to integrate quarter-tone labels as well.[152] The stimuli for relative pitch perception studies can be presented sequentially (melodically), or simultaneously (harmonically).

Musical interval perception also involves the categorical perception of intervals. Categorization reduces the amount of information carried by sound events, removing information about the precise tuning of a pitch or interval. The interval retains only its semitone category label.[153] Categorical perception studies investigate the acceptable range of interval sizes that belong to a certain interval category, and attempt to determine identity functions for different types of intervals. These studies determine how different in magnitude two intervals must be before they are perceived as belonging to different interval categories. Perceptual discrimination is easier across category boundaries; stimuli are more likely to be judged as different if they fall into different categories.[154] Categorization of musical intervals is not an innate sensory process; it is a learned skill and can be improved with training.[155] Parncutt suggests that musicians may be very good at categorizing pitches and intervals, but as a result their absolute perception abilities may be hampered because they tend to group stimuli according to *a priori* categories. Sounds differing in pitch by up to a quarter-tone may be perceived categorically by trained musicians.[156]

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[152] Burns and Ward (1978) asked participants to use semitone labels and quarter-tone labels; Callender and Rogers (2006) integrated quarter tones and eighth tones in their study on judgments of voice-leading distance.
[153] Parncutt, 44.
[154] *Ibid*, 29.
[155] Burns, 230.
[156] Parncutt., 45; 60.

Research in musical interval perception falls into one of a few categories based on the experimental design and the task performed by the listener.[157] The three main methods for studying the perception of musical intervals are adjustment, identification, and discrimination. In adjustment tasks, participants are presented with two sequential or simultaneous tones. One frequency is fixed and the other is variable and under the control of the listener. They are then asked to adjust the variable tone to reproduce a specified musical interval. The musical interval can be specified verbally, or it can be presented aurally by the experimenter. In the first case, the participant adjusts the interval to match an internal standard; in the second case, the participant adjusts to a physically-presented standard. Various experiments discussed later in this chapter imply DLs in the range of 10 to 30 cents for adjustment tasks of pure intervals.[158]

Identification tasks can be classified according to how many alternative responses the participant has available relative to the number of different stimuli. In absolute identification, the listener has as many response alternatives as there are different stimuli. The goal of this type of experiment is to assess identification resolution, or how consistently participants apply the response labels. In category scaling, the participant has more stimuli than response categories. Researchers can determine a category-scaling identification function from these experiments, which determines how these categories divide the sensory spectrum. In magnitude estimation studies, the participant has many more response alternatives than stimuli. Participants can estimate the magnitudes of the

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[157] For a detailed account of the experiment designs and tasks, see Burns, 215-264.
[158] Burns and Ward summarize some of these findings in the introduction of their article "Categorical perception—phenomenon or epiphenomenon: Evidence from experiments in the perception of melodic musical intervals," *Journal of the Acoustical Society of America* 63, no. 2 (Feb. 1978): 456.

interval size as any positive number. However, magnitude-estimation functions are often step-like, accentuating the semitone categories of 12-tone Western scales.

In discrimination tasks, participants must determine whether two stimuli are the same or different (AX discrimination task), or whether the third stimuli presented in a series is the same as the first or the second (ABX discrimination task). Discrimination tasks can determine JNDs or DLs for the magnitude of musical intervals. The major difference between adjustment, identification, and discrimination tasks is the operative memory time-scale. Tasks that involve both short-term memory (or trace memory) and long-term memory (or context memory) optimize performance.[159] Adjustment tasks can involve both long-term and short-term memory, depending on whether the subject tunes to an internal or external standard. Discrimination tasks, unlike identification tasks, do not typically involve long-term memory. Identification tasks are not a comparison between the "lingering image of the pitches themselves, but between their conceptual categories," and do not typically involve short-term memory.[160] Discrimination studies are more sensory-oriented, whereas identification studies are more cognitively oriented.

Each interval has a different category width; that is, different intervals have varying ranges of acceptable frequency ratios that elicit a certain category identification response. The category width depends on the type of interval, but not necessarily on the magnitude of the interval. Hall and Hess found that the average standard deviation of category judgments (which can determine category width) for a perfect fifth is much smaller than the standard deviation for a minor seventh (a large interval) or a major

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[159] Burns, 227.
[160] Snyder, 128.

second (a small interval).[161] Although researchers have found a tendency for participants to stretch large intervals and condense small intervals in adjustment tasks, the category widths are more dependent on interval type and not simply related to interval size.[162]

The first study to estimate JNDs from the standard deviation observed in adjustment tasks was Moran and Pratt (1926). The authors of the paper attested that for each musical interval, there is a phenomenological range "over which a given characterization applies."[163] In other words, there is a range above and below the pure interval where the interval will still be characterized by listeners according to its pure interval size. To test this hypothesis, the authors designed an experiment in which listeners adjusted one of two simultaneous sine tones to produce to a given interval. A reference pitch was given with one variable pitch oscillator, and the subjects adjusted the pitch of the second oscillator to produce the desired interval. All adjustments were made according to the internal standards of each subject for the intervals.

Moran and Pratt obtained JNDs for 11 musical intervals. The smallest JND was found for the perfect fourth (13.5 cents), and the largest was found for the tritone (22.1 cents). The average JND for all intervals was 18 cents, or less than a fifth of a semitone. They conclude that deviation from the pure interval ratio beyond a fifth of a semitone would not necessarily place an interval in a position which would demand assimilation either to the interval above or below. This suggests that intervals based on increments of at least a fifth of a semitone can be perceived as different from their nearest semitone-

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[161] Donald E. Hall and Joan Taylor Hess, "Perception of Musical Interval Tuning," *Music Perception* 2, no. 2 (Winter 1984), 180.

[162] See Andrzej Rakowski and Andrzej Miskiewicz, "Deviations from Equal Temperament in Tuning Isolated Musical Intervals," *Acoustical Archives* 10, no. 2 (1985), 96; Hall and Hess, 175; Joos Vos and Ben G. van Vianen, "Thresholds for discrimination between pure and tempered intervals: The relevance of nearly coinciding harmonics," *Journal of the Acoustical Society of America* 77, no. 1 (January, 1985), 176.

[163] Helen Moran and Carroll C. Pratt, "Variability of Judgments on Musical Intervals," *Journal of Experimental Psychology* 9 (1926), 493.

based intervals. In other words, Moran and Pratt suggested that listeners can perceive microtonal intervals of at least one fifth of a semitone as their own relevant interval categories. Intervals that deviate from the pure interval by less than a fifth of semitone may be perceived as slightly mistuned versions of the prototype—in this case, Moran and Pratt assumed it was the pure interval.[164] Moran and Pratt also estimate that "each interval of a 'psychophysical scale' would have an 'interval of uncertainty' of about 40 cents."[165] Thus, there is a window approximately 40 cents wide between interval categories in which identification is more uncertain.

In 1968, Houtsma estimated the DLs for melodic intervals in a pairwise discrimination task.[166] Participants were asked to determine which of the two intervals presented in a trial was larger. The JNDs were determined using a 75% correct point. Houtsma found an average JND of 16 cents for the octave. JNDs were also determined for the intervals of the chromatic scale for one participant, ranging from 13 to 26 cents. This range is very similar to the range determined in Moran and Pratt's experiment. Although the stimuli, experimental designs, and method of the statistical analysis of the data differ, the results found in Houtsma and in Moran and Pratt are in good agreement. Houtsma, however, did not determine JNDs in relation to pure interval ratios.

In a 1977 study, Jane A. Siegel and William Siegel conducted a series of experiments investigating absolute pitch and interval identification for musicians and non-musicians, the possible role of categorical perception in identification of intervals,

[164] Rakowski (1985) showed that interval adjustments by trained musicians do not imply that just interval ratios serve as category prototypes.
[165] Moran and Pratt, 499.
[166] A.J.M. Houtsma, "Discrimination of frequency ratios," [Abstract], *Journal of the Acoustical Society of America* 44, (July 1968), 383. Burns reports the findings of this study in the chapter "Intervals, Scales, and Tuning," 228.

and the effect of contextual cues on these tasks. The participants for the absolute pitch experiment were trained musicians with absolute pitch and non-musicians, and the participants for the relative pitch interval identification experiment were trained musicians without absolute pitch and non-musicians. In the primary experiment examining relative pitch, subjects listened to 21 different intervals ranging from the unison to the major third in 20-cent increments. The stimuli were sinusoidal, and presented sequentially. Subjects were asked to assign one of the five interval labels: unison, minor second, major second, minor third, or major third. Siegel and Siegel obtained identification functions for both groups of subjects—musically trained and untrained. Their results for the musically trained participants demonstrated consistent usage of all five interval-category labels, regular, symmetrical naming distributions, well-defined category boundaries, and good within-subject agreement between the two test sessions.[167] The results for the non-musicians did not exhibit any of these traits. They concluded that participants with musical training have well-defined "mnemonic anchors which represent the standard semitone intervals defined by their subculture."[168] Trained musicians, therefore, perceive musical intervals in a categorical manner. Siegel and Siegel found no significant effect of contextual cues on the ability of trained musicians to reliably use interval category labels.

For the second experiment investigating absolute pitch, the experimental design was similar to the first. Listeners were asked to identify the pitches by the note names C, C♯, D, E♭ and E. The stimuli were sinusoidal tones, ranging from C4 (262 Hz) to E4 (330 Hz), in 20-cent increments. The results were similar to those of the first experiment;

[167] Jane A. Siegel and William Siegel, "Absolute identification of notes and intervals by musicians," *Perception and Psychophysics* 21, no. 2 (1977), 144.
[168] *Ibid*., 146.

the musicians with absolute pitch were able to reliably label pitches and had well-defined category boundaries. Non-musicians were unable to reliably perform the task.[169]

Edward Burns and W. Dixon Ward conducted a separate study concerning the perception of sequential musical intervals (1978). The study investigated categorical pitch perception for musically trained and untrained subjects. In the primary experiment, identification and discrimination functions were obtained for frequency ratios over the range from 250 to 500 cents. Participants first had to label each frequency ratio as one of five musical intervals: major second, minor third, major third, fourth, or tritone. Participants also performed a similar identification task with quarter-tones over a range of ratios from 300 to 500 cents, labeling each interval as one of the following categories: minor third, lower quartertone (between minor third and major third); major third; higher quarter tone (between major third and fourth); or fourth. For the discrimination task, participants were presented with two sequential intervals and asked to judge which of the intervals was larger. The frequency of the first tones of the intervals was always randomized in the experiments over a range of 360 cents to prevent listeners from basing their discrimination judgments on absolute pitch height rather than interval size. In the same study, Burns and Ward also examined the possibility of temporal effects on discrimination ability, and conducted an experiment in which the time interval between stimuli was varied. No significant temporal effect was found.[170]

Burns and Ward concluded that musical intervals are perceived categorically by trained musicians. The musically-trained participants were able to consistently and reliably use the labels for the intervals spaced by semitones, but most could not reliably

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[169] *Ibid*., 146.
[170] Burns and Ward, 461.

identify the quarter-tone stimuli. This does not imply, however, that the subjects were unable to differentiate the quarter-tone stimuli; they were just inconsistent at identifying and applying the correct labels. Burns and Ward estimated an overall average interval-width DL of 37.7 cents for trained musicians and 74.5 cents for untrained listeners. They also found that musically trained subjects exhibited "smaller interval-width DL for ratios at identification category boundaries than for ratios within categories."[171] The within category boundary DLs are higher, which indicates that participants accepted large variations in interval size when considering identification labels. Near category boundaries DLs are lower, indicating that discrimination is better across categories.

Edward M. Burns and Shari L. Campbell determined that trained musicians were able to "differentially identify intervals separated by 30 cents with an accuracy of about 70%."[172] This finding contradicts Burns and Ward (1978), which concluded that musicians could not reliably use quarter-tone labels separated by 50 cents, but the experimental designs of the two studies differed. In an adjustment task, they found that their musically trained participants produced standard deviations of 18.2 cents for the chromatic-semitone intervals; and 20.9 cents for quarter-tone intervals. These were not significantly different from each other, leading the authors to conclude that there is evidence that trained musicians can perceive and adjust quarter-tone intervals as accurately as semitone intervals.[173]

In a 1985 study, Andrzej Rakowski and Andrzej Miskiewicz conducted a series of experiments to determine the "zones of tolerance," or category boundaries, for the

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[171] *Ibid*., 456.
[172] Burns, 226.
[173] Edward M. Burns and Shari L. Campbell, "Frequency and frequency-resolution by possessors of absolute and relative pitch: Examples of categorical perception?" *Journal of the Acoustical Society of America* 96, no. 5, vol. 1 (November, 1994), 2715.

ascending and descending melodic intervals found in the chromatic scale.[174] They were also interested in testing the hypothesis that some intervals have a stronger "memory trace," meaning they are more recognizable, identifiable, and reproducible.[175] Intervals with smaller dispersions of intonation (small category widths) would be thought to have a stronger memory trace; intervals with large dispersions of intonation (large category widths) would have weak memory traces. To test the hypothesis, the experimenters had musically trained participants adjust one of two variable pitch oscillators to produce the different intervals. The task was carried out using both pure and complex tones, and the listeners adjusted the variable pitch both above and below a reference tone (500 Hz).

Rakowski and Miskiewicz were able to conclude from the data that musicians tend to tune small intervals narrower and large intervals wider than the equally-tempered versions of those intervals.[176] The authors conjecture that this observation is a generalization of the octave-stretch principle. It could also be due to harmonic tension and tonal expectation; for example, a major seventh is tuned wider because its expected resolution is outward to an octave, and a semitone is tuned smaller because of its expected resolution inward to the unison. They also concluded that tuning up from the reference tone was easier because those intervals had smaller dispersions in intonation than the same intervals tuned below a reference tone.[177] Their study provided evidence in agreement with Burns and Ward (1978) and Siegel and Siegel (1977), that musical

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[174] Rakowski and Miskiewicz, 96. The term comes from an earlier study in interval perception; See N.A. Garbuvoz, "Zonnaya prioroda zvukovysotnogo swukha," in *Problemy fizyologicheskoy akustyki* 2 (Moscow: Izdat Akad. Nauk SSSR, 1949).
[175] Rakowski and Miskiewicz, 98.
[176] *Ibid*., 95.
[177] *Ibid.*, 101

intervals are perceived categorically by musicians. The timbre of the sound did not seem to have any effect on the intonation adjustments.[178]

A similar study by Rakowski in 1990 expanded on the previous experiments. In this experiment, trained musicians were asked to tune a variable oscillator to produce intervals within and without musical contexts. Participants tuned above and below a reference; and the waveforms of the stimuli were both pure and complex. Rakowski compared the data from the experiment to the interval sizes found in Pythagorean tuning, just intonation, and equal temperament. No correlation was found between freely tuned intervals and the Pythagorean or just intervals.[179] Thus, listeners do not necessarily use or favor the just interval ratios for category prototypes. The author confirmed earlier findings; with no musical context, small intervals (seconds and thirds) were tuned smaller and large intervals (sevenths and sixths) are tuned larger than their equally-tempered counterparts.[180] The study also provided evidence for the validity of the memory strength hypothesis. Using interquartile ranges, Rakowski obtained a metric for the memory strength for each interval. Intervals with strong memory traces were the major second, minor third, perfect fourth, perfect fifth, major sixth, minor second, major third, and octave. The minor sixth, minor seventh, major seventh, and tritone had weak memory traces.[181] Thus, the intervals commonly found in melodies (seconds, thirds, fourths, and fifths) have strong memory traces and smaller intonational variance.

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[178] *Ibid*., 95.
[179] Andrzej Rakowski, "Intonation Variants in Musical Intervals in Isolation and in Musical Contexts." *Psychology of Music* 18, no. 1 (1990), 62.
[180] Rakowski., 61.
[181] *Ibid*., 62.

When given a musical context, Rakowski found that the mean value of the interval ratio was affected, and the variability was reduced.[182] The musical context portion of the experiment presented the participants with four-note melodies. The intonation of the second note of each melody was under the control of the subject. The second note was always B4, but it was preceded by either an augmented fourth, diminished fifth, major seventh or minor seventh, and followed by a whole step, a semitone step up, a whole tone step down, a semitone step down, or a minor third leap up. Rakowski found that melodic tension and the contour of a melody influence the tuning of the interval size.[183] If an interval is followed by its correct resolution (i.e., a diminished fifth resolves downward, and augmented fourths resolves upward, a minor seventh resolves downward, and a major seventh resolves upward), then the variability in the intonation is far less. The results of the two experiments led Rakowski to conclude that there are many factors affecting intonational variance. Acoustical factors (such as frequency beats and inharmonicities), psychological factors (such as masking, pitch change with loudness, and octave stretch), and musical expression factors (such as harmonic tension and contour) all affect the variability of intonation.[184]

Acceptability judgments are another type of response obtained in musical interval perception studies. In Hall & Hess (1984), subjects were presented with simultaneous complex tones between 250 and 800 Hz. Listeners were asked to judge, on a scale of 1 to 7 (1 being highly acceptable, 7 being highly unacceptable), how acceptable the tuning of the musical interval would be in performance. Twenty-five different tunings were presented for each interval (12 wider than pure; 12 narrower than pure; and the pure

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[182] *Ibid*., 60.
[183] *Ibid*., 66.
[184] *Ibid*., 71.

interval), with a maximum of 36 cents deviation from the pure interval ratio. They found that average ratings were a function of interval type, and the unison, octave, fourth, fifth, twelfth, and major tenth exhibit the best fits.[185] Their findings also suggest that listeners have a greater tolerance (not preference, as Moran and Pratt concluded) for mistuned thirds and sixths in the direction of their equal-tempered counterparts. In agreement with Moran and Pratt, Hall and Hess estimate windows of "boundary fuzziness" to be between 20 and 40 cents.[186]

Hall and Hess also ranked the intervals from greatest to least sensitivity in mistuning: unison, octave, twelfth, fifth, major tenth, fourth, major sixth, major third, minor sixth, tritone, minor seventh, major second, major seventh, and minor second. They found that the easiest interval categories to distinguish were the boundary between unison and minor second and the boundary between major seventh and the octave, which provides evidence the that absolute pitch perception is more finely tuned than relative pitch perception. The most difficult category decision to make was between the major sixth and the minor seventh: all four of their subjects placed the boundary above 969 cents, "thus classifying the harmonic seventh more often as a major sixth than as a minor seventh."[187] Their rankings resemble the rankings of Moran and Pratt for smallest to greatest JNDs and Rakowski's strength of memory trace groupings, but do not coincide exactly.

Hall and Hess also suggest that tuning judgments are a combination of beat-rate detection between nearly-coinciding harmonics and deviations in interval size.[188] Slight

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[185] Hall and Hess, 175.
[186] *Ibid*., 181.
[187] *Ibid*., 181.
[188] *Ibid*., 190.

mistunings may depend on beat-ratios, but larger mistunings may depend on deviations in interval size.[189] These results support the findings of Rasch (1985). In an experiment with musically trained listeners, Rasch presented short musical fragments with a melody and bass. The harmonic intervals between melody and bass were mistuned, and thus the melodic intervals also changed. Rasch concluded that "deviating interval size was probably of more importance in the perception of harmonic mistuning than the presence of beats."[190]

Joos Vos and Ben C. van Vianen examined the role of nearly coinciding harmonics in discrimination between pure and tempered simultaneous intervals (1985). Their purpose was "to find and comprehend a general rule to describe the possible relation between discriminability and type of interval."[191] The study presented intervals as simultaneous complex tones with fundamental frequencies in a ratio of p:q. In a 2AFC task, listeners were presented with two intervals and had to decide which of the two intervals was tempered. They concluded that the presence or absence of beats was a significant factor for the discrimination of pure intervals from slightly tempered intervals.[192] Vos and van Vianen also estimated discrimination thresholds for 13 intervals and showed that increased frequency-ratio complexity (the sum of p and q) also increased discrimination thresholds. In other words, as frequency-ratio complexity increased, discrimination ability decreased. In agreement with Hall and Hess (1984), the size of the interval was not a significant factor in estimating discrimination ability. However, the effect of frequency-ratio complexity decreased with an increased degree of tempering.

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[189] *Ibid*., 191.
[190] Rudolf Rasch, "Perception of Melodic and Harmonic Intonation of Two-Part Musical Fragments," *Music Perception* 2, no. 4 (Summer 1985): 441-458.
[191] Vos and van Vianen, 176.
[192] *Ibid*., 176.

Sensitivity to tempering was highly dependent on the type of interval, increasing for intervals with more coinciding harmonics.

Tuning System Perception

One of the earliest studies to investigate the ability of listeners to discriminate between tuning systems was Ward and Martin (1961). In ABX and AX discrimination tasks, musically trained listeners compared prerecorded ascending diatonic scales in different 12-tone tuning systems. The stimuli were presented in one of two timbres: a flute-like (simple) timbre, and a spectrally complex timbre. The tuning systems compared were 12-TET to just intonation, and 12-TET to a version of 12-TET in which the third, sixth, and seventh scale degrees were altered by varying amounts from -6 to -30 cents. Ward and Martin concluded that only 3 of the 20 participants in the study could reliably tell the difference between just intonation and 12-TET when the intervals were performed melodically. The largest difference between diatonic melodies in just intonation and 12-TET (16 cents) is below the ABX discrimination threshold but above the AX discrimination threshold. Listeners could reliably tell the difference between tuning systems when differences were large enough (approximately 20 cents for ABX tasks, and approximately 10 cents for AX tasks).[193]

In a 1988 study on the acceptability of different twelve-tone tuning systems, Joos Vos compared short two-part musical fragments in Pythagorean tuning, equal temperament, and meantone, as well as two other historical 12-tone tunings and two hypothetical tuning systems where the fifths were tempered 2 cents wider than pure and

[193] W. Dixon Ward and Daniel W. Martin, "Psychophysical Comparison of Just Tuning and Equal Temperament in Sequences of Individual Tones," *Journal of the Acoustical Society of America* 33, no. 5 (May, 1961), 587.

10 cents narrower than pure. The stimuli were 24 fragments from Part VI of the *Musae Sioniae* by Michael Praetorius (1609). Vos found that the acceptability ratings did not significantly change between pure fifths and fifths that were 5.4 cents narrower than pure. When fifths were tempered by more than 5.4 cents, or by any amount wider than pure, acceptability ratings strongly decreased.[194] In musical contexts, both the perception of "beats or roughness and the detection of changes in interval-size may affect the degree to which tempered intervals are experienced as 'impure' or 'out of tune.'"[195] Vos found that overall acceptability could be predicted from a linear combination of the purity ratings of isolated harmonic fifths and major thirds. He determined that if there were an equal number of fifths and major thirds in the musical fragment, then the tempering of the major thirds would have a greater effect on the ratings. They concluded that for small amounts of tempering ($–5.4<T<0$), deviations in melodic intervals were unlikely to affect overall acceptability. For larger amounts of tempering ($T>0$ and $T<–5.4$), they predicted that deviations in melodic intervals (especially the minor second, major second, and minor third) would affect overall acceptability.[196] Richard Parncutt suggests that a wider window of acceptable mistunings (0.1-0.3 semitones, or 10 to 30 cents) does not affect the musical meaning or function.[197]

A 1986 study by Vos and van Vianen examined the subjective purity ratings for complex melodic intervals. They found that tempering had to exceed 35 cents before ratings were significantly affected, and that discrimination thresholds for the fifth and major third ranged from 25 to 40 cents. The 35-cent difference necessary to significantly

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[194] Joos Vos, "Subjective acceptability of various regular twelve-tone tuning systems in two-part musical fragments." *Journal of the Acoustical Society of America* 83, no. 6 (June 1988), 2283.
[195] Vos, 2283.
[196] *Ibid,*, 2391.
[197] Parncutt, 44.

affect ratings falls just below the difference between the 12-TET intervals and 31-TET intervals that have been widened or narrowed by a fifth of a tone (38.71 cents). Though Vos and van Vianen were not interested in listeners' ability to discriminate between tempered and pure intervals in this study, the subjective ratings provide evidence that listeners do perceive deviations of at least a fifth of a tone differently than smaller deviations. These subjective impressions can cue listeners in a discrimination task.

Perception of Voice-Leading Distance

In 2006, Clifton Callender and Nancy Rogers conducted a study which asked listeners to rate voice-leading distances between two trichords. They specifically wanted to test the validity of the "taxicab metric", as well as the effects of tuning environment and the direction of motion of the voices. The "taxicab metric" is a linear metric that measures the displacement of each voice in terms of semitones. According to this metric, a voice-leading in which two voices are static and a single voice moves by a whole tone and another voice-leading in which one voice is static and two voices move by semitone are equally distant. The "taxicab metric" does not account for the differences in common-tone retention between the two abovementioned cases. Callender and Rogers tested the linearity assumption of the "taxicab metric" by comparing it with actual perceptions of voice-leading distance. In the first experiment, they presented listeners, who were all trained musicians in the Florida State University music program, with trichords in which one, two, or three voices moved by whole tone, semitone, quarter tone or an eighth of a tone. The stimuli in the experiment were designed to either hold total displacement constant while varying the number of common tones between trichords, or hold the number of common tones constant while varying the total displacement.

Callender and Rogers found that the sum of the total displacement of all the voices was highly correlated to judgments of distance.[198] Increasing the number of common tones also reduced the perceived distance between trichords. Interestingly, they found that displacement of a whole tone in a single voice was rated as being a smaller distance than two voices moving by semitone. In this case, listeners privileged the retention of common tones over total displacement. While the "taxi cab" metric equates these two motions as being equidistant, perceptually they are not. For stimuli involving quarter tones and eighths of tones, Callender and Rogers found that the opposite was true: listeners rated a single voice motion of a quarter-tone as being more distant than two voices moving by eighths of a tone. In this case, listeners privilege total displacement over common-tone retention. Callender speculates that this is due to categorical perception: "microtonal tunings may be perceived as alterations of a single pitch rather than as motions from one pitch to another."[199] In other words, an eighth of a tone is perhaps too small to demand a new interval category, but a quarter tone is not and may demand a new interval category.

In the second experiment, Callender investigated the influence of direction of motion, tuning environment, and chord content on ratings of distance. He found that the traditional Neo-Riemannian transformations P (Parallel, which transforms a triad into its parallel by moving the third of a major triad down by a semitone, and the third of a minor triad up by a semitone), R (Relative, which transforms a triad into its relative by moving

[198] Callender and Rogers, 1686.
[199] *Ibid.,* 1689.

the fifth of a major triad up by a whole tone, and the root of a minor triad down by a whole tone), and L (Leading-tone exchange, which transforms a triad by moving the root of a major triad down by a semitone, and the fifth of a minor triad up by a semitone) were rated as being particularly close. This is in agreement with Krumhansl (1998), who found that triads related by the Neo-Riemannian transformations were found to be perceptually close.[200] Triads related by root motion of perfect fourth (P4) or perfect fifth (P5) were rated as being close, but not as close as the L, P, and R relations. Within the P4/P5 category, motions that resembled i-V were rated as closer than those from I-v, indicating that the prevalence of the latter in tonal music may influence ratings of distance. Root motions by step were rated as being the most distant. [201]

Ascending motions were also generally rated as being more distant. Callender speculates that this is due to a general feeling of increased tension with ascending motion, and that tension may be perceived as distance. However, the opposite seems to be true for intervals that are a semitone or smaller: ascending motion is rated as being less distant than descending motion. Callender suggests that Lerdahl's theory of melodic attraction and the paradigm of leading-tone resolution may play a role: a motion that leads a pitch to its expected resolution is rated as being less distant than the motion in the opposite direction, away from the more hierarchically stable tone.[202]

The results of Callender and Rogers' study suggest that the "taxi cab" metric, "while reasonable, underemphasizes common tones in standard tuning and displacement size in microtonal tunings, suggesting that displacements do not necessarily combine in a

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[200] Carol L. Krumhansl, "Perceived Triad Distance: Evidence Supporting the Psychological Reality of Neo-Riemannian Transformations," *Journal of Music Theory* 42, no. 2 (Autumn, 1998), 279.
[201] Callender and Rogers, 1690.
[202] *Ibid*., 1689-1690.

static, linear manner."[203] The "taxi cab" metric does properly account for perceptually relevant factors such as direction of motion, type of motion (parallel, contrary, and oblique), chord content, harmonic implications, or the tuning environment. Callender and Rogers conclude that perceptual voice-leading distance, like many perceptual phenomena, is not linear.

In music-theoretical research, voice-leading distance has been measured by chord similarity.[204] Similarity/dissimilarity has been suggested as a measure of perceptual distance; the more dissimilar two stimuli are the farther apart they are in perceptual space. This is the concept behind multidimensional scaling techniques.[205] Callender's research suggests that proximity in pitch (for example, two pitches differing by a quarter tone) can be perceived as perceptually distant and not necessarily as mistuned versions of the same thing. It is possible that this phenomenon could extend to the slightly smaller fifths of tones found in Vicentino's enharmonic music.

Conclusion

The experiments reported in the following chapter ask participants to discriminate between two-chord progressions in 12-TET and 31-TET; in the 31-TET version, one or neither of the chords is dotted (raised by a fifth of a tone). Based on the findings of the studies reviewed in this chapter, musically-trained listeners should be able to discriminate

[203] *Ibid*., 1686
[204] See Clifton Callender, "Voice-Leading Distance as a Measure of Similarity," under review; Straus, 305-352.
[205] For an introductory discussion of multidimensional scaling, see Richard Parncutt, *Harmony: A Psychoacoustical Approach* (New York: Springer-Verlag, 1989), 12; Multidimensional scaling was developed by J.B. Kruskal and the technique is used for experiments in which each stimulus is compared with each other stimulus to produce a configuration of stimuli in a Euclidean space. The axes of this space are possible parameters affecting similarity judgments. Although this type of analysis is not used in discrimination tasks, the philosophy behind the technique is that judgments of similarity/dissimilarity can be represented by distances in space.

between 12-TET and 31-TET when the dotted chords are involved. In terms of absolute pitch height, the differences between the dotted notes in 31-TET and their 12-TET counterparts are well above the threshold of discrimination for complex tones in all of the ranges of the vocal parts.[206] This difference is not the same for each note due to the different sizes of semitones in the two tuning systems, but it is at least 22.6 cents and at most 58.1 cents. Listeners should, therefore, be able to discriminate between excerpts in which one of the two chords is dotted and the other is not based solely on differences in absolute pitch height.

The difference in the sizes of melodic intervals produced within each voice do not consistently fall above the thresholds of discrimination. The complex texture of four-voice polyphony also makes isolating and listening to individual melodic intervals difficult. The musical and acoustical contexts of the experimental stimuli are far more complex than the isolated intervals used in most of the aforementioned studies. The smallest estimated JND for melodic intervals is around 10 cents and the largest around 45 cents. When an interval is widened by the enharmonic diesis, which occurs in ascending undotted-to-dotted and descending dotted-to-undotted sequences, the smallest melodic difference in interval sizes between 12-TET and 31-TET is 16.5 cents for the minor semitone (116.5 cents versus 100 cents), and the largest is 58.1 cents for the diminished fifth (658.1 cents versus 600 cents). When an interval is narrowed by the enharmonic diesis, which occurs in descending undotted-to-dotted or ascending dotted-to-undotted sequences, the smallest difference in cents between 12-TET and 31-TET is 19.4 cents for the diminished fifth (580.6 cents versus 600 cents), and the largest is 61.0 cents for the minor semitone (39.0 cents versus 100 cents). The smallest differences are just below or

[206] See Moore and Moore (2003), Ward and Martin (1961).

around the thresholds of discrimination for musical intervals, and around the 16-cent threshold estimated by Ward and Martin for the discrimination of different 12-tone tuning systems.

Also confounding the situation is categorical perception of musical intervals. Although the differences in the sizes of the melodic intervals formed by the individual voices may be sufficiently large for discrimination purposes, they may not exceed the 40-cent window of "boundary-fuzziness" suggested by Siegel and Siegel, Burns and Ward, and Moran and Pratt. However, the roughness of the triads in 12-TET may be another clue to aid in judgments. Vos and Hall and Hess concluded that the perception of beats in simultaneous intervals aided in judgments of acceptability of tempered intervals.[207] The thirds in Vicentino's system are pure and the thirds of 12-TET are too wide. Thus the purity of the triads should also be detectable to listeners through the presence of frequency beats.

The multi-dimensional nature of the listening task may also have an effect on the ability of the listeners to discriminate between the two tuning systems. Many of the discrimination threshold studies used stimuli in isolated and controlled contexts: that is, they presented intervals sequentially or simultaneously. In the musical context of the Vicentino excerpts, listeners are presented with stimuli that have both sequential intervals between the pitches found in a single voice *and* multiple simultaneous intervals found between each voice with the other voices.[208] Because the listeners' attention is divided between these different intervals, their ability to discriminate any of the differences may not be as acute as it would be in the context of isolated intervals. It could also be the case

[207] See Hall and Hess, 181; and Vos, 2283.
[208] There are six simultaneous intervals found in a four voice texture between the following pairs of voices: bass and tenor; bass and alto; bass and soprano; tenor and alto; tenor and soprano; and soprano and alto.

that with multiple simultaneous and sequential clues, listeners may be able to more easily discriminate between tuning systems.

It has been suggested that small deviations in pitch are not perceived as differences in frequency, but rather as differences in color, timbre, or feeling.[209] As Scott Makeig suggests, an affective experience of music may increase a listener's perceptual efficiency.[210] In a real music listening experience, the stream of events is often too dense and complex to analyze everything in quantitative terms. To simplify the cognitive processing of information, we retain impressions of events rather than exact information. This theory of affective perception is also conducive to Vicentino's theory of interval affect. The qualitative impression of a musical event can be altered by small differences in the quantitative building blocks—the intervals. Although listeners might not be able to determine which excerpt was tuned higher or which interval had a greater magnitude, impressions such as brightness, darkness, cheerfulness, and sadness might help to differentiate between the stimuli.

With the exception of Vos's study that used excerpts from Praetorius, most previous research has not used real musical examples. Although the recordings for the 12-TET versions and the 31-TET versions were edited and retuned with post-production software and may contain artifacts, they originate from the same track and were engineered at the same time to eliminate differences in sound quality as much as possible. The singers' vibrato was attenuated in both the 12-TET and 31-TET versions to assist in stabilizing the pitch of each note. However, the complex musical texture of four

[209]Paul C. Boomsliter and Warren Creel, "Extended Reference: An Unrecognized Dynamic in Melody," *Journal of Music Theory* 7, no. 1 (Spring, 1963), 16-22.
[210] Scott Makeig, "Affective Versus Analytic Perception of Musical Intervals," in *Music, Mind, and Brain: The Neurophysiology of Music*, ed. Manfred Clynes (New York: Plenum Press, 1982) 232.

polyphonic voices and the uncontrolled musical performance (i.e., recordings of real singers performing the music with dynamic expression and different colorations) may also make it more difficult to detect the tuning differences between the excerpts. What is lost in the complexity and the control of stimuli is in some way regained with a more real dynamic music listening process.

Even in view of these confounding factors, it is hypothesized that the differences in interval size and absolute pitch height between 12-TET and 31-TET when the enharmonic diesis is involved are great enough to be detectable by musically trained listeners. Differences between the two systems when the enharmonic diesis is not involved may be too small to be perceptible. The following chapter reports the results of an empirical study that investigates this hypothesis.

CHAPTER FOUR: An Empirical Investigation of the Perception and Discrimination of Vicentino's 31-tone Tuning System

This chapter reports the results of two experiments that investigated the ability of trained musicians to discriminate between acoustically and musically complex performances of short musical excerpts in 12-TET and 31-TET, and the extent to which the voice-leading and harmonic properties of the music may have affected discrimination performance.

All of the musical stimuli for the experiments were taken from the 1555 treatise *Ancient Music Adapted to Modern Practice* by Italian composer and music theorist, Nicola Vicentino.[211] The polyphonic compositions found in this treatise demonstrate the use of the microtonal step of the minor enharmonic diesis, an interval that Vicentino adapted from ancient Greek music theory. Vicentino's minor enharmonic diesis is one fifth of the 31-tone equal-tempered whole tone in size, or 38.7 cents. Placing a dot above the notated pitch is Vicentino's convention for indicating that the note be raised by a minor enharmonic diesis. Chords that consist of dotted notes in 31-TET, then, contain pitches that are substantially higher than their undotted 31-TET and 12-TET counterparts. The difference in absolute pitch height between a dotted note in 31-TET and its 12-TET counterpart always exceeds 22.6 cents. This is above the 20.8-cent threshold of discrimination for complex tones determined by Moore and Moore (2003); thus, all dotted notes should be distinguishable from their 12-TET versions.[212]

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[211] Vicentino, 209-222.
[212] Moore and Moore, 157.

When a dotted pitch is preceded or followed by an undotted pitch in 31-TET, the melodic intervals between adjacent pitches are also widened or narrowed by a fifth of a tone. The estimated threshold for discrimination of sequentially presented melodies in an ABX discrimination task is around 20 cents (Ward and Martin, 1961).[213] Burns and Ward (1978) estimated a mean DL of 37.7 cents for all melodic intervals; Rakowski estimates discrimination thresholds between 20 and 45 cents. However, Hall and Hess (1984), Rakowski (1985), and Vos and van Vianen (1985) all concluded that DLs are dependent on the interval type; intervals such as the major third, perfect fourth, perfect fifth, octave, and unison have very low discrimination thresholds.[214] The differences in size between these 12-TET melodic intervals and their widened or narrowed 31-TET counterparts are well above the thresholds, and these interval motions are common in the music. Therefore, progressions between undotted and dotted chords (or vice versa) should contain discriminable differences in absolute pitch height and relative melodic interval sizes in each of the voices. Experiment 1 investigates the extent to which the differences in pitch height and interval size between 12-TET and 31-TET are discriminable in a complex polyphonic musical setting, and examines a set of musical parameters that may be associated with higher discrimination performance.

[213]Ward and Martin, 587.
[214]Hall and Hess, 175; Rakowski and Miskiewicz, 96; Vos and van Vianen, 176.

EXPERIMENT 1

Method

Participants

Participants were recruited from McGill University and the Montréal area, and were compensated for their participation. All participants were highly musically trained; they were required to be in at least their second year of university-level music studies. Participants also had to have normal hearing and be regularly practicing musicians. Percussionists and keyboardists were excluded from the study because it was thought by the experimenters that musicians who specialize in fixed-pitch instruments might not be as sensitive to tuning differences as vocalists or variable-pitch instrumentalists. There were 16 male participants and 14 female participants, averaging 22.3 ± 2.9 years of age, with 14.8 ± 3.8 years of musical training.

Stimuli

The stimuli for the experiment were excerpts taken from recordings of four polyphonic compositions by Nicola Vicentino: *Dolce mio ben, Musica prisca caput*, *Soav'e dolc'ardore*, and *Madonna, il poco dolce*. The recordings were made by Professors Jonathan Wild and Peter Schubert at McGill University with the support of a grant from the Fonds Québécois de la recherche sur la société et la culture (FQRSC). Professor Schubert instructed and conducted four professional singers (soprano, alto, tenor, and bass) to render a reference recording. The compositions listed above were performed by the ensemble without observation of the notated dots; the singers observed only the chromatic accidentals. Later, each singer individually recorded their respective parts while listening to the reference recording. The individual tracks were then retuned using the commercial post-production software Melodyne to produce 12-TET and 31-TET versions of the each of the compositions. Middle C (C4, 262 Hz) was used as the reference frequency to which all other pitches were tuned. The vocal parts were then remixed into a single track to produce recreated performances in precise tuning systems.

The stimuli were excerpts of two-chord progressions from the aforementioned recordings. The two versions of each excerpt (31-TET and 12-TET) were to be compared. The excerpts were chosen so that each chord in the progression had the same number of voices (i.e., no voices entered or dropped out of one of the chords of the excerpt). The excerpts were also triadic, with no embellishing tones. Ten excerpts were chosen to fit into one of the following categories: *dotted-to-undotted* (DU, in which the pitches of the first chord of the excerpt in the 31-TET version are raised by the minor enharmonic diesis and the pitches of the second chord are not), *undotted-to-dotted* (UD, in which the pitches of the second chord of the excerpt in the 31-TET versions are raised by the minor enharmonic diesis and the pitches of the first chord are not), or *neither* (NE, in which neither chord of the excerpt in 31-TET involves pitches raised by the minor enharmonic diesis).

Apparatus

Stimuli were digitally stored on an iMac computer and were played through a Grace Design m904 amplifier to Dynaudio Acoustics loudspeakers in an acoustically-treated, sound-proof booth (Industrial Acoustic Corporation, model 1203). The experimental interface was created using Adesign software by Pierresoft.com. It was displayed on the iMac computer monitor and responses were entered using the computer mouse.

Procedure

The stimuli were presented in stereo over loudspeakers in an acoustically-treated, sound-proof booth at 65 db SPL. Participants were centered between the loudspeakers at a distance of about one meter from them and were seated in front of a computer monitor. The stimuli were presented in an ABX discrimination paradigm. In a single trial, the same two-chord progression was presented in three versions, and each version was separated by a short silence. Version A and version B were always different; one was the 12-TET version and one was the 31-TET version of the excerpt. Version X was identical to either version A or version B. The participant was asked to identify whether version X corresponded to version A or version B. A prompt on the computer monitor informed the participant which version they were currently hearing (A, B, or X), and the versions were always played in that order. Once all three versions had played, another prompt appeared on the monitor asking the participant to decide whether X was the same as A or B. Participants entered their responses by clicking with the mouse either 'A' or 'B' on the monitor to indicate their choice. Participants could not enter a response until all versions of the excerpt finished playing. Each trial was played only once, and the participants could not repeat or revisit any of the trials.

Equal numbers of X=A and X=B were included for each of 30 excerpts, which were presented in a randomized order. The 30 excerpts were subdivided into three groups of 10 according to the tuning differences found in each. The *undotted-to-dotted*

(UD) group consisted of excerpts in which the second chords of the 12-TET and 31-TET versions of the excerpt differed in terms of tuning, and the first chords were tuned more similarly (UD vs. U′U′, where U′ represents the 12-TET versions of the chords). The *dotted-to-undotted* group (DU) consisted of excerpts in which the first chords of the 12-TET and 31-TET versions of the excerpt differed in terms of tuning, and the second chords tuned more similarly (DU vs. U′U′). The *neither* group (NE) consisted of excerpts in which neither chord of the 31-TET versions was dotted (raised by a fifth of a tone), and thus tuning differences were very small. It took approximately 10 minutes to complete a block of 30 excerpts, and there were four blocks to ensure that all possible orders (12-TET/31-TET/12-TET, 12-TET/31-TET/31-TET, 31-TET/12-TET/12-TET, and 31-TET/12-TET/31-TET) were presented. This made for a total of 120 trials.

Results

The goal of this study was to determine if trained musicians could discriminate between musical excerpts in 12-TET and 31-TET when the minor enharmonic diesis was involved. Several voice-leading and harmonic features of the excerpts were analyzed to determine if they could be associated with discrimination performance. Figure 4-1 displays the proportion of correct responses by excerpt group with 95% confidence intervals.[215]

[215]Confidence intervals are statistical estimates of the true value of a population parameter based on data gathered from a sample. A 95% confidence interval gives a range of values in which we can be 95% confident that the true population parameter value lies.

The data were analyzed using a generalized linear mixed model.[216] Excerpt group (DU, UD, or NE) and individual excerpts nested within excerpt groups were treated as fixed effects in the model; participant ID and excerpt group were treated as random effects. This statistical model was chosen over the traditional repeated-measures analysis of variance (ANOVA) because it more accurately accounts for the variance between subjects in a repeated measures design, and it relaxes the assumption of normality.[217] The model determined that excerpt group (DU, NE, or UD) had a significant effect on performance in the discrimination task ($F(2,58)=66.68$, $p<0.0001$), as did the effect of hierarchical nesting ($F(27,783)=3.37$, $p<0.0001$). The contrast parameterization of the model showed that correct response rates in the UD group were highly significantly different from those of both the DU group ($F(1, 58)=88.82$, $p<0.0001$) and the NE group ($F(1, 58)=122.32$, $p<.0001$). There was no significant difference in performance between the DU and NE groups ($F(2, 58)=3.23$, $p=0.08$). Overall, listeners were able to reliably detect the differences in tuning systems even when the minor enharmonic diesis was not involved. All three groups could elicit above-chance performance (95% confidence intervals), as shown in Figure 4-1.

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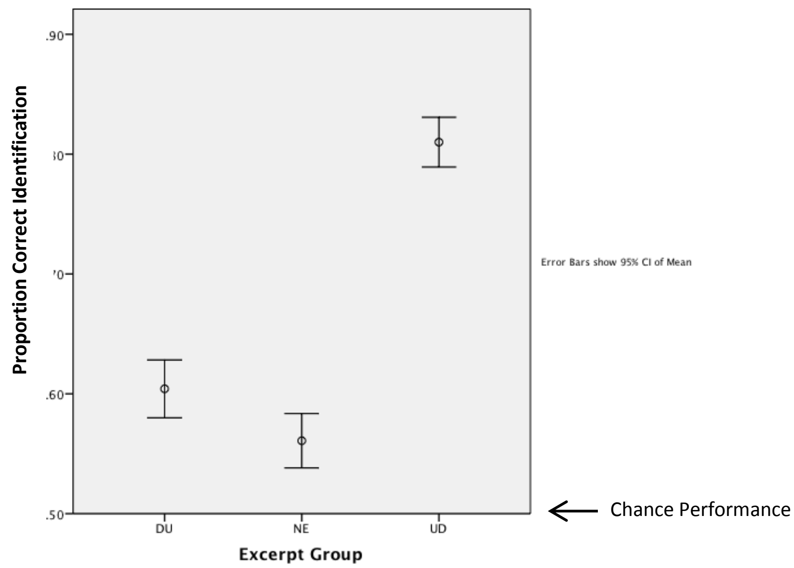
[216] Generalized linear mixed models include random effects and fixed effects. Fixed effects are non-random predictors for response variables; random effects are variable and are included because it is assumed that there are random differences in the population. Random effects are often used to better account for the differences in responses between subjects.

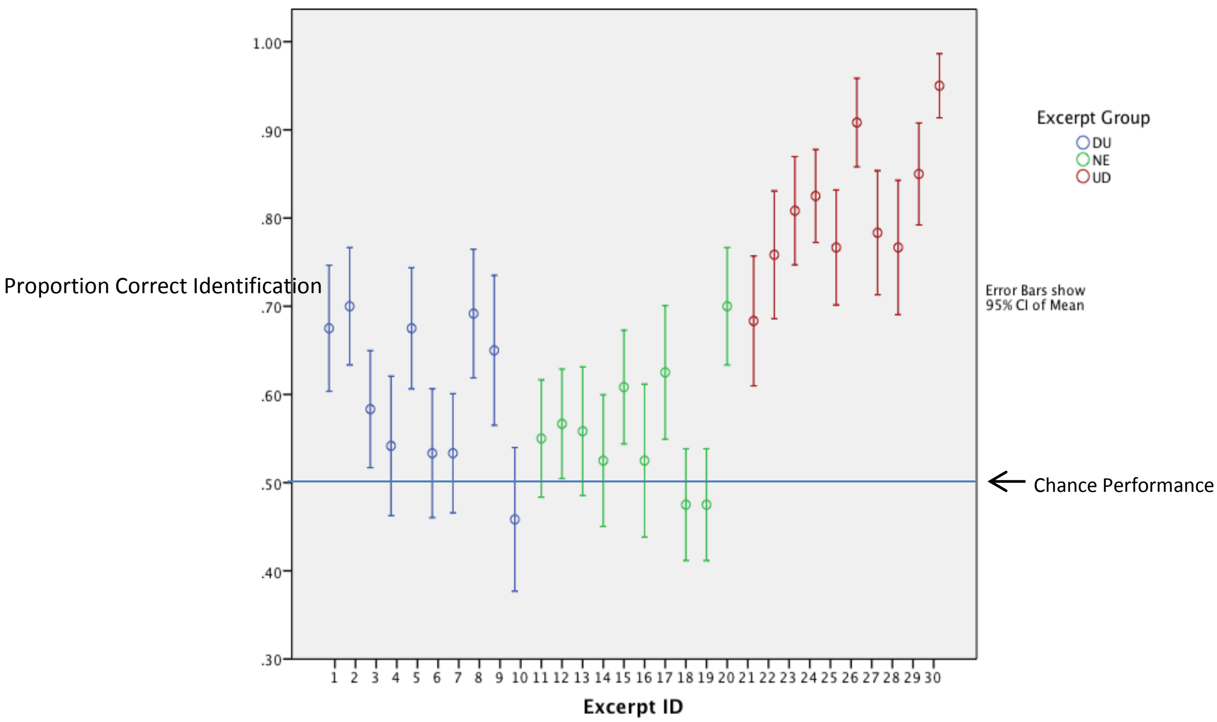
[217] See Brady West, Kathleen B. Welch, and Andrzej T. Galecki, *Linear Mixed Models: A Practical Guide Using Statistical Software* (Boca Raton: Chapman & Hall/CRC, 2007), 1-18; C.B. Dean and Jason D. Nielsen, "Generalized linear mixed models: a review and some extensions," *Lifetime Data Anal* 13 (2007), 497-500. If a distribution of values for a random variable adheres to normality assumption, this means the distribution is bell-shaped, with most of the values clustering around a single mean value.

Figure 4-1. Proportion of correct responses by excerpt group in Experiment 1



Confidence intervals (95%) were also produced for individual stimuli to investigate which excerpts elicited above-chance performance (Figure 4-2). All of the excerpts involving the minor enharmonic diesis (such as the dotted notes found in the DU and UD groups) elicited above-chance performance except DU_04, DU_06, DU_07, and DU_10. Performance for all NE excerpts was not significantly above chance, except for excerpts NE_05, NE_07, and NE_10. Figure 4-2 displays the probability of correct responses for each excerpt with the 95% confidence intervals.

Figure 4-2. Proportion of correct responses by excerpt in Experiment 1



Using information gathered from questionnaires, the discrimination abilities of the participants were assessed according to their primary instrument type (voice, string, or wind), and whether or not they reported to have absolute pitch. It was thought by the experimenters that perhaps vocalists might be more sensitive to the tuning in vocal performance, and that possessors of absolute pitch might perform differently than non-possessors. However, the instrument type had no significant effect on discrimination ability ($F(2,810)=0.17$, $p=0.84$). There was also no significant effect of absolute pitch possession on performance ($F(1,810)=0.04$, $p=0.83$). This finding contradicts Miyazaki (1993), who determined that possessors of absolute pitch performed slightly worse than non-possessors on roaming relative pitch identification tasks, presumably because they rely on absolute pitch relationships for frequencies that could not be assimilated into one of the 12 chromatic pitch categories.[218]

Musical Parameters

A group of variables relating to the voice-leading, harmonic, and acoustical properties of the excerpts were tested to investigate which factors contributed significantly to the probability of correctly discriminating between the 31-TET and 12-TET versions. All of the values for each parameter were standardized.[219] This was done so that parameter estimates could be compared in terms of the magnitude of effect size.

The voice-leading parameters examined were the sum of the total displacement in semitones of all the voices in the 12-TET versions, maximum displacement in semitones in the 12-TET versions, the number of common tones between the two chords in the 12-TET versions, and whether or not the excerpt realized the step of an enharmonic diesis in a single voice. An analysis of the correlation of these possible parameters revealed that total displacement and maximum displacement were highly correlated; total displacement was retained and maximum displacement was dropped. The only voice-leading parameter with a significant effect on performance was total displacement ($F(1,866)=14.42$, $p=0.0002$). Common tone retention did not have a significant effect ($F(1, 863)=0.48$, $p=0.49$). The realization of the step of an enharmonic diesis in a single voice also had no significant effect ($F(1,863)=0.71$, $p=0.40$).

The harmonic parameter tested was the difference between the harmonic distances as measured by the minimum number of edge flips on the 12-TET *Tonnetz* and 31-TET

[218] Ken'ichi Miyazaki, "Absolute Pitch as an Inability: Identification of Musical Intervals in a Tonal Context," *Music Perception* 11, no. 1 (Fall 1993), 55.
[219] Values were standardized by converting to z-scores.

Tonnetz. The *Tonnetze* are conceptual diagrams that map pitches in tonal space; successive lines of perfect fifths, major thirds, and minor thirds interconnect to form lattices of triadic relationships (see Figure 2-3 in Chapter Two for a diagram of 31-TET *Tonnetz*). This was found to have a significant positive effect on the probability of correct identification ($F(1,866)=9.60$, $p=0.002$).

The acoustical parameters examined included the duration (in seconds) of each excerpt; the sum of the difference in cents between each of the congruent voices in the 12-TET and 31-TET versions in the first chord only; and the sum of the difference in cents between each of the congruent voices in the 12-TET and 31-TET versions in the second chord only. The duration of the excerpt had a significant negative effect on performance ($F(1, 866)=7.08$, $p=0.008$); longer excerpts elicited lower performance. The sum of the difference in cents (for either the first chord or for the second chord of each excerpt) is a measure of the differences in absolute pitch height of the notes comprising the chord in the 12-TET or 31-TET versions. The sum of the difference in cents between the second chords of the excerpt had a highly significant effect ($F(1, 866)= 80.14$, $p<0.0001$); the difference in cents between the first chords of the excerpts did not exhibit a significant effect ($F(1, 863)=0.59$, $p=0.44$).

Because the values of the musical parameters were standardized, the parameter estimates can be interpreted as relative effect sizes. The difference in cents between the second chords of the excerpts had the largest effect on performance, followed by total displacement, absolute difference in harmonic distance on the *Tonnetze*, and the duration in seconds.

Post-hoc Analyses

The excerpts were analyzed to determine if any shared the same voice-leading pattern, consisted of the same harmonic chords, or reversed the voice-leading pattern and harmonic pattern of any other excerpt (i.e., one excerpt retraces the voice-leading and harmony of another, thus reversing the directionality of all the intervals and the harmonic progression). The goal of the post-hoc analyses was to determine if the excerpts with similar voice-leading patterns had similar odds of correct identification. Excerpts that share the same chords but have different voice-leading patterns would have the same difference in cents between the two versions of the excerpts. Those excerpts that share voice-leading patterns at different pitch levels represent cases in which the voice-leading is held constant while the difference in cents between the two versions of the excerpts varies. And lastly, those excerpts that reverse voice-leading patterns at the same pitch level might show an effect of directionality; if the total difference in cents is constant and the voice-leading patterns are is reversed, then the direction of the intervals may be playing a role.

This set of excerpts only offered a few instances of the above-mentioned cases. Those excerpts that share the same chords are DU_07 and DU_09, and UD_05 and UD_06. For each of these pairs of excerpts, the odds of correct identification were significantly different (DU_07 vs. DU_09: $F(1,783)=25.38$, $p<0.0001$; UD_05 vs. UD_06: $F(1,783)=8.41$, $p=0.004$), suggesting that voice-leading patterns may overpower the differences in cents between the versions of the excerpts. The only excerpts to reverse the voice-leading patterns at the same pitch-level are DU_02 and UD_04. A post-hoc comparison revealed that these two excerpts were significantly different in terms of correct-response rates ($F(1,783)=8.41$, $p=0.0259$), suggesting that directionality may also affect discrimination in a four-voice texture when total difference in cents and voice-leading distance is held constant. This evidence supports the conclusion of Callender and Rogers (2006) that voice-leading is not perceptually linear and symmetric, as most metrics for quantifying voice-leading distance assume.[220] Excerpts DU_02 and UD_02 exhibit the same voice-leading pattern at different pitch-levels, and they are *not* significantly different in terms of the odds of correct identification ($F(1,783)=1.01$, $p=0.31$). DU_02 is the only DU excerpt to share voice-leading patterns with an excerpt in the highly discriminable UD group. These analyses provide further evidence that the specific voice-leading patterns may affect discrimination ability.

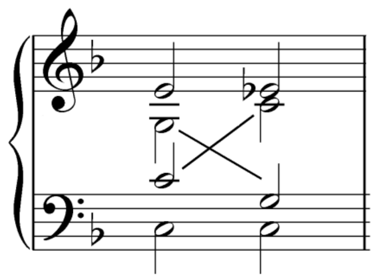
Discussion

The results of Experiment 1 confirm the hypothesis that musically trained musicians can reliably tell the difference between 12-TET and 31-TET, even when the enharmonic diesis is *not* involved. A significant asymmetry was observed between the DU and UD groups; performance was significantly better when participants were discriminating between versions of UD excerpts than when they were discriminating between versions of DU excerpts. The tuning differences between the 12-TET and 31-TET versions are much more pronounced within these groups than within the NE group; the differences in tuning are also similar in the UD and DU groups. Mean discrimination performance for the DU group of excerpts, however, was not significantly different from the mean performance for NE excerpts, even though the NE excerpts exhibited smaller differences in tuning between the 12-TET and 31-TET versions.

[220] Callender and Rogers, 1686.

Of the musical parameters investigated, it was found that total displacement, the absolute difference between distances on the 12-TET and 31-TET *Tonnetze*, the difference in cents between the second chords of the excerpts, and duration (in seconds) of the excerpt had a significant effect on discrimination performance. It was originally thought that the total displacement would have a negative effect on the discrimination performance because a change in interval magnitude of a fifth of a tone (the minor enharmonic diesis) might be much more noticeable when the interval is small; a fifth of a tone is a larger percentage of the entire frequency ratio for a smaller interval than for a larger one. Progressions with large displacements would most likely have several voices moving by leap and might be harder to discriminate. The opposite effect was observed, however. This may be due to the definition of 'voice' used in calculating the total displacement. A 'voice' was determined by the score; in other words, the voices were the written soprano, alto, tenor, and bass parts. Those excerpts with large total displacements tended to be excerpts with higher common tone retention, but large leaps that occurred as the result of a voice exchange. For instance, if tenor and alto both leap a perfect fourth in opposite directions to exchange pitches and avoid parallel perfect intervals (Figure 4-3), the chord itself has not changed but the voices have switched relative positions. When this happens in 31-TET and one of the two chords in the excerpts is dotted, all of the pitches are raised by a fifth of tone. This would then be compared to the static 12-TET version where the pitches do not move. Harmonically static motion in 12-TET compared to voices that move by discriminable amounts in 31-TET elicited higher performance, but tended to have high total displacements as a result of the voice exchanges. When total displacement was measured by proximity (a 'voice' is determined by proximity in pitch, not by written voice-parts), the conclusion did not change, although the significance of total displacement decreased (F(1,866)=6.54, p=0.011).

Figure 4-3. Voice-leading reduction of UD_10; voice-exchange



The absolute difference in harmonic distances as measured by the number of edge-flips on the 12-TET *Tonnetz* and the 31-TET *Tonnetz* had a significant effect. In a 12-TET environment, static harmonic activity (in a progression from D-major to D-major, for example) has a harmonic distance of 0. In a 31-TET environment, a harmonic motion from D-major to D-dot-major has a harmonic distance of 6. In general, progressions that would be harmonically distant in 12-TET remain harmonically distant in 31-TET. Progressions between undotted and dotted chords (or vice versa) that would be harmonically close if the dots were ignored (i.e., performing the music in a 12-tone environment) are much more distant on the 31-TET *Tonnetz*. For instance, C-major to A-minor has a harmonic distance of 1 on the 12-TET *Tonnetz*; a 31-TET version from C-major to A-dot-minor has a harmonic distance of 7. A distant 12-TET progression such as C-major to F♯-major has a harmonic distance of 4; a 31-TET version from C-major to F♯-dot-major has a harmonic distance of 5.

The difference in absolute distance is thus greater for chords that are harmonically closer in 12-TET, but one of the two chords is dotted in the 31-TET version. The alteration of raising or lowering one of two harmonically close chords by a fifth of a tone, then, increased discrimination performance. The 31-TET alteration of what would have otherwise been a harmonically close chord progression is thus more noticeable than alterations of distantly related chords. Callender and Rogers (2006) and Krumhansl (1998) have shown that harmonic distances of 1 on the 12-TET *Tonnetz* are rated as being perceptually close. The findings of Experiment 1 suggest that tuning alterations to otherwise perceptually close chords are more noticeable.

The length of the excerpts was found to have a negative effect on discrimination ability. This is most likely due to the limits of short-term memory. Performance in discrimination tasks is highest when the participant is able to rely on long-term and echoic memory cues. As the length of the excerpt increases, it becomes more difficult for the listener to retain an accurate impression of the stimuli in the echoic memory. Shorter excerpts make for closer comparisons because the trace impressions of the A, B, and X versions are relatively fresh in the memory.

Another factor that may affect discriminability is the quality of the voice-leading of each excerpt. Sixteenth-century counterpoint was subject to dozens of rules concerning the proper treatment of polyphonic voices. These principles were established by master composers and teachers and followed so as to produce quality compositions. David Huron has suggested recently that the principles of voice-leading exist because they preserve the individuality of parts in music.[221] To be heard as distinct voices in

[221]David Huron, "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles," *Music Perception* 19, no. 1 (Fall 2001): 1-64.

music, the contour of each part must segregate into its own auditory stream. Using perceptual principles, Huron has shown that the rules of voice-leading exist to promote segregation of voices and to discourage a blending or confusion of voices. Excerpt DU_07 breaks the voice-leading rule of consecutive fifths, which occurs when two voices create fifths by contrary motion, either by moving from the twelfth (octave plus a fifth) to the fifth or vice versa. Excerpt NE_10 also exhibits a voice crossing and voice-overlap to avoid octaves by similar motion (the effect is that the highest voice still forms an octave by similar motion with the tenor). Although the similar octave is avoided and is not realized in the score, the voice crossing and voice overlap may be confusing the segregation of the soprano and alto voices, giving the perceptual impression that the rule against octaves by similar motion has been violated. These two excerpts contained the most blatant voice-leading errors, but it is not possible to quantify the quality of the voice-leading. It is interesting to note, however, that these two excerpts elicited above-chance performance in the discrimination task.

The complexity of the musical stimuli used in this experiment makes it difficult to isolate effects. The excerpts were not normalized for loudness or balance between the voices; they were taken from expressive performances. There may also be an effect of the lyrics; the singers sang the appropriate lyrics for their parts, and so consonant and vowel sounds vary greatly between the excerpts. The engineering of the excerpts may also have had an effect. Although measures were taken to reduce differences between the 12-TET and 31-TET versions of the recordings, the post-production software could have changed more than the pitch of the recordings and introduced noticeable artifacts.

The asymmetry of performance for the DU and UD groups, in conjunction with the highly significant effect and large effect size of the difference in cents between the second chords of the excerpts, led to a second experiment that would tease out the extent to which the stimuli presentation was affecting discrimination performance. If the participants rely more heavily on a comparison across the versions of the second chords of the excerpt and ignore, to some extent, the first chords of the excerpt, then the nature of the discrimination task may be playing a role. In DU excerpts, the differences in the absolute pitch height between the 12-TET and 31-TET versions are greater for the first chord than for the second; the opposite is true of the UD excerpts. Experiment 2 investigated the extent to which listeners relied on the absolute pitch differences of the final chords in the discrimination task by retuning the 12-TET versions of each excerpt to alter the pitch height of the final chords.

EXPERIMENT 2

The goal of the second experiment was to determine the extent to which the nature of the experimental paradigm affected discrimination performance. In Experiment 1, it was determined that participants were significantly less able to discriminate between DU excerpts than between UD excerpts. We thought that this asymmetry may be attributable to the nature of the experimental design. Because the stimuli are between 2 and 6 seconds long, the final chord of each excerpt might have the strongest impression that participants retain in their memory. Thus, when the endings of the excerpts in each trial do not match in terms of pitch height (i.e., in the UD vs. U′U′ case), it is easier for participants to discriminate between the tuning systems. When the endings 'rhyme', as in the DU vs. U′U′, it is more difficult to discriminate between the excerpts because the significant points of comparison—the endings—are extremely similar in terms of pitch height. We therefore control for this in the current experiment by creating a complementary set of stimuli in which the 12-TET versions are tuned up by a fifth of tone; this effectively moves the pitches of the 12-TET scale closer to the corresponding dotted notes of the 31-TET scale, thus alternating the ending pitch height schemes to DU vs. D′D′ and UD vs. D′D′ (D′ represents the 12-TET version of the chord that has been raised by a fifth of a tone).

Method

Participants

A sample of participants similar to that of Experiment 1 was recruited for Experiment 2 from McGill University and the Montréal area. They were compensated for their time. All participants were highly musically trained; they were required to be in at least their second year of university-level music studies. They had to have normal hearing and be regularly practicing musicians. As in Experiment 1, percussionists and keyboardists were excluded. There were 7 male participants and 8 female participants, averaging 23 ± 5.3 years of age, with 15.8 ± 6.1 years of musical training.

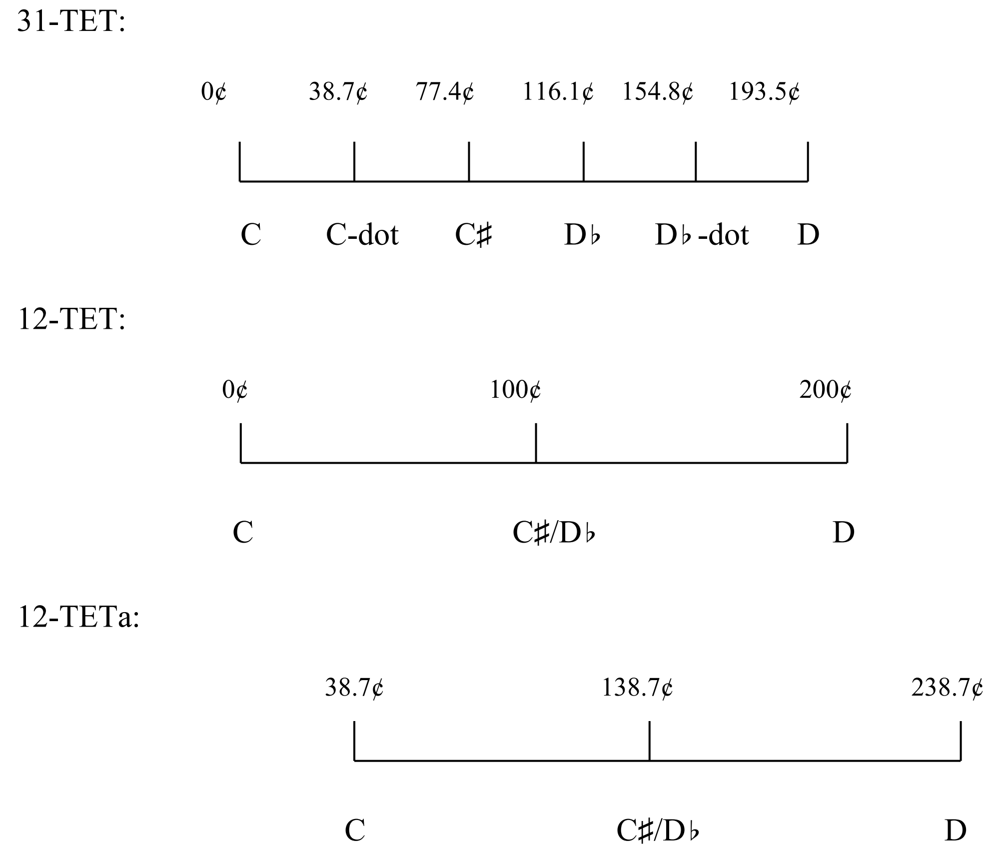
Apparatus

The apparatus for Experiment 2 was identical to that of Experiment 1.

Stimuli

The stimuli for this experiment included 20 of the 30 excerpts used in the Experiment 1, retaining only the UD and DU excerpts. These 20 excerpts were tuned in one of three ways: 31-TET, 12-TET, or 12-TETa, in which all of the pitches in the 12-TET version were raised by the minor enharmonic diesis, or one fifth of a tone. The purpose of producing a 12-TETa version was to alternate the 'rhyme' schemes of the DU and UD excerpts. Experiment 1 asked participants to compare UD with U′U′ and DU with U′U′, where U′ represents the 12-TET version, which is closer in terms of absolute pitch height to the undotted notes of 31-TET. Experiment 2 also included UD vs. D′D′ and DU vs. D′D′, where D′ represents the 12-TETa version, which is closer in terms of absolute pitch height to the dotted notes of 31-TET. Thus there were forty comparisons to make: twenty 31-TET vs. 12-TET (10 UD vs. U′U′ and 10 DU vs. U′U′), and twenty 31-TET vs. 12-TETa (10 UD vs. D′D′ and DU vs. D′D′). The 12-TET and 12-TETa versions were not directly compared. Figure 4-4 illustrates the differences between 12-TETa, 12-TET, and 31-TET.

Figure 4-4. Divisions of the whole tone (in cents) for 31-TET, 12-TET, and 12-TETa



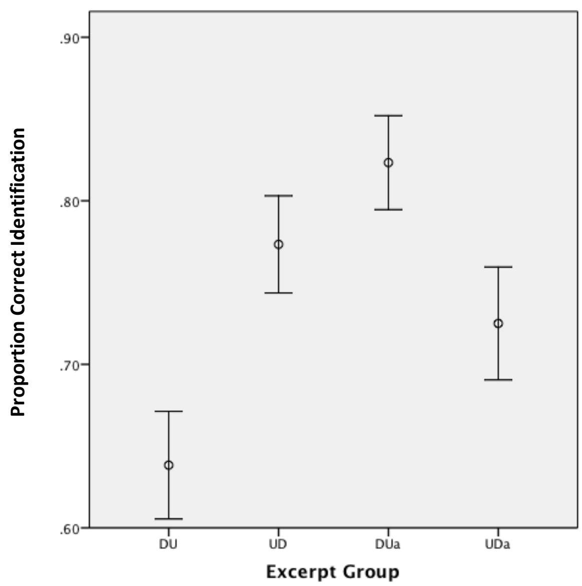
Procedure

The procedure for Experiment 2 was nearly identical to the one used in Experiment 1. Participants performed the ABX discrimination task with four blocks of 40 excerpts. There were 10 UD excerpts (UD. vs. U′U′), 10 DU excerpts (DU vs. U′U′), 10 DUa excerpts (DU vs. D′D′), and 10 UDa excerpts (UD vs. D′D′). The UD and UDa groups were identical in terms of musical content, as were the DU and DUa groups; they only differed in terms of which 12-TET version (12-TET or 12-TETa) was being compared to the 31-TET version. Each block took approximately 15 minutes to complete.

Results

In Experiment 2, we were interested in determining whether there was an effect of cognitive 'rhyme' in the presentation of the stimuli. Figure 4-5 shows the proportion of correct responses for each of the groups of excerpts with 95% confidence intervals. All four groups elicited performance that was significantly above-chance, as shown in Figure 4-5.

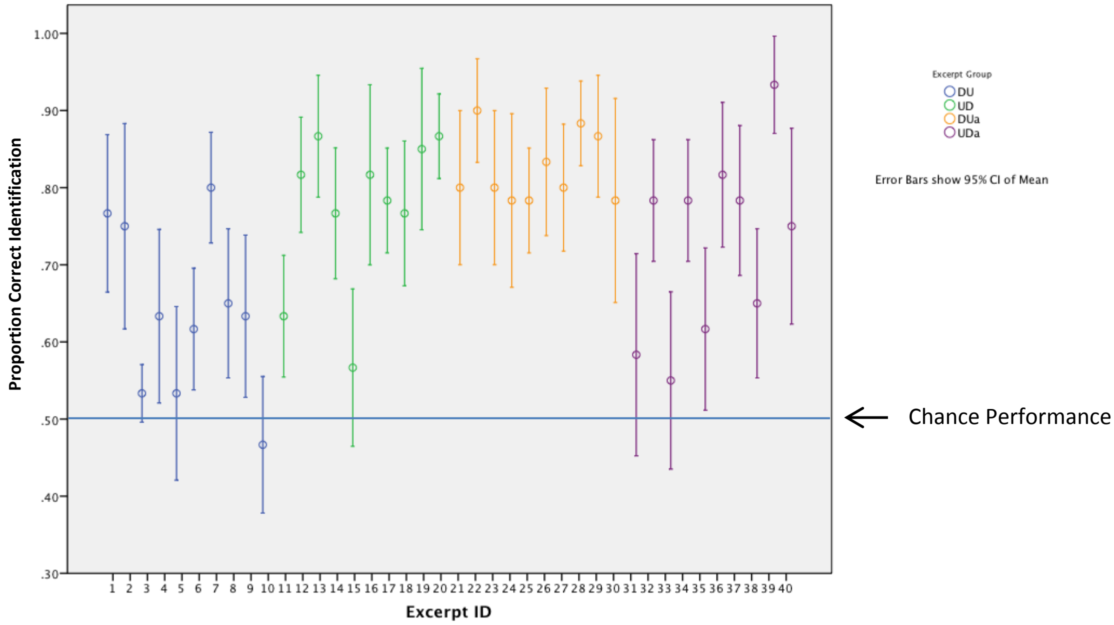
Figure 4-5. Proportion of correct responses by excerpt group in Experiment 2



The data were again analyzed using a generalized linear mixed model, in which excerpt group (DU, UD, DUa, and UDa) and individual excerpts nested within group were treated as fixed effects and participant ID was treated as a random effect. The model revealed that excerpt group and individual excerpt nested within excerpt group had significant effects on the odds of correct identification ($F(3,546)=18.66$, $p<0.0001$ for excerpt group; $F(3,546)=2.80$, $p<0.0001$ for effect of nesting). The DU excerpt group was significantly different from the DUa group ($F(1,546)=49.29$, $p<0.0001$), the UD group ($F(1,546)=27.29p<0.0001$), and the UDa group ($F(1,546)=12.73$, $p=0.0004$). Contrast parameterization revealed that the UD group was not significantly different in terms of performance from either the DUa group ($F(1,546)=3.51$, $p=0.0617$) or the UDa group ($F(1,546)=2.48$, $p=0.1160$). Performance for the DUa group and the UDa differed significantly ($F(1,546)=11.58$, $p=0.0007$). When the DU and DUa data were contrasted with the UD and UDa data, no significant difference in performance was observed ($F(1,546)=0.96$, $p=0.3266$). When the DU and UDa (ending 'rhyme') data were contrasted with the UD and DUa (no ending 'rhyme'), a highly significant difference was observed ($F(1,546)=36.29$, $p<0.0001$).

Figure 4-6 displays the proportion of correct response for each excerpt with 95% confidence intervals. The individual DU excerpts that elicited above-chance performance in Experiment 2 differed slightly from those found in Experiment 1. Of the DU excerpts, DU_01, DU_02, DU_04, DU_07, DU_08, and DU_09 elicited above-chance performance. Of the UD excerpts, only UD_05 did not elicit above-chance performance. All of the DUa excerpts elicited above-chance performance, but performance for UDa_01, UDa_03, and UDa_05 was not significantly above chance.

Figure 4-6. Proportion of correct responses by excerpt in Experiment 2



The results of Experiment 2 confirm the findings of Experiment 1; UD and DU groups both elicit above-chance performance. In addition, performance for the UDa excerpts and the DUa excerpts was also significantly above chance.

Discussion

The results of Experiment 2 provide evidence to support our hypothesis that there is an ending 'rhyme' effect. Discrimination ability significantly improved for the DU excerpts when the 12-TETa version was compared to the 31-TET version. This eliminated the ending rhyme so that the final chord of each version of the excerpt was dissimilar in terms of pitch height. Conversely, the UD performance did not significantly change when 12-TETa was compared to 31-TET.

The results of the Experiment 2 show that listeners can more easily discriminate between the two tuning systems when the pitch height of the final chords is dissimilar. This effect may be due to the limitations of short-term memory; because the excerpts are several seconds long with a brief pause between versions, the last thing heard leaves the strongest memory trace as it is freshest in the listener's mind. This facilitates the comparison process because the listener is able to recall pitch height more accurately when it is still in the recent short-term memory. The effect is not entirely symmetrical, meaning that the size of the effect observed between the DU and DUa groups would be as large as between the UD and UDa groups. Because the improvement in the DUa group was not as equally matched by drop in performance in the UDa groups, it cannot be assumed that the ending effect is symmetrical. Though the absence of an ending rhyme may improve discrimination performance, it is not the only factor. The UDa group has significantly higher odds of correct identification than the DU group, even though both groups exhibit the ending rhyme. The data suggest that discrimination performance is still better for the UDa and the UD groups than the DU group, and that the ending effect does not account entirely for this difference.

Conclusion

Evidence from the two experiments reported in this chapter support the hypothesis that musically trained listeners can generally detect the differences between 12-TET and 31-TET even when the enharmonic diesis is not involved. Discrimination performance is best for excerpts in which the tuning of the second chord of the excerpt differs greatly between 12-TET and 31-TET. The observed asymmetry in performance for the UD and DU groups of excerpts suggests that specific musical contexts may affect discrimination performance. The analysis of musical parameters supports this hypothesis; total displacement, absolute difference in distances on the *Tonnetze*, and the difference in cents between the second chords of the excerpts were all found to have a significant positive effect on performance. Excerpt duration had a significant negative effect. The post-hoc analysis of specific pairs of excerpts also provided evidence that voice-leading patterns and directionality may overshadow discriminable acoustical differences.

The results of Experiment 2 confirmed that participants relied heavily on the difference in pitch height between the final chords of the excerpts, but this ending effect was not symmetrical and could not wholly account for the differences in performance between the UD and DU groups. Future work along these lines is necessary to isolate and simplify the individual voices of the stimuli to target the psychological processes involved.

CONCLUSION

Nicola Vicentino represents the musical avant-garde of sixteenth-century Italy; his musical philosophy emphasized emotional expression in music and established the ear of the listener as the ultimate judge of a composition. In the first chapter, I provide biographical information to contextualize Vicentino's position in the sixteenth-century Italian musical environment. I review the extant works by Vicentino and discuss the philosophical, theoretical, and practical ideas found in his treatise, *Ancient Music Adapted to Modern Practice.* Vicentino believed that the affective powers of music are summoned by compositional resources and choices, chiefly the intervals employed. Vicentino adapts the ancient Greek theory of genera as a source of various interval sizes, including the microtonal interval of the minor enharmonic diesis—an interval one fifth of tone in size. Vicentino developed a tuning system that equally divides the octave into thirty-one minor enharmonic dieses. Vicentino claims that the affect of the minor enharmonic diesis is sweet and smooth, and that listeners are moved by its subtle nuance.[222] The listeners' perceptions and emotions were always at the forefront of Vicentino's theoretical and practical discussions. Therefore, an empirical investigation of the perception of Vicentino's enharmonic music is not contradictory to his musical thinking.

In Chapter Two I analyze and characterize the voice-leading and harmonic features of Vicentino's compositional writing in terms of the use of the minor enharmonic diesis. I outline the voice-leading and harmonic properties available in Vicentino's 31-tone tuning system, and demonstrate that Vicentino restricts his writing to only a handful of the possibilities available in his system when incorporating the

[222]Vicentino, 67-68; 203.

enharmonic diesis. From any given chord, there are 23 possible harmonic motions that can produce the step of the minor enharmonic diesis, yet Vicentino only uses a portion of these possibilities. These enharmonically-related harmonic motions are always between undotted and dotted chords in Vicentino's music, even though it is possible to have enharmonic motions between chords that do not involve dotted pitches. Vicentino only uses the intervals he describes in *Book I on Music Practice*, and never the 31-TET inversionally-related intervals. In undotted-to-dotted enharmonically-related chord progressions, Vicentino favors root motion by ascending minor enharmonic diesis, and this small step is almost always realized in the score. In dotted-to-undotted enharmonically-related chord progressions, Vicentino favors root-motion by descending proximate fifth, and less frequently realizes the step of the minor enharmonic diesis in the score. Thus, undotted-to-dotted and dotted-to-undotted progressions are characterized by different harmonic root-motions and voice-leading patterns.

In Chapter Three I review the relevant psychoacoustical literature and develop the hypothesis that musically trained listeners are able to hear the microtonal inflections found in Vicentino's enharmonic writing. Although the psychoacoustical research has shown that musicians can detect differences in pitch height and interval size of the same magnitude as those found between 12-TET and 31-TET, the empirical data reported in Chapter Four show that in a complex musical listening experience these differences are not always perceptible. Certain musical and acoustical features of Vicentino's music seem to highlight the differences and encourage discrimination performance; larger displacements, greater absolute differences on the 12-TET and 31-TET *Tonnetze*, greater differences in cents between the second chords of the excerpts, and shorter durations all encourage higher correct-response rates. Analyses comparing pairs of excerpts that share voice-leading patterns, illustrate identical harmonic chord content, or exhibit mirror-image voice-leading and harmonic progressions demonstrate that voice-leading considerations may overpower acoustical differences. I also found that the design of the experiment had a significant effect on discrimination ability; participants relied heavily on the differences in pitch height between the final chords of the excerpts when making judgments. This result is most likely due to limitations of short-term memory in the discrimination task; the final chord of each excerpt leaves the most recent impression of the stimuli for comparison. The effect of the difference in absolute pitch height between the final chords of the excerpts was not symmetrical, however; it was found that while performance on DU excerpts significantly improved when the 12-TET versions were retuned in order for the final chords to match more closely, performance on the UD excerpts did not equally decrease. These findings suggest that the musical contexts of the UD excerpts may have a stronger positive effect on discrimination, whereas the musical contexts inherent to the DU group mask the differences between the tuning systems.

Through analytical and empirical study of Vicentino's use of the minor enharmonic diesis, I show that the nuances of Vicentino's microtonal tuning system are generally (but not always) perceptible to trained musicians. This study provides preliminary information for further investigation into the perception of different musical tuning systems. Future work could explore the perception of various tuning systems in different styles of music, and investigate the behavioral responses to these diverse, but often overlooked, musical resources.

BIBLIOGRAPHY

Aristotle. "2. Aristotle: From the *Politics*." In *Source Readings in Music History from Classical Antiquity Through the Romantic Era.* Edited by W. Oliver Strunk. New York: Norton, 1950.

Aristoxenus. "Book II." In *The Harmonics of Aristoxenus*, edited by Henry S. Macran, 187-208. Oxford: Clarendon Press, 1902.

Barbour, J. Murray. *Tuning and Temperament: A Historical Survey.* East Lansing, MI: Michigan State Press, 1951.

Bent, Margaret. *Composition, Counterpoint, and* Musica Ficta. New York: Routledge, 2002.

Berger, Karol. *Theories of Chromatic and Enharmonic Music in Late 16th Century Italy*. Edited by George Buelow. Studies in Musicology, no. 10. Ann Arbor: UMI Research Press, 1980.

Blackburn, Bonnie J., Edward E. Lowinsky, and Clement A. Miller, eds. *A Correspondence of Renaissance Musicians*. New York: Oxford University Press, 1991.

Boethius. "Boethius: From the *De Institutione Musica*." In *Source Readings in Music History from Classical Antiquity Through the Romantic Era.* Edited by W. Oliver Strunk. New York: Norton, 1950.

_____. *Fundamentals of Music*. Translated by Calvin M. Bower. Edited by Claude V. Palisca. New Haven: Yale University Press, 1989.

Boomsliter, Paul C., and Warren Creel. "Extended Reference: An Unrecognized Dynamic in Melody." *Journal of Music Theory* 7, no. 1 (Spring 1963): 2-22.

Burns, Edward M. "Intervals, Scales, and Tuning." In *The Psychology of Music*. 2nd ed., edited by Diana Deutsch, 215-64. San Diego: Academic Press, 1999.

Burns, Edward M., and Shari L. Campbell. "Frequency and Frequency-Resolution by Possessors of Absolute and Relative Pitch: Examples of Categorical Perception?" *Journal of the Acoustical Society of America* 96, no. 5. (November 1994): 2704-19.

Burns, Edward M., and W. Dixon Ward. "Categorical Perception—Phenomenon or Epiphenomenon: Evidence from Experiments in the Perception of Melodic Musical Intervals." *Journal of the Acoustical Society of America* 63, no. 2 (February 1978): 456-68.

Callender, Clifton, and Nancy Rogers. "Judgments of Distance Between Trichords." Paper presented at the 9th Annual Conference on Music Perception and Cognition. Alma Mater Studiorum University of Bologna, August 22-26, 2006.

Cohn, Richard. "Introduction to Neo-Riemannian Theory: A Survey and a Historical Perspective." *Music Theory Spectrum* 42, no. 2 (Autumn 1998): 167-80.

_____. "Maximally Smooth Cycles, Hexatonic Systems, and the Analysis of Late-Romantic Triadic Progressions." *Music Analysis* 15, no. 1 (1996): 9-40.

Dean, C. B., and Jason D. Nielsen. "Generalized Linear Mixed Models: A Review and Some Extensions." *Lifetime Data Anal* 13 (2007): 497-512.

Dowling, W. Jay, and Dane L. Harwood. "Musical Scales." In *Music Cognition*, 90-123. Academic Press Series in Cognition and Perception. San Diego: Academic Press, 1986.

Einstein, Alfred. *The Italian Madrigal.* Vol. 1. Princeton: Princeton University Press, 1949.

Hall, Donald E., and Joan Taylor Hess. "Perception of Musical Interval Tuning." *Music Perception* 2, no. 2 (Winter 1984): 166-95.

Handel, Stephen. "Phonemes: Notes and Intervals." In *Listening: An Introduction to the Perception of Auditory Events*, 265-319. Cambridge, MA: MIT Press, 1989.

Houtsma, A. J. M. "Discrimination of Frequency Ratios." [Abstract] *Journal of the Acoustical Society of America* 44 (July 1968): 383.

Huron, David. "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles." *Music Perception* 19, no. 1 (Fall 2001): 1-64.

Huygens, Christian. *Le cycle harmonique (Rotterdam 1691); Novus cyclus harmonicus (Leiden 1724) / Christiaan Huygens; with Dutch and English translations*. Edited and translated by Rudolf Rasch. Utrecht: Diapason Press, 1986.

Kaufmann, Henry W. *The Life and Works of Nicola Vicentino.* Vol. 11, *Musical Studies and Documents* [n.p.]: American Institute of Musicology, 1966.

Kidger, David M. *Adrian Willaert: A Guide to Research*. New York: Routledge, 2005. http://lib.myilibrary.com?ID=20440.

Krumhansl, Carol L. "Perceived Triad Distance: Evidence Supporting the Psychological Reality of Neo-Riemannian Transformations." *Journal of Music Theory* 42, no. 2 (Autumn 1998): 265-81.

Lowinsky, Edward E. "The Musical Avant-Garde of the Renaissance or: The Peril and Profit of Foresight." In *Art, Science and History in the Renaissance,* edited by Charles S. Singleton, 113-62. Baltimore: Johns Hopkins Press, 1967.

Main Donald, John H., and W. John Braun. *Data Analysis and Graphics Using R: An Example Based Approach.* New York: Cambridge University Press, 2010.

Makeig, Scott. "Affective Versus Analytic Perception of Musical Intervals." In *Music, Mind, and Brain: The Neurophysiology of Music*, edited by Manfred Clynes, 227-50. New York: Plenum Press, 1982.

McKinney, Timothy. *Adrian Willaert and the Theory of Interval Affect: The Musica Nova Madrigals and the Novel Theories of Zarlino and Vicentino*. Burlington, VT: Ashgate, 2009.

Miyazaki, Ken'ichi. "Absolute Pitch as an Inability: Identification of Musical Intervals in a Tonal Context." *Music Perception* 11, no. 1 (Fall 1993): 55-72.

Monelle, Raymond. "The Search for Topics." In *The Sense of Music: Semiotic Essays*, 14-40. Princeton: Princeton University Press, 2000.

Moore, Brian C.J. "Pitch Perception." In *An Introduction to the Psychology of Hearing*. 2nd ed., 115-49. New York: Academic Press, 1982.

Moore, Brian C. J., and Geoffrey A. Moore. "Discrimination of the Fundamental Frequency of Complex Tones with Fixed and Shifting Spectral Envelopes by Normally Hearing and Hearing-impaired Subjects." *Hearing Research* 182 (2003): 153-63.

Moran, Helen, and Carroll C. Pratt. "Variability of Judgments on Musical Intervals." *Journal of Experimental Psychology* 9 (1926): 452-500.

Morris, Robert D. "Voice Leading Spaces." *Music Theory Spectrum* 20, no. 2 (Autumn 1998): 175-208.

Noorden, Leon van. "Two Channel Pitch Perception." In *Music, Mind, and Brain: The Neuropsychology of Music*, edited by Manfred Clynes, 251-70. New York: Plenum, 1982.

Palisca, Claude V. *Music and Ideas in the Sixteenth and Seventeenth Centuries.* Vol. 1, *Studies in the History of Music Theory and Literature*. Edited by Thomas J. Mathiesen. Chicago: University of Illinois Press, 2006.

Parncutt, Richard. *Harmony: A Psychoacoustical Approach.* Edited by Manfred R. Schroeder. New York: Springer, 1989.

Perkins, Leeman. “Towards a Theory of Text-Music Relations in the Music of the Renaissance.” In *Binchois Studies*, edited by Andrew Kirkman and Dennis Slavin, 313-29. New York: Oxford University Press, 2000.

Rakowski, Andrzej. “Intonation Variants in Musical Intervals in Isolation and in Musical Contexts.” *Psychology of Music* 18, no. 1 (1990): 60-72.

Rakowski, Andrzej, and Andrzej Miskiewicz. “Deviations from Equal Temperament in Tuning Isolated Musical Intervals.” *Acoustical Archives* 10, no. 2 (1985): 95-104.

Rasch, Rudolf. “Perception of Melodic and Harmonic Intonation of Two-Part Musical Fragments.” *Music Perception* 2, no. 4 (Summer 1985): 441-58.

Siegel, Jane A., and William Siegel. “Absolute Identification of Notes and Intervals by Musicians.” *Perception and Psychophysics* 21, no. 2 (1977): 143-52.

Silbiger, Alexander. *Introduction to Four Enharmonic Madrigals*, *by Nicola Vicentino*. Edited by Alexander Silbiger. Houten: Diapason, 1990.

Snyder, Bob. *Music and Memory: An Introduction*. Cambridge, MA: MIT Press, 2001.

Straus, Joseph. “Uniformity, Balance, and Smoothness in Atonal Voice Leading.” *Music Theory Spectrum* 25, no. 2 (2003): 305-52.

Twining, Thomas. *Aristotle’s Treatise on Poetry, Translated: With Notes on the Translation, and on the Original; and Two Dissertations, on Poetical, and Musical Imitation* [Originally published in 1789]. Westmead, Farnborough, Hants, England: Gregg International Publishers Limited, 1972.

Vicentino, Nicola. *Ancient Music Adapted to Modern Practice.* Translated by Maria Rika Maniates. Edited by Claude V. Palisca. New Haven: Yale University Press, 1996.

Vos, Joos. “Purity Ratings of Tempered Fifths and Major Thirds.” *Music Perception* 3 (1986): 221-57.

_____. “Subjective Acceptability of Various Regular Twelve-tone Tuning Systems in Two-part Musical Fragments.” *Journal of the Acoustical Society of America* 83, no. 6 (June 1988): 2383-92.

Vos, Joos, and Ben G. van Vianen. “Thresholds for Discrimination Between Pure and Tempered Intervals: The Relevance of Nearly Coinciding Harmonics.” *Journal of the Acoustical Society of America* 77, no. 1 (January 1985): 176-87.

Walker, D.P. “Musical Humanism in the 16th and Early 17th Centuries.” *Music Review* 2 (1941): 1-13, 111-21, 220-27.

_____. *Studies in Musical Science in the Late Renaissance.* London: Warburg Institute, 1978.

Ward, W. Dixon, and Daniel W. Martin. "Psychophysical Comparison of Just Tuning and Equal Temperament in Sequences of Individual Tones." *Journal of the Acoustical Society of America* 33, no. 5 (May 1961): 586-88.

West, Brady, Kathleen B. Welch, and Andrzej T. Galecki. *Linear Mixed Models: A Practical Guide Using Statistical Software.* Boca Raton: Chapman and Hall/CRC, 2007.

Wier, C. C., W. Jesteadt, and David M. Green. "Comparison of Method of Adjustment And Forced-choice Procedures in Frequency Discriminations." *Journal of the Acoustical Society of America* 57 (1975): S27(A).

Wild, Jonathan, and Peter Schubert. "Historically Informed Retuning of Polyphonic Vocal Performance." *Journal of Interdisciplinary Music Studies* 2, no. 1 (2008): 121-139.

TABLE OF APPENDICIES

Musical Scores and Analysis (excerpts indicated with brackets)

Madonna, il poco dolce


(NE_04)
NE_05
S.
A.
T.
B.
- po lun - - go pian - to, il
po lun - go pian - to il trop - po lun -
trop - po lun - go pian - to, il trop - po lun -
po lun - go pian - - to,
E- E+ F+ F#- G- G+ E+ E- D+ D-
20
DU_04
trop - po lun - go pian - to,il trop - po lun - go pian - to,
- go pian - to, il trop - po lun - go
- go pian - to, il trop - po lun - - go pian - to,
il trop - po lun - go, pian -
D+ D- A+ A- F+6 Bb+ B- G× C+ A+ D- D+ Eb+ C6-
25
UD_05
M'han - no ri - dot - toà tan - to, Che'l pian - ger
pian - to, M'han - no ri - dot - toà tan - to,
M'han - no ri - dot - toà tan - to, M'han - no ri - dot - toà tan -
- to, M'han - no ri - dot - toà tan - to,
E- G- A+6 A-6 D- D+ D+ G+ G- D+ G- G+


29
DU_03
NE_06
S.
semp - pr'e sos - pi - rar, Che'l pian - ger sem - - pr'e
A.
Che'l pian - ger sem - pr'e sos - pi - rar, Che'l pian - ger sem - pr'e
T.
to, Che'l pian - ger sem - pr'e sos - pi - rar, Che'l pian - ger
B.
Che'l pian - ger sem - pr'e sos -
D+ C6+ E+ A- A+ Bb+ G-6 B- C+ A- F+
33
NE_07
sos - pi - rar mi'è ca - - ro,
e sos - pi - rar, mi'è ca - ro, Che'l pian - ger
sem - pr'e sos - pi - rar, mi'e ca - ro, Che'l pian - ger
- pi - rar mi'e - ca - ro, Che'l pian -
D- Bb+ G- D- D+ G+ (C+) D+ D+ Bb6+
37
NE_08
UD_06
DU_05
Che'l pian - ger sem - pr'e sos - pi -
sem - pr'e sos - pi - rar, Che'l pian - ger sem - pr'e
sem - - pr'e sos - pi - rar miè ca - ro, e sos - pi -
ger sem - - pre e sos - pi -
Eb+ C-6 C+6 E- F+ G- E- G+ D+ D+ Bb6+


(DU_05)
NE_09
41
S.
rar mi'è ca - - - ro.
A.
sos - pi - rar, mi'è ca - ro.
T.
rar mi'è ca - ro.
B.
rar mi'è ca - ro.
Eb+ D+ D- A+ D+

Musica prisca caput


13
S.
- ne-bris mo - do sus - tu - lit al - - tis, Dul -
A.
- ne-bris mo - do sus - tu - lit al - tis, sus - tu - lit al - tis, Dul - ci -
T.
- ne-bris mo - do sus - tu - lit al - tis, Dul - ci - bus
B.
- ne-bris mo - do sus - tu - lit al - tis, Dul - ci -
F+ C+ F+ C+ F+ Bb+ G+
17
S.
- ci - bus ut nu - me-ris, Dul - ci - bus ut nu - me -
A.
bus ut nu - me - ris, Dul - ci bus ut nu - me -
T.
ut nu - mr - ris Dul - ci - bus ut nu - me -
B.
bus ut nu - me-ris, Dul - ci - bus ut nu - me -
C- C+ F+ D- D+ G+ G- G+ C- C+
21
S.
ris pris - cis cer - tan - ti - a fac - tis, Dul - ci - bus
A.
ris pris - cis cer - tan - tia - a fac - tis, Dul - ci - bus
T.
ris pris - cis cer - tan - ti - a fac - tis, Dul - ci - bus
B.
ris pris - cis cer - tan - ti - a fac - tis, Dul - ci - bus
F+ D+ G+ G- D+ G+ A♭+

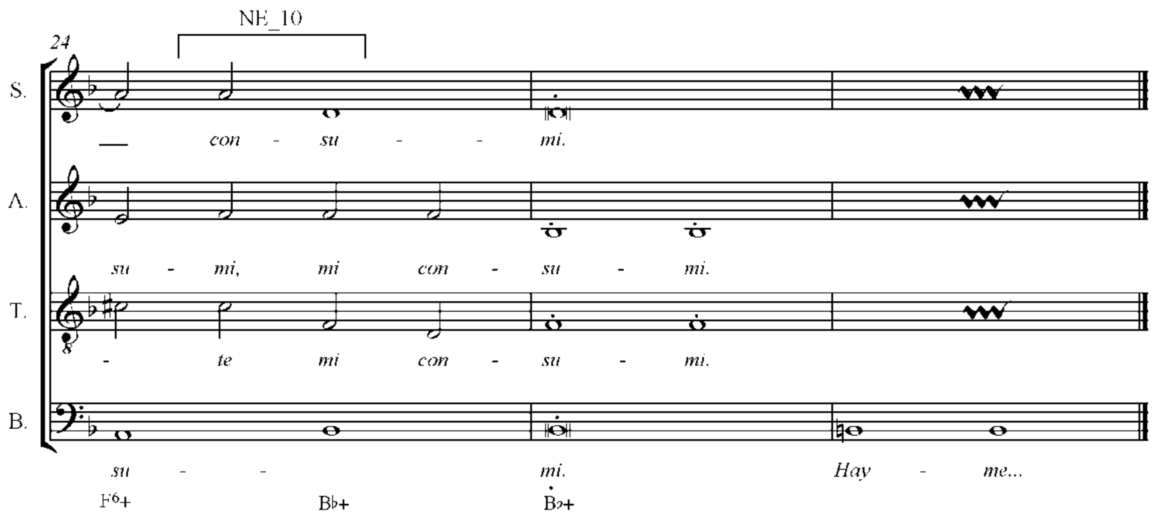

25
S.
ut nu - me-ris pris - cis cer - tain - ti - a fac - - tis,
A.
ut nu - me - ris pris - cis cer - tan - ti - a fac - tis, Fac -
T.
ut nu - me-ris pris - cis cer - tan - ti - a fac - -
B.
ut nu - me-ris pris - cis cer - tan - ti - a fac - tis,
A- A+ B♭+ B+ B- C+ F+
29
S.
Fac - ta tu - a Hyp - po - li - te, Fac - ta tu -
A.
ta tu - a, Hyp - po - li - te Fac - ta tu -
T.
-tis, Fac - ta tu - a, Hyp - po - li - te Fac - ta - tu -
B.
Fac - ta tu - a, Hyp - po - li - te, Fac - ta tu -
G+ C+ B⁶dim C+ C+ F+ B♭+ B♭+
34
S.
a. Hyp - po - li - te, ex - cel - sum su - per ae -
A.
a, Hyp - po - li - te, ex - cel - sum su - per ae -
T.
a Hyp - po - li - te, ex - cel - sum su - per ae -
B.
a, Hyp - po - li - te, ex - cel - sum su - per ae -
G+ G+ C+ C+ F+ D+


UD_07
UD_08
39
S.
the-ra mit - tat, Fac - ta tu - - a, Hyp - po - li-
A.
the-ra mit - tat, Fac - ta tu - a, Hyp - po - li - te,
T.
the-ra mit - tat, Fac - ta - tu - a, Hyp - po - li - te,
B.
the-ra mit - tat, Fac - ta tu - a, Hyp - po - li - te,
D- A+ D+ F+ F+ D+ G- B♭+ G- G+
DU_06
UD_09
DU_07
44
S.
te, ex - cel - sum su - per ae - the - ra mit - tat.
A.
ex - cel - sum su - per ae - the-ra mit - - tat.
T.
ex - cel - sum su - per ae - the - ra mit - tat.
B.
ex - cel - sum su - per ae - the-ra mit - - tat.
G+ C+ A- A+ A+ D+

Soav'e dolc'ardore

Dolce mio ben


13
S.
men - te Che tan - to dol - ce - men - te mi con -
A.
Che tan - to dol - ce-men - te fan - no che dol - ce -
T.
dol - ce - men - te, Che tan - to dol - ce - men - te mi con -
B.
tan - to dol - ce - me - te, Che tan - to dol - ce - men - te
B♭+ G- G+ G- A♭+ A♭+ D♭+ B♭- B♭+
17
S.
su - mi, Che tan - to dol - ce - me - te fan - no che
A.
men - te, Che dol - ce - men - te mi con - su - mi, mi con -
T.
su - mi, Che tan - to dol - ce -
B.
fan - no che mi con - su - mi, Che dol - ce - men - te
E♭+ C6+ G+ G+ C+ A- A+ D+
21
S.
dol - ce - men - te mi con - su - mi, mi
A.
su - mi, fan - no che dol - ce - men - te mi con -
T.
men - te mi con - su - mi, dol - ce - men -
B.
mi con - su - mi, mi con -
D+ G+ G- C- C+ D+ D- A- A+


NE_10
24
S.
— con - su - - mi.
A.
su - mi, mi con - su - mi.
T.
- te mi con - su - mi.
B.
su - - mi. Hay - me...
F6+ B♭+ B♭+