DISSONANCE WITHIN DISCORDANCE: THE INFLUENCE OF EQUAL TEMPERAMENT ON THE AESTHETIC EVALUATION OF SECOND VIENNESE ATONALITY

by

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THESIS ABSTRACT

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This thesis draws a distinction between the nature of intonation and tuning in tonal and atonal music. I describe the musical aesthetic of the Second Viennese School as conditioned by and born out of equal temperament. In contrast, tonal music often employs intonation that varies from equal temperament significantly. These contrasting notions are explored through an examination of two historically opposed ideologies that concern consonance and dissonance. This thesis suggests that the aesthetic evaluation of twelve-tone atonal music may be informed by its theoretical limitation to the equally tempered scale. It is *dissonance within discordance*, referring to a preponderance of dissonant harmony within a dissonant medium of tuning. Supplementary audio files are included to support this thesis. Examples 1-9 compare various chords and progressions in just intonation and equal temperament. Example 10 is a midi version of “Yesterday I Heard the Rain,” arranged by Brent Graham, in equal temperament.

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CHAPTER I

INTRODUCTION

The research presented here is principally concerned with the relationship between just intonation, equal temperament, and atonal music (specifically, twelve-tone music). More generally, it is concerned with what might be called the "philosophy of music theory." Another way of putting it, as some theorists have, is the "analysis *of* analysis." This thesis includes an examination of the relationship between dodecaphonic music and equal temperament, with the intention of elucidating an oft-overlooked paradox. I want to explore the relative "fit" of just intonation to tonal and twelve-tone music. Also, I want to evaluate the aesthetic assertions that could be made as a result of my investigation of temperament's fit with these different musical styles. Though this inquiry is influenced by the field of music cognition, perception, and psychology, the nature of the arguments considered are typically epistemologically oriented. The disciplines of the sources presented vary from historical and philosophical accounts to empirical contributions from musical acoustics and psychological research. Crucial findings from certain musically-inclined scientific publications will be provided to support the arguments.

I do not intend to make arguments in favor of specific value systems, aesthetic plateaus or other crude subjectivities; just because a musical phenomenon may be more "dissonant" or "discordant" does not make it aesthetically inferior or "imperfect." If anything, the departure that twelve-tone music takes from just intonation is arguably one of the most compositionally innovative aesthetics to have been developed. Thus, though it may seem that I am describing dodecaphonic music as “unnatural,” I in no way intend to suggest that it is “inferior.” On the contrary, the peculiarity of atonal music—in regards to its marriage to equal temperament—needs further inquiry. The root of atonal music in an inherently discordant medium (the equally tempered scale) may explain many of its qualities that many listeners find intriguing; it also may provide an idea as to why the "average"—even highly trained—listener perceives it as harsh and unpleasantly dissonant.

The heart of this thesis centers around the assumption that dodecaphonic music is often considered aesthetically dissonant. This is often because harmonies realized within a dodecaphonic piece—which for Schoenberg and Webern at least, tend to avoid familiar tonal sonorities and references—bear a weaker relationship to simple, just intervals than tonal harmonies do, even though these harmonies are usually written for and performed in the same tuning system: equal temperament. How can this be possible? By way of tonality's incessant emphasis on diatonic collections that closely—though still through compromise—mirror the simplest, just intervals. Though equally-tempered thirds are very wide in comparison to the just major third (about 14 cents difference), tonal music continually emphasizes octave doubling and "perfect" fifths, the latter of which is the nearest to the whole ratio it reflects, with the exception of the former (the 2:1 octave). Because the essence of the twelve-tone aesthetic specifically espouses an eschewal of tonal references, the “reflection” twelve-tone equally-tempered tonal music “captures” of just intervals is further compromised. A new degree of dissonance has been introduced in Second Viennese twelve-tone atonality, not just merely the "emancipation of dissonance," cited by Schoenberg himself, but a level of discordance related to the tuning system it was born out of. This notion of further dissonance within a framework of discordance (or, the inexact replication of just intervals through equal temperament) may provide insight into what leads to the great, seemingly unparalleled dissonance atonality projects. Dodecaphonic atonality is dissonant not only because of the complete departure from tonality its precepts embark—it is even more dissonant due to its conditioned medium of twelve-tone equal temperament, which is in turn a dissonant representation of justly intonated intervals.

Before continuing to an examination of the previous literature relevant to this topic, further details surrounding this idea must be brought under scrutiny. What is the significance of just intonation? How does twelve-tone equal temperament relate to just intonation? Do performers even realize justly tuned intervals, since the piano and other equally-tempered instruments are so prominent, and have been for at least a century? If twelve-tone equally-tempered dodecaphony may be *physiologically dissonant*, what does this mean for dodecaphonic music?

This leads to the final question proposed above: how can just intonation - the intoning and performance of simple, non-beating ratios - be related to a musical aesthetic such as twelve-tone atonality? If singing (and playing, for string and wind instruments) pure intervals is somehow innate for musicians, it is clear that twelve-tone equal temperament—the tuning system to which much of the Western-European common-practice repertoire is prescribed to—is a significant compromise. Still, it is a compromise that nonetheless bears a degree of resemblance to pure, non-beating intervals; those that correspond to the overtones within the harmonic series. The pure 2/1 octave is retained (most ears would not stand it otherwise), and the equally tempered fifth is very close to its "true" 3/2 ratio. Of course, twelve-tone atonal music uses these intervals as well (though, sparingly, depending on the piece). However, as mentioned previously, I contend that because tonal music—even post-tonal and freely atonal music that has tonal references—centers itself around these whole ratio, intervallic approximations (with an emphasis on pitch centricity, diatonicism, chromaticism for the purpose of diatonicism, modulation, etc.), the listener's experience of dissonance is mitigated. In a dodecaphonic work which expressly avoids such diatonicism and tonal harmonies, the basic reference equally-tempered tonality makes to pure intervals—which can be directly related to the overtones of the harmonic series—is lost. This contributes significantly to the aesthetic evaluation—often flat-out aural rejection—of many twelve-tone works, even among listeners that are trained, practicing, professional musicians. In such an aesthetic, it would seem that the role of just intonation is completely lost, and thus, the role of pure intervals further undermined. This thesis attempts to address these questions. There is continued debate regarding the role of the harmonic series in the development of the triad, and much of what has made this a curious inquiry is the lack of consensus concerning human predisposition towards intervals that closely resemble the overtones contained within the harmonic series.

CHAPTER II

CONSONANCE AND DISSONANCE

> From this fact it is clear that musical practice, composition, and theory can never disregard the conditions laid down by the facts of the existence of pure intervals and the desire of the ear to perceive them wherever possible in tonal combinations.[1]

The debate over what constitutes consonance and dissonance is as old as the music-theoretic tradition itself. Indeed, most historical narratives begin with Pythagoras; the ancient fable of his intervallic discovery remains a legend that is more than well-known. The Greeks, being the first known civilization to embrace the marriage of mathematics and musical sounds, were also the original arbiters of the consonance-dissonance distinction. By understanding and representing the concept of a musical interval as a whole ratio, consonance was discretely defined for the first time.

An involved discussion of tuning systems, along with the general problem of tuning, is not within the purview of this thesis. It is certainly worth mentioning, however, that this problem of tuning persists in the world of music to this very day. There are still a multiplicity of arguments and opinions among musicians and scholars as to what exactly constitutes musical consonance and musical dissonance. The rest of this chapter will mention those arguments and opinions that are relevant to this thesis before continuing to explore the aforementioned notion of dissonance within discordance.

This chapter's opening excerpt, from Hindemith's *Craft of Musical Composition* illustrates one side of a dichotomy to which many theorists—past and present—have adhered. This dichotomy concerns a very general question: what exactly *is* musical

1 Paul Hindemith, *Craft of Musical Composition, Book I,* 4th ed., trans. by Arthur Mendel (New York: Associated Music Publishers, 1945), 45.

consonance? What about dissonance? How do we, as sentient human beings, hear and understand the distinction between the two? It is a very complex question that has many facets, many of which are relevant to music theory, and many of which are relevant to the discipline of physics. In short, both scientists and music theorists find themselves similarly opposed on a proper definition of consonance and dissonance. Hermann von Helmholtz and Carl Stumpf are examples of scientists falling into this dichotomy, while Paul Hindemith and Arnold Schoenberg exemplify a similar tendency as theorists.

Scientific Consonance and Dissonance

In considering a more scientific understanding of what exactly constitutes consonance and dissonance, it is important to mention the work of the famous 19th-century German scientist, Hermann von Helmholtz (1821-1894). Helmholtz's seminal work, *On the Sensations of Tone as a Physiological Basis for the Theory of Music,* unquestionably remains one of the most significant contributions to the study of acoustics, physiological acoustics, and their relation to the historical tenets of the music-theoretic tradition.[2] In *Sensations of Tone*, Helmholtz outlines an extensive, “mechanistic” explanation for the consonance-dissonance distinction, which he in turn uses to explain the foundations of innate human preference for consonances over dissonances. Helmholtz's theory of consonance concerns the presence of beating, and is rooted in earlier conceptions of consonance—coincidence theories—based on the coincidence of partials between multiple frequencies. Simply put, "...he conceived of

2 Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, 2nd English ed., trans. by Alexander J. Ellis (New York: Dover, 1954)

dissonance as a sensation of roughness caused by the interference patterns of the sound waves."[3]

Arthur H. Benade provides a straightforward, scientific definition in his *Fundamentals of Musical Acoustics*:

> When two sinusoidal driving forces that have roughly equal frequencies are brought to act upon a single object, they alternately aid and counteract one another as the two oscillations run in and out of step. The swelling and shrinking of the resulting vibration amplitude is called beating. It takes place at a frequency equal to the difference between the two driving frequencies.[4]

Below is a graphic depiction of beating (Figure 1).[5]

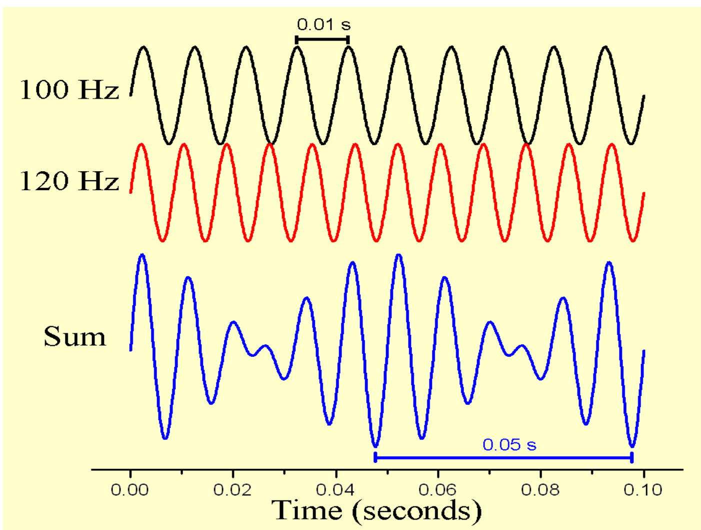

Fig. 1: Graph demonstrating acoustical beating between two sine waves. In adding the two frequencies together—which only differ by 20 hz—an "irregular" waveform results, manifesting itself as perceived "roughness," or "dissonance."

3 Burdette Green and David Butler, "From Acoustics to *Tonpsychologie," The Cambridge History of Western Music Theory*, ed. Thomas Christensen (New York: Cambridge University Press, 2002, 260.

4 Arthur H. Benade, *Fundamentals of Musical Acoustics*, 2nd ed. (New York: Dover, 1990), 241.

5 "Beats," *Physics of Music*, (Accessed August 13, 2014) http://www.phy.mtu.edu/~suits/beats.html

The relationship between acoustical beating and the concept of dissonance will be examined again—both later in the chapter and as an important piece of evidence in support of my larger claim.

Helmholtz also hypothesized about the workings of the inner ear—the cochlea—and the role human perception plays in distinguishing between consonance and dissonance. For Helmholtz, accounting for the limitation of the human senses while investigating the physics of sound—in order to determine ultimately what is consonant and dissonant—was imperative. By understanding the way in which the human ear receives and processes sound, Helmholtz believed a finer explanation of consonance and dissonance could be cultivated. As Burdette Green and David Butler write, "Helmholtz modified the traditional 'outside to inside' model by drawing attention to the anatomy of the ear and the sensory phase of perception - a step toward attending to the "'inside.'"[6]

According to Burdette Green and David Butler in their article from *The Cambridge History of Western Music Theory*, "From Acoustics to *Tonpsychologie*," (from which two of the above quotations are taken) Helmholtz wasn't the only scientist interested in developing a cogent, detailed account of the nature of consonance and dissonance. Carl Stumpf (1848-1936) held joint responsibility for what Green and Butler refer to as "...two major epistemological shifts..."[7] Furthermore, as stated in the introduction to their article: "Helmholtz, the empiricist, advanced physical and physiological acoustics; Stumpf, the mentalist, established a psychological frame of

6 Burdette Green and David Butler, "From Acoustics to *Tonpsychologie," The Cambridge History of Western Music Theory*, ed. Thomas Christensen (New York: Cambridge University Press, 2002), 246.

7 Ibid., 246.

reference - *Tonpsychologie* (the psychology of musical sound)."[8] These two revolutionary 19th-century scientists anticipated what would eventually be known as music psychology and music cognition—*Tonpsychologie*, and *Musikpsychologie*, respectively—though as Robert Gjerdingen points out, this "...distinction seems less clear-cut today...[9]

Green and Butler's article will prove immensely useful in briefly describing the conclusions drawn by Helmholtz and Stumpf concerning the consonance-dissonance distinction, the former of which I will expand on here. As mentioned, Helmholtz adopts a mechanistic approach to understanding the vibration of sound; the inner ear acts as a sympathetic resonator that processes or resolves frequencies that it receives. In Green and Butler's words, "Helmholtz believed that sympathetic vibration is the only natural analogue to the resolution of compound into simple vibrations by the ear."[10] In addition, Helmholtz was a staunch advocate of the harmonic series for the basis of consonance, and ultimately, musical theory and practice. Here are Green and Butler again: "At bottom, the harmonic series is Helmholtz's building block. It shaped his entire theory of hearing, his explanation of consonance and dissonance, and ultimately his theory of harmony and tonality."[11] He did not reach his stance without complication, however, including the problematic naturalist assumptions so common to one side of the consonance-dissonance debate. Helmholtz's conviction involved a commitment to a physiological predilection towards just intervals and the harmonic series. However, he *did* recognize that musical theory and practice involved digressions from these essential

8 Ibid., 246.

9 Robert Gjerdingen, "The Psychology of Music," *The Cambridge History of Western Music Theory,* ed. Thomas Christensen (New York: Cambridge University Press, 2002), 956.

10 Green and Butler, 260.

11 Ibid., 262.

physical properties of sound--that to a certain extent, enculturation and environment influence how these properties are manipulated:

> We pass on to a problem which by its very nature belongs to the domain of esthetics [sic]. When we spoke previously, in the theory of consonance, of agreeable and disagreeable, we referred solely to the immediate impression made on the senses when an isolated combination of sounds strikes the ear, and paid no attention at all to artistic contrasts and means of expression; we thought only of sensuous pleasure, not of esthetic [sic] beauty. The two must be kept strictly apart, although the first is an important means for attaining the second.[12]

It is clear that Helmholtz distinguished between the raw, scientific notion of perceptual consonance—"sensuous pleasure"—and consonance as defined by less rigid terms. This is musical, or *artistic* consonance; consonance in a specific musical context, unrelated to dissonance as beating. Music theory, in part, serves as a method of explanation for understanding, manipulating and identifying these contextual, aesthetically consonant structures and patterns, but always underlying the final musical product are the elementary constituents that allow said product to be created. Helmholtz did not want the fundamental, scientific ideas behind consonance and dissonance to become lost in a sea of purely aesthetic debate, but he of course recognized the role of aesthetics—a result of artistic agency—upon phenomena that are "purely physical."[13]

Despite his wise distinction between what could be called scientific vs. aesthetic consonance and dissonance (or objective vs. subjective, as termed by Claude Palisca[14]), Helmholtz's scientific approach rendered him indebted to the harmonic series, and by

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12 Hermann von Helmholtz, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, 2nd English ed., trans. by Alexander J. Ellis (New York: Dover, 1954), 234

13 Ibid., 234.

14 Claude Palisca, "Scientific Empiricism," *Seventeenth Century Science and the Arts*, ed. by Hedley Howell Rhys (Princeton, New Jersey: Princeton University Press, 1961), 136.

extension, whole ratio tuning. According to Green and Butler,"...he ended up with a harmonic theory that has all of the limitations of a harmonic series-based system...hobbled by reliance on the just scale with its inability to support modulation, and he had no solid basis for the minor chord, the minor scale, or the subdominant harmonic function."[15] Furthermore, "...Helmholtz decided that the minor triad was 'inferior' to the major triad..."[16]

While Helmholtz certainly harbored an unabashed commitment to the harmonic series, it was not unfounded, and it is important to understand his devotion to the physical phenomenon. As Green and Butler put it, "Helmholtz conceived of consonance as a sensory response caused by two factors, the affinity of the upper partials of two or more tones and the absence of acoustic beats among these partials."[17] For Helmholtz, the preponderance of acoustical beating proved to be the ultimate answer for what constituted dissonance; this not only included beating between the fundamentals of frequencies tuned "improperly"—as demonstrated earlier in the chapter—but the beating of conflicting partials between multiple frequencies that are either mistuned, have inharmonic timbres, or both. Thus, as Helmholtz concluded, the nature of consonance can be explained in terms of sounds, or combinations of frequencies, with an absence of beating between both their fundamentals and the overtones generated between them.

Psychologist Carl Stumpf rests comfortably on the other side of the consonance-dissonance debate that I am attempting to describe. Coming at least a generation after Helmholtz, Stumpf's explanation for the consonance-dissonance distinction had no

15 Green and Butler, 261.

16 Ibid., 261.

17 Ibid., 261.

particular concern with the realm of acoustics, psychoacoustics, or with any of Helmholtz's groundbreaking discoveries. Stumpf's understanding of what distinguished consonance from dissonance was more psychological in nature; indeed, he deemed his theory *Tonpsychologie*, after which his seminal publication was also named. "Stumpf coined the term *Tonpsychologie* to designate a new discipline that placed musical acoustics and physiology in the service of psychology."[18] For Stumpf, the perception of consonance vs. dissonance among tones had much more to do with mental and psychological associations with emotion and experiences than the extrinsic, observable properties of vibration. A Stumpfian would say that perceptual (or scientific, objective, etc.) consonance *is* psychological consonance, which has nothing to do with acoustical beating of colliding, inharmonic partials. It is simply a matter of "tonal fusion," according to Stumpf, that permits the perception of consonance. From Green and Butler: "Where Helmholtz had held that beats among upper partials of complex tones generate dissonance, Stumpf asserted instead that dissonance is a psychological response: the perception of lack of tonal fusion of two tones."[19] Stumpf's concept of tone psychology lost its following as the development of Behaviorism and Gestalt psychology became more popular in the early 20th-century. "His theory of tonal fusion appears to have little influence...Perhaps tonal fusion is such an apparent sensory attribute that his elementary findings inspired little comment."[20] I would tend to agree. However, elements of Stumpf's psychological conception of consonance and dissonance resemble many conceptions

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18 Ibid., 263.

19 Ibid., 264.

20 Ibid., 266.

adhered to by music theorists—theorists that both anticipate and succeed Stumpf. In fact, forms of the opposing theories date back to the clash between Aristoxenian and Pythagorean methods of considering the consonance-dissonance distinction, as both Alex Wand and David Cohen assert. Wand writes:

> The concept of consonance has proven to be a malleable one, whose multiple understandings have gone through many expansions and evolutions. In the 6th century B.C., Pythagoras judged consonance, or *symphonos,* in terms of mathematical ratios. He recognized that the pitch of a string is related to its length and that the degree to which two simultaneous tones sound consonant is determined by the simplicity of their length ratios. For example, a ratio of 2/1 is considered simpler, and therefore more consonant, than one of 4/3, because the integers involved are smaller. Two centuries later, another prominent Greek theorist, Aristoxenus, presented a radically different viewpoint: that the musician's ear should be the ultimate arbiter of consonance.[21]

As I mentioned before, this consonance/dissonance debate has raged on since the earliest formations of music theory as a discipline—there is, I think, no disagreement on this among scholars. Cohen's article, "Metaphysics, Ideology, Discipline: Consonance, Dissonance, and the Foundations of Western Polyphony" makes a rather fascinating and compelling argument for consonance—and more generally, unity—as an ancient Westernized metaphysical "ideology." Cohen characterizes the scientific, acoustical view of consonance and dissonance as inherently naturalist. "It is precisely the spurious "naturalness" of the hegemony of consonance that qualifies the normal view as an ideology, an ideology that, while undergoing a most remarkable development in the discipline of music, has still remained, fundamentally, an ideology of consonance."[22]

21 Alex Wand, "On the Conception and Measure of Consonance," *Leonardo Music Journal* 22 (2012): 73.

22 David Cohen, "Metaphysics, Ideology, Discipline: Consonance, Dissonance, and the Foundations of Western Polyphony," *Theoria* 7 (1993): 8.

While I certainly find flaws with the naturalist argument myself, I think if we abandon the idea that "natural" somehow equates to "superior," and adopt more of a sense of it being a potential "condition," the aesthetic plateaus I mentioned in the introduction can be avoided more easily.

Green and Butler's conclusion regarding what they deem "the legacy of Helmholtz and Stumpf" strongly suggests that modern, current conceptions of musical consonance rely much more upon subjective, aesthetic judgment rather than objective, scientific definitions-- those explanations that concern beating, overtones, and their frequency coincidences and collisions. As stated in their closing section:

> Even basic notions of consonance and dissonance have been encumbered with multiple, often contradictory, meanings. For musicians these constructs depend on musical contexts that are subject to the stylistic norms of the culture. In functional harmony, verticalities exhibit levels of tendency or attraction, stability or instability; in color harmony the identical structures are generally devoid of these characteristics but instead exhibit levels of color tension. Such fluid characteristics seem far removed from the scientist's neatly defined notions of fusion, sensory consonance (euphony), or sensory dissonance (roughness).[23]

There is no doubt that the consonance-dissonance distinction is as complex as Green and Butler suggest, and that subjective musical context—not merely empirical, objective, scientific definitions and measurements of consonance/dissonance—informs one's ear in an aesthetic evaluation of a musical composition. In fact, I would even concede that subjective, or psychological consonance and dissonance (essentially, any sort of musical parameter that is not directly related to how the intervals/harmonies are being tuned) *usually* has the more important role in informing the listener's judgment as

23 Green and Butler, 264.

to whether or not a piece of music is aesthetically appealing. There are certainly more factors than how a piece may be tuned, and an accurate assessment of what makes a composition aurally effective and pleasing *need not* include the manner in which the intervals are tuned. Typically, it is simply a given and not even considered, as equal temperament has often been treated. Yet, many listeners marvel at the beautiful, sonorous sound a trained a cappella chorus can produce; or the hair-raising dominant seventh chords that barbershop quartets regularly lock into; even the intonation of string and wind ensembles, which have the capacity to approximate a tuning that incorporates Pythagorean and just intervals in some acceptable fashion. These listeners—non-musicians and musicians alike—are often completely unaware that the tuning of these harmonies may have a significant effect on the aesthetic attractiveness of the performance medium (and subsequently, the composition). It is in these instances that I believe semblances of Helmholtz's understanding of the consonance-dissonance debate—as opposed to Stumpf's—begin to bear more validity. As will be demonstrated, tuning instruments—primarily keyboard instruments—to twelve-tone equal temperament introduces a lot of beating (defined and discussed earlier), and hence, roughness. Indeed, any composition performed in twelve-tone equal-temperament will contain a healthy amount of beating between its intervals and harmonies. However, tonal music—ranging from functional to the centric post-tonal—is not usually considered overbearingly dissonant when it is performed in equal temperament. In a way, this suggests that the Stumpfian view is more compelling: tonal music in equal temperament isn't dissonant because listeners, by and large, don't consider equally tempered intervals (and their concomitant harmonies) dissonant. Compositions utilizing equal temperament appear perfectly satisfactory, and the consonant, equally-tempered intervals which comprise tonally idiomatic chords and scales exhibit no seriously noticeable degree of dissonance, as long as the instrument has been tuned "properly."

How, then, can Helmholtz's definition of consonance as absence of sound wave roughness be understood if equal temperament is so well accepted? This is where the paradox surrounding dissonance within discordance arises, following an assertion central to this thesis: Though I consider tonality and atonalityas being conditioned by twelve-tone equal temperament, the greater "tuning vocabulary" of the former is much easier to access and is indeed accessed in musical performances without fixed tuning. Music that employs a greater abundance of consonant intervals and tonal references is less aesthetically objectionable in large part due to the ease of tuning these intervals closer to their harmonic approximations. In contrast, the harmonic language of the Second Viennese School presupposes twelve-tone equal temperament as not only the generator of the chromatic scale, but also as a strict method of tuning and intonation. The paradox, as I posit, is thus: even harmonies and scales that could not have been conceived without equal temperament as a system of tuning—the octatonic and whole tone scales immediately come to mind—are tuned closer to pure in ensembles unrestricted by fixed tuning. It is almost as if there is a dialogue between the intonation of ensembles capable of tuning adjustments and our familiar, irreplaceable equally-tempered scale. Scales and chords abandon their harmonic "prototypes" when they become equally tempered. Once the "universe" of temperament is established, however, new harmonies (e.g. octatonic and whole tone) and more distant key areas can be explored without having to retune instruments. These musical constituents, which temperament allowed possible, now get reinterpreted—or retuned, as it were—by the ensemble. This is what is meant by a "dialogue" between intonation and systems of tuning. These ideas will be explored in further detail towards the end of this section.

Music-Theoretic Consonance and Dissonance

The contrasting explanations given by Helmholtz and Stumpf regarding the consonance-dissonance distinction run in tandem with observations made by music theorists since the inception of the discipline. As the bounds of tonality began to expand (or break, depending on who you ask) in the 20th-century, many theorists began to align themselves with the more subjective, or "psychological" end of the consonance-dissonance spectrum I have described. As both casual listeners and trained musicians became engrossed by the tuning standardization of the keyboard, the discordance that that tuning system presents became more tolerable, and equally-tempered intervals became understood as perfectly acceptable equivalents to their harmonic approximations. As microtonal composer Kyle Gann puts it: "We divide the octave into 12 equal intervals not because it sounds better that way—it doesn't at all, it's slightly buzzy with audible beating between sustained pitches—but so we can transpose any music to any key."[24] Furthermore, Gann writes: "On a more subtle level, after I've been immersed in just intonation for a couple of weeks, equal temperament music begins to sound insipid, bland, colorless."[25]

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24 Kyle Gann, "Just Intonation Explained," *Kylegann.com* (1997) (Accessed March 14, 2015) www.kylegann.com/tuning.html

25 Ibid.

Perhaps the most notorious 20th-century critic of equal temperament is composer and theorist, Harry Partch, whose own inspiration from Helmholtz's observations led to an entire manifesto-like book: *Genesis of a Music*.[26] Dedicated to re-discovering just intonation as a tuning medium and dispelling the "myth" of equal temperament, Partch described his various systems of just intonation in meticulous detail, and even designed and constructed his own instruments in order to accommodate his idiosyncratic tunings. Partch proved to be a catalyst for the musical movement known as microtonality, many of whose proponents begin with the preservation of just intonation as common philosophical and aesthetic ground.

With the exception of the microtonalists, the significance of just intonation and other alternative tuning systems has not been seriously considered among 20th-century academic scholarship. As Jonathon Walker puts it, "Just intonation has long been considered a theoretical chimera..." and "is commonly dismissed as an impractical, utopian system..."[27] Early music scholar Ross Duffin's comments are nearly identical. "Just intonation has a reputation as a chimerical, theoretical system that simply cannot work in practice."[28] While many 20th-century theorists retained devotion to the harmonic series—with some even maintaining a more naturalist, Helmholtz-oriented stance—most admit the ubiquity of equal temperament to be such a strong cultural tradition that its discrepancies from the harmonic series are so negligible to be considered irrelevant. 20th-

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26 Harry Partch, *Genesis of a Music* (New York: Da Capo Press, 1974).

27 Jonathan Walker, "Intonational Injustice: A Defense of Just Intonation in the Performance of Renaisssance Polyphony," *Music Theory Online* 2.6 (1996) (Accessed September 4, 2014) www.mtosmt.org/issues/mto.96.2.6/mto.96.2.6.walker.html

28 Ross Duffin, "Just Intonation in Renaissance Theory and Practice," *Music Theory Online* 12.3 (2006) (Accessed September 4, 2014) www.mtosmtorg/issues/mto.06.12.3/mto.06.12.3.duffin.html

century composer and theorist Paul Hindemith is a perfect example of the former, a quotation from whom opened this chapter. Hindemith's statement completely dovetails with Helmholtz's conception of consonance and dissonance. The ear desires not only "pure intervals," but in "tonal combinations." However, probably the most provocative statement is the first sentence of this passage—which appears to prove consistent with Helmholtz's consonance theory. For Hindemith, the ears of both musicians and listeners strive for pure intervals, but the sacrifice of this purity is necessary—for the sake of practical purposes and other musical aesthetics (ease of modulation, for example).

> There is no solution of the scale riddle that can reconcile these opposite necessities. Purity must be neglected or the possibility of unhindered polyphony sacrificed. ...the chromatic scale in equal temperament, such as we know on our keyboard instruments...too, is necessarily a compromise, but the sort of compromise represented in commerce by the use of money in place of barter. The small change of music, the twelve-tone series of the equally tempered scale, has become the musician's universal medium of exchange. Except for the octave, not a single one of its intervals is exactly equal to a pure interval of the overtone series…but the difference is just big enough for the ear to perceive it without being disturbed by it in polyphony.[29]

The "opposite necessities" refer to the age-old conflict between just intonation and temperament; it will be mentioned briefly now, but explained in more detail in the next section. To put it simply, strict just intonation is usually not viable for music employing some kind of tonal center—especially functionally tonal music. If pure intervals are strictly adhered to, the pitch will drift; the ear often doesn't tolerate such significant pitch gradations, especially if they occur over a short span. This is often understood and perceived as being "out of tune," or going "flat," or "sharp." While it could be said that musicians aim to achieve pure tuning as much as possible, it also must be admitted that

29 Paul Hindemith, *Craft of Musical Composition*, *Book I,* 4th ed., trans. by Arthur Mendel (New York: Associated Music Publishers, 1945), 28.

they simultaneously strive to maintain a consistent center of pitch. What is considered *in tune* is dependent upon both vertical (harmonic) and horizontal (melodic) circumstances. Hindemith addresses this "scale riddle" in the *Craft:*

> The intervals formed by the tones of the scale do not all have the same proportions as their prototypes in the overtone series. But in polyphonic music, the measuring ear continually seeks the pure intervals of the overtone series, and is dissatisfied not to find them....Polyphonic music demands that the tones may at any time be able to change their tonal significance by relating themselves to changing roots...A tone that has, for example, already served as a third must be able to become root, fifth, or seventh in succeeding chords. It is however, impossible, as we shall see, for one tone to perform all these functions without change of pitch. Thus, either the purity of nature must be disregarded or the pitches must be movable, which would take away from this type of scale its most characteristic feature.[30]

In addition, Hindemith states that ensembles unrestricted by fixed tuning will naturally assume the purest tuning possible, especially for vertical sonorities employing familiar consonances (triads). While he considers it a necessary "medium of exchange" for musicians and composers, Hindemith is sure to comment on the dissonance introduced by tempered intervals. "...the ear is subject to a certain danger in being exposed only to music constructed of tempered intervals; it accustoms itself to their clouded qualities, and like a jaded palate loses its sense of natural relations."[31] Again, Hindemith expresses dissatisfaction with equal temperament, but admits that it is essentially necessary for functional tonality (Helmholtz, who was also a well-versed music theorist, made similar concessions in *Sensations of Tone*).

Hindemith's idiosyncratic reclassification of the traditional consonances and dissonances also suggests an underlying commitment to the idea of consonance as

30 Hindemith, 27.

31 Ibid., 28.

frequency and partial coincidence—further resembling Helmholtz's theory. To any musician familiar with Hindemith's counterpoint textbook and his musical language, quartal and quintal harmony tends to appear quite prominently. This is a direct result of his unique use of the overtone series to generate the chromatic scale, intervals, and ultimately his entire musical language. While Hindemith's consonance/dissonance ranking of intervals does not really differ from traditional orderings in functional tonality, the method in which he employs them in a composition does. Hindemith's treatment of fourths and fifths in counterpoint is consistent with Helmholtz's understanding of consonance and dissonance due to the fact that octaves and fifths—tuned purely—oscillate at smaller integer proportions, making them maximally "pure," or "beatless." Thus, for Hindemith, a ubiquity of quartal and quintal contrapuntal writing—effectively used—in a given piece of music would theoretically be closer to the psychoacoustician's sensory, or objective consonance. In this way, Hindemith further allows his aesthetic judgment of what is consonant or dissonant to be significantly informed by the definition posited by Helmholtz over half a century earlier.

Hindemith revisits the performance considerations involved with intonation vs. temperament in chapter 11 of the *Craft*, entitled "The Comma." Towards the beginning of this chapter there is a passage that is directly relevant to the primary assertion of my thesis:

> Singers and players achieve the solution of the comma problem for the most part without realizing it...When, however, the harmonic relations become too opaque, or when the roots of combinations follow one another in an order which is not unambiguous, the ear becomes uncertain. The singer or the player does not then know where to make the adjustment, and

> he sings or plays out of tune. That is why passages based upon extreme chromaticism or enharmonic change are difficult--and for choral singers often impossible-to produce in pure intonation, even after all the experience that singers have had in the course of music history.[32]

In this passage, Hindemith has alluded to at tuning phenomenon that brings us toward the subject of my investigation—rampant chromaticism cannot be completely tuned in just intonation, yet the most well-trained, "in-tune" ensembles (those without fixed tuning restrictions, of course) often tune closer to harmonic intervals, when possible. The introduction of serious chromaticism makes the use of tempered intervals more likely, since just intonation becomes much more difficult to sort out globally (i.e., the pitch will drift intolerably). Often at the expense of heavy chromaticism comes the intonation of various chords and intervals—remember, this is the compromise entailed with tempered tunings. The best ensembles, however, do not let this dissuade them in their decisions regarding intonation, and will often attempt to keep as many intervals within a vertical sonority as harmonically tuned as possible. Here is where the central question concerning this thesis arises: how can the practice of just intonation be related to a musical aesthetic such as Schoenberg's twelve-tone atonality? If singing—and playing, for string and wind instruments—intervals closer to their harmonic relationships is somehow innate for musicians, would a performance of a Second Viennese dodecaphonic work tuned with just intervals violate the precepts of the style? While equal temperament is a convenient "medium of exchange" for composition, the sheer use of this analogy implies recognition that purer tuning is possible, and in fact occurs during performance, if the ensemble allows for flexible intonation. However, as I argue, the "medium of exchange"—twelve-

32 Ibid., 44.

tone equal temperament—*is* the basis for Second Viennese atonality, and Hindemith's metaphor begins to break down.[33] The twelve-tone aesthetic is directly related to equal temperament's division of the octave, yet equal temperament's division of the octave is a tuning compromise that "represents," "reflects," or "mirrors" pure intervals very closely. In this sense, it would appear that just intonation and Second Viennese atonality are not compatible. This leads to the argument of my thesis for which I will continue to build a case: if performers and listeners tend to approximate and prefer purer tuning when tempered instruments are removed, a properly "emancipated" twelve-tone composition can be understood as being dissonant for not only the preponderance of music-theoretic dissonance it employs, but also due to its basis in a tuning system that inherently contains sensory dissonance. Schoenberg's twelve-tone aesthetic is more acoustically removed than an aesthetic employing a greater semblance of tonal resources. As mentioned in the introduction, this idea can be characterized as *dissonance within discordance,* which—as I hypothesize—plays a role in the aesthetic evaluation of twelve-tone music.

Of course, the tendency of ensembles unrestricted by fixed tuning to approximate just intervals has been contested, with evidence of performers tending towards both temperament and just intonation; these sources will be discussed further below. Nearly all of these studies concede that musical context—whether it's a micro-parameter such as the procession of one interval or chord to another, or larger dimensions such as the greater harmonic language of a composition--determines the type of intonation employed in performance, as well as the type of intonation preferred by listeners. While it has been

33 Ibid., 155. Hindemith writes: "The decline in the value placed upon tonality is based on the system of equal temperament, a compromise which is presented to us by the keyboard as an aid in mastering the tonal world, and then pretends to be that world itself." (155)

repeatedly argued throughout history that due to the direct relationship between tonal and sensory consonance, tonality is an inherent, biological tendency, this is typically considered an erroneous and naturalist assumption by most scholars. I will take this time to remind the reader that though I am connecting the unprecedented dissonance of twelve-tone atonal music to the sensory dissonance of temperament, this in no way implies any sort of aesthetic superiority for tonal music. Sensory consonance is not necessarily *superior* to sensory dissonance, even if some physical or biological predisposition towards the former may exist. While I am attempting to identify psychoacoustical explanations for the commonly perceived harshness of Second Viennese atonal harmony, it is important to remember that subjective, musical context—what is closer to *psychologically* consonant and dissonant—often ultimately informs the listener's aesthetic experience of a piece. As I see it, a biological tendency can easily be averted, or modified/adapted into something that may resemble a phenomenon of enculturation. It is no contradiction, in my eyes, to imagine a biological predisposition that has been removed, transformed, or aesthetically repurposed. Music-theoretic consonance and dissonance, in my mind, is one such repurposing.

Perhaps tonal centricity—and more consonant music, in general—is so culturally enforced it has *become* just as "preferred," or "innate," as something biologically rooted would be. It is not inaccurate to imagine a situation in which a society is completely removed from music lacking any tonal organization—there are myriad musical cultures other than that of Western Europe, of course. However, it is often noted by musicologists and theorists that some semblance of pure intervals—insofar as it relates to sensory consonance—is apparent among many non-Western musics. Nonetheless, whether biological or cultural, the origin of tonal music in the natural harmonic series— which can perhaps account for its cultural ubiquity—continues to be maintained, as mentioned by Ross Duffin:

> It is…thought that the prevalence of the octave, fifth, fourth and major and minor thirds in the lower part of the harmonic series contributed to the development of our concept of harmony, in which those intervals form the most common components of chords. Chords in the Western (that is, European) music tradition, therefore, are not merely a culturally evolved arrangement of musical sounds into a system but a natural phenomenon based on the physical science of acoustics.[34]

The musical aesthetic of the Second Viennese School, I hope to demonstrate, is inherently more removed from the harmonic series, which Duffin deems "…a natural phenomenon based on the physical science of acoustics."[35]

The most significant music theorist to consider the development of tonality a purely cultural phenomenon is none other than the founder of the Second Viennese School himself. Arnold Schoenberg (1874-1951), the ingenious composer and theorist behind twelve-tone atonal composition, finds himself deeply rooted in the subjective end of the consonance-dissonance debate. Thus, he largely ignores any sort of significance that just intervals may have for the purposes of Western music theory—despite his own arguments that appeal to the overtone series as the generative basis for the tempered scale. Ultimately, though, Schoenberg was convinced that equal temperament was a perfectly satisfactory tuning system, and saw no real problems with the discrepancies between tempered and pure intervals. In fact, Schoenberg preferred equal temperament,

34 Ross Duffin, *How Equal Temperament Ruined Harmony (and Why You Should Care)* (New York: W.W. Norton & Company, 2007), 21.

35 Ibid., 21.

and considered it imperative in the performance of his music (this dovetails with my idea that 12-tone atonality is more inherently conditioned by equal temperament than tonal music). In his exchange of letters with 20th-century tuning theorist Joseph Yasser, Schoenberg makes comments that are undoubtedly worth mention.

> Indeed, whenever I have had occasion to take up intonation with string players, I have always insisted on its tempered form…And I believe that a listener who, in his hearing, combines other tones than those that I have indicated, is not sufficiently cultivated. To be musical, then, means to have an ear in the sense of music and not in the sense of nature. A musical ear must have assimilated the tempered scale. And a singer who produces natural pitches is unmusical, just as one choosing to act on a street in a 'natural' way would be considered indecent.[36]

Despite his continual reference to the overtone series as the basis for the 12-tone chromatic scale, Schoenberg ultimately rejects tuning systems that fall outside of equal temperament, even going as far to suggest that singers approximating pure intervals are closer to savagery than civilization. In my mind, while it is a very ethnocentric statement by Schoenberg, I think it is fundamentally necessary for him to make these assertions—the unique aesthetic of the Second Viennese School depends upon it! Since tonality is bound to tuning and intonation falling outside of equal temperament—and yet, is paradoxically married to it, as mentioned—it makes sense for Schoenberg to reject tuning schemes other than equal temperament. Only the latter can facilitate his Second Viennese technique. Yasser himself points toward the conflict in Schoenberg's reasoning in his own footnote to the statement: "It is worth noting how drastically Schoenberg severs all connections between his music and natural intonation, after having expended so much effort to prove the dependence of the chromatic (twelve-tone) scale on the series of

36 Joseph Yasser, "A Letter from Arnold Schoenberg," *Journal of the American Musicological Society* 6, no. 1 (1953): 60-61.

partials."[37] This schism in Schoenberg's thought is directly indicative of the objective vs. subjective considerations regarding consonance and dissonance. Schoenberg wants to provide an objective, more naturalist argument for the derivation of the equally tempered chromatic scale, so he cites the overtone series. However, when the overtone series leads to alternative tunings and forms of intonation, Schoenberg rejects them and embraces equal temperament in order to preserve the subjective element of the consonance-dissonance consideration, without which he would have had difficulty justifying the Second Viennese aesthetic.

Temperament—as nearly any musician knowledgeable about the subject would say—is an inherent part of Western tonal grammar and syntax, and is necessary, at least in some form, for functionally tonal music. Pure intervals, however, as I and many others would attest, are more euphonious than tempered intervals; furthermore, they formed the scales and chords that led to the construction and subsequent codification of equal temperament. An interesting way of thinking about this notion can be invoked by considering what our standard system of musical notation truly represents, which came to me from something that I overheard in a discussion between two theorists. One claimed that our notational scheme is based on the layout of the piano keyboard, with twelve equal divisions of the octave. The other scoffed heartily, maintaining that clearly, musical notation is derived not from the modern piano keyboard—and subsequently the equally tempered scale—but from the gamut, which has its origins in Pythagorean and syntonic tunings. Now, while I am no medieval music scholar—and thus cannot immediately verify the veracity of the latter theorist's assertion—I do consider it another way of

37 Ibid., 61.

understanding equal temperament's manner of "capturing," or "mirroring" intervals based on integer proportions. As Hindemith would put it, equal-temperament—and thus, notation as well—are somewhat analogous to mediums of exchange in barter. The first music was vocal music, ostensibly, and diastemic notation—arguably the earliest progenitor of the modern staff—helped preserve and codify the familiar scales of early monophony and organum. It was not until later that keyboard instruments were invented, as a way of providing a fixed referential medium for the Guidonian hexachordal system.

In any case, Schoenberg's position in his *Harmonielehre* (Theory of Harmony), somewhat antithetical to the position Hindemith takes in the quotation that began this chapter, suggests the other face of the consonance/dissonance dichotomy. Discovery of higher partials (greater dissonances) means more dissonant intervals can and should be permitted; furthermore, musicians will eventually adapt to such a system, and it will become a new primary method of musical and compositional pedagogy. However, as I would argue, the higher the partials become, the less they resemble the intervals given within equal temperament. Schoenberg's position is rooted in the assumption that equally tempered intervals are close enough to match their whole-ratio counterparts, which many theorists (myself included) do not necessarily agree with. A musical culture's understanding and perception of consonance, for Schoenberg, could be manipulated to such a degree that his twelve-tone, self-described "pantonal" method of composition could usurp any prior preference for consonant intervals (including tonal consonances). From the *Harmonielehre*:

> …the expressions 'consonance' and 'dissonance,' which signify an antithesis, are false. It all simply depends on the growing ability of the analyzing

> ear to familiarize itself with the remote overtones, thereby expanding the conception of what is euphonious, suitable for art, so that it embraces the whole natural phenomenon.[38]

Schoenberg clearly aligns himself with a subjective consideration of the consonance-dissonance debate; “what is euphonious, suitable for art” is, for Schoenberg, fundamentally removed from Helmholtz’s conception of consonance. Furthermore, I believe Schoenberg would assert that the aesthetic value of a musical style is not necessarily dependent on reference to intervals that resemble the first six partials of the harmonic series. The “…growing ability of an analyzing ear to familiarize itself with the remote overtones…” suggests that Schoenberg considers twelve-tone atonal music capable of replacing tonality as the dominant musical trend and practice within the academy (and ultimately, among society).

Schoenberg's ideas concerning the consonance-dissonance distinction anticipate another central argument to my thesis - the discordance of equal temperament due to its inharmonicity[39] and approximation of pure intervals, and the implications this has for twelve-tone atonality as prescribed by Second Viennese School. Schoenberg’s own ideas regarding intonation and temperament have been documented, and his very statements demonstrate a commitment to equal temperament as the sole tuning system available to and in use by musicians and composers.

38 Arnold Schoenberg, *Harmonielehre,* trans. by Roy Carter (Los Angeles: University of California Press, 1978), 21.

39 The term inharmonicity will be explained later in this paper.

CHAPTER III

RECONCILIATION OF INTONATION AND TEMPERAMENT

> But it is only fixed pitch instruments like keyboards that are definitively locked into a single tuning. Winds, brass, and strings can and do change their intonation with musical circumstance…pitch manipulations by the musician are heavily context dependent. Similarly, choirs sing very differently a cappella than when accompanied by a fixed pitch instrument.[40]

So, which is it? Do listeners, both musicians and non-musicians, gravitate toward purer tuning as criteria for aesthetic preference? Does the compromise tempered tuning introduces (which will be discussed further in Chapter IV) significantly inform the aesthetic evaluation of music? These questions—as will be emphasized later and as the introduction suggests—involve the relative "fit" of the music in question. In further anticipation of this idea, suppose that tonality were capable of functioning in both adaptive just tunings—tunings closer to just intonation—as well as twelve-tone equal temperament. Can twelve-tone atonality exist within a non-fixed pitch, adaptive tuning scenario? How would certain intervals, especially in complex, multi-pitched verticalities of long duration, be tuned? Would ensembles capable of just intonation necessarily perform these harmonies in twelve- tone equal temperament? As already mentioned, Paul Hindemith discusses this performance problem in *his Craft of Musical Composition*—especially in regards to singers—suggesting that music with a preponderance of chromaticism will disturb the performer's natural inclination to tune intervals and chords as purely as possible. Composer Walter Piston invoked a similar question in his 1968 interview with Peter Westergaard (mentioning tuning scenarios in Schoenberg's music

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40 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 59-60.

toward the end):

> The student learns to play in tune by imitating his teacher and listening to other good players. You've never heard of a teacher teaching his students to distinguish between the tempered and untempered scale. The method has nothing to do with physics; it's just habit forming, but it means that they get to know what scale degree they are playing. It becomes so instinctive that many do not know they do it, and when they play any little phrase they will hear it in some key--it may not be the right one, but the point is they will play it with a tonal sense. I once experimented by asking all the quartets I knew who played the Schoenberg quartets, 'How do you go about getting it in tune?' They all seem puzzled at first, but finally practically all said, 'We keep playing until it sounds in tune to us.' I said, 'Fine,' but I wondered if that was what Schoenberg wanted.[41]

While Piston's remarks suggest that enculturation determines the tuning of certain pitches among ensembles capable of adaptive intonation, they also intimate that tonal enculturation—a product of Westernized, codified, tonally-oriented, disciplined musical training—is so powerful that intervals may be intonated differently in even the most tonally ambiguous musical contexts. I wish to connect this apparently ingrained musical tendency—whether it is through physiological proclivity or substantially reinforced enculturation—to aesthetic problems commonly associated with twelve-tone atonality from the Second Viennese School. Most musicians would not question the assertion that atonal music is often considered unpalatable due to centuries of tonality, reinforced at every level of society; even within the most prestigious conservatories. For many atonal enthusiasts, the hegemonic tradition of tonal music has made it impossible for atonal music to become broadly culturally supported, and thus, most ears have not adapted to

41 Peter Westergaard, "Conversation with Walter Piston," *Perspectives of New Music* 7, no. 1 (1968): 15.

the musical language of twelve-tone music.[42] After many centuries of enculturation and discipline, it is certainly possible that musical practice is so bound by tonal music—itself at least partially rooted in consonance as absence of beats—that the inharmonicity introduced in a highly dissonant piece of twelve-tone music, which is based more on equal temperament than “pure” harmonies, informs and affects the listener's aesthetic evaluation of the work. There is literally more physical dissonance present in a twelve-tone atonal work due to its strict equally-tempered medium of tuning. This does not stop performers from varying the intonation in compositions that employ all twelve tones equally, as Walter Piston has mentioned, and as will be demonstrated in short order.

One of the practical consequences of using strict just intonation in performance is comma drift (alluded to earlier in one of the Hindemith excerpts, aptly titled “The Comma”). The Pythagorean comma is a small interval that results from tuning seven just fifths, in succession, and attempting to sound the final pitch with the initial pitch. Instead of reaching an octave, the final pitch is about a quarter of a semitone higher than it should be—this turns the “circle” of fifths into a theoretically infinite “spiral” of fifths. This can be seen below in Figure 2, which I have borrowed from William Sethares' *Tuning, Timbre, Spectrum, Scale.*[43]

42 As my advisor Jack Boss has confirmed in our meetings, twelve-tone atonal composition was expected and enforced in the academy during the 1960s-1980s, proving dominant in prestigious conservatories and schools of music.

43 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 53.

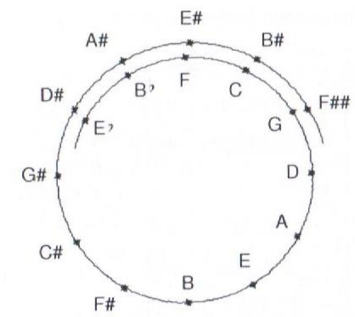

Fig. 2: A theoretically infinite Pythagorean spiral, the result of tuning consecutive just fifths.

Similarly, the syntonic comma describes the small interval between four just fifths, and two octaves and a just third. Figure 3 illustrates this discrepancy.[44]

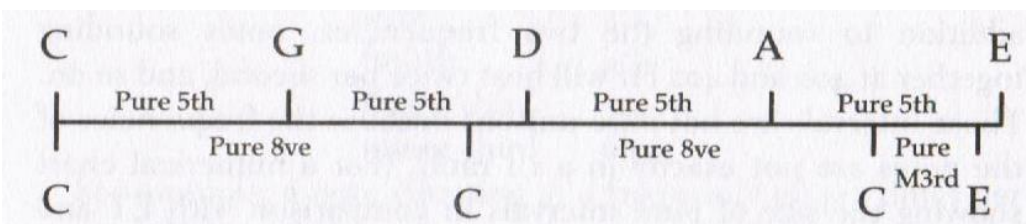

Fig. 3: Illustration of the syntonic comma.

The syntonic comma is usually involved in comma drift, in which certain pitches are retuned, often by this micro-interval, depending on their context. For instance, the Pythagorean ditone (major 3rd scale degree in Pythagorean tuning) is much higher than a just major third, and would need to be slightly lowered—by a syntonic comma—to create a pure third with the tonic of the scale (as opposed to its usual value, which would need to remain high to form a just fifth with the submediant scale degree). The implication is that performers, if not restricted by a fixed pitch instrument, will make such adjustments

44 Ross Duffin, *How Equal Temperament Ruined Harmony (and Why You Should Care)* (New York: W.W. Norton & Company, 2007), 34.

in performance. Indeed, such ensembles—a cappella choirs and string ensembles come to mind—will tend toward just intonation in vertical, harmonic situations, and Pythagorean tuning in more horizontal, melodic situations. As Rudolf Rasch notes in his article "Tuning and Temperament," "…from the nineteenth century onwards--one of the characteristics of Pythagorean tuning, high sharps and low flats…became the underlying principle in melodic intonation."[45]

Pythagorean tuning is considered a form of just intonation. In order to close the theoretical spiral that would result from stacking continuous just fifths, both tunings modify the final pitch in the series so that the spiral closes, creating the circle of fifths. However, what happens to the comma? It becomes imparted onto one of the notes in the tuning. The result is a noticeably out of tune interval, also known as a wolf interval, between one of the fifths in the scale.

Twelve-tone equal temperament divides the Pythagorean comma (also known as "tempering out") equally among the chromatic scale. The result is a system of tuning that approximates just intonation, but also allows modulation to a greater number of keys than Pythagorean or other just tunings without having to retune the instrument. Equal temperament could be considered a descendant of both Pythagorean and syntonic systems, in which the purity of the fifths and thirds are retained as much as possible, respectively. However, as Hindemith would argue, and as I would agree, this is at the expense of all keys sounding equally *out of tune*, and in the best tuned performances—away from tempered instruments—not all twelve pitches are kept equal. Comma drifts occur in order to accommodate just intervals, and the ear routinely tolerates these

45 Rudolf Rasch, "Tuning and Temperament," *The Cambridge History of Western Music Theory,* ed. by Thomas Christensen (New York: Cambridge University Press, 2002), 198.

deviations, which depart from temperament, due to the resonant intervals and harmonies they allow.

Even well-trained singers have a tendency to sacrifice consistency of pitch center and interval sizes for the sake of purer intonation of harmonic sonorities. Furthermore, diatonic sonorities cannot be tuned in just intonation without either modifying the local pitch center or singing said sonorities out of tune. From Mark Lindley's New Grove article on just intonation:

> In the 1650s Giovanni Battista Benedetti, a mathematician and physicist, pointed out in two letters to the distinguished composer Cipriano de Rore… that if progressions such as that shown in ex.1[Figure 4 below] were sung repeatedly in just intonation, the pitch level would change quite appreciably, going up or down a comma each time.[46]

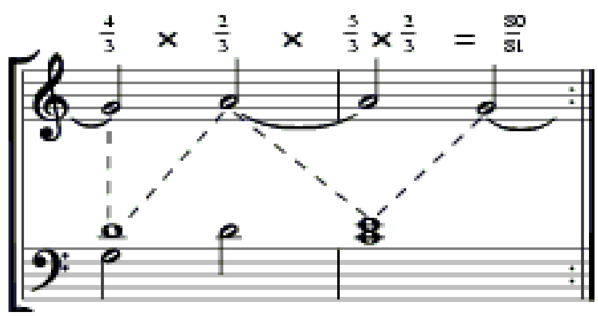

Fig. 4: Chord sequence with pitch drift. As Benedetti demonstrated, each time this simple progression is sounded in just intonation, the pitch will fall a syntonic comma.

The example in the quotation has been reproduced above. Comma drift will be discussed once more with both visual and musical examples in Chapter IV.

The opposing yet interactive binary of intonation and temperament dovetails with the consonance and dissonance dichotomy outlined earlier. One end of the argument declares intonation wholly relevant and dependent on a tendency toward tuning intervals purely, while temperament's most ardent proponents argue that tempering is absolutely

46 Mark Lindley, "Just Intonation," *New Grove Dictionary of Music and Musicians*, 29 vols., ed. by Stanley Sadie (London: Macmillan, 2001), XIII, 291.

necessary and only affects interval quality negligibly. These arguments entail the same commitment—or lack of—to tuning systems that bear a closer resemblance to just intonation. Lindley's aforementioned article provides a very brief history of each school of thought's opposing arguments, which manifested themselves once again in the 16th-century debate between Gioseffo Zarlino and Vincenzo Galilei.

> …Zarlino (1558) argued that although voices accompanied by artificial instruments would match their tempered intonation, good singers when unaccompanied would adhere to the pure intervals of the 'diatonic syntonic' tetrachord…Zarlino eventually became aware that this would entail a sour 5th in any diatonic scale…but he held that the singers' capacity to intone in a flexible manner would enable them to avoid such problems without recourse to a tempered scale…In 1581 Vincenzo Galilei, a former pupil of Zarlino, denied that just intonation was used in vocal music, and asserted that the singers' major 3rd 'is contained in an irrational proportion…' [47]

Claude Palisca discusses the scientific and music-theoretic history of an identical conflict, framing it as a historical dialogue in his chapter "Scientific Empiricism in Musical Thought" from *Seventeenth Century Science and the Arts*, edited by Hedley Howell Rhys. The article explores the relationship between science and music theory, or more generally, the interaction between science and aesthetics in regards to music during the 17th-century (as well as before). Palisca discusses a myriad of historical figures—both scientific and musical—who exemplify an identical dichotomy, including Zarlino and Galilei. Palisca refers to the famed polemic between Zarlino and Galilei as a "classic case of the interrelations between music and science in this period."[48] Though the disciplines of "musical art and musical science…began to acquire their separate modern identities

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47 Ibid., 291.

48 Claude Palisca, "Scientific Empiricism," *Seventeenth Century Science and the Arts*, ed. by Hedley Howell Rhys (Princeton, New Jersey: Princeton University Press, 1961)

[during the sixteenth century],"[49] as Palisca astutely notes, I maintain that the two are still very much in tandem—especially when it comes to the distinction between consonance and dissonance. These interactions continued further into the 20th century, and the contrasting opinions of Helmholtz and Stumpf, as well as Hindemith and Schoenberg, are more (relatively) recent manifestations of this perpetual historical dialogue.

With all the conflicting implications of intonation and temperament, how can the two be reconciled? It would appear that the two methods of tuning are completely at odds; yet, despite the surface dichotomy present amongst myriad figures that cling to merely one or the other, just intonation and temperament can be reconciled in a way that preserves pure tuning significantly. Twelve-tone equal temperament is one way, arguably, to deal with the problem, but there are no just intervals beyond the octave, and the major third is noticeably sharp. Before our current system of temperament became the dominant tuning scheme, other systems of temperament were in use, including those that retained pure thirds. Meantone temperaments, one of the most popular of these, sought to preserve these thirds—often at the expense of flattened fifths—in as many keys as possible without sacrificing their purity. Quarter-comma meantone is one such example, which divides the Pythagorean comma into four parts and distributes it evenly amongst the fifths in the scale. Well temperament (and all its variations), which Bach is ostensibly known for popularizing with the *Well-Tempered Clavier*, has less uniformity of tuning across keys, but remains ideal in many. As William Sethares points out, however, this wasn't necessarily considered a problem—keys that contained stray intervals were considered to have individual identities, which technically, equal temperament

49 Ibid., 92-93.

eliminates. “Each key in a well-temperament has a unique ‘tone color,’ ‘key-color,’ or ‘character’ that makes it distinct from all others…many Baroque composers considered these distinctive modes an important element of musical expression, one that was sacrificed with the rise of 12-tet.”[50] All of these forms of temperament can be thought of as compromises, yet they are compromises that intended to preserve intervals as close to just values as possible. They are all forms of syntonic temperaments, as Sethares defines in his article “Invariance in Controller Fingerings Across a Continuum of Tunings,” which “…presume that there is an underlying Just Intonation (JI) tuning system which is mapped to a regular tuning in a structured way so that certain intervals retain their identity.”[51]

Theorists, scientists, and musicians alike have attempted to reconcile intonation and temperament for centuries, and continue to do so today—despite the dominance of equal temperament in contemporary society. This reconciliation manifests itself in performances that are removed from fixed-tuning. As Hindemith would posit, performers seek to minimize the dissonance between partials for held intervals and harmonic sonorities, but will also compromise this preference in order to retain a consistent center of pitch.[52] These two tendencies exhibit a symbiosis that suggests a dialogue between various forms of just intonation and equal temperament, as opposed to strict prescription

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50 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 64-65. 12-tet is common moniker for twelve-tone equal temperament.

51 Andrew Milne, William Sethares, & James Plamondon, “Isomorphic Controllers and Dynamic Tuning—Invariant Fingering Over a Tuning Continuum,” *Computer Music Journal* 31, no. 4 (2007): 17. Sethares provides a unique perspective on the problem of tuning and temperament, and presents mathematical and computational methods of maximizing just harmonies while minimizing comma drifts.

52 I.e., not going sharp or flat.

of the latter. These issues will be revisited in Chapter IV, with more examples that attempt to demonstrate the reality of this phenomenon.

Related Psychoacoustical Considerations

> The terms consonance and dissonance have been used here in a perceptual or sensory sense…to be distinguished from consonance in a musical situation. Musical consonance has its root in perceptual consonance, of course, but is dependent on the rules of music theory, which, to a certain extent, can operate independently from perception.[53]

Before moving on to Chapter IV, there are several invaluable psychoacoustical sources regarding the consonance-dissonance distinction that are worth mentioning. These sources consider Helmholtz's explanation for the distinction between consonance and dissonance—a preponderance of beating between partials, as discussed previously—and the interaction of this apparent phenomenon of sensory consonance with what is often deemed "musical consonance/dissonance." Most of the sources end up conforming to the familiar nature vs. nurture dichotomy present in the contrasting arguments of Helmholtz and Stumpf. Helmholtz's theory of dissonance is still very popular among the psychoacoustical discipline, despite his observations often being considered too reductionist for many theorists to take seriously. While his wholehearted commitment to the *senario* certainly takes the form of the naturalist stance—or fallacy, as it were—I believe there are searing truths to Helmholtz's investigations, and modern psychoacoustics has not wholly abandoned his contributions.

A central concept to the discipline of psychoacoustics that was disseminated beginning in the mid-20th century is the concept of the critical band. In a revival of Helmholtz's theories (which despite their popularity among scientists became dormant

53 Rudolf Rasch & Reinier Plomp, "The Perception of Musical Tones," *The Psychology of Music*, 2nd. ed., edited by Diana Deustch (San Diego: Academic Press, 1999), 106.

following his death) acousticians Reinier Plomp and Willem Levelt published a 1965 article in *Journal of the Acoustical Society of America* entitled "Tonal Consonance and the Critical Bandwidth." In it, Plomp and Levelt detail their own experiments—conducted on human subjects—concerning the nature of consonance, dissonance, and frequency correspondence and collision. As stated in their introduction to the article:

> In this paper, the relation between beats and consonance is studied again. To avoid misunderstandings, it may be useful to emphasize in advance that our sole concern is the question of why consonance is related to simple frequency of ratio. Though the concept of consonance is rather vague and may be different for musicians and laymen, this relationship is always involved. In our opinion, consonance refers to the peculiar sensorial experience associated to isolated tone pairs with simple frequency ratios. We use the term *tonal consonance* to indicate this characteristic experience.[54]

As I understand it, Plomp and Levelt's tonal consonance identifies a congruency between musical consonance and the sensation of pitch itself. Thus, it could be deduced that music that employs a preponderance of tonal resources (primarily harmonic and contrapuntal), is inherently more related to sensory consonance. The perception of pitch, or fundamental pitch, is more closely related to tonal consonances. Since our ears discern a pitch depending on which harmonic series (or series') a combination of sound waves best fits, introducing tempered intervals leads to more sensory dissonance, subtly distorting the intervals and harmonies through dissonant beating. Thus, the perception of tones and the greater harmonies they form is disturbed. As David Butler mentions in *The Musician's Guide to Perception and Cognition*:

> More recently, Pierce has suggested that there are two pitch mechanisms: a place mechanism that predominates as we listen to musical tones, and a time periodicity mechanism that is evoked primarily by complexes

54 Reinier Plomp and Willem Levelt, "Tonal Consonance and the Critical Bandwidth." *Journal of the Acoustical Society of America* 38 (1965): 548.

> of higher harmonies. Pierce has gone on to suggest that our pitch-recognition response is guided by the most perceptually salient partials of the tone.[55]

Furthermore, Butler concludes: "The periodicity shared by upper partials of complex tones seems to govern our sense of pitch when this is the best acoustical evidence available to us."[56] This "periodicity" refers to the regular, maximally beatless overlap of partials between frequencies, which in turn leads to what we decipher as a clear pitch. As Butler notes, "Periodicity theory…was offered by Schouten…who stated that upper harmonic partials of a complex tone are grouped perceptually into a residue pitch equivalent to the tone's fundamental."[57]

One final portion from Butler's text has been reproduced below, as it is directly relevant to questions posed by this thesis:

> If there is any physical or physiological basis for the perceptual regularity of the octave, it is probably to be found in the harmonic relations of tone partials and in perceptual harmonic distortion…It might even be that aural harmonics confer some perceptual advantage upon combinations of tones that best match the aural harmonics…To infer beyond this that physical and physiological harmonic relations adequately explain musical harmony and tonality—as has often been done—has its dangers.[58]

While it may certainly be a stretch to make a direct connection with tonality and the phenomenon of aural harmonics—which Butler deems "…only a small twist on

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55 David Butler, *The Musician's Guide to Perception and Cognition* (New York: Schirmer Books, 1992), 44. The author of the findings he is referring to is Allan Pierce, a prominent 20th-century acoustician.

56 Ibid., 60.

57 Ibid., 41.

58 Ibid., 52.

Helmholtz's theory…"[59]—I do think that this may not only account for the "perceptual regularity of the octave," but of the perfect fifth, and the harmonic major third as well. Furthermore, the fact that a tendency to tune pitches in accordance with harmonic ratios when away from temperament may have physiological underpinnings is fascinating. It is indeed a "danger," but one that is an inherent risk in discussing these topics. It is important to remember that this does not imply an aesthetic *superiority* for just vs. tempered intervals[60] (or for tonal vs. atonal music), but could merely suggest a basic human proclivity for understanding consonance and dissonance that may further account for the discordance of Second Viennese atonality.

While it has been referenced several times, I have not yet explained the term inharmonicity—I will briefly digress and do so now. Inharmonicity is defined as the degree to which a tone's partials do not line up with the harmonic ratios of the natural overtone series of its fundamental. While all instruments will exhibit some degree of inharmonicity, the effect is exacerbated in piano keyboards, due to the tension of the strings themselves as well as colliding partials between tempered intervals. A more accurate way of saying this is that tempered intervals themselves lead to a greater number of inharmonic partials, as tempered major thirds differ especially from those present in the harmonic series.[61] Indeed, octaves must be stretched to accommodate the colliding

59 Ibid., 52.

60 Though, it would depend on whom you ask. Personally, I revel in singing just intervals, but recognize that in performance, some method of tempering intervals—I think of it as "taking a little off the top"—is both a reality and a necessity in most cases.

61 In this way, inharmonicity, usually considered an unavoidable consequence of strings and air columns as oscillators, may become especially worse with tempered intervals.

partials, and most pianos exhibit stretched tunings, with a flatter lower register and a sharper upper register.[62]

The greater the inharmonicity, the greater the number of partial collisions. Thus, more sensory dissonance—as Helmholtz would maintain—is present in a sound with a preponderance of inharmonic partials. This is what I mean in saying equal temperament may be more discordant due to increased inharmonicity—sensory dissonance that as I posit, becomes curbed among ensembles unrestricted by fixed tuning.

I will now return to Plomp and Levelt's 1965 study in order to briefly describe what they identified as critical bands and the critical bandwidth. A critical band is a range of frequencies in which two tones are still perceived to be a unison, while the critical bandwidth is the range between two frequencies in which their pitches are perceived to be different.[63] The graph from Plomp and Levelt's article is included below, in Figure 5.

If the difference between two simple tones falls within this area of the critical bandwidth, sensory dissonance is maximized. Plomp and Levelt connected this idea to Helmholtz's theory of dissonance—a preponderance of beating among partials of tones—positing that the disturbances of critical bands amongst these partials contributes to sensory dissonance, and in turn, musical dissonance.

62 "About the Tuning of the Piano: Inharmonicity" (Accessed October 6, 2014)
http://www.postpiano.com/support/updates/tech/Tuning.htm
To me, this suggests that equal temperament is more discordant that we realize because piano tuners themselves deviate from its ideal, completely equal division of the octave in order to accommodate harshly colliding partials, especially in upper registers.

63 Theresa Veltri, "Critical Bands" (Accessed January 20, 2015)
http://www.psychologyofmusic.co.uk/criticalband.pdf
Veltri uses "atonal music" and "tone clusters" as examples of critical bandwidth.

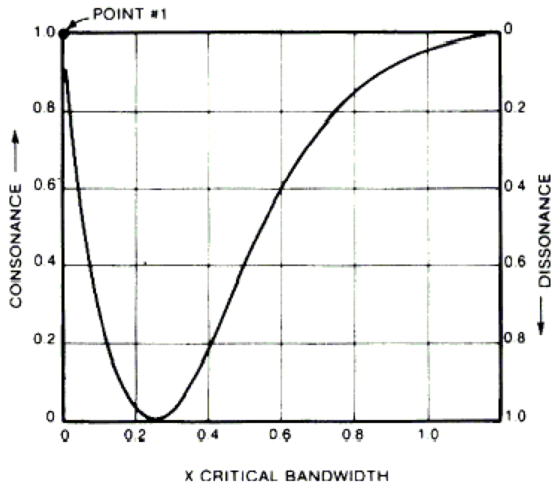

Fig. 5: Graph of two tones as the frequencies are slowly separated from unison to octave. The most dissonant region lies within about ¼ of the critical bandwidth.

The next graph (Figure 6) illustrates that the typical ordering of Western consonant and dissonant intervals dovetails with Plomp and Levelt's published results in 1965; it would seem sensory consonance exhibits some kind of relationship to musical consonance.[64] William Sethares, in his 1998 text *Tuning, Timbre, Spectrum, Scale,* discusses Plomp and Levelt's findings. Note that these are for two *complex* tones, with the first 6 harmonics present in each:

> Observe that figure 4.4 [Figure 6 below] contains peaks at many of the just intervals. The most consonant interval is the unison, followed closely by the octave. Next is the fifth (3:2), followed by the fourth (4:3), and then the thirds and sixths. As might be expected, the peaks do not occur at exactly the scale steps of the 12 tone equal tempered scale. Rather, they occur at the 'nearby' simple ratios. The rankings agree reasonably well with common practice…Thus an argument based on sensory consonance is consistent with the use of just intonation…at least for harmonic sounds.[65]

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64 Reinier Plomp and Willem Levelt, "Tonal Consonance and the Critical Bandwidth." *Journal of the Acoustical Society of America* 38 (1965): 556.

65 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 87.

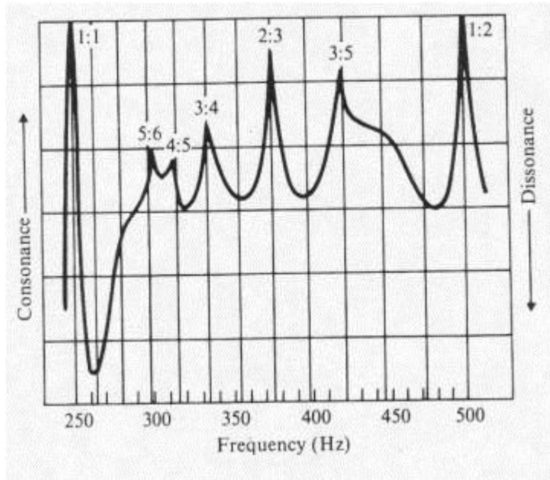

Fig. 6: Consonance ratings for intervals generated between two complex tones.

Plomp and Levelt's experiments propelled Helmholtz's groundbreaking discoveries into the 20th-century, and they remain relevant today in the 21st-century as a result—for both theorists, and psychoacousticians. Though it is a dangerous connection to make, as evidenced by Butler's comment, these findings may suggest *some* tendency toward intervals that are closest to their harmonic resemblances, which in turn could explain a preponderance of sensory consonance in tonal music. As Sethares himself concludes,

> The words 'consonance' and 'dissonance' have been used in at least five different senses throughout history, and many of these conflicting notions are still prevalent today. Sensory consonance, with its emphasis on roughness and beats, provides the most pragmatic definition…it leads to physical correlates which can be readily measured.[66]

While I won't be quantitatively measuring dissonance of tonal and atonal works in this thesis, in Chapter IV will provide audio examples, which upon comparison should permit reasonable, qualitative speculation for *dissonance within discordance*.

66 Ibid., 88.

Eric J. Heller's text, *Why You Hear What You Hear: An Experiential Approach to Sound, Music and Psychoacoustics* is a prime example of Helmholtz's theory of sensory consonance and dissonance remaining influential into the 21st-century. Published in 2013, Heller's text contains comments relevant to the notion of dissonance as partial collision (which in turn creates more critical bandwidth clashes, as Plomp and Levelt discovered). In the section "Dissonance and Temperament," Heller writes, "If quantitative science cannot substitute for qualitative efforts of music theorists, it can at least inform those efforts."[67] Furthermore, and more significantly, "There will never be a way to fully quantify dissonance, since it is a human impression of sound, differing from one listener to the next, differing by experience and training, and differing by musical context. However, one can make rough and qualitative estimates of dissonance."[68]

These "rough and qualitative estimates of dissonance," for this thesis' purposes, can be thought of as a direct result of acoustical dissonance within both the tuning of a piece, as well as the intervals employed. In essence, though it is a "human impression of sound, differing from one listener to the next"—which is consistent with a more subjective, context-dependent notion of consonance vs. dissonance—equally-tempered, twelve-tone atonal music is significantly more likely to contain greater sensory dissonance than tonal music confined to the same tuning system. Of course, just as a reminder, this is not to insinuate that tonal music is superior to atonal—as the traditional naturalist position would hold—or vice-versa. It is simply an acoustical and sensory observation that may lead one to speculate about factors that inform negative aesthetic

67 Eric J. Heller, *Why You Hear What You Hear: An Experiential Approach to Sound, Music, and Psychoacoustics* (Princeton, New Jersey: Princeton University Press, 2013), 510.

68 Ibid., 510.

reactions toward Second Viennese atonality. Could untempering the tuning mitigate this problem? What would twelve-tone music tuned closer to pure intervals sound like? Would it make a difference at all? As Walter Piston would ask, what would Schoenberg think?

Lastly, to briefly return to a comment from Butler's *Guide to Perception*. Butler states: "…sensory consonance and "higher-level" cognitive awareness of style dependent (and style defining) conventions of pitch relationships in music are not entirely unrelated, but the former certainly does not offer a satisfactory explanation of the latter."[69] This may be the case for music employing a healthy abundance of tonal consonances, because the equally-tempered intervals are "close enough" to reasonably satisfy the ear. In tonal compositions—and even in borderline atonal, yet centric pieces—these very "style dependent and style defining conventions of pitch relationships" *are* more related to sensory consonance. However, for more dissonant, twelve-tone atonal compositions, the tuning of these intervals—which can be linked to sensory consonance— may remain a variable in the aesthetic judgment of the music; in part because these very "conventions of pitch relationships" are *less* related to sensory consonance.[70] The immediate impression of a discordant, twelve-tone piece may be that it sounds out of tune. If these intervals, especially consonances, are tuned more accurately, the resonance and purity of the sound will noticeably improve. Conversely, it could be argued that the tuning of an atonal piece is less important than in a composition employing some degree of tonal centricity—if the intervals are dissonant to begin with (and if there are a lot of them),

69 David Butler, *The Musician's Guide to Perception and Cognition* (New York: Schirmer Books, 1992), 118-119.

70 The question, then, really isn't "does atonal music contain more sensory dissonance than tonal music?" But , "does this dissonance matter?"

perhaps tuning them closer to pure won't have as much of a resonant effect as with tonal consonances. Is it really less important, though, or can twelve-tone atonal compositions depend on careful intonation—away from tempered instruments, of course—to find the purest, most harmonically resonant tunings for their chromatic harmonies? Paradoxes abound. The conclusion of this thesis will discuss and attempt to resolve them.

Twelve-tone music, thus, will theoretically contain a greater abundance of sensory dissonance (or roughness) due to its equally-tempered conditions and increased employment of dissonant intervals within this discordance of equally-tempered tuning. *Theoretically*. Chapter IV of this thesis will provide arguments and evidence to support this assertion further.

CHAPTER IV

THE DISCORDANCE OF EQUAL TEMPERAMENT: EXPLORING THE RELATIVE "FIT" OF MUSICAL STYLE TO TUNING

> As the modern Western instrumental families grew, they were designed to play along with the 12-tet piano, and the tunings' dominance became a stranglehold. It is now so ubiquitous that many modern Western musicians and composers are even unaware that alternatives exist.[71]

As evidenced, several dynamic bodies of discourse remain active in describing and characterizing the conflicting implications—both aesthetic and practical—between intonation and tuning. While there is evidence to suggest that musical performers removed from instruments that are not fixed in tuning (namely keyboard instruments) play both in equal temperament as well as in various forms of Pythagorean and/or other just tunings, it is the evidence of the latter that is important and relevant to the present discussion. This penultimate fourth chapter will elaborate further on equal temperament as an inherent aesthetic compromise, or, discordant by definition. It will also revisit the problem of intonation and tuning to support the notion that equal temperament is a dissonant system of tuning that is not necessarily ideal in many performance mediums. Lastly, the concluding remarks of this section—as well as the thesis as a whole—will attempt to draw a connection between the nature of performance and listening criteria. If there is evidence to suggest that performers shy away from equal temperament in even a dodecaphonic musical work[72], and that listeners largely prefer tunings with pure thirds and fifths (as well as other intervals with minimal beating), the frequent aesthetic

71 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 55.

72 Michael Kimber's "Intonation Variables in the Performance of Twelve-tone Music" provides evidence that establishes this tendency, which will be mentioned in this chapter.

backlash atonal music receives—starting with the Second Viennese School—to me, at least, begins to make a lot more sense. Without question, my personal experience as an unaccompanied ensemble singer has guided my perspective on this topic and has been a significant impetus for this thesis. I will include some personal anecdotes in the conclusion to this investigation, which despite being subjective, are nonetheless relevant to the arguments presented.

How and Why Is Equal Temperament Discordant?

> Despite its high theoretical prestige in the sixteenth century, just intonation was already known to be inappropriate as a tuning system for keyboards. A solution to the problem inevitably involved altering or *tempering* certain intervals.[73]

Even the most ardent proponents of equal temperament as a tuning staple and standard are often forced to admit that the system—no matter its practical value—is a compromise. A relatively recent critical analysis of equal temperament is Ross Duffin's 2007 New York Times best seller, How Equal Temperament Ruined Harmony, and Why You Should Care. While the title is certainly provocative—and perhaps a little sensational—Duffin's short text provides a succinct, informative account of the history of temperament, including the advantages and problems it introduces. As Duffin makes clear, twelve-tone equal temperament is a relatively recent phenomenon, considering the multiplicity of tunings that were available to musicians and composers at the turn of the 19th-century. In the introduction, Duffin makes an aesthetic clarification that I'd like to echo:

> I hasten to point out that I didn't call this book "How Equal Temperament Ruined Music." I don't believe that. It's the sound of the

73 Rudolph Rasch, "Tuning and Temperament," *The Cambridge History of Western Music Theory*, edited by Thomas Christensen (New York: Cambridge University Press, 2002), 201

> music, the *harmony*, that has been compromised by the exclusive use of ET in performance. Modern musicians would disagree because they're used to it, and because it's convenient. But what I want to show in this book is that…in some respects ET doesn't sound as good as some of the alternatives.[74]

Similarly, I would say that equal temperament, despite all its compromises, has been indispensable for Western music. However, as Duffin points out, it has also compromised our sensitivity to purer harmonies, and has led musicians to the obvious misnomer of its existence as the only tuning system available and in use. In addition, as I have been contending throughout this paper, ensembles unrestricted by equal temperament can gravitate *away* from equal temperament in pieces that are written *in* equal temperament. I maintain that it is because of the listening musician's tendency to align partials in tonal consonances that leads to these sorts of deviations.

It will be useful to provide some visual and auditory examples that demonstrate the difference between familiar harmonies in just intonation and equal temperament. Figures 7 and 8 show waveforms of triads tuned in just intonation and equal temperament.[75]

Fig. 7: Waveform of a C major triad in just intonation; note the consistent, periodic structure of the frequency. The natural harmonics are reinforcing themselves due to the pure tuning of the third and fifth.

74 Ross Duffin, *How Equal Temperament Ruined Harmony (and Why You Should Care)* (New York: W.W. Norton & Company, 2007), 17-18.

75 Benjamin Coy, "An Introduction to Temperament," *Jayfriedman.net* (2009) (Accessed December 12, 2014) http://www.jayfriedman.net/articles/an_introduction_to_temperament

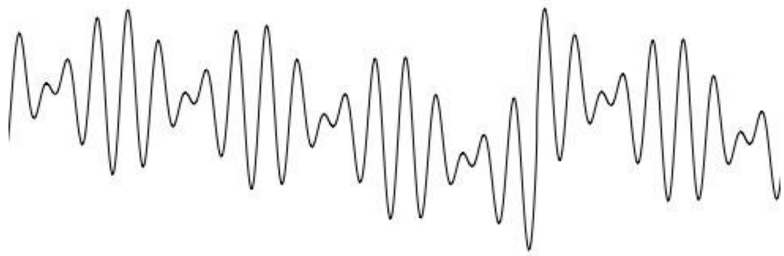

Fig. 8: Waveform of C major triad in twelve-tone equal temperament. Notice the irregularity of the waveform, in comparison to the just major triad. This is a result of beating, taking place between misaligned partials in the harmony. This can clearly be heard in the audio sample.

The tuning of these triads can be compared by listening to audio examples 1 and 2 (see supplemental files for all audio examples), in just intonation and equal temperament, respectively. The beating in the latter example is clearly audible, while the former exhibits none of the same acoustic clashes. Nearly all the listeners I have played these examples for immediately noticed (and usually preferred) the greater consonance achieved in the just triad. The inharmonic clashes among partials in the tempered triad were conspicuous at the very least, especially upon comparison to the just version.

Interestingly, inharmonicity—explained previously—is essential to the tone of the piano keyboard itself, despite being considered an "objectively" dissonant phenomenon.[76] This indicates that the influence of what is *subjectively* dissonant or consonant—now more in the realms of tension and release—can be powerful enough to distract listeners from the harsh beating of equally tempered harmonies. It will be demonstrated shortly that the harmonies become clearer when a work is orchestrated, as the increased

76 Brian Blood, "Music Theory Online: Pitch, Temperament, and Timbre." *Dolmetsch Online* (2014) (Accessed October 6, 2014) http://www.dolmetsch.com/musictheory27.htm
As Blood recounts, "…Harvey Fletcher with collaborators found that the spectral inharmonicity is important for tones to sound piano-like. They proposed that inharmonicity is responsible for the 'warmth' property common to real piano tones."

harmonic timbres of the instruments—as well as purer intonation, as I contend—contributes to the concordance of the sound. An orchestral arrangement, even of a Second Viennese twelve-tone work, will almost always contain less sensory dissonance.

While these examples provide a very rough idea of the difference between the two, it is important to at least contextualize these triads a little. Three versions of "God Save the King" illustrate the consequences of using both just intonation and equal temperament. Figure 9 reproduces the opening of this progression.[77]

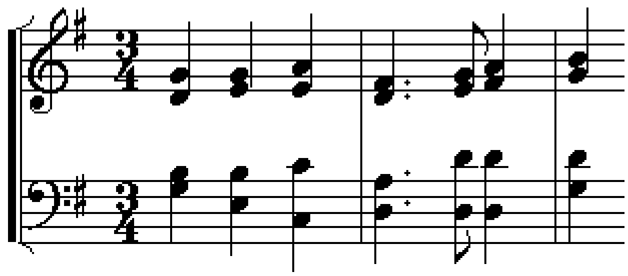

Fig. 9: "God Save the King" opening

Audio example 3 demonstrates that if strict just intonation is employed—keeping all common tones identical—the center of pitch drifts depreciably as the progression repeats. However, notice the quality of the harmonic sonorities. Though they do drift in pitch over time, each chord is tuned completely just. Example 4, in equal temperament, contains healthy beating in each of the chords, but G major remains at exactly the same pitch level. Finally, audio example 5 is another version in just intonation, which compromises by tuning the A above the V chord (measure two, beat one) a syntonic comma higher than the A that precedes it in the soprano. This keeps everything at the

77 Olivier Bettens, "Renaissance 'Just Intonation,' Attainable Standard or Utopian Dream? Outline of a Model Based on Zarlino's Theory" (Accessed January 30, 2015) http://www.medieval.org/emfaq/zarlino/article1.html

same pitch level, with pure harmony throughout, but may sound a little jarring at first. Ensembles removed from temperament will make these kinds of adjustments. As the reconciliation between temperament and intonation takes place, both retention of pitch level and purely tuned harmonies are being prioritized by performers.

All temperaments entail beating between some of their intervals, but equal temperament is the only tuning of its kind that contains beating between every consonance, with exception to the octave. As has been mentioned, the major third bears the brunt of the comma distribution, and is 14 cents sharper than its pure harmonic ratio. This means that all major thirds, in all keys, will be sharp by about 14 percent of a semitone. In fast music, this beating is usually not noticeable, but in sustained and slower passages, it becomes conspicuous, and most groups—if they are really listening—will try to tune these thirds pure if the melodic context allows.

More Problems for Intonation and Tuning

Up until this point, frequent references have been made to the discrepancy between intonation and tuning. The last chapter provided a few short examples that demonstrate this distinction, including the potential ramifications of untempered tuning. Music theory—and as it turns out, science—have attempted to reconcile the two for centuries. Comma drift was explained briefly earlier, but this section will be dedicated to further demonstrating the validity of just intervals as a performance tendency. After discussing use of just intervals in choral performance, as well as comma drift, I will provide examples to support these claims. Using short audio segments, comparisons will be drawn between intervals, chords, and real musical passages, tuned in equal temperament and just intonation (or use of intervals from both). If I can reasonably posit that the impact of these tuning discrepancies—while often subtle—affect the way listeners hear and judge a piece, I believe it is possible to establish a connection between this tendency and its aesthetic implications for the precepts of Schoenberg's twelve-tone method. Again, just to revisit the primary question that this thesis is pursuing: if the Second Viennese aesthetic is rooted in twelve-tone equal temperament as a obligatory tuning—which from Schoenberg's own statements seem to indicate as much—yet, performers regularly depart from equal-temperament in non-fixed pitch scenarios in order to minimize acoustic dissonance between partials of tones—can a connection be made between this schism, and what I am calling dissonance within discordance? Last but not least, can this provide some insight into why many listeners' less-than-affable feelings toward twelve-tone atonal music persist, even in the academy?

William Sethares shares what he calls a "simple experiment" in *Tuning, Timbre, Spectrum, Scale* that can account for a tendency towards intervals that are maximally beatless and closer to just than equally-tempered tunings. I have experimented with this as well to demonstrate the out of tune, sharp quality of the equally-tempered major third—both for myself, and for my students! Upon producing a single drone pitch from the piano, it is simple, and arguably more intuitive—even for an amateur—to tune major thirds to their 5/4 ratio against the drone. As Sethares details,

> It is easy to experience dissonance for yourself. Play a note on an organ (or some other sustained, harmonically rich sound) that is near the low end of your vocal range. While sounding the note loudly and solidly…sing slightly above, slightly below, and then swoop right onto the pitch of the note. As you approach the correct pitch, you will hear your

> voice beating against the organ, until eventually your voice "locks into" the fundamental…Now sing a major third above the sustained organ note, again singing slightly above and slightly below. Listen carefully to where your voice goes…does it lock onto a "true" 12-tet third? Or does it go somewhere slightly flat? Listen carefully to the pitch of your locked-in voice…if you are truly minimizing the dissonance, then the fourth partial of your voice will lock onto the fifth partial of the organ, and you will be singing a "just" major third…Can you feel how it might be tempting for a singer to synchronize in this way?[78]

To answer his last question: Yes, I can! The account provided by Sethares dovetails completely with my own experience of tuning intervals and I tend to agree with his observations. If singers are attentive enough to the intonation of intervals and greater harmonies (and perhaps even in cases when they are not), they will tend toward minimizing the acoustic dissonance by aligning partials between frequencies—in conformity with intonation closer to just values. Personally, I especially notice this when practicing a choral part while playing another voice part in the piano. Often, I would sing intervals that sounded perfectly in tune against the opposite part I played, but when I checked the exact intonation of my line—by playing both lines on the keyboard—I would find that some intervals I chose were not quite the same on the piano, and some even sounded more euphonious.

To get an idea of how these intervals and the consequence of using them—comma drift—it is useful to compare tunings in context. Below are examples of a few short harmonic progressions, each tuned differently. I am indebted to Rudi Seitz and his

78 William Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer-Verlag, 1998), 87.

extremely informative and useful website, from which these progressions are borrowed (Figures 10 and 11).[79,80]

Fig. 10: Descending Thirds Progression with Ascending 5-6 LIP

Fig. 11: Chromatic Thirds Progression, in Equal Temperament and Just Intonation

Audio example 6 is a midi sample of the descending thirds progression in strict just intonation, while example 7 is the same passage tuned in equal temperament. These examples can be found in the supplementary files. The end of each audio example compares the final C major triad with the first. As can be heard in the just intonation version, the final chord is flat by a syntonic comma. However, all the chords are tuned pure, and exhibit no harsh beating on their own. By contrast, the equally-tempered version's initial and final chords are tuned identically—with no drift—but at the expense of dissonant beating in each harmony.

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79 Rudi Seitz, "Mathieu's Virtual Return," *Rudiseitz.com* (2014) (Accessed January 30, 2015) www.rudiseitz.com/2014/01/01/mathieus-virtual-return/

80 Rudi Seitz, "Diesis III," *Rudiseitz.com* (2014) (Accessed January 30, 2015) www.rudiseitz.com/2014/01/04/diesis-iii/

The second example (Figure 11) demonstrates an even larger comma drift, the greater diesis. A visual example of the greater diesis can be seen below (Figure 12).[81]

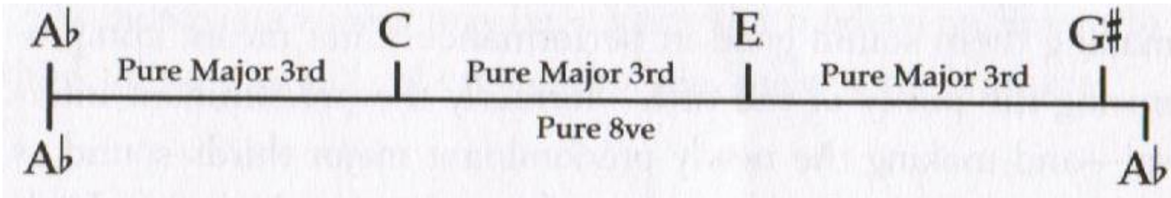

Fig. 12: The greater diesis, or the interval between three pure thirds and a perfect octave.

Audio examples 5 and 6 contain this chromatic thirds progression, in equal temperament and just intonation, respectively. As in Figure 10, the equal tempered version contains conspicuous beating in each triad, but does not fall in pitch. The chords in the just version sound brilliantly concordant, but the pitch drifts by a greater diesis within just three chord changes.

Barbershop quartets are commonly cited as evidence of just intonation in performance. Specifically, they are known for the "barbershop seventh," which is a dominant seventh chord tuned in accordance with harmonic ratios (tuned to the harmonic proportions 4:5:6:7 of a fundamental). When these pitches are lined up with their exact harmonic frequencies, the overtones reinforce each other, creating a maximally concordant, resonant, blended sound. The chord often leads to combination tones, typically a false fundamental an octave or two below the root of the seventh chord. The purity of this harmony is unmistakable, and upon comparison to the ever-familiar equally-tempered dominant seventh, it pales.

81 Ross Duffin, *How Equal Temperament Ruined Harmony (and Why You Should Care)* (New York: W.W. Norton & Company, 2007), 32.

Listen to Realtime's recording of "Yesterday I Heard the Rain" and compare it to the equally-tempered version I have resynthesized (audio example 10, in the supplementary files) using midi vocal samples from Sibelius 6.[82] While Realtime has made their own addendums to the original arrangement, the version I have created shouldn't be too difficult to compare. Listen especially for the various predominant>dominant motions that take place, both in the home and secondary keys. The most brilliantly tuned of these take place in the CD recording at 0:16, 0:38, 0:56, 1:07, 2:23, and 2:34. At the request of Brent Graham, the arranger, I have agreed to not disseminate the original score, but have reproduced the first two of these chord changes solely for visual aid. My recomposed changes are below, in Figure 13.[83]

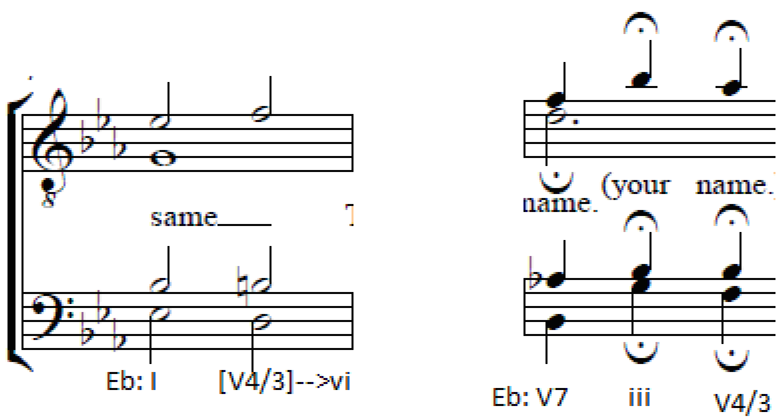

Fig. 13: "Yesterday I Heard the Rain," measures 4 and 8

While all of these dominant seventh (or should I say barbershop seventh?) harmonies are unquestionably more euphonious than the equally tempered versions, the one that stands out to me is the $V^{4/3}$ in measure 8 (second chord change in Figure 9).

82 Realtime, "Yesterday I Heard the Rain," *Four Brothers*, Independent, 2007, compact disc.

83 My sincerest thanks to Brent Graham for his correspondence and for sharing his arrangement with me.

Once the group tunes all of those notes to their harmonic proportions, a clear, almost overwhelming combination tone—a low Bb, the root of the dominant being sustained—is unmistakable. Having possessed this recording for nearly ten years, my hair continues to stand on end throughout the entire performance and I am unable to shake the affect this sort of intonation has had on my own judgment of consonance. It is a striking sound, and cannot be replicated in equal temperament. Does this mean that these sorts of brilliant, purely tuned sonorities are off limits to dodecaphonic music? If Second Viennese atonality prescribes twelve tones, equally spaced, how can anything resembling these sorts of tuning scenarios take place?

Two different versions of Maurice Ravel's work for piano, Menuet Antique, can be compared aurally to demonstrate the discordance of temperament, and the degree to which our ears have adapted to a sound with such a preponderance of beating. I compared a piano recording of the piece[84] to a performance of Ravel's original orchestration.[85] To get the full effect of tuning discrepancy between recordings, listen to the piano version first. Then, listen to the orchestral version, and then the piano version once more. It may be subtle for many, but for myself and many of my colleagues, the tuning depreciation was significant between the recordings. Especially at the first cadence—a C# major triad—is the difference noticeable. In a way, this describes a possible counterpart to dissonance within discordance: consonance within discordance. This could be thought of as a preponderance of consonant intervals within a dissonant medium of tuning, which is

84 Maurice Ravel, *Menuet Antique,* from *Ravel: Piano Works*, Pascal Rogé (piano), Decca 440836, 1994, compact disc.

85 Maurice Ravel, *Menuet Antique,* from *Ravel: Orchestral Works*, Orchestre Symphonique de Montreal, conducted by Charles Dutoit, Decca 000639702, 2005, compact disc.

what twelve-tone equally-tempered tonal music employs. Paradoxically, the music that has been written in and for equal temperament—ostensibly—becomes tuned in a more consonant fashion when fixed-pitch instruments are removed from the ensemble; not exactly just intonation, and not exactly strict equal temperament, but a reconciliation of the two. Will the effect be similar for a piece composed in the Second Viennese style, or will the tuning have a negligible impact on how concordant we judge the harmonies? This will be explored in the final section of this chapter, in which dissonance within discordance will be discussed once more, and two examples of Schoenberg's op. 33a compared aurally.

Michael Kimber's 1974 D.M.A. thesis, "Intonation Variables in the Performance of Twelve-tone Music," will prove imperative for the primary argument of this investigation. In this paper, Kimber directly corroborates Walter Piston's observation about twelve-tone intonation – that performers unrestricted by fixed tuning will adjust their intonation—even within a dissonant, atonal setting—in accordance with Pythagorean and just intervals. Thus, even though a twelve-tone work is *theoretically* limited to the equally tempered scale, multiple versions of pitches –separated by Pythagorean and/or syntonic commas—are employed.

> Noting that pitch adjustments for harmonic reasons have persisted despite traditional notation's inability to express them, the writer proposes that the twelve-tone composer's decision to relinquish, in effect, the available written means of distinguishing enharmonic pitches need not be interpreted to mean that such distinctions must cease to exist in performance.[86]

As Kimber details further:

86 Michael Kimber, "Intonation Variables in the Performance of Twelve-tone Music," (D.M.A. thesis, The Catholic University of America, 1974), 2.

> The present writer…began to discover early in the study of Riccardo Malipiero's *Ciaccona di Davide*, a twelve-tone work for viola and piano composed in 1970, that the same note did not always have the same pitch, but even more importantly, that this pitch variability was consistent, not random or haphazard. For example, at certain places in the music pitches identifiable as Pythagorean E, F, B*b* and B occurred, while in other specific instances their less likely Pythagorean enharmonics, F*b*, E#, A# and C*b*, could be consistently and positively identified. It became apparent that in spite of the composer's choices of notation, pitches must be aligning themselves to form coherent, untempered intervallic patterns with surrounding pitches.[87]

Even within highly chromatic, dodecaphonic music performers will attempt to tune intervals as purely as the context allows. Since the premise of 12-tone harmony relies on equal temperament as a medium of tuning, what I am calling *dissonance within discordance* leads to an inherent aesthetic schism for both performers and listeners.

Dissonance within Discordance

This thesis entangles an understood symbiosis between conditioning and inherent, biological proclivity; thus, I argue that both objective and subjective factors are at play in the judgment of aesthetic consonance and dissonance. There are simply too many factors to consider when discussing a listener's general, "aesthetic evaluation" of a piece of music, but the type of intervals and harmonies employed—including the way in which they are tuned—could be thought of a sort of primordial parameter to a musical composition or performance. As Michael Kimber's thesis demonstrates, performers, unrestricted by fixed tuning, will tend toward purer intervals—compromising the equal division of the octave—even within the context of a composition utilizing a chromatic twelve-tone row.

87 Ibid., 20.

Singers adjust intonation depending on circumstance. Pure intervals, if possible, are approximated often, especially for consonant verticalities of considerable duration. The longer a relatively consonant sonority is held—say a major triad—the greater the chance it will be tuned closer to its harmonic proportions. The same could be said for a justly tuned dominant seventh chord. The Realtime barbershop quartet's recording of "Yesterday I heard the Rain," arranged by Brent Graham, indicates that ensembles approaching just harmonies sound unquestionably more concordant (at least to my ear) than equal tempered harmony. The resonance of these harmonies has a profound affect that tempered harmonies cannot achieve. Due to *dissonance within discordance*, twelve-tone music would seem to be prohibited from achieving such tunings. Indeed, other scholars have made congruent points regarding the aesthetics of dodecaphonic music.

Similar to Fred Lerdahl's prolongational criteria *salience* and *stability,* atonality transfers or shifts the tension-release element from consonance vs. dissonance (interval selection, tuning selection) to other musical parameters. As Lerdahl says in "Cognitive Constraints on Compositional Systems,"

> Sensory consonance and dissonance can in turn form the basis for *musical* consonance and dissonance, where in a general sense consonance is equivalent to stability and dissonance to instability. Thus a seventh in Classical tonal music resolves to a sixth not just out of cultural convention but because the syntactical resolution is supported by sensory experience.[88]

Lerdahl goes on to say that dissonance can in fact be manipulated to be more stable that sensory consonance in a musical situation, but that "the stability conditions"—highly correlated with sensory consonance—"will be relatively ineffectual unless they are

88 Fred Lerdahl, "Cognitive Constraints on Compositional Systems," *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition,* edited by John A. Sloboda (New York: Oxford University Press, 1988), 245.

supported by sensory consonance and dissonance."[89] According to Lerdahl, "…a stability condition says 'Musical context aside, this structure is judged as more stable than that.'"[90] I would further submit that the stronger the tuning, the greater the stability. *Dissonance within discordance* forces atonal music to rely more on salience than stability. Could retuning some of the more consonant sonorities in a twelve-tone work increase its reliance on stability conditions?

Robert Gjerdingen's article "The Psychology of Music," (quoted in passing in Chapter II) from *The Cambridge History of Western Music Theory* mentions very similar concerns towards its conclusion. Gjerdingen writes, "…like Francés, Lerdahl has stressed the limitations in human musico-cognitive abilities as crucial factors in the difficulties that many serial and post-serial musics have had in gaining an audience"[91] Gjerdingen mentions Robert Francés, who he describes as "…among the first to raise a cautionary flag about the perception of twelve-tone music."[92] In my mind, the aesthetic schism between the tendency towards just intonation and the premise of Second Viennese atonality is one of such "limitations in human musico-cognitive abilities." The tuning of already dissonant intervals within a discordant tuning medium enhances the greater, "global" dissonance of a composition. Inharmonicity and mistuned intervals become more ubiquitous in a musical aesthetic bound to equal temperament—as Second

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89 Ibid., 245.

90 Ibid., 243.

91 Robert Gjerdingen, "The Psychology of Music," *The Cambridge History of Western Music Theory,* edited by Thomas Christensen (New York: Cambridge University Press, 2002), 976.

92 Ibid., 976
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Viennese atonality is defined—and as Hindemith puts it, "…the ear becomes uncertain…"[93]

Which intervals are favored in twelve-tone atonal contexts? Will ensembles not restricted by tuning adjust their intonation depending on the melodic or harmonic content of a twelve-tone composition? What are the aesthetic implications of this? Equal temperament forces dissonance into the compositional aesthetic. There is much significance in Schoenberg's pantonality, though it is still rooted in the tuning system itself—the "medium of exchange" –than Ptolemic based scales and tuning systems which set to achieve a purer tuning scheme. Would twelve-tone music sound better if it used harmonies closer to just intervals? It is a difficult question to answer—and can't completely be answered here—but it must be addressed in order to argue for *dissonance within discordance*.

To provide some seed for argument, two different examples of Schoenberg's op.33a, *Klavierstücke* have been included for aural comparison. The first is a recording of the original piano version, performed by Glenn Gould[94], and the second is an orchestration I found, arranged by Keith Kusterer, and performed by the Columbia College of Chicago Orchestra.[95] Simply put, there are things that I do not hear in the piano version that are more apparent in the orchestral arrangement. Upon comparison—especially in some of the harmonies in the registral extremes of the instruments—I find it

93 Paul Hindemith, *Craft of Musical Composition, Book I,* 4th ed., trans. by Arthur Mendel (New York: Associated Music Publishers, 1945), 44.

94 "Arnold Schoenberg – Piece for Piano Op. 33a," [n.d.], YouTube video, 2:44, (Accessed January 29, 2015) March 2008, www.youtube.com/watch?v=dIhPqZdrAyk

95 Keith Kusterer, "Schoenberg's Klavierstück Op. 33a (Kusterer Orchestration)," performed by the Columbia College of Chicago Orchestra (Accessed January 29 2014) 2010 www.soundcloud.com/keithkusterer/schoenbergs-klavierst-ck-op

reasonable to posit that the tendency toward closer-to pure intervals enhances the sensory consonance of certain sonorities. At the very least, to my ear, the pitches are clearer in many of the dense chromatic chords, and there is no question that the harmonic timbres of the orchestral instruments contribute significantly toward marginalizing colliding partials. But, is this what Schoenberg would have wanted? Furthermore, is this what listeners desire?

CHAPTER V

CONCLUDING REMARKS

The impetus for this paper arose as a direct result of my own experience with tuning intervals in unaccompanied ensembles, and how attempting to tune highly chromatic works[96] almost always seemed to lead to pitch fluctuation, mistuned chords, or both. After dealing with tuning issues in a cappella ensembles for the last eleven years, I finally began to seriously consider: What leads to discrepancies in intonation for a cappella choral groups? Certainly it couldn't *all* be sheer mistakes on behalf of the groups I was in; in fact, in many of the rehearsals and performances we had achieved, in my mind, superior tuning to that of the piano keyboard, even when the chords did not exactly align with the tuning of the instrument. Eventually, I asked myself: what drives these decisions in intonation? If performers exhibit a tendency to modify the tuning of a piece composed in equal temperament, does this mean music with more chromaticism will inevitably be tempered, or do performers accommodate? Do they sing in between the piano's cracks, and adapt in even the most chromatic circumstances? Eventually, I thought to connect this practical performance problem to Schoenberg's Second Viennese aesthetic, in which equal temperament would seem a necessity. Could its complete departure from forms of untempered intonation—still manifest in tonal contexts--possibly account for the unpleasant reactions so many listeners and performers exhibit upon experiencing 12-tone harmony? These questions led me to idea of *dissonance within discordance*; that Schoenberg's dodecaphony is not only dissonant due to the preponderance of chromaticism it employs, but also due to its limited projection within

96 Even heavily diatonic tonal music!

a discordant tuning medium.

Though innately this thesis is very epistemological in nature, and ultimately, may come down to the entirely subjective argument of "what one listener/musician considers consonant or dissonant vs. another," accepted, empirical, psychoacoustical definitions of sensory consonance and dissonance have been provided, discussed in detail, and in fact proven relevant to the distinction. Having listened to the audio examples, can said that dissonance within discordance is a possible catalyst for the aesthetic problems commonly associated with Second Viennese atonality, or, Schoenberg's twelve-tone technique. If performers avoid tempered intervals in pieces supposedly composed in equal temperament, this yearning for harmonic intervals could account for an inherent "hurdle"—*dissonance within discordance*—that musicians and non-musicians face in performing and listening to dodecaphonic music.

Due to the transference of tension and release to parameters other than sensory consonance and dissonance (from *stability* to *salience* conditions, for Lerdahl), atonal music can be difficult to grapple with aurally. Atonality only relatively "fits" in a tuning system that is discordant by definition. Or does it? Upon comparison of the two versions of Schoenberg's *Klavierstucke*, striving to achieve purer intonation in twelve-tone music may prove to be a significant aim. Many, my professors included, admitted to the greater purity in many of the sonorities. Harmonies that were previously tempered now stand out more, such as in quartal and quintal sonorities and places that feature thirds and triadic evocations.

While many microtonalists have embraced the idea of just tunings that explore octave divisions greater than twelve tones, I am not aware of any that have attempted to consciously and systematically retune a twelve-tone composition. In my future research, I hope to learn about and obtain technology that will allow me to experiment with such "retunings." It would be very interesting to see the result of such a project, and I hope to integrate it into future versions of this thesis and as my research expands. As noted by composer John Luther Adams:

> In his insightful Music Primer Lou Harrison observes that Schoenberg's excellent ear led him to understand that in equal temperament there is no real 'tonality,' since all the intervals (except the octave) are untrue. In this light it's not too hard to imagine Schoenberg's twelve-tone techniques as the musical equivalent of gridlock. Rather than sit stalled in a dodecaphonic traffic jam, American composers since Harry Partch (many of whom have felt less of an investment than our European counterparts in equal temperament) have chosen to retune.[97]

While Adams' language is a little strong, the idea he is getting at runs congruous to *dissonance within discordance*. Perhaps experimenting with different tuning schemes can in fact enhance the concordance of otherwise acoustically dissonant sonorities, enhancing the aesthetic appeal in the process. To speculate even further, I personally have noticed that atonal compositions that involve some level of orchestration tend to have greater programmatic recurrence. Atonal vocal compositions, especially dodecaphonic ones, are not performed often, and seem to receive less time in the performance realm. There is much room for experimentation, and I look forward to future expansions of these ideas.

Schoenberg's cognitive dissonance in regards to temperament, tuning, and the overtone series appears once again in a response to a letter from Dr. Robert Neumann. Despite his reservations surrounding any tuning scheme removed from twelve-tone equal

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97 John Luther Adams, "Microtonality: Off the Grid/Out of the Box," *New Music Box*, September 2000. www.newmusicbox.org/articles/microtonality-off-the-grid-out-of-the-box/

temperament (for tonal, and atonal music, at least), Schoenberg's progressive outlook on cultural and musical development allows him to concede that equal temperaments larger than twelve notes per octave may indeed be necessary—in the future. Most importantly, Schoenberg maintains a stance that I believe has allowed atonal music to have relative success, even though its premise is rooted in twelve-tone equal temperament. "It is not merely tone that makes music, but timing (*das Zeitmass*) as well; and it is typical of dilettantes of all fields and tendencies that they are devoid of all feeling for at least one or the other – tone or timing."[98]

There is much more to the aesthetic appreciation twelve-tone music *has* received than sheer "timing," though Schoenberg himself recognized that not "…merely tone makes music…" This would seem to dovetail with the notion of *dissonance within discordance*. However, I also think twelve-tone music remains relatively prominent due to the true, complete alternative it presents to tonal systems. It may not be thought of as harmonically intuitive, but the Second Viennese technique nonetheless presents a highly innovative, aurally idiosyncratic form of music that can quell a sense of repetitiveness that a ubiquity of tonal harmony may induce. Finally, twelve-tone harmony confronts the listener and beseeches them to hear in a completely different manner; it challenges any sort of human gravitation toward pure intervals, and consequently, tonal harmony. This ultimately contributes to a more eclectic and progressive musical culture, in which plurality of musical style remains imperative.

Dissonance within discordance can have potential practical and analytical applications for my future research. One immediate application would be to survey the

98 Arnold Schoenberg, *Harmonielehre,* trans. by Roy Carter (Los Angeles: University of California Press, 1978), 425.

intervallic content of various twelve-tone rows across Second Viennese (and other twelve-tone) composers and rank them in terms of the most dissonant and consonant adjacent intervals within the row. Then, performances could be compared between piano and instrumental versions, and new perspectives on analyses could be formed if intonational departures enhance the concordance of the sound. For instance, if a series of perfect fourths appears in a twelve-tone row, these will be more prominent and will come through the texture if stacked vertically and sustained (orchestration permitting). Another potential application would be to compare the intervallic content of rows from vocal works and compare them with those for just instruments. Did composers consciously alter row content to make it easier on the singers performing the music?

Despite *dissonance within discordance* being a mostly epistemological notion, these practical and analytical applications could provide unique insights into how we hear atonal harmony. If using pure intervals among consonances in twelve-tone rows can influence a performer's and listener's interpretation of a piece, perhaps conscious retuning of a work of Schoenberg's is the first step. I plan and hope to acquire the means to experiment with such retunings, in further research for this topic as well as for my own edification.

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