11 Chant and the Leading Tone

The tonic of a scale is often the higher tone of a semitone interval. The origin of the rising leading-tone effect can be traced to structural properties of religious (Gregorian) chant, although chant itself does not include leading tones. Christian chant was an oral-aural tradition. Repertoires were first notated on a musical staff (like a graph of pitch against time) in the eleventh century, and polyphony emerged in the twelfth and thirteenth centuries. I propose that scale steps (individual sung tones) in chant vary in consonance, depending on how well their audible partials match the prevailing diatonic scale—a form of pitch commonality. Consonant tones were sung more often. The scale step fa *was more consonant than* mi *because the audible harmonics of* fa *better matched the prevailing diatonic scale. That made* fa *more stable than* mi*, which can explain the tonicizing function of rising leading tones in later polyphony.*

Background: Speech versus Song

Both speech and song convey a mixture of lexical and prosodic meaning. The meaning of speech is mainly lexical (like that of words in a dictionary), whereas that of song is more prosodic (depending on changes in pitch, loudness, timbre, and articulation). Prosodic aspects of speech communicate important meanings such as approval and intentionality (Esteve-Gibert and Prieto 2018). In music, specific pitch-time contours occasionally have lexical meanings, a well-known case being the leitmotif in Wagner's operas.

Although language and music vary in their details from one culture to the next, they also have quasi-universal features. One of them is the arbitrary nature of relationships between sound and meaning in language. The sound of a word such as "typewriter" or "laptop" has nothing to do with its meaning, and so the connection is arbitrary. The auditory system of a child quickly learns an enormous number of such arbitrary relationships. Only occasionally does the meaning of a word depend on its sound, the "meow" of a cat being an example (onomatopoeia).

The similarity of speech and song, and their clear separation in only one species (human), suggest that they have a common origin in earlier acoustic-gestural communication (Stumpf 1911/2012) or "musilanguage" (S. Brown 2001). The musilanguage of our distant primate ancestors was possibly comparable with, or based on, motherese or baby talk (Dissanayake 2001). Speech and song may have separated in human evolution during the emergence of what archeologists call *human behavioral modernity*—a complex collection of human behaviors that also include art and religion. Very approximately, behavioral modernity must have started 100,000 years ago (Parncutt 2019b).

Speech is about everyday communication, whereas music is more special, confined to rituals or ritual-like situations. In a broad definition of ritual that includes both religious ceremonies and playful caregiver–infant interactions or lullaby singing, we can say that music communicates abstract (nonlexical) ritual meanings. It also emotionally marks important social changes (birth, marriage, death, healing, new identity, new leader), with implications for social cohesion and psychological health (Lloyd et al. 2008).

As mentioned, both speech and song involve pitch-time patterns called prosody or melodic contour. In song, attention is focused on pitch contours and their emotional connotations, whereas in speech, attention is focused on phonemes (timbres) and lexical meanings. In that regard, both are hierarchically organized. Both have rhythm, but only musical rhythm is perceived to be isochronous. People can usually tap at almost equal time intervals to musical rhythm, which they can also do together, tapping in synchrony (phase locked). It is harder for a group to chant regular speech together, because speech is rhythmically less regular and more variable.

A human speaker normally produces four or five phonemes per second (Tendera et al. 2019). The rate of tones in melodies spans a wider range, from very slow to very fast (say, two to ten per second; Palmer 1997). The average pitch interval between successive melodic tones in the music of the world is approximately a whole tone (or a frequency ratio near 8:9 or 9:10; P. G. Vos and Troost 1989); the range of a melody is usually limited to about an octave. Melodic phrases tend to rise at the start and fall at the end (Huron 1996), just as the fundamental frequency of speech goes up and down with breathing (inclination), but prosodic changes from one word or sound to the next (due to expressive intention—important for understanding the message) may be bigger in language than in music (e.g., S. E. Miller et al. 2010).

Melodic and linguistic quasi universals may depend on universals of human biology and physiology: what fundamental frequencies, noises, and acoustic resonances can be produced comfortably by the human vocal tract, the dependence of voice frequency on subglottal pressure, how fast and accurately the sounds can be produced and perceived, or how sound memory works. Auditory processes such as temporal and spectral discrimination, Gestalt perception, and auditory scene analysis are also relevant.

Gregorian Chant

These generalizations about song apply equally to European plainchant and specifically to Gregorian chant, which emerged in Europe in the ninth century, based on oral traditions of Jewish and Christian song and ritual dating back to the fourth century (Möller and Stephan 1991). Chants were learned by ear and classified into modes, which helped singers memorize the repertoire: "classification of material is generally a sign that it was intended to be memorized" (Berger 2005, 5). From the twelfth century, as student singers started to learn polyphonic composition, "musicians were less concerned with learning basic rules and more with memorizing various alternatives for setting melodic formulas" (Berger 2005, 6).

Many chants are confined to six tones, called the hexachord (*ut, re, mi, fa, sol, la*). The intervals between adjacent tones in a hexachord are whole tone, whole tone, semitone, whole tone, whole tone. From the eleventh century, students learned how to match the hexachord to the chants in their repertory. Today, a hexachord can be played on the white keys of the piano in two places, starting on C (CDEFGA) or G (GABCDE). If transposed to start on F, a black key is introduced (FGAB♭CD).

The only semitone in the hexachord lies between *mi* and *fa*. In later music, and before today's conventions for marking accidentals emerged, tones that acted as *mi* were sometimes marked by predecessors of the sharp symbol, such as the square-looking *b quadratum* corresponding to B♮ in the hard hexachord GAB♮CDE. Tones that acted as *fa* were sometimes marked by predecessors of the flat symbol, such as the rounder-looking *b rotundum* corresponding to B♭ in the soft hexachord FGAB♭CD (cf. Henderson 1969).

Some modes happened more often than others. Willi Apel (1958, 142–165; as cited in W. E. Thomson 1999) commented that in the tonal chant repertory, “the *protus* [D modes] and *tetrardus* [G modes] occupy a considerably more prominent place than the other two, there being approximately 750 chants in the *protus* [D modes], 450 in the *deuterus* [E modes], 250 in the *tritus* [F modes], and 900 in the *tetradus* [G modes]” (38).

But there is more to mode classification than the final (which was D, E, F, or G in the medieval eight-mode system) and the authentic/plagal distinction (i.e., higher/lower ambitus relative to the final). Modes also have different reciting tones (also referred to as psalm tone, tenor, confinalis, dominant, or repercussion), which can make different modes sound more or less similar. Another problem is the occasional use of B♭. If a B♭ appears in a D mode, as a minor 6th above the final D, the result sounds like a transposition of an A mode, in which F is a minor 6th above A.

Ambiguities of that kind mean that Apel’s numbers are only approximate. Nevertheless, some simple explanations come to mind for his observations about the frequency of occurrence of modes. The reason why the E and F modes were less common than the D and G modes may be due to dissonances within the scale relative to the final: the E-F semitone in the E modes, and the F-B tritone in the F modes. These intervals may have been perceived as dissonant or at least unrelated—even when the tones were not sounded simultaneously. In the white-note diatonic scale, G and A seem more consonant as finals because their upper and lower neighbors are a whole-tone away rather than a semitone—a more consonant interval. Final G is flanked by F and A, and final A by G and B. Because B is relatively dissonant (due to the tritone between B and F), final G has an advantage over A.

Melodic C/D

Both simultaneous and successive sounds can be heard as consonant or dissonant (C/D). Under ideal conditions, such as when chant is sung in a resonant space with no background noise, about ten harmonics are audible in each tone, the 9th and 10th harmonics being about a whole tone apart. That has interesting implications for the C/D of successive whole-tone and semitone intervals:

- When the interval between the fundamentals is a whole tone, harmonics eight, nine, ten, and eleven of the lower tone almost line up with harmonics seven, eight, nine, and ten of the upper tone, producing a feeling of pitch commonality. For example, in the interval G2-A2, both tones have harmonic partials near G5, A5, B5, and C♯6. The interval is perceived as consonant.

- If the interval is a semitone, the audible spectra do not overlap. There is no pitch commonality, and the interval is perceived as dissonant.
- If the interval is a perfect 5th, the 3rd harmonic of the lower tone lines up with the 2nd harmonic of the upper tone, producing pitch commonality. If the interval is a perfect 4th, the 4th harmonic of the lower lines up with the 3rd of the upper. In both cases, there is perceptible pitch commonality. In both cases, the interval is perceived as consonant.
- If the interval is a tritone, there is again a lack of pitch commonality, and the interval is perceived as dissonant.

These arguments can explain why whole-tone intervals are so common in melodies, including chant. They are relatively easy to intone (sing in tune) because part of the audible spectrum of one tone lines up with part of the spectrum of the other. By comparison, the semitone interval seems arbitrary; it is not anchored to anything in the stimulus. The same comparison can be made between perfect 4ths and 5ths, on the one hand, and the tritone, on the other.

The effect can be observed in similarity judgments of successive complex tones, as perceived by nonmusicians (who presumably do not recognize specific intervals). Similarity is greater for an interval of two semitones than for an interval of one semitone—but only when the tones are harmonic complex (not when they are pure). The same applies to the tritone when compared with perfect 4ths and 5ths (Parncutt 1989, 120, figure 5.5a).

The preference for whole-tone intervals in Western chant is unsurprising, given that the whole-tone interval is the world's most common melodic interval (P. G. Vos and Troost 1989). That raises the possibility of an alternative explanation. In many musical styles (e.g., those based on pentatonic scales), the whole-tone interval may be the smallest for which the two pitches are perceived to be categorically different, especially considering the importance of song for the prehistorical development of music and the imprecision involved in vocally generating intervals (Pfordresher and Brown 2016). From the available evidence, it is unclear which of the two explanations—pitch commonality or categorical pitch perception—is preferable.

A third explanation involves the amount of information we can store in short-term memory, which according to George Miller (1956) is seven items.

That seems to explain seven-tone diatonic scales, but only on the assumption that tones an octave apart are equivalent. In fact, octave equivalence may have been less important for medieval chant than for later polyphony and MmT. In any case, if one tone in a melody is transposed up or down by an octave, and the others stay where they are, the melody's contour is totally changed, which radically changes the melody's character (Dowling 1978).

Counting Tones

Why did some modes happen more often than others? In a reductionist approach, we might start by counting individual tones, regardless of mode, and ask how often each scale step happens.

The biggest chant corpus available for computer-based statistical analysis is the *Liber Usualis*, a book of Catholic chants that was transcribed from oral tradition and edited by monks from Solesmes Abbey in late nineteenth-century France. The corpus can be analyzed online, courtesy of Distributed Digital Music Archives & Libraries Lab (DDMAL; Schulich School of Music, McGill University, Montreal, Canada; ddmal.music.mcgill.ca). Over the centuries, the repertory could have been influenced by Renaissance and Baroque polyphony and hence by MmT (Dodds 2003). In that case, it does not necessarily reflect chant performance in the Middle Ages.

The distribution of scale-step prevalence in the *Liber Usualis* is shown in figure 11.1(a). The most commonly notated tones are G and A, and the least common (apart from B♭) is B. That is no surprise for chant theorists, who know (referring to the twelve-mode system of Glarean) that modes beginning on G and A are relatively prevalent, whereas the mode on B does not exist in practice due to the tritone above the final. The figure shows that tones C, G, and A happen more than twice as often as B; for a psychologist wondering about statistical significance, that is a big effect.

To check these findings, I counted scale steps by hand in another large collection of Gregorian chants. The corpus of John Bryden and David Hughes (1969) was obtained from "five selected manuscripts . . . the Antiphonals of Lucca and Worcester, and the Graduals of Benevento, St. Yrieix, and Sarum" (vol. 1, vii–viii). The results are shown in figure 11.1(b).

The most striking difference between the two analyses is the reversed relationship between C and D. In Bryden and Hughes (1969), D happens more often than C, whereas in the *Liber Usualis*, C happens more often than D. The latter is surprising, given the medieval four-mode system in which only

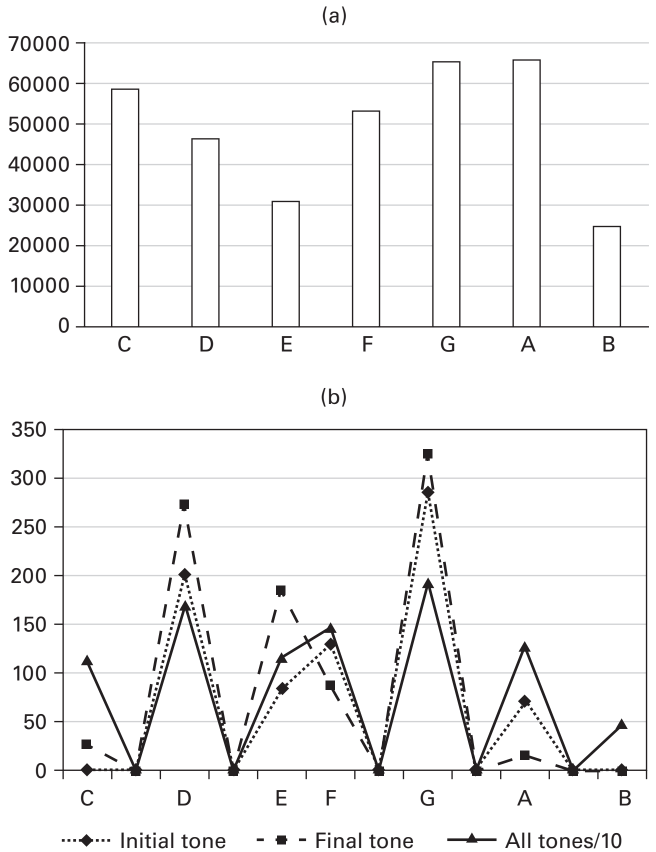

Figure 11.1
Frequency of occurrence of diatonic scale steps in Gregorian chant, calculated in two contrasting ways: (a) by analyzing the *Liber Usualis* using the search machine of DDMAL and (b) by analyzing randomly selected chants from J. R. Bryden and D. G. Hughes (1969) by hand. In (b), results for "all tones" (full line) have been divided by ten for ease of comparison.

D, E, F, and G were recognized as finals. The prevalence of the tone A in *Liber Usualis* is also surprising.

The reason for the difference evidently involves tone repetition: some tones are repeated more often than others, as shown in figure 11.2. Tone repetition was included in *Liber Usualis* as made available by DDMAL, but not in the Bryden and Hughes (1969) collection. Each final in the medieval modal system (D, E, F, and G)—of which G was the most prevalent, followed by D—had its own tenor or reciting tone/note, which was often repeated. For

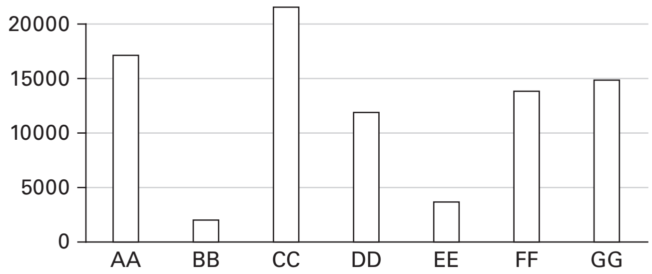

Figure 11.2
Tone repetitions in *Liber Usualis* according to DDMAL: how often a given tone is immediately followed by a repetition of the same tone.

the higher-pitched authentic modes, the tenor was A, C, C, and D, respectively. As a rule, the tenor was a 5th above the final, but it was a 6th higher for the mode on E to avoid the dissonance of B. For the plagal modes, with their lower ambitus, the tenor was a usually a 3rd lower: F, A, A, and C, respectively (avoiding B for the mode on G). The analysis of the *Liber Usualis* in figure 11.1(a), with peaks at A, G, and C, is consistent with these points.

Pitch Commonality and Tonal Affinity

Both parts of figure 11.1 are consistent with the assumption that individual scale steps vary in consonance (Parncutt 2019a). The tone G sounds consonant because all its audible partials (assuming they are harmonics one to ten) correspond to diatonic scale steps: G, D, B, F, and A in different octave registers. Psychoacoustic experiments suggest that the mistuning of the 7th harmonic relative to 12-EDO (about 1/3 semitone) is seldom noticeable in typical musical contexts. The tone B sounds dissonant because about four of its audible partials do not correspond to diatonic scale steps (F♯ in two octave registers, and D♯ and C♯ in one each). For similar reasons, C sounds more consonant than B, and F sounds more consonant than E, the difference being smaller for F and E. In medieval terms, *fa* is more consonant than *mi*—and is therefore sung more often.

A simple model based on the number of audible partials corresponding to scale steps—a form of pitch commonality—predicts that G should be the most prevalent tone. But such a model cannot explain why the tones A and G are about equally common in the DDMAL analysis. As mentioned, a possible reason involves reciting tones. Or perhaps the tone A is more common because the subtonic–final relation G-A (at the end of a chant on A) avoids semitone intervals by the widest possible margin: the scale tones adjacent to both G and A lie a whole tone away on both sides. Similarly, the mode on F does not necessarily happen more often than the mode on E, even if scale degree F happens more often than the scale degree E. The final on E may sometimes be preferable because its subtonic lies a more consonant major 2nd below it, whereas the tone below final F is a semitone below.

A theory of scale-step consonance in chant, in which tones happen more often if their audible partials belong to the prevailing diatonic scale, recalls Helmholtz's (1877) theory of tonal affinity (*Tonverwandschaft*). In the interpretation of Benjamin Steege (2012):

> Helmholtz's theory of tonal affinity required just two seemingly intuitive assumptions, which were nevertheless of a distinctly speculative psychological character: first, what is normally thought of as a singular tone sensation is in fact composed of a manifold bundle of less noticeable discrete sensations, which "the ear" tends to associate by unconscious habit and to identify as constituting a single perception, and second, that despite this unconscious synthesis, listeners tend, even under ordinary circumstances, to retain some intuitive "feeling" for the presence or absence of the constituent sensations, the partial tones. On the basis of the potential greater or lesser degrees of coincidence between the partials of any two tones, Helmholtz supported that a tone would sound inherently more related (*verwandt*) to some tones than to others. (130)

In this way, Helmholtz formulated two ideas that were central to Terhardt's approach to pitch and music. First, virtual pitch (Helmholtz's "single perception") depends on harmonic patterns within more complex spectral-pitch patterns (his "manifold bundle of less noticeable discrete sensations"); the relationship involves a learned process of pattern recognition ("unconscious habit," "unconscious synthesis"). Second, two sounds sound related if they have pitches in common. Helmholtz's idea of *Tonverwandschaft* was confined to common spectral pitches ("greater or lesser degrees of coincidence between the partials"). The idea was developed by Terhardt et al. (1986), who considered not only common spectral pitches, but also (and primarily) common virtual pitches.

Early chant singers were presumably unaware of variations in the C/D of individual tones, although some realized they were avoiding B due to the tritone to F. They could not have imagined a theory of pitch commonality

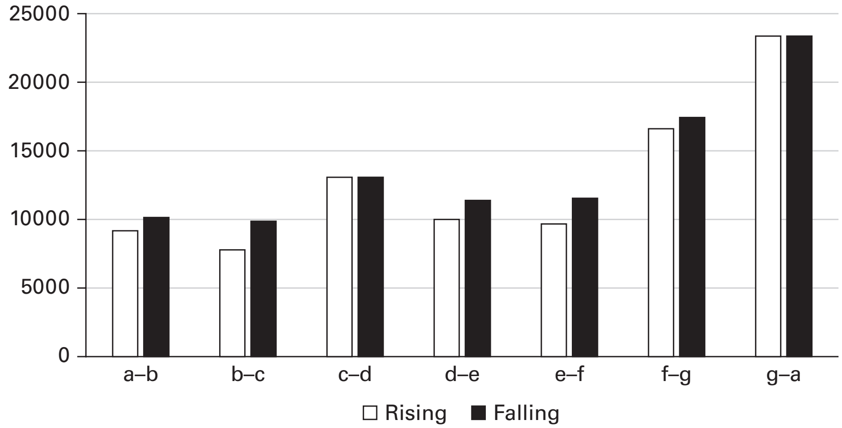

Figure 11.3
Stepwise movement in *Liber Usualis* according to DDMAL. The first white bar on the left shows how often the tone A (in any register) is followed by the tone B in a rising step in the entire corpus. The first black bar on the left shows how often the tone B (in any register) is followed by the tone A in a falling step.

between individual tones and their diatonic context if they were unaware of the audible harmonics within each sung tone. Instead, they preferred some chants over others, or considered some chants more suitable for certain purposes (and hence certain texts) than others. Those preferences may have involved intuitions about the C/D of individual tones. Figure 11.1 suggests that as the chant tradition evolved over the centuries, more consonant tones tended to be sung more often, as chant melodies that emphasized more consonant tones were sung more often.

Counting Intervals

Given that most melodic motion in chant (and most melody) is stepwise, it is interesting to consider melodic progressions systematically, from any tone to its upper or lower diatonic neighbor. Figure 11.3 counts all stepwise movements in *Liber Usualis*. The figure shows that melodic seconds between some scale steps happen about twice as often as between others—another big difference that invites explanation.

Consider first the difference between falling and rising versions of the same interval. In general, falling steps happen slightly more often. Melodies of all kinds tend to start with a rising leap followed by a series of falling steps—a kind of implication–realization relationship (Narmour 1990). The effect is small in chant due to the relative absence of larger leaps.

The peaks at G-A and A-G are striking. Tones G and A may be common either because their partials match the prevailing scale or because they are surrounded by relatively consonant whole-tone intervals (F-G and A-B). The only stepwise motion in which neither tone has a semitone neighbor is G-A. Scale steps B, C, E, and F may be avoided because they are next to dissonant semitones (B-C and E-F). Interval C-D is more common than D-E; of the three tones (C, D, and E), E is the most dissonant, having two audible non-diatonic harmonics (G♯ and F♯), whereas C and D have only one each (B♭ and F♯, respectively).

F-G is more prevalent than A-B, presumably because B is the most dissonant diatonic tone, with the largest number of audible partials that do not correspond to diatonic scale steps. Assuming octave equivalence, the audible partials of B include three non-diatonic pitch classes (F♯, D♯, and C♯), whereas E has only two (G♯ and F♯). The dissonance of B can explain why A-B and B-C are the least common melodic seconds. Of the two, B-C happens less often (at least for rising intervals) because the B-C semitone is more dissonant than the A-B whole tone.

These explanations are provisional and have not been explored systematically, nor have the predictions been quantified in a model. Their explanatory power is evidence for the validity of a theory of scale-tone prevalence in chant that is based on pitch commonality—either between each tone (including its audible partials) and the scale or between successive tones.

The Leading Tone

In 1855, the Belgian Jesuit composer Louis Lambillotte argued that Gregorian tonality, and in particular the *mi-fa* semitone, was full of what Fétis had called "appellative" elements (Christensen 2019). But he was listening to chant with nineteenth-century ears and incidentally had no qualms about harmonizing chant with modern chord progressions.

Even if there are no leading tones in chant, a statistical analysis of chant can give us a clue to the origin of leading tones in early polyphony. Returning to figure 11.1, if we focus on the two semitone intervals (E-F and B-C), it is clear that the higher tone of the semitone happens more often than the lower tone. The reason for the difference probably involves the non-diatonic harmonic partials of B and E. The difference is bigger for B-C because the audible harmonics of B clash more audibly with the prevailing scale. Modern empirical research in music psychology has shown that melodic tones that happen more often are more likely to be perceived as stable points of reference (Lantz et al. 2020; Oram and Cuddy 1995). We therefore expect F and C to be perceived as stable references in chant, and B and E to be relatively unstable. Consistent with this prediction, Guido used colored lines for *do* (yellow) and *fa* (red) in his graphic notation (van Waesberghe 1951). The colors not only attracted attention to the semitone intervals, but also marked the more stable of the two tones in each case.

These considerations can explain why leading tones in MmT tend to rise rather than fall. In the notated polyphony of the fourteenth century (composers such as Vitry, Machaut, Landini, and Ciconia; see Jürgensen 2011), some tones did not conform to the prevailing diatonic scale; their pitches were determined by the rules of *musica ficta* (not by notated accidentals, as in later music). These new tones created new semitone intervals against their diatonic neighbors, which contributed to tonal expectations: “Renaissance music is highly directional, and shows clear tonal goals that are often articulated by means of cadences” (Stern 1981, 5).

The only semitone in the hexachord *ut-re-mi-fa-sol-la* is *mi-fa*. Medieval listeners may have heard non-diatonic tones as either *mi* or *fa*, depending on whether the more stable neighbor was a semitone higher or lower. Therefore, non-diatonic tones in medieval and Renaissance polyphony tended to rise by a semitone to a diatonic tone, making the target tone more stable and creating a temporary reference pitch (cf. Jürgensen 2011). In that way, they tonicized the more stable tone (in Schenkerian terminology).

Jennifer Bain (2003) explained that “because descending semitones are completely absent at final cadences, their tonal effect is one of relative weakness” (333). In addition, Bain (2005) pointed out that “implied semitone motion can contribute fundamentally to the projection of tonal structure in a song” (60) and “this acute concern in medieval notational and pedagogical systems with the placements of semitones suggests very strongly that they are important to tonal organization” (73). In particular, “semitone placement can contribute to the strength or weakness of a cadence” (75). Such remarks are consistent with a chant-based theory of the origin of rising leading tones, and can explain why we take for granted that “leading tones” will rise unless otherwise stated.

Ernst Kurth (1917) argued that although the leading tone is usually the 3rd of V in MmT, the origin of the rising leading-tone effect must be sought elsewhere: "The semitone is a symbol of increased intensity of force. In this final 'chromatic' step to the octave of the tonic [at the conclusion of an ascending major scale], the 'working-off' of the leading note is completed, i.e. of its vital force, manifested to an enhanced degree . . . (The explanation of the effect of the leading note, to be found in very many harmony textbooks, according to its place in the dominant chord, rests on a confusion between cause and effect)" (G. Chew 1983, 37, his translation; the text in parentheses is from Kurth).

Imagine a piece of early music that does not conform exactly to a diatonic scale, so it cannot be transposed onto the white keys of the piano. The underlying scale might for example be what later theorists called harmonic minor, or natural minor with a sharpened leading tone. There are three semitone intervals in the harmonic minor scale: $\hat{2}-\hat{3}$, $\hat{5}-\hat{6}$, and $\hat{7}-\hat{1}$. If early polyphony was based on chant, and if familiarity with chant influenced how early polyphony was perceived, any non-diatonic tone that did not belong to the prevailing diatonic might have been perceived as either *mi* or *fa* if it was heard to be a semitone above or below an existing scale step. The tone would be perceived as *mi* if its main diatonic neighbor was a semitone higher in pitch and as *fa* if it was lower. In the melodic minor, we might expect scale steps $\hat{3}$, $\hat{6}$, and $\hat{1}$ to be tonicized in this way. For $\hat{1}$ and $\hat{3}$, that is no problem—they are part of the tonic triad. The tonicization of $\hat{6}$ creates ambiguity that is resolved by the emotionally laden falling-semitone resolution to $\hat{5}$ (cf. Cooke 1959, as criticized by Clarke 1989b).

A psychoacoustic theory of melodic tonicization by leading tones might be divided into two parts. First, there is a general tendency to resolve dissonances through small steps, independent of direction. That is consistent with the principle of grouping by pitch proximity in auditory scene analysis, as well as the trill threshold (G. A. Miller and Heise 1950; Shonle and Horan 1976). Steve Larson and Leigh Vanhandel (2005) referred to musical magnetism, while for Jamshed Bharucha (1996), the effect was one of melodic anchoring; a music theorist might refer to the "rule of the semitone." Second, rising leading tones tonicize more strongly than falling semitones because in chant and medieval polyphony, *fa* is more stable than *mi*.

Implications

The ideas in this chapter have interesting implications for musical intonation. Pythagorean theorists assumed that chant was ideally tuned, with "pure" octaves (1:2), 5ths (2:3), and 4ths (3:4). Whether that was true in practice, we do not know. At the time, equipment for measuring intonation in live performance did not exist; reliable measurements have only become possible in recent decades (and are still problematic; Devaney et al. 2011).

We can now revisit this question theoretically. Listeners may perceive the audible harmonics of chant relative to the prevailing diatonic scale. Individual tones may be perceived as consonant if the audible harmonic series above them belongs to that scale. The audible harmonics include the 5th, which lies a Just major 3rd above the 4th. If the theory is correct, the major 3rds between C and E, F and A, or G and B in Gregorian chant may ideally be Just. That would be consistent with evidence that the relative prevalence of scale steps in chant depends on how well the audible harmonics match the diatonic scale.

But one can argue, equally convincingly, that chant was tuned to Pythagorean ratios. The traditional argument that tuning depended mainly on 4th, 5th, and octave intervals remains valid. That being the case, the ideal tuning of chant may have been a compromise between Just or Pythagorean. Therefore, any such compromise may be acceptable for historically informed modern chant performances, with 12-EDO being one such compromise. (A major 3rd is 386 cents in Just tuning, 408 cents in Pythagorean tuning, and 400 cents in 12-EDO.) But discussions of this kind may be irrelevant if the intonation of real singers in real performance is not accurate enough to distinguish between Just and Pythagorean.

This chapter has presented a new approach to the structure of medieval chant. The theory is consistent with the idea that musical pitch structure generally depends on the audible partials of each sound—even if listeners are not aware that they are hearing those partials. A partial may be considered audible if a listener can hear the difference between a sound including the partial and the same sound in which only that partial is missing. More generally, a psychological theory of musical pitch structure should ask which partials in musical sounds are audible (as spectral pitches) and which are not. It should then ask how the conscious perception of pitch in music might depend on those audible partials. Terhardt's theory of virtual pitch offers a way forward. It allows us to ask: Which spectral and virtual pitches are audible in a musical passage? How do the virtual pitches depend on spectral pitches? Which of these pitches are consciously perceived? How can the answers to these questions shed light on music-theoretical questions?

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