Enrichment of Music Theory Pedagogy by Computer-based Repertoire Analysis and Perceptual-cognitive Theory

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Introduction

Theories of harmony and counterpoint vary from the most *deductive* (or reductionist), explaining isolated abstract examples by reference to abstract rule systems and tacitly assuming the existence of a normative style (for example, Fux, 1725; Lovelock, 1956; Krämer, 1991), to the most *inductive* (or historical), based directly on scores from different historical styles and periods (for example, de la Motte, 1988). Both approaches have specific pedagogical advantages: the deductive method allows for the complexity of the tonal system to be broken down into easily learnable steps, while the inductive method refers directly to primary source material, and acknowledges stylistic diversity. Modern harmony texts such as Forte (1974), Aldwell and Schachter (1978), Piston (1978), Pratt (1984) and Levine (1995) are situated at different points between these extremes.

Both deductive and inductive approaches to music theory may be enriched by the methods, findings and theories of *systematic musicology*: deductive approaches by relevant perceptual theories, and inductive approaches by context-sensitive statistical analyses of notated music. Most music theories refer in some way to both (psycho)acoustics (for example, the harmonic series) and statistical properties of relevant repertoires (for example, any claim that a given procedure is more prevalent than another, in a given style). Several influential music theories have relied heavily on perceptual-cognitive theory (for example, Riemann's 1877 theory of *beziehendes Denken*, or referential thinking; Hindemith's 1942 theory of *combination tones*; Lerdahl and Jackendoff's 1983 theory of *generative grammars*). Statistical analyses of the musical repertoire – or, failing that, subjective considerations of frequency of occurrence, or *prevalence*[1] – are often used as explanatory tools in music theory (Budge, 1943; Jeppesen, 1946; McHose, 1947; de la Motte, 1988; Eberlein, 1994).

In recent decades, rapid developments in computer technology and psychological research methods have enabled advances in both perceptual theory relevant

to music (Terhardt, 1974a, 1976; Parncutt, 1989; Bregman, 1990; Krumhansl, 1990; Tillmann et al., 2000) and the application of statistical procedures to the analysis of musical scores (Huron, 1999). Computers are routinely used to run psychoacoustical experiments (including digital sound synthesis and analysis), to analyse large historical databases of musical scores, and (in both cases) to carry out statistical analyses.

With relatively few exceptions (for example, Lerdahl, 1988; Larson, 1997a), music theorists have been slow to take advantage of these developments – perhaps due to the political landscape of universities, which tends to isolate music theorists from scientific colleagues with similar interests. But given the long music-theoretic tradition of direct or indirect reliance on perceptual theory and statistical analysis, and the evident ability of perceptual-statistical approaches to cast new light on age-old questions of why musical elements function in the way that they do, the gradual incorporation into theory texts and courses of modern improvements in both fields would appear inevitable. Here, I describe specific ways in which this kind of integration may occur.

The materials I will describe lend themselves to either traditional or computer-assisted instruction. A computer-assisted course in harmony and counterpoint might integrate the following four modules:

1. Implementations of relevant perceptual-cognitive models such as roughness and fusion of sonorities, pitch salience, perceived relationships between sonorities, perceptual grouping in the auditory scene, melodic expectancy, tonal stability and tension, key relationships, and so on (details below).
2. Tools for statistical analyses of databases of musical scores (cf. *Humdrum*: Huron, 1999).
3. The theory of *pitch-class sets* (pc-sets; Forte, 1974).[2] Usually applied to atonal music, pc-set theory may also shed light on perceptual and historical aspects of different tonal systems (for example, Parks, 1989). It provides a framework within which all possible pitch patterns in the chromatic scale (chords, functions, harmonic sequences ...) can be systematically investigated with respect to given perceptual parameters and constraints.
4. Sound, so that students can hear the materials they are working with in the above three cases.

Of course, the system would need to be user-friendly and flexible. The various modules would be interconnected in an open design, allowing for unanticipated future extensions. The creation of such a system would be a major, but fruitful, research project.

A course in music theory incorporating perceptual theory and statistical analysis could be designed in various ways and at various levels (high school, conservatory, university undergraduate, graduate). Students might first carry out statistical analyses of scores in a given repertoire (cf. Krumhansl et al., 1999). They would be encouraged to repeatedly refer back to the scores themselves – to study the specific contexts in which musical patterns of interest occur. They would then adjust their analyses to account appropriately for context. Following Meyer (1973), context-dependent analyses of this kind may be regarded as summary representations of the syntax of a given style.

Students might then attempt to simulate their statistical data using perceptual models. The aim would be to test the validity of the models, and to explore the extent to which the perceptual parameters being modelled may have influenced the historical development of tonal syntax.[3] Beginning with the assumption that all possible patterns in the chromatic scale are candidates for musical elements, students might systematically enter selected pc-sets (or T_n-sets: Rahn, 1980)[4] into relevant models. Results would also be compared with the properties and functions of musical elements in conventional harmonic theory, and with students' musical intuitions.

Statistical analyses of musical patterns divide into two broad categories: those that depend on the location of a predetermined tonic (for example, prevalence of scale steps in a major or minor key), and those that do not. Often, a piece of music has no clearly defined tonic, or the exact location of modulations is unclear (Thompson and Cuddy, 1992), making a tonally based analysis problematic. The following presentation of selected teaching materials begins with analyses of music that are not limited by this constraint.

Effects that are Independent of Tonality

The simplest consideration is the *range of absolute pitches* used in music. Most musical pitches are confined to the range of the treble and bass staves.[5] Why? Presumably, because the range of the bass and treble staves corresponds roughly to the range of the human voice (women, men, children). But why is pitch in *instrumental* music mostly confined to the bass and treble staves, even though instruments such as the double bass and piccolo – and, of course, the piano – are not? Perceptual theory provides an answer: the *pitch salience* (clarity, prominence, attention-getting power) of harmonic complex tones is greatest in the range of the treble and bass staves – a consequence of the co-evolution of the ear and the voice (Terhardt et al., 1982; Huron, 2001). If pitch plays an important role in musical structure, as it does in both western and most non-western musics (because of the way the ear is attuned to the non-musical human environment: Parncutt, 1998), musical tones with clearer pitches tend to be favoured over those with less clear pitches.

Next, we may ask whether there are any interesting statistical regularities in *melodic intervals* in music. For example, which are more prevalent in melodies: rising or falling seconds? In advance, one may hypothesize that all intervallic possibilities are regularly tried out by composers. So there should be no big variations in melodic interval prevalence, in a large, representative sample of music. Wrong! Systematic musicological research (for example, Vos and Troost, 1989) has shown that these distributions are far from a flat. First, easily the most prevalent melodic interval in western music is the major second (M2). Minor seconds (m2s) occur about half as often. Beyond the M2, larger intervals are generally less prevalent than smaller (with a couple of obvious exceptions: perfect fifths (P5s) are more prevalent than tritones, and perfect octaves (P8s) than major sevenths (M7s)). Music with many large melodic intervals (for example, Webern) is unusual. Second, smaller intervals (especially seconds) tend to fall more often than rise, and larger intervals (starting with the perfect fourth or P4) more often rise than fall – with the exception of the P5, which (in western music) tends to fall more often than rise. Vos and Troost observed the same two effects in a wide range of non-western melodic styles, suggesting that they are good candidates for musical universals, and motivating us to look for a psychological explanation.

The predominance of M2 intervals in melodies may be explained by Bregman's (1990) theory of stream fusion and segregation (see also Miller and Heise, 1950; Noorden, 1975): in the *auditory scene*, tones that are close to each other in pitch and time (gestalt principle of proximity) are more likely to be grouped perceptually (*melodic fusion*). A musical melody is a good example of such a unit (although melodic coherence also depends on higher-level style-dependent cognitive factors: Deutsch, 1999). The relative rarity of the m2 by comparison to the M2 may be due either to performance limitations (tuning the voice while singing), perceptual limitations (categorical perception of pitch: Burns, 1999), and/or cognitive limitations on memory for scale steps (Rakowski, 1997). The second effect – the asymmetry between rising and falling intervals – is harder to explain. Melodic phrases typically begin low, rise to a peak, and fall again at the end (Huron, 1996), imitating the rising and falling of pitch between breaths in speech. Musically, this pattern could be matched either by a rising leap followed by several falling steps (regarded by Meyer, 1973 and Narmour, 1977 as an implication followed by a realization), or by several rising steps followed by a falling leap. The first of these two patterns better matches speech intonation, in which a fast intake of breath associated with a sudden increase in pitch is followed by a slow exhalation (while speaking) associated with a gradual decrease in pitch known as *pitch declination* (Cohen et al., 1982; Fujisaki, 1983; Ladd, 1984).[6]

Consider now melodic fragments of three tones. Having heard two tones, listeners tend to expect a third tone at certain pitches and not at others. For example, if the first two tones form a rising leap, listeners expect a step in the opposite direction, especially if the second tone is near the top of the tessitura of the instrument or voice (Hippel and Huron, 2000). *Melodic expectancies*, expressed as probabilities of continuation as a function of pitch, can be generated quite accurately by a system of perceptual-cognitive rules (Krumhansl, 1995; Larson, 1997b; Schellenberg, 1997).

Consonance and *dissonance* have been defined in various, sometimes inconsistent, ways, in both music theory (Cazden, 1980; Tenney, 1988) and psychoacoustics (Plomp and Levelt, 1965, give a historical overview). A possible reason is that, like timbre (Grey, 1977), consonance is psychologically multidimensional. One of the most important of these dimensions is the *roughness* that is perceived on the surface of the sound. The roughness of a harmonic interval is associated with beating between almost-coincident partials (pure tone components). The strength of the roughness sensation can depend on the amplitudes and frequencies of all partials in both tones (Plomp and Levelt, 1965; Terhardt, 1974b; Rakowski, 1982). Historically, listeners' tolerance and preference for roughness changed as the syntax of western music developed.

Of the 12 *harmonic intervals* within an octave that can be formed by typical musical tones, the P8 is the least dissonant, followed by the P5. The relative dissonance of the other ten intervals depends on the spectral envelope of the tones, the octave register in which they are presented, the criteria according to which dissonance is judged, and the musical experience of the listeners. According to Malmberg (1918), this order is M6, M3, P4, m6, m3, TT (tritone), m7, M2, M7 and m2.

Consonant harmonic intervals tend generally to occur more often than dissonant ones in tonal music – a fact that can easily be demonstrated using statistical software. Prevalence distributions of harmonic intervals depend further on the number of voices in the texture, and which voices are chosen for the analysis; for example, in mainstream tonal music, the P4 interval occurs more often between upper voices than between an upper voice and the bass (see discussion on chord inversion below).

Harmonic fusion may be defined as the tendency for a harmonic interval or chord to blend perceptually into a single sound (DeWitt and Crowder, 1987). It may be explained in the context of Terhardt's (1974a, 1976) theory of the perception of pitch, consonance and harmony (Parncutt, 1988, 1989, 1993), as follows. A musical sonority (complex tone or chord) generally evokes several different pitches, which may be perceived either simultaneously (*multiplicity*), or separately, at different times and in different contexts (*ambiguity*). If one of these pitches is much more salient than the others, it may be the only pitch to be noticed (consciously perceived), and the sonority will fuse. Terhardt's theory predicts the relative perceptual salience of a sonority's pitches in two stages. First, the salience of each *spectral pitch* (corresponding to an audible partial) is calculated. Second, *virtual pitches* are identified by looking for harmonic patterns among the spectral pitches; their salience is calculated on the basis of the spectral pitch saliences. In this approach, harmonic P8s, P5s and P4s between musical tones fuse better than other intervals because their spectra include a more clearly audible and complete harmonic series, which leads to a more salient main virtual pitch.[7]

Eberlein (1994) counted how often sonorities such as major and minor triads and various kinds of seventh chords occur in tonal music (cf. McHose, 1947). He obtained the following rank order: major triad, minor triad, major-minor (dominant) seventh, diminished seventh, minor added sixth chord (or half-diminished seventh), triad with suspended fourth, minor seventh and diminished triad. Psychologically, these data can be explained if we assume that music-theoretically consonant chords are more prevalent in tonal music, and that harmonic consonance is a combination of smoothness (lack of roughness) and fusion (Terhardt, 1974a, 1976): chords without second intervals (major, minor, diminished triad; diminished seventh) tend to be less rough, and chords with a clear, unambiguous root (major triad, major-minor seventh) fuse more easily (Parncutt, 1988).

In a representative sample of polyphonic keyboard works by J.S. Bach, Huron (1991) found that, while fused harmonic sonorities (the triads and seventh chords just listed) tend generally to be favoured, there is an additional tendency to *avoid* fused harmonic *intervals* (P8, P5, P4) between individual voices within a contrapuntal texture. The reason is presumably that fused intervals threaten the perceptual independence of the voices. The prevalence of thirds and sixths in two-part tonal writing may be accounted for similarly, by combining a general preference for consonant intervals (P8, P4/P5, thirds/sixths) with a tendency to avoid intervals that easily fuse (P8, P5/P4).

The twin ideals of avoiding roughness and promoting fusion can also explain the main *voicing* rules (inversion, doubling, spacing) of conventional harmony theory (Lippius, 1612; Rivera, 1984). Regarding inversion, root positions are generally more prevalent than first inversions, followed by second inversions (Eberlein, 1994). This is presumably because root positions fuse more easily (Parncutt, 1996). According to this argument, second inversions are least prevalent because their root is most ambiguous: it can be either the bass (as in the double suspension from 6-4 to 5-3) or the fourth above the bass (as in a passing 6-4 within a Schenkerian 10-8-6 voice exchange; see Forte and Gilbert, 1982). Regarding doubling, the root of major and minor triads is more often doubled than the other voices; again, this encourages fusion.

Regarding spacing, intervals within the upper three voices of a four-voice texture seldom exceed an octave. But the interval between bass and tenor is limited only by the ranges of those voices; and small intervals between bass and tenor sound muddy (rough) in the lowest register and tend to be avoided. These familiar conventions have physiological origins. Each hair cell on the basilar membrane of the inner ear acts like a filter; it only passes frequencies within an interval proportional to a *critical band*.[8] Critical bandwidth depends on spectral frequency: above about A_4 (a') it lies between two and three semitones, and at lower frequencies it gradually widens (when measured in semitones). Roughness is experienced when two pure tones of about equal amplitude lie within the same critical band (Plomp and Levelt, 1965), such as when thirds are sounded in the bass. On the other hand, the degree of fusion decreases as the number of critical bandwidths between a pair of partials increases.[9] This may be why chord voicings with large intervals between the upper voices tend to be avoided.

Table 9.1 Prevalence of root progressions between root-position triads in eighteenth- and nineteenth-century music

	Rising P4	Falling P4	Rising 3rd[a]	Falling 3rd	Rising M2	Falling M2	Total
Maj-maj	64	19	0	0	6	2	**91**
Maj-min	60	1	2	9	5	0	**77**
Min-maj	5	20	1	15	5	3	**49**
Min-min	21	5	0	0	1	0	**27**
Total	**150**	**45**	**3**	**24**	**17**	**5**	**244[b]**

The numbers in the body of the table are chord counts in Eberlein's (1994, pp. 422–3) sample whose qualities correspond to the left column of the table and whose roots traverse the intervals given in the top row. Notes to the table:

a. The two chords have one tone in common for P4 progressions, two for third progressions, and none for M2 progressions. For the third progressions, the quality of the interval (M3 or m3) depends on the quality of the triads; e.g., the rising third between major and minor triads is a M3.

b. The total number of successive pairs of major and minor triads counted by Eberlein in his sample was 251. Omitted from the table are five root progressions of a rising m2 (three from minor to major, two from major to major) and two mode changes on the same root (one major to minor, one minor to major).

The next important statistical property of harmony to consider is the prevalence of specific progressions of two chords. Table 9.1 shows the prevalence of chord progressions between major and minor triads, based on a representative sample of scores composed between 1700 and 1850 by J.S. Bach, Handel, Mozart, Beethoven and Mendelssohn. The first point to notice is that root progressions through a P4 (or P5) are more prevalent than through a third – even though progressions through a third have two tones in common (rather than one). Why? Two contrasting perceptual-cognitive explanations warrant consideration. The first involves the way the brain learns and processes information. In simulations of musical learning with self-organizing neural nets, the cycle of fifths emerges spontaneously among the network units (simulated neurons) corresponding to the 24 major and minor triads or keys (Leman and Carreras, 1997; Tillmann et al., 2000). To achieve this result, it is not necessary to input tonal music to the model; all that is required is the pc-salience profiles or the 24 triads (Parncutt, 1988) or the stability profiles of the 24 keys (Krumhansl and Kessler, 1982, hereafter called the *K-K profiles*). Both are presented in Figure 9.1.[10] An alternative explanation invokes the psychological phenomenon of *categorical perception* (see, for example, Burns, 1999): stimuli that are similar or close in their main perceptual attributes (pitch, loudness, timbre, duration) may be assigned to the

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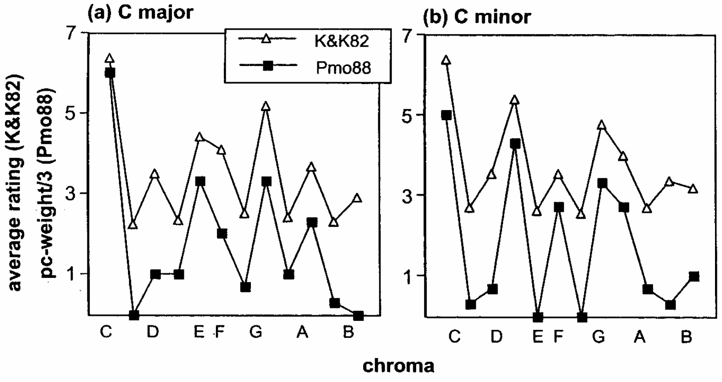

Open triangles: K-K profiles, that is, experimental goodness-of-fit ratings on a seven-point scale, averaged over three cadential progressions (IV-V-I, II-V-I, VI-V-I) and a single tonic triad (I).

Filled squares: *pitch-class weight* according to Parncutt (1988) with root-support weights P1/P8 = 10, P5 = 5, M3 = 3, m7 = 2, M2/M9 = 1, m3 = 0, divided by 3 for ease of comparison.

Figure 9.1 Comparison of major and minor K-K profiles with calculated chroma salience within the corresponding tonic triad

same perceptual category, and hence take on essentially the same meaning. For example, the lexical meaning of the vowel /a/ is independent of the speaker's regional accent or first language. Returning to harmony: triads in third relationships have more tones in common than not, and so may be perceived as a prolongation of the one harmony (a single category), with a melodic change in one voice – consistent with Riemann's concept of *parallel harmony*.[11] But triads in fifth relationships clearly separate into different harmonic categories or functions. And of all possible pairs of harmonically distinct triads, triads in fifth relationships have the strongest harmonic relationship (pitch commonality: Parncutt, 1989).

According to Table 9.1, root progressions of a P4 or M2 between root-position major or minor triads more often rise than fall, but root progressions of a third (M3 or m3, depending on the qualities of the chords) more often fall than rise. This asymmetry may be explained by considering the *subsidiary pitches* of a chord – perceived pitches that are not physically present or notated, but correspond to missing roots of incomplete harmonic series, and are therefore predicted by Terhardt's pitch theory. Figure 9.1 (lower line, filled squares) shows theoretical predictions for the salience of each pc when a major or minor triad is sounded. As a rule, the more salient the pc, the more likely it will function as the root (Parncutt, 1988). The figure shows that both major and minor triads have salient subsidiary pitches at fifth and third intervals *below* the root. As a result, in progressions through a falling fifth, falling third, or rising second, subsidiary pitches in the first chord coincide with actual notes in the second. Extending the theory of Meyer (1973) and Narmour (1977), the subsidiary pitches in the first chord may be regarded as *implications* that are *realized* in the second chord (Parncutt, 1996).

A final aspect of tonal syntax that is largely independent of tonality is *voice leading*. In contrapuntal textures, students learn to avoid leaps between successive tones in upper voices, and to avoid parallel P5s and P8s between any pair of voices (Lippius, 1612; Rivera, 1984). Both these principles may be explained by Bregman's (1990) theory of stream fusion and segregation. The individual parts in a contrapuntal texture will hang together perceptually and be heard as melodies if intervals between successive tones are small (steps), and other familiar melodic procedures are followed (such as following a leap by a step in the opposite direction). Moreover, each melody in the texture will be separately perceptible if intervals between simultaneous tones in different voices are consistently larger than intervals between successive tones in the same voice, and if parallel P5s and P8s are avoided. Parallel motion encourages harmonic fusion (gestalt principle of common fate), which is further enhanced if the intervals concerned are among the lowest in the harmonic series (P8, P5).

Effects that Depend on Tonality

Various authors (Krumhansl, 1990; Järvinen, 1995; Cuddy, 1997; others cited by Krumhansl) have investigated the prevalence of the twelve pcs in major and minor key contexts – how often the tonic tone (1^) is sounded in comparison to the dominant tone (5^), and so on. Prevalence profiles in major and minor keys closely resemble the K-K profiles of those keys. In general, more prevalent tones tend to be perceived as more stable than less prevalent tones, regardless of tonality (church modes, blues scales, North Indian *thats*, and so on: Krumhansl, 1990; Cuddy, 1997; Cooper, 1998).

Prevalence profiles also closely resemble pc-salience profiles of major and minor triads (Figure 9.1). A simple but speculative explanation is that, in major and minor tonalities, it is the final triad – not the final tone – that functions as the tonic (cf. Riemann, 1877; Schenker, 1906); and this triad, in order to achieve closure, needs somehow to *represent* the preceding music, or to *realize the implication* created by the preceding music. Since the tonic triad is the musical element that best follows a musical passage in a major or minor key, Krumhansl's probe tone fits well with a preceding tonal passage if the tone well represents the tonic triad – that is, if it has high salience within that sonority.

The pc-salience profile is historically older, and therefore arguably more fundamental for tonal theory, than the K-K profile. Major and minor triads first became commonplace in the fifteenth century (Old Hall Manuscript, Fauxbourdon, Dufay, Ockeghem), suggesting that their pc-salience profiles were also cognitively internalized at that time; then, as now, pitch salience influenced how well a given tone followed a given chord.[12] But it was not until the early Baroque (seventeenth century, especially Monteverdi) that a range of music-syntactic developments – including changes in the way dissonances were prepared and resolved, a preference for major or minor triads rather than open P5 sonorities at the end of phrases, a stronger feeling of forward progression, the consolidation of the subdominant-dominant-tonic progression, and the clear demarcation of modulations and tonal areas – suggested that major-minor tonality had established itself (Dahlhaus, 1967).

In the previous section, I briefly considered doublings within chord voicings, but without regard to temporal context. In a tonal context, doubling depends on tonal stability as represented by the K-K profile (Huron, 1993): the more stable the tone, the more likely it will appear simultaneously in different octaves. This principle parsimoniously explains why the leading tone (7^) and non-diatonic tones (#1^, and so on) are seldom doubled – in the K-K profiles, these six chroma are the least stable of the twelve.[13] It also explains why, for example, the best tone to double in the submediant triad (VI) is the third rather than the root, in both major and minor keys: just as doubling the root of a chord clarifies its root and so enhances its consonance, doubling the tonic (or other stable scale degree) clarifies the tonality of a passage.

Voice leading also depends on tonal context: progressions from one scale step to another tend to occur in a particular direction. A familiar example is the progression from leading tone to tonic, which is more prevalent than tonic to leading tone. Generally, a progression from a tonally unstable tone to a tonally stable tone (or from a non-chord tone to a chord tone) is more prevalent than the reverse (Pinkerton, 1956; Youngblood, 1958; both cited in Krumhansl, 1990). Moreover, less stable tones are perceived as more related to more stable tones that follow them, than vice-versa (Krumhansl, 1979, 1990), suggesting that the perception of relatedness (like most other aspects of music perception) is learned from musical experience. The strength of the tendency or expectation to resolve in a particular direction (yearning) depends on the difference in stability and the smallness of the interval between the two tones (Bharucha, 1996). Similarly, chord functions more often progress from unstable to stable than the reverse (McHose, 1947);[14] the same asymmetry is found in perceptual judgements of relatedness (Bharucha and Krumhansl, 1983; Krumhansl, 1990).

A final statistical regularity in this quick overview is the rank order of prevalence of diatonic triads, which according to Budge (1943) is I, V, IV, II, VI, VII and III, in both major and minor keys (Krumhansl, 1990). This pattern cannot be explained by the K-K profiles alone. It is also influenced by the perceptual-cognitive bias toward falling-fifth progressions, and toward progressions from less to more stable chords.

Conclusion

A harmonic theory that takes the chromatic scale as its starting point may be applied to a wider range of styles than more conventional, diatonically-based theories. Lerdahl (1989, pp. 66–7) commented that:

> The conventional wisdom, at least in the United States, holds that Schenkerian theory explains diatonic tonal music and pitch-set theory explains atonal music (chromatic tonal music is a source of discomfort). This scenario is implausible from a psychological standpoint if only because it presupposes two entirely different listening mechanisms. We do not hear *Elektra* and *Erwartung* in completely different ways. There is a good deal of 20th-century music – Bartók or Messiaen, for instance – that moves smoothly between tonality (broadly speaking) and atonality. In short, the historical development from tonality to atonality (and back) is richly continuous. Theories of tonality and atonality should be comparably linked.

A perceptual-statistical approach to harmony based on the chromatic rather than the diatonic scale can help to bridge the gap between music theories based on the major-minor system and music theories associated with other styles: the impressionist tonalities of Debussy and Ravel, serial and non-serial forms of atonality, bebop jazz, and even harmonic and contrapuntal styles from the Middle Ages and Renaissance where clear mappings may be made between diatonic and (hypothetical) chromatic scale steps. Such a pluralistic approach is consistent with trends toward postmodernism and neotonality.

Pluralism also includes tradition. Traditional harmony theory will, of course, never be replaced by the proposed newer methods. But methods such as these could usefully extend, complement, enrich, diversify and revitalize traditional approaches.

Notes

1. In the rest of this chapter, the term *prevalence* means frequency of occurrence; *frequency* is reserved for spectral or fundamental frequency.
2. A pitch class (pc) is a pitch considered without regard to its octave register (for example, all A flats and G sharps belong to the same pc).
3. Recent explorations of the relationship between perceptual theory and music history (Tenney, 1988; Eberlein, 1994) have highlighted social and physical influences on the compositional conventions of different historical periods. These influences limit the extent to which perceptual models can account for musical syntax. Relationships between predictions of perceptual models and statistical properties of tonal-harmonic syntax are largely *indirect*; directly, our perception of music depends mostly on musical conditioning (Lundin, 1947; Parncutt, 1989).

4. T_n-sets are invariant under transposition but not inversion. For example, major and minor triads belong to the same pc-set, but to different T_n-sets.
5. A good introductory project for students using a statistical analysis program might be to calculate and compare prevalence distributions of musical pitches across different styles and instrumental forces. The shape of the distribution is remarkably constant: an inverted U centred near D4 (d') with most of the area under the curve falling within the treble and bass staves (cf. Huron, 1993b).
6. Of course, the fundamental frequency of a speech utterance rises and falls from word to word. Pitch declination is more precisely defined as a gradual decline in the peaks and valleys of the pitch contour.
7. The music-theoretically familiar explanation that octaves, fifths and fourths are found in the lower reaches of the harmonic series is only *indirectly* correct. The harmonic series cannot meaningfully explain anything about music perception until its own perceptual function is clarified. According to the gestalt principle of closure, the missing elements of a familiar pattern are perceptually filled in. The harmonic series is an example of such a pattern. A perceptual model incorporating this pattern (Terhardt et al., 1982; Parncutt, 1989) can account for the perception of pitch in incomplete harmonic complex tones, such tones with a missing fundamental and tones with only odd harmonics.
8. According to Pickles (1988, p. 264), 'simultaneous masking patterns produce wider resolution bandwidths than do basilar membrane and neural tuning curves'.
9. Fusion has been found to fall as frequency separation increases between both AM pure tones (Bregman et al., 1985) and noise bursts (Turgeon, 2000). An alternative explanation is that the auditory system is familiar with harmonic complex tones, in which intervals between partials are larger in the bass.
10. It is not clear whether this connectionist approach can explain the predominance of fifth progressions in Renaissance and Baroque music, in which not all triads in the chromatic scale are typically available or in use.
11. In a major key, for example, Riemann regarded both IV and II as species of subdominant; see de la Motte (1988).
12. It would be interesting to investigate this claim systematically, for example in the context of the proposed course.
13. The traditional, and equally valid, explanation is that the doubling of leading and chromatic tones normally produces parallel octaves.
14. Typically, a relatively large increase in tension, e.g. I-#IV°, is followed by a series of smaller decreases, for example #IV°-V-I. This is analogous to the previously mentioned asymmetry in melodic interval distributions.

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