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# TONAL MUSIC THEORY—A PSYCHOACOUSTIC EXPLANATION?

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## ABSTRACT

From the seventeenth century to the present day, tonal harmonic music has had a number of invariant properties such as the use of specific chord progressions (cadences) to induce a sense of closure, the asymmetrical privileging of certain progressions, and the privileging of the major and minor scales.

The most widely accepted explanation has been that this is due to a process of enculturation: frequently occurring musical patterns are learned by listeners, some of whom become composers and replicate the same patterns, which go on to influence the next “generation” of composers, and so on. In this paper, however, I present a possible psychoacoustic explanation for some important regularities of tonal-harmonic music. The core of the model is two different measures of pitch-based distance between chords. The first is voice-leading distance; the second is spectral pitch distance—a measure of the distance between the partials in one chord compared to those in another chord.

I propose that when a pair of triads has a higher spectral distance than another pair of triads that is voice-leading-close, the former pair is heard as an alteration of the latter pair, and seeks resolution. I explore the extent to which this model can predict the familiar tonal cadences described in music theory (including those containing tritone substitutions), and the asymmetries that are so characteristic of tonal harmony. I also show how it may be able to shed light upon the privileged status of the major and minor scales (over the modes).

## 1. BACKGROUND

*Tonal-harmonic music* (also known as *harmonic tonality*, or *major-minor tonality*) is the most familiar form of music in the West, and the world. It uses particular successions of chords to establish a central or “home” tone or chord called the *tonic*; it was the principal form of art music from the 17th to the early 20th century, and is still used in the majority of contemporary pop, jazz, film and other incidental music (see Dahlhaus (1980), Krumhansl (1990), Hyer (2002), for similar definitions). It is characterized by a consistent set of *regularities* (the rules of voice-leading and chord progression that are described in music theory texts such as Schoenberg (1978), Macpherson (1923), Piston & Devoto (1987)).

In a *psychoacoustical* approach, models of perceptual qualities (e.g., pitch, loudness, dissonance, timbre, tension, etc.) are developed as functions of acoustical variables (e.g., the frequencies and amplitudes of the partials that make up a tone or chord) on the basis of empirical data (responses of listeners in laboratory experiments).

Psychoacoustic approaches can largely explain why certain simultaneities of notes (chords) are typically considered dissonant while others are considered consonant (notably the major and minor triads that are so important in both the theory and practice of Western tonal music) (Helmholtz, 1877; Kameoka & Kuriyagawa, 1969; Parnrott, 1988; Plomp & Levelt, 1965; Sethares, 2004). However, to date, there has been no widely accepted psychoacoustic explanation for several of the most important and mysterious aspects of tonal-harmonic music: those that are concerned with the horizontal aspects of tonality (horizontal in the sense of conventional notation, i.e., temporal) and the interrelationships of the horizontal and vertical. These include:

### 1.1 Harmonic Cadences

A succession of consonant chords can induce feelings of expectation and resolution that are not produced when the same chords are played in isolation, or in a different order. For example, many music theorists and listeners feel that in the chord progression F-major – G-major – C-major, the second chord arouses the expectation of resolution to the third, thus providing a sense of closure. Chord progressions such as these are called cadences, and they are typically used in tonal music to mark the ends of phrases, or entire sections. Interestingly, cadences are commonly constructed with only consonant triads (the example above is the familiar IV – V – I cadence; other common cadences using only major and minor triads are ii – V – I, iv – V – i, and iv – V – I), so the expectation cannot be explained as being the result of the resolution of harmonic dissonance.

### 1.2 Tonal Asymmetries

Functional music theory, and general descriptions of musical practice (see, e.g., Piston & Devoto (1987), and Dahlhaus (1990)), indicate that cadences generally follow the pattern S – D – T (in a functional context, S refers to subdominant chords such as ii or IV, D to dominant chords such as V or vii<sup>o</sup>, and T to tonic chords such as I or vi). Reversing the order of the subdominant and dominant chords is considered to significantly weaken the effectiveness of the cadence.

Similarly, chord progressions whose roots descend by fifth and third are generally preferred over those that ascend by fifth or third (for data from 18th and 19th century music see Eberlein (1994)).

These are examples of *tonal asymmetry*—the order of presentation of the harmony significantly impacts upon the effect it induces in a listener and, as a result, certain orderings of chords are preferred (and used more often) than others. Other examples of tonal asymmetry can be found in the movement between keys rather than between chords.

Such asymmetries (which have been demonstrated in numerous experiments, e.g., Brown (1988), Cuddy & Thomson (1991), Toivainen and Krumhansl (2003)) are an important part of human perception of tonality, and the inability of most existing theories to account for these asymmetries is well acknowledged (see, e.g., Krumhansl (1990) and Woolhouse (2007)).

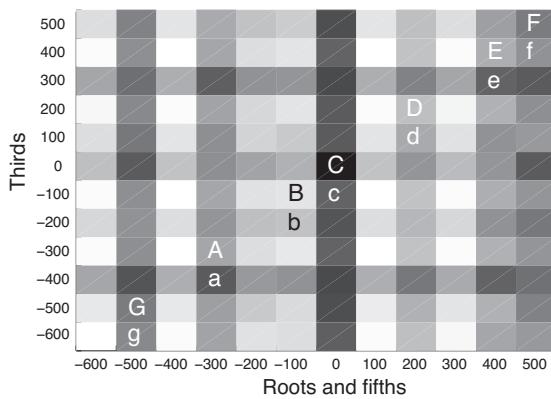
### 1.3 Privileged Scales and Modes

The theoretical construct of church modes, which was prevalent until the end of the 16th century, gave no explicit privileged status to any of the six possible finals of the diatonic scale (the hexachord from C to A), or the four possible finals of the traditional modal classification system (D, E, F, G)—although the finals D and G (as well as the tones D and G at any position) were generally more prevalent than E and F (Parncutt, 2009).

Tonal music, on the other hand, privileges the major scale (which derived from the Mixolydian with F $\sharp$ ) and the minor scales (which derived from the Dorian with B $\flat$  and/or C $\sharp$ ); none of the other modes of the diatonic scale survived into common practice. This small number of different scales and modes within which harmonic tonality is “embedded” is perhaps one of its most important regularities.

## 2. THE MODEL

The model calculates two types of pitch distance between chords. The first is a familiar voice-leading distance, which is calculated as the sum (or other  $L_p$  metric) of the distances moved by each voice to connect two chords. The second is the spectral distance between two chords, which is a measure of the overall similarity between the pitches of the partials in one chord compared to another. This latter distance is used to model the affinity or fit of two chords.



**Figure 1:** Spectral distances between a reference C-major triad and all possible three-voice triads with a perfect fifth.

Figure 1 shows the calculated *spectral distance* between the spectral pitches (first ten harmonics of each tone) of a reference major triad and all 12-tone equal temperament triads that contain a perfect fifth. The horizontal axis shows the pitch distance from the reference triad’s root and fifth, the vertical axis shows the pitch distance from the reference triad’s third, so the spatial distance between triads is equivalent to their (Euclidean) three-part voice-leading distance. All root-position major and minor triads lie on the central diagonal and some of these have been labeled for reference. The darker the grey the smaller the spectral distance from the reference triad (i.e., the greater their spectral affinity).

This model suggests that the triad pair {C-major, d-minor} has greater spectral affinity than the neighboring triad pair {C-major, D-major}; the triad pair {C-major, F-major} has greater spectral affinity than the neighboring triad pair {C-major, F $\sharp$ -major}; the triad pair {C-major, e-minor} has greater spectral affinity than the neighboring triad pair {C-major, E-major}; and so forth. These results seem indicative of the tonal function of these triad pairings: the latter pair in each case is typically heard as requiring resolution, the former pair in each case is not.

I hypothesize that when a triad pair has higher spectral distance than a *comparison* triad pair that is voice-leading-close (i.e., it is a neighbor in the above Figure), it is likely to be heard as an alteration of that comparison pair (e.g., C-major – D-major is likely to be heard as an alteration of C-major – d-minor). (Triad pairs that have a greater spectral distance than a voice-leading-close neighbor are denoted *active*.)

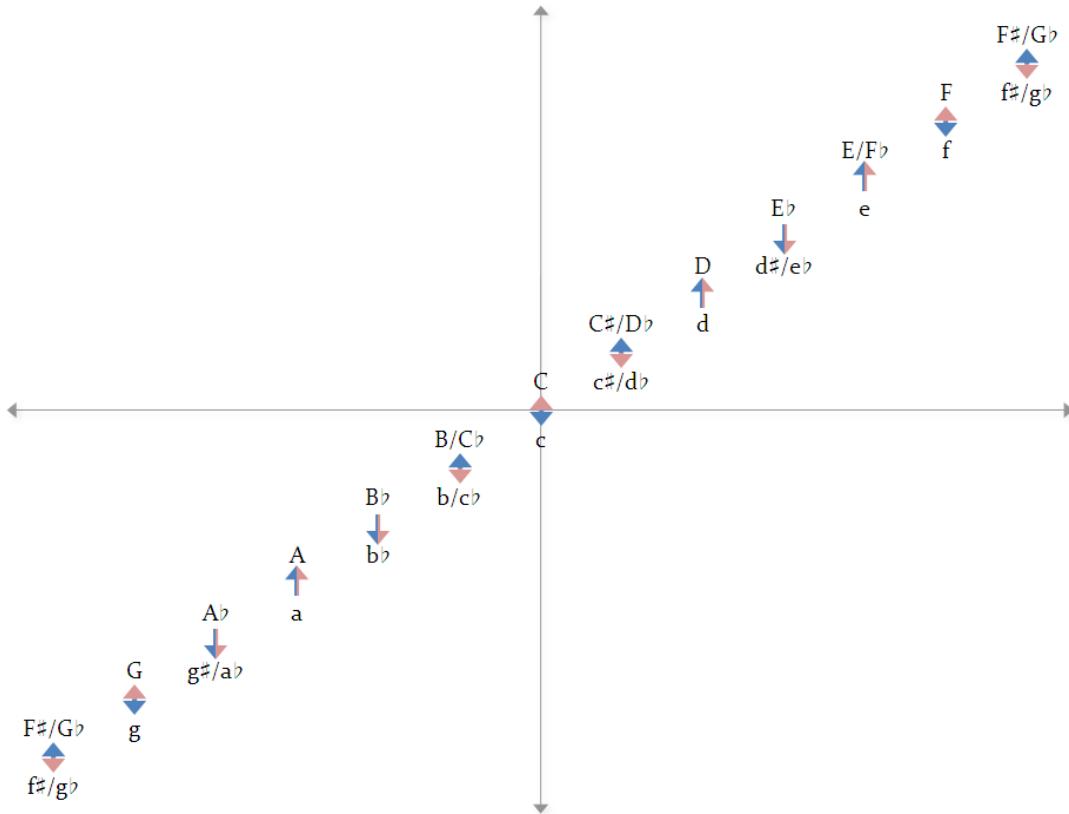
Furthermore, I hypothesize that if a tone is heard as an alteration of another tone, we might expect it to resolve by “continuing” its motion in the same direction as its alteration to another tone that is not heard as an alteration (e.g., in the progression C-major – D-major, the altered tone F $\sharp$  is resolved by continuing to G, hence creating the cadence C-major – D-major – G-major, which is the familiar IV – V – I cadence).

### 2.1 Cadences and Tonal Activity

This suggests a template for effective harmonic cadences:

- Three triads are played ( $T_1 \rightarrow T_2 \rightarrow T_3$ ) such that:
- $T_2$  is **active** (when paired with  $T_1$ )
- $T_3$  is **inactive** (when paired with  $T_1$  and  $T_2$ )
- $T_2$ ’s active tone resolves to the **root** of  $T_3$

Disregarding transposition, there are 1,152 different progressions of three major or minor triads. Of these, very few (only two—the IV – V – I and ii – V – I progressions) satisfy all the above constraints, a few more can satisfy most of them (e.g., iv – V – I, IV – V – I,  $\flat$ II – V – i).



**Figure 2:** Tonal activities (due to parallel comparisons) of all possible triad pairings.

Figure 2 summarizes the activities of all possible pairings of major and minor triads due to comparison with their parallels. The reference triad is C-major or c-minor. The arrows point from a triad pair with lower spectral activity to a triad pair with higher spectral activity. Blue arrows are used when the reference triad is C-major, pink arrows when the reference triad is c-minor.

For example, F-major is at the base of a blue arrow—this means that the pair C-major – F-major has lower spectral distance than the pair C-major – f-minor, which means F-major is likely to be heard as inactive when paired with C-major. But F-major is at the point of a pink arrow—this means that the pair c-minor – F-major has higher spectral distance than the pair c-minor – f-minor, which means F-major is likely to be heard as active when paired with c-minor. In this latter case, the tone A $\sharp$  is heard as an alteration of A $\flat$ .

Similarly, the chart shows that D-major is likely to be heard as active when paired with either C-major or c-minor, because it is at the point of both a blue and a pink arrow. In both cases it is heard as an alteration of d minor (hence the altered tone is F $\sharp$ ).

## 2.2 Asymmetries

Figure 2 shows that, given two major triads a whole-tone apart, the upper triad is likely to be heard as an alteration, not the lower (D-major is at the point of a blue arrow, B $\flat$ -major is at the base of a blue arrow). This mirrors the functional preference for S – D – T over D – S – T (in the former, the active triad can be resolved directly to the tonic, in the latter, it cannot).

Similarly for two major triads separated by a major third, the upper triad is more active (E-major is at the point of a blue arrow, A $\flat$ -major is at the base of a blue arrow), hence we might expect to see the S – D – T progression  $b\text{III}$  – V – i more often than the D – S – T progression V –  $b\text{III}$  – i. There are many other similar asymmetries shown in Figure 2.

## 2.3 Privileged Scales

Given a diatonic scale (e.g., the white-note diatonic scale), the only triad pairs the model predicts as tonally active are those that contain the tritone between them (i.e., one of the triads contains F, the other contains B). In the context of the white-note diatonic

scale, these two tones, therefore, tend to be active (the F will tend to be heard as an alteration of F♯, the B will tend to be heard as an alteration of B♭). Their natural resolutions are, therefore, to E and C (respectively).

The two triads that contain both resolution tones are C-major and a-minor. C-major contains these tones as its root and third; a-minor as its third and fifth. So we might expect the white note diatonic scale to have a strong tonic on C-major and a less strong tonic on a-minor. Hence the privileging of the Ionian and Æolian modes of the diatonic scale.

The harmonic minor scale is generally used to harmonize melodies in the minor modes. As a scale, it is typically thought to be melodically unsatisfactory due to the augmented second between the sixth and seventh degrees. Hence the use of the descending and ascending melodic minor scales when moving between these two degrees. So why, despite these melodic problems, is the harmonic minor scale the basis for the harmonization of minor mode melodies?

As discussed above, the Æolian mode's tonic is not felt to be as strong as the Ionian mode's tonic because the former's root is not a resolution tone, while the latter's root is a resolution tone. Sharpening the seventh degree of the Æolian mode (which transforms it into the harmonic minor scale) creates an important new active pairing, that is not available in the diatonic scale, and which enables the “tonic” of this harmonic minor scale to have a root that is a resolution tone.

The new non-diatonic pairing is the progression, shown in Figure 2, from c-minor to D-major. Played after c-minor, the triad D-major is active (heard as an alteration of d-minor). The active note F♯ resolves to the root of the tonic g-minor triad (this being the minor iv – V – i cadence). In the diatonic scale, no minor triad can have a resolution tone as its root: in the harmonic minor, this is possible—the sharpening of the Æolian mode's 7th degree, therefore, enhances the degree of closure on its tonic.

### 3. DISCUSSION

The above analyses have demonstrated some agreements between the predictions of a psychoacoustically-based model and conventional tonal music theory. These analyses should be viewed in the context of existing experimental tests which have also provided strong support for the model—the model's predictions for the “cadential effectiveness” of 72 different progressions of three root-position major and minor triads were compared against seven-point ratings given by thirty-five participants, and achieved  $R^2_{\text{adj}} = .78$ ,  $F(4, 67) = 64.69$ ,  $p = .000$  (Milne, 2009).

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