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THE EFFECTS OF VARIATIONS OF DURATION
ON MUSICIANS' PERCEPTIONS OF TONIC
IN TONALLY AMBIGUOUS THREE-NOTE SETS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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*****

The Ohio State University
1996

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ABSTRACT

The purpose in this study was to examine the relationships between pitches, and between pitch and durational pattern. Most of the theoretical literature discusses tonal organization, showing an evolution in the concept of tonality as a hierarchical system of pitch relations revolving around a central pitch. The empirical literature has progressed from placing tonal organization as inherent in sounds to placing it in the mind of the listener based on learned patterns.

This study found rich tonal relations, which can be described in terms of a general schema. This schema is learned and is activated by the local relations of pitches and their temporal-order patterns. However, durational pattern was not found to affect listeners' choices of tonic, at the tempo used.

It is posited that the tonal schema is a process in which learned patterns of rare intervals, such as the tritone and minor seconds and their temporal ordering, are initially employed for the first identification of a dominant-functioning note, preferably the leading tone, which leads to a tonic response. Once the leading tone (or other dominant
representative) and tonic have been established, a template or hierarchy of tonal expectations and suitability of tonic response is engaged, against which the musical stimulus may or may not match. If the stimulus and expectations do not match, then the rare-interval apparatus is engaged again in order to identify a new dominant and consequently the new tonic. Further research is indicated for placing the role(s) of rhythmic elements within the schema.
In memory of my grandmother, Sadie B. Hyre (1895–1992)

and

in honor of my grandparents, Paul and Ruth Strader
I wish to express my thanks to a number of people who have supported me throughout this project:

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INTRODUCTION

This study examines empirically the influences of two types of relations found in music on listeners' choices of tonic: those between pitches, in tonality, and that which exists between pitch and rhythm, in temporal orderings and durational patterns. Chapter 1 contains a review of relevant theoretical and experimental literature, including material pertaining to the history of the concept of tonality in Western music, early psychological theories, and recent studies in psychology and music theory regarding tonality and tonal organization and the relation-ship of rhythm to pitch. Chapter 2 presents the hypotheses and the stimuli used to test them, and Chapter 3 presents the experimental procedure. Chapter 4 contains the results of the study and discussion of how they relate to the hypotheses and to currently held models of tonality. Finally, a proposal for the operation of tonality as a function of the enculturated listener and pedagogical implications of the study are discussed, and suggestions for further related research are made.
CHAPTER 1

REVIEW OF LITERATURE

INTRODUCTION

Instruction in music theory has traditionally tended to concentrate on the pitch aspect of music, with an emphasis on the organization of pitches in a given piece or style. Listening, of course, is a fundamental activity of music and, for tonal music, is founded on the relationships involved in a given piece within a given tonal system. However, theory and analysis tend to become rather sight-bound (as opposed to aurally-bound) pencil-and-paper exercises and speculation, concentrating on structures in specific pieces, usually by using particular systems of analysis. These systems stem from a long history of various theories of tonal relations, such as those of Rameau in the eighteenth century, Fétis and Riemann in the nineteenth century, and Schoenberg and Schenker in the early twentieth century. The insights of these theorists provide the foundation for current thought and research (theoretical and empirical) on tonality and will be discussed shortly.
However, the issue of aural key-finding on the part of a listener is not specifically addressed by any of the tonal theories that have been passed down. Generally, while discussing various tonal relationships, the key of a piece or section is assumed *a priori*, or students are told how to determine key by looking at the score. It is necessary to learn the complex relationships among pitches by means of score study or within a known key context, but this manner of teaching and learning ignores the vast population of enculturated but musically illiterate listeners who understand and enjoy the many kinds of art and popular music which fall under the umbrella of "tonal music." How do both formally educated listeners and naive listeners understand what they are hearing? What are the cues that guide them through a piece? These questions are especially important for music students, particularly when learning aural skills such as solfege and dictation. But a fundamental question underlying these and similar queries may be, "How is tonic established in the mind of the listener?"

The beginnings of answers to these questions may lie in a brief examination of the evolution of the concept of tonality, followed by a treatment of the more recent literature on the subject. Such an understanding can help shed some light on what are now often regarded as typical tonal relationships. It may be said that it is precisely because they are typical that they are so important.
BRIEF HISTORY OF THE CONCEPT OF TONALITY

One of the most important relationships (and of particular interest in the present study) is that of the leading tone to tonic. Rameau (1722/1971) was among the first to discuss the leading tone as occupying a unique place within the tonal system:

... the tones and semitones found in the various intervals of the diatonic progression should alone suffice to make matters clear. We should pay close attention then to the place the semitones occupy in each mode, both ascending and descending...if we keep on the watch for the leading tone, which is always a great help wherever it occurs, it will be hard to go wrong. (pp. 283-284)

In three sections of his treatise (p. 220, pp. 237-238, pp. 283-284), Rameau stressed the importance of the leading tone, generally in relation to the tritone, minor seconds, and specific chords (e.g., the dominant triad and seventh chords), indicating that the composer's control of these elements causes the leading tone, and consequently the tonic, to be emphasized. However, Rameau did not indicate how the initial establishment of either leading tone or tonic takes place aurally.

Fétis (1853) first defined tonality (tonalité) in the manner with which music theorists are familiar today (although it was not a universal definition from his time through the early twentieth century). His definition is based on a distinction which had long been made in
eighteenth- and nineteenth-century France between two terms that both tend to be translated as "scale": gamme and échelle. "The gamme can...be regarded as the table of sounds of a mode or a species; the échelle is the notated form of that: the one contains the denominations of the sounds, the other the notes..." (Nicolas Etienne Framery and Pierre Louis Ganquené (Eds.), 1791, Encyclopédia Méthodique: Musique, vol. 1, p. 478; cited in and trans. Kosar, 1984, p. 19). Kosar suggested that it may be more appropriate to equate échelle with scale and gamme with the major and minor diatonic collections, a distinction which was not made in English-language literature on the subject until this century. Kosar elaborated Fétis's position by explaining that Fétis believed that tonalité was based on the intervallic relationships formed by the notes of the major and minor collections (gammes), and that these relationships create the tonalité (quoting Fétis, 1853, trans. Kosar, 1984):

The results of the harmonic and melodic affinities of the major and minor scales give to the successions of both genres a character of necessity which is designated in general under the name of tonalité. (Fétis, 1853, p. 2)

...What is tonalité? Its answer, in general terms, can be expressed thus: Tonalité is formed from the collection of necessary relations, successive or simultaneous, of the sounds of the scale [gamme]. (Fétis, 1853, p. 22)

...All the consonant and dissonant relationships of a unique scale are established and demonstrated as much in successive as in simultaneous order: each note of the scale, whatever the circumstances of its connection with the others, has in all circumstances proper and special harmonies. (Fétis, 1853, p. 45)
Fétis, like Rameau, elaborated an important concept in the theory of music. The distinctions that he made are necessary for understanding the stylistic norms of the music of that time. The general concept is still valid today.

Brown and Butler (1984) empirically examined Fétis's claims about tonality, particularly with regard to the tritone between fa and ti and "the resolution of these two notes to those which are separated from them by only a semitone, as ti followed by do, and fa followed by mi." (Fétis, 1853, p. xxxix; trans. Kosar, 1984) They found that Fétis correctly identified crucial interval relationships and the importance of the dominant, and the harmonies associated with it, in determining tonal center.

Riemann's (1893) contribution to the understanding of tonality is considerable, particularly his classification of chords into three categories (subdominant, dominant, and tonic). However, most relevant to the present study is his recognition of the harmonic functions of individual notes:

Every note of a melody owes its aesthetic effect in great measure...to its harmonic meaning. And by the harmonic meaning of a note we understand its relation, as accurately perceived by the ear, to other notes of the same melody or...to notes of other accommodating melodies.

One NOTE compared with other notes...is either itself the fixed point, the PRIMA RATIO, starting from which the others are considered, or, conversely, it is in its turn considered in its relation to some other note... (p. 2, emphasis original)
He also posited that any member of a particular triad could represent the function of the triad, such that, for example, any member of a dominant triad (sol-ti-re) can represent the dominant function:

The ear comprehends a tone with its direct relatives (third and fifth or their octaves)...as belonging together in closer unity, and distinguishes them from all more distant relatives in forming one compound sound, which we will call a CLANG; each of the three tones can represent the clang, and even if the prime [root] be not sounded itself, it is possible to understand the third or fifth as representing the clang. (p. 7, emphasis original)

Riemann also codified uses of rhythm and meter, noting that rhythm can be used to change the function of chords:

As regards the assistance of rhythm in the change of meaning of clangs, we will...remark that chords falling on accented beats receive increased attention, whereas to those entering on unaccented beats we readily ascribe only transitional importance....

Any harmonic step [around the circle of fifths] going beyond a dominant (i.e., resorting to the dominant, foreign to the scale, of a dominant) is sufficient impulse for a modulation to the dominant in question, but to overcome the resistance offered by our feeling of tonality, in the first place the assistance of rhythmical relations is needed. (pp. 144, 146, emphasis original)

Schenker's (1906/1954) contributions to the concept of tonality include the idea of scale-steps and a hierarchy of levels of the tonal function of those scale-steps as determinants of tonal organization in a piece of music. He recognized that some notes tend to be perceived as more important than others and that the importance was relative to
where the note occurred in a piece on a large scale and in relation to its immediate predecessors and successors on a more local level. In this regard, Schenker noted that "not every triad must be considered a scale-step; and it is most important to distinguish between C as the root tone of a triad and C as a scale-step" (pp. 138-139). This follows from his description of the intervals found between scale-steps in the major and minor diatonic systems. Of relevance to this study is his use of minor seconds, which he considers in only two positions: between the third and fourth scale-steps and between the seventh and eighth scale-steps. For Schenker, intervals and scale-steps are primarily means for defining and limiting key choices and describing modulations between keys. For this purpose he describes an interval as "univalent if it occurs on only one step of the diatonic system; thus belongs to only one key; and admits of only one interpretation. An interval is plurivalent if it has its locus on two or more scale-steps; belongs, accordingly, in two or more keys; and admits of two or more interpretations" (p. 127). Minor seconds occur in two places in the major scale and therefore can be interpreted in two major keys.

The concepts of mode mixture and tonicization were very important to Schenker's concept of tonality because they allowed for chromaticism within the diatonic framework. Mode mixture was shown to be an allowance for chromaticism, without a change of tonic, based on the absorption of the
church modes into his system of major-minor tonality. In mode mixture, the chromatic notes tend to resolve to certain diatonic notes, a process which serves to reinforce the tonic that is in operation. Tonicization, on the other hand, is the process that occurs when, as Schenker described it, "each step manifests an irresistible urge to attain the value of the tonic for itself as that of the strongest scale-step" (p. 256). The process generally is one of introducing the dominant of the note or scale-step to be tonicized and then resolving the dominant appropriately. This usually produces at least one chromatic note, which functions as a new leading-tone that is subsequently resolved to the new (temporary or long-term) tonic.

Schoenberg's (1954/1969) contribution to the concept of tonality includes recognition that "a triad standing alone is entirely indefinite in its harmonic meaning; it may be the tonic of one tonality or one degree of several others. The addition of one or more other triads can restrict its meaning to a lesser number of tonalities" (p. 1).

According to Schoenberg (1954/1969), the establishment of tonality is done in the most basic way by the exclusive use of all its tones. A scale (or part of one) and a certain order of the harmonies affirm it more closely....Distinguishing a tonality from those tonalities which resemble it most is the first step towards its unmistakable establishment....

The chords which express a tonality unmistakably are the three main triads: I, IV, and V. IV [in C
major], by contradicting f#, excludes the dominant of G major; the b♭ of V excludes the subdominant's b♭.... (pp. 11-13)

However, Schoenberg recognized that chromaticism is usually employed in such ways that not only is the key of the piece not destroyed, but it is actually enhanced. He explained the use of chromaticism, and modulation, in terms of what he called "regions"—segments within a key, "which are carried out like independent tonalities" (p. 19). He further elaborated:

The concept of regions is a logical consequence of the principle of monotonality. According to this principle, every digression from the tonic is considered to be still within the tonality, whether directly or indirectly, closely or remotely related. In other words, there is only one tonality in a piece, and every segment formerly considered as another tonality is only a region, a harmonic contrast within that tonality.

Monotonality includes modulation—movement towards another mode and even establishment of that mode. But it considers these deviations as regions of the tonality, subordinate to the central power of a tonic. Thus comprehension of the harmonic unity within a piece is achieved. (p. 19, emphasis original)

Schoenberg summarized his position on the key and chord relationships generated by tonality¹ (or monotonality) in his "Chart of the Regions" (1969, p. 20; see Figure 1.1 below).

¹ Schoenberg's (and other writers') synonymous use of the terms "key" and "tonality," and his unique term, "monotonality," are indicative of the rather loose ways in which the terms "key" and "tonality" tend to be used by music theorists and others when discussing overall pitch organization within pieces. In this discussion and this project, "tonality" is taken as a broad abstraction for which "key" is the actual instantiation. Thus, "tonality" refers to interval relationships and "key" refers to specifically named notes.
It contains more than the 24 major and minor keys because he recognized that contexts, and therefore the relationships, between keys and chords with enharmonic spellings are different.

![Chart of the Regions](image)

**Abbreviations**

- **T** means tonic
- **D** means dominant
- **SD** means subdominant
- **t** means tonic minor
- **sd** means subdominant minor
- **v** means five-minor
- **sm** means submediant minor
- **m** means mediant minor
- **SM** means submediant major
- **M** means mediant major

[N.B. All symbols in capitals refer to major keys; those in small letters to minor keys.]

Figure 1.1. Schoenberg's "Chart of the Regions," a) tonal relationships; b) regions for C major (1969, p. 20)
EARLY PSYCHOLOGICAL THEORIES

By the late nineteenth and early twentieth centuries, issues regarding the comprehension of melodies and tonality were beginning to be studied empirically by psychologists such as Theodor Lipps (1885/1926), Max Meyer (1900, 1903), and W. Van Dyke Bingham (1910). Many studies, such as those of Helmholtz (1877) and Stumpf (1883), tended to follow lines of reasoning similar to that of eighteenth- and nineteenth-century music theorists, justifying various (tonal) musical phenomena through "natural" properties such as the harmonic series and other acoustical attributes of the sounds in music or by physiological characteristics of the ear. These studies were important for their discoveries and descriptions of the physical properties of sounds and their generators, and of the physical and physiological characteristics of the ear for hearing sounds, but they were criticized by researchers such as Lipps, Meyer, and Bingham, for not taking into account the listener's learned responses to pitch organization in real music.

Although Lipps and Meyer also tended to work from the basis of "natural" or acoustical principles, particularly the ratios of the harmonic series, they (independently) noted the same phenomenon in listeners' responses to musical stimuli, a finding which has since become known as the "Lipps-Meyer Law." Lipps did not actually label it; Meyer referred to it as "the law of the powers of 2," because 2 represented the
fundamental pitch (and the first overtone, the octave) of a vibrating string and was always present in the harmonic series of the tone that was usually identified as the tonic:

...when tones related to each other as $2^n:3, 5, 7, \text{etc.}$, come together, there exists a natural tendency for the latter members to move in the direction of the first members of the ratios [i.e., the tones represented by 3, 5, 7, etc., are perceived as being resolved by the tone represented by $2^n$]. (Lipps, p. 225)

Meyer (1903) also noted the tendency of listeners to prefer endings of the lowest note in three-note melodies when no "tonic" was present (a note whose ratio to one of the other two is by a power of 2). He called this "the effect of the falling inflection," and also asserted that this effect was usually negated when a "tonic" was present and was stronger when the tonic was the lowest note.

Bingham (1910) was one of the first music psychologists to describe musical properties and define tonality in terms of the listener's perceptions rather than of qualities inherent in the sounds that were heard. His definition of tonality is consistent with that of Fétis and is familiar to us today, in contrast to the then-prevailing notion of "tonality" which was described by G. Rich in 1919: "The most usual description of the purporting attribute for which we are using the term tonality is that it recurs in every octave, so that two notes lying exactly an octave apart have the same tonality but different pitch" (p. 158). In the
early twentieth century, then, what was typically called "tonality" by psychologists studying the perception of music is what today's music psychologists call "tone chroma" or what music theorists now call "pitch class."

Bingham defined tonality as follows:

By a tonality is meant a group of mutually related tones, organized about a single tone, the tonic, as the center of relations. Subjectively a tonality is a set of expectations, a group of melodic possibilities within which the course of the successive tones must find its way, or suffer the penalty of not meeting these expectations or demands of the hearer and so of being rejected as no melody. Of these demands, that for an end on a certain tone is the strongest and most characteristic.

It is not meant to imply that this tonality...is present in consciousness as a group of auditory images. Often there is only a single simple auditory or vocal-motor image or percept to be detected. The tonality consists in the attitude of which the image is merely the superficial manifestation or sensory core. One can image [a tone] as a tonic in the key of e or as a median [sic] in the key of c, and the auditory image will be identical in the two cases, but not the total psychosis [sic]. There will be an entirely different organization of expectations, an entirely different attitude, an entirely different set of anticipations and demands, a preparedness for one set of experiences, but not for another. (pp. 36-37)

RECENT THEORIES OF TONALITY AND TONAL ORGANIZATION

As with the widely regarded theories and early empirical studies cited above, much of the more recent literature in music theory and in the psychology of music has been devoted to the use and organization of pitch in tonal music. This literature includes the speculations and key maps of Longuet-Higgins and Steedman (1971), and Longuet-Higgins (1976, 1978, 14

Of particular interest is the attempt by Longuet-Higgins and Steedman (1971) to build an algorithm based on "note lengths and positions on the keyboard" (p. 223) for reproducing the correct notation (pitch and rhythm) of several Bach fugue subjects. To achieve this end, the authors developed a key-discovery method (separate from that for rhythm, which was based on meter). The authors based their "harmonic algorithm" on Longuet-Higgins' key maps (first propounded in 1962, then expanded in 1965, and further elaborated in connection with the algorithm in 1971; see below, Figure 1.2). Major and harmonic minor key maps were the only ones used.

Figure 1.2. Key maps adapted from Longuet-Higgins and Steedman's two-dimensional map of pitch-space (1971, p. 232).
The algorithm is a rather cumbersome method involving the brute-force manipulation of key-maps for all twenty-four major and minor keys, which are treated equally. The process is mainly one of elimination by using all of the possible maps which encompass all of the notes. If more than one map remains, a "tonic-dominant preference rule" is invoked: First prefer the map in which the first note of the melody is the tonic; if that criterion for the first preference cannot be met, then interpret the first note of the melody as the dominant and use the appropriate map. If no map meets any of these criteria, then "accidentals" (i.e., chromatic notes) must be involved.

Chromaticism is especially problematic in this algorithm. It is dealt with by accommodating as many of the notes as possible, then looking at the remaining notes and invoking the "semitone rule":

In a chromatic scale, the first two notes are always related by a diatonic semitone, and so are the last two. By a "diatonic" semitone we mean the interval between B and C in C major—a move of one step to the left and one step downwards in a key diagram. (1971, p. 236)

Note the visual, a priori assumptions about the first two and last two notes of a chromatic scale. A listener has no way of knowing the spelling of a chromatic scale without seeing it. In "The perception of melodies" (1976), Longuet-Higgins makes the standard music-theoretical distinction.
between "diatonic" and "chromatic" semitones. "Diatonic" means the use of different note names (with appropriate accidentals) for two pitches, while "chromatic" means the same note name with accidentals. Longuet-Higgins' point, though, is probably a valid one: A chromatic note is interpreted according to the context in which it occurs, particularly as it relates to the note that follows it. Thus, if the succeeding note is above the chromatic note, the chromatic note will most likely be interpreted as a sharped note, as in the succession, G-G♯-A; if the succeeding note is lower, then the chromatic note will most likely be interpreted as a flatted note, as in the succession, A-A♭-G. (Pertinent discussions on this may be found in Proctor, 1977, and Brown, 1992.)

What the authors have done is set up an algorithm, based on \textit{a priori} assumptions, which attempts to fit all the notes into a whole, as a whole, instead of as a time-ordered step-by-step, note-by-note process. This is best summarized by Longuet-Higgins (1976/1987):

\begin{quote}
[T]he tonality of any note cannot in general be established unambiguously until the following note has been heard. It is perhaps surprising that such a limited amount of context should usually suffice for the purpose, but it should be remembered that it is really the key of the melody which creates the tonal context in the first place. (p. 120)
\end{quote}

The first part of this statement seems to make perfect sense. It is reasonable to assume that the context within
which a note is placed includes not only what comes before it, but also what comes after it. But then Longuet-Higgins states that the key creates the context. This is a sort of chicken-and-egg problem: At the very start of a piece, the listener cannot know what the key is until the first several notes have been heard. In that sense, the context creates the key. After the key has been established, however, then it is reasonable to expect that the key at least influences the context that follows. Unfortunately, Longuet-Higgins and Steedman's algorithm does not suitably address the problem of the initial establishment of the key by using the immediate local tonal cues.

As noted above, there are currently two leading perceptual models for tonal organization: tonal hierarchy, and intervallic rivalry. These models, described below, tend to be treated as mutually exclusive, but there may be ways in which they are compatible. These will be explored later.

**Tonal hierarchy**

The tonal hierarchy model of pitch relations derives in part from Leonard B. Meyer's (1956) discussion of the "hierarchical" nature of tonal systems with reference to the seeming stability of the tonic:

...tonal systems are generally hierarchical: tones which are active tendency tones on one level may be focal substantive tones on another level and vice versa. Thus in the major mode in Western music the tonic tone is the tone of ultimate rest toward which all other
tones tend to move. On the next higher level the third and fifth of the scale, though active melodic tones relative to the tonic, join the tonic as structural tones; and all other tones, whether diatonic or chromatic, tend toward one of these. Going still further in the system, the full complement of diatonic tones are structural focal points relative to the chromatic notes between them. (pp. 214-215)

Carol Krumhansl (1979; with Shepard, 1979; with Kessler, 1982) has similarly proposed the existence of a hierarchy of musical pitches in which certain pitches fit better into a key and consequently are considered to be more stable than other pitches and can be ranked accordingly. These studies found preferences first for the tonic itself, followed by the dominant and the mediant, then the remaining four diatonic pitches, and finally the nondiatonic pitches. In terms of C major, these preferences are, respectively, C; G and E; D, F, A, and B; and, C#/D♭, D#/E♭, F#/G♭, G#/A♭, and A#/B♭.

In Krumhansl (1979), listeners were presented with a context of the C major triad, ascending C major scale, or descending C major scale, followed by a pair of tones, and were asked to judge "how similar the first tone is to the second tone in the tonal system suggested by the context" (p. 353). Generally, members of the tonic triad received higher ratings than the other diatonic tones. However, this could have been an artifact of the test, inasmuch as the C major triad was one of the contextual patterns, and the test items were not transposed to other keys. The listeners may have been primed for those three notes.
In spite of this criticism, however, there were other results of relevance to the present study. First, Krumhansl found that "the identity of the second tone had a larger effect on the similarity ratings than the identity of the first tone" (p. 356). This is a temporal order effect. Similarity ratings were higher when "the first tone was less closely related to the tonality of the context and the second tone was more closely related to the tonality" than when the reverse was true (p. 358).

The other result of interest is that of pitch height, or pitch proximity, which was also a factor in similarity ratings. Pitches that were close together registrally were judged more closely related than those that were farther apart, especially when the notes were nondiatonic.

The latter two studies used the probe-tone technique, in which a context was established and followed by a single pitch that was judged by listeners according to criteria such as completion of the context stimulus or well-fittedness of the probe tone within the context. In Krumhansl and Shepard (1979), the context was either an ascending or descending major scale without the concluding tonic. The task was to judge "how well each of the 13 (equally tempered chromatic) tones...completed ascending or descending C major scales" (p. 583). Again, only C major was used, risking a bias by the end of the test toward those pitches that occur in C major. West and Fryer (1990) noted that there was also a possibility
of primacy or recency effects (i.e., influence of the first
or last tones), or "increased memorability of repeated notes"
(p. 254).

In Krumhansl and Kessler (1982), twelve contexts were
presented and different keys were used (although not all
transpositions). The contexts were a complete ascending
major scale; complete harmonic minor scale; major triad;
minor triad; diminished triad; dominant seventh chord; and
six cadences: IV-V-I; ii-V-I; vi-V-I; iv-V-i; ii°-V-i, and
VI-V-i. The task was to rate "how well the probe tone fit,
in a musical sense, with the element just heard" (p. 340).
"Tone profiles," representations of the averaged ratings of
all twelve chromatic pitches, were generated for each
context. The tone profiles that had the highest correlations
with each other in this study were those for the major chord
with the three major cadences and for the minor chord with
the three minor cadences. The averaged results for these
contexts were used for the tone profiles that were published
(see Figure 1.3, below). The profiles for the scales,
diminished triad, and dominant seventh chord were not shown
or discussed. (Krumhansl (1990, p. 29) contains a brief
discussion of the results for the scales and the differences
between them and what was ultimately used. The scales
produced profiles in which scale degrees nearest the tonic
(2, 6, and 7) were rated higher and scale degree 3 was
slightly lower.)
The major key tone profiles generated in Krumhansl and Shepard (1979), and in Krumhansl and Kessler (1982) generally follow the outline of the tonal hierarchy described in Krumhansl (1979). In spite of the different instructions for making judgments (completeness vs. fitting in), the tonic received the highest ratings, followed by the dominant and
the mediant, the other diatonic tones, and finally the nondiatonic tones.

The question here, then, is how to interpret and use these results. The ranking and scaling of the results have produced a model which Krumhansl has asserted is a ranking of the relative "stability" of the function of each of the chromatic pitches with reference to the tonal system. This position has drawn criticism from Butler (1988; 1989; 1990a; 1990b) because it is static in nature and does not recognize that individual pitch classes can operate on more than one level of harmonic function in a piece, as, for example, a C acting as the root of a chord in C major at one time (or the third of an A minor triad or fifth of an F major triad) while at another time functioning as a dissonance with some other chord. In other words, all Cs are not created equal—a fact that is not addressed by the tonal hierarchy model.

Like Schoenberg, Krumhansl also equates tonality with key: "Tonality is synonymous with key, and implies a central tone with all other tones tending toward it in one way or another." (1979, p. 348) Thus, the profiles are assumed to be key-specific, but transposable, creating a total of 24 major and minor key tone profiles. Unlike Schoenberg, however, Krumhansl does not allow for multiple interpretations of the same pitch within a single key.

A use of tone profiles of particular relevance to the present study is a "key-finding algorithm" proposed by
Krumhansl (1990, pp. 77-110; devised in collaboration with Mark Schmuckler). Her formula utilizes durational information in addition to the tonal hierarchy and major and minor key tone profiles, producing a process that is fundamentally different from that of Longuet-Higgins and Steedman. Notwithstanding the static and rigid nature of the tonal hierarchy and the tone profiles, Krumhansl maintained that her algorithm was superior because it allowed the possibility that there could be a complex of keys apparent to the listener at any given time ("multiple key hypotheses," p. 78), one of which can be considered as the primary key and the others as closely related and subordinate.

There are three steps to Krumhansl's key-finding algorithm: 1) from the segment or piece in question, assess the total durations of all twelve pitch-classes; 2) compare these values with the tone profiles of all 24 major and minor keys; 3) evaluate the correlations between the duration information and the tone profiles. Each pitch-class's correlation will be "a measure of the degree to which the durations of the tones in the input segment match the tonal hierarchy of each key."

(Krumhansl, 1990, p. 80) Consequently, the higher the correlation, the less ambiguous the key.

This algorithm rests on the assumption that the total amount of time that any given pitch occurs in a piece is proportional to its relative position in the tonal hierarchy.
This assumption was based on a statistical study by Hughes (1977) (cited in Krumhansl, 1986/1990) of the overall durational distribution of tones Schubert's *Moments Musicaux*, op. 94, no. 1. Hughes found that the "tonal orientation," or the total durations of the pitches, differed from the "tonal organization" of the piece, such that while this piece is organized and understood through salient features, such as harmonic progressions, to be in C major, the tonal orientation is G major because G had the highest total duration. Krumhansl compared a profile of Hughes' total

![Figure 1.4. Hughes' (1977) tone durations with Krumhansl and Kessler's (1982) G major tone profile (Krumhansl, 1990, p. 72)](image_url)
durations for this piece with the G major tone profile and found that the two correlated (see Figure 1.4, above). Krumhansl concluded that, in spite of the fact that the profiles correlated for the key of the dominant of the piece and not for the key of the piece itself, statistical evaluation of total durations compared to the tonal hierarchy is a valid measure of listeners' perception of key.

Several other criticisms of this approach can be made. First, with regard to the use of total durations as a measure of key: It does not account for the context, i.e., temporal order, of the pitches. A piece can have more of G than C and still be in C, because of the placement of the pitches or harmonic progression; but if total durations are the rule, then G would be the key of choice. Particularly in the case of the dominant, its position as both a member of the tonic triad and the dominant allows for relatively high frequency and duration. Krumhansl (1990) even remarked on this: "...although the tonic occupies the highest position in the hierarchy of tonal functions, the dominant may play a more important role in establishing the key, and this is reflected in its greater frequency" (p. 69, with regard to frequency distributions found by Youngblood (1958) and Knopoff and Hutchinson (1983)). The listener can determine a tone's function at any given time only by its use at that time. Conversely, C does not have to be present much (or at all) for C major to be implied: As Krumhansl noted and as most
theorists would agree, the dominant is more important for that role. C needs only to be present in the most strategic places, such as cadences, and only long enough to be heard, in order to confirm that it is indeed the tonic.

Another criticism, similar to that made above for theoretical approaches, is that the assessment of total durations is a snapshot, whole-picture approach that is irrelevant to the act of listening. Listening can occur only over time, one sonority after another, during which instant judgments about key must be made in order to make sense of what is being heard.

Butler (1989) similarly criticized the assumptions made for the comparison of durations to the tonal hierarchy. He particularly noted that profiles of durations taken from smaller segments of a given piece can vary greatly from each other as well as from that of the entire piece, and that they consequently could not account for changes in harmony and key that are associated with modulation and tonicization.

Butler (1989, 1990a) also questioned the overall generalizability of such a method, giving as an example the second piece of Schubert's Moments Musicaux. He found that the profile of the sums of the durations did not conform to the shape of the major key tone profile. The duration profile did show a similar spike on the dominant, but even reorienting the duration profile to the dominant did not provide a match to the major key tone profile. In addition,
Butler pointed out that applying this kind of "counting system" to tonal music can be misleading also from the standpoint of enharmonic spellings:

The blindness of the counting system to time orders of tones is matched by its insensitivity to their harmonic implications. For example, the pitch A♯ has strong harmonic implications in some sections of Schubert's Opus 94, No. 2, and the pitch G♯ has different (but equally strong) harmonic implications at other points in the piece. Yet, one must add their durations indiscriminately in the same column when compiling durational weightings of pitch classes. (1989, p. 228, note 9)

Butler's (1989) final criticism regarding the relationship between duration profiles and tone profiles came with a comparison of Krumhansl and Kessler's major and minor key tone profiles with the duration profiles of their respective context stimuli (which he called "stimulus profiles"; see Figure 1.5, below). Butler suggested that the similarity between the tone profiles and their respective stimulus profiles "reflects a stimulus artifact in the design of Krumhansl and Kessler's experiment, rather than a reflection of mental representations of pitch relations" (pp. 230-231). Thus, it is possible that the tone profiles are applicable only to the contexts from which they were derived and are therefore not generalizable beyond those contexts.
Figure 1.5. Major and minor stimulus profiles (total durations of pitches in context patterns, Krumhansl and Kessler, 1982) compared to major and minor key tone profiles, from Butler (1989), pp. 231, 232.
With regard to the second step of Krumhansl's key-finding algorithm, that of comparing the duration "profiles" with the 24 major and minor tone profiles: This step assumes the premise that "goodness-of-fit" within a given context is actually a reliable (and generalizable) indicator of "stability" within a hierarchy of tones. Even if this premise is valid, the brute-force aspect of this step (actually the whole algorithm) is difficult to accept given the amount of information to process and the time (or lack of it) that a listener has available in which to make decisions during the course of a piece.

   The second step of the algorithm, in conjunction with the first, is set up such that any concept of the tonal relationships conferred by the use of solfège syllables is nonexistent, because the pitch information is placed within the framework of the twelve pitch-classes, regardless of enharmonic interpretations. The total durations of each pitch-class are compared with all tone profiles from all keys. It does not take into account the possibility that listeners are hypothesizing and revising as they go along in a piece. These decisions would necessarily be made on-the-fly and always with incomplete information: Determination of key is nearly always done before the end of a phrase, section, or piece, which, as theorists are quick to point out, are points of confirmation of key.
Cuddy and Badertscher (1987) compared their experimental results (described below) to Krumhansl and Kessler's tone profiles, although one of their aims was "to evaluate the efficacy of each [melodic context] pattern in producing a sense of key" (p. 612). The instructions to the listeners were to provide "honest, subjective evaluations of how well the final note [the probe tone] of each pattern provided a musical completion to the pattern" (p. 616). The task in and of itself was not different from that of Krumhansl and Shepard (1979), but there is some difference in the interpretation of the probe tone values: Cuddy and Badertscher called their results "tonality profiles," which could be taken to mean that the probe tone was meant to be interpreted as a tonic and not merely as a stable tone within a given scale.

The context patterns used by Cuddy and Badertscher are shown in Figure 1.6, below; they were not presented in other transpositions. The resulting tonality profiles are presented in Figure 1.7.

![Figure 1.6. Context patterns used by Cuddy and Badertscher (1987).](image-url)
The profiles for the major triad and major scale are very close to those of Krumhansl and Kessler (1982), although there are some differences. For example, the major triad received a much higher rating for F (the subdominant) than for E (the mediant), while the major scale received higher ratings for B (the leading-tone) than for A (the submediant). The diminished triad, on the other hand, has a completely different profile that cannot be reconciled with Krumhansl and Kessler's tone profiles. The preferred pitches were F#, and B. Cuddy and Badertscher interpreted these profiles to mean that the major triad and major scale were "tonally 'very
strong'," and that the diminished triad "did not recover a profile that could be considered tonal" (p. 618). It is posited here that this is a misinterpretation of the function of the diminished triad (i.e., the context created by it) and the meaning of the probe tone itself. Obviously, the probe tone was not considered by the evaluators to represent a tonic.

Brown, Butler, and Jones (1994) replicated and expanded the Cuddy and Badertscher (1987) study. They noted that C and F# are both logical tonal resolutions of the tritone: If B is considered to be ti and F to be fa, then C is the tonic; if the relationships are reversed, and B is fa and F (E#) is ti, then F# is the logical tonic.

Furthermore, by reordering the stimulus materials (see Figure 1.8, below), Brown, Butler, and Jones got very different results, as shown in the profiles in Figure 1.9. The primary aim of the reorderings was to show the effects of temporal order on the resulting profiles of responses.

Figure 1.8. Reorderings of context patterns, used by Brown, Butler, and Jones (1994).
The rearrangement of the major triad was designed to address the possibility that the regular recurrence of C in the pattern made C the most highly rated response. Thus, placing C at the beginning and end would eliminate the possible rhythmic influence; C remains in favored positions, but F and G are also likely responses. The random ordering of the C major scale is still predicted to receive mostly C responses. The B diminished triad is reordered to place the members of the tritone in the optimal ordering for yielding a C response.

Surprisingly, the reordered C major triad was rated as best completed by F, followed by C and G, and also by D♭/C#. The reordered major scale received the predicted ratings, and the reordered B diminished triad was rated as best completed by C, whereas F# received very poor ratings (see Figure 1.9, below).

In their discussion of the tonal hierarchy and intervallic rivalry models, Brown, Butler, and Jones noted that the tonal hierarchy model reflects a listener's application of musical knowledge based on a given specified tonal context. It emphasizes the stability of certain prominent pitches—tonic, mediant, dominant—that happen to be outlined by those interval classes more common in the diatonic set. The strength of the tonal hierarchy model lies in descriptions of ways these common intervals reinforce key....Given a fixed cognitive anchor pitch, the presentation of more-common intervals of the diatonic set...supports tonal functions within the tonal framework of the anchor pitch. Their reinforcing function contribute importantly to the jagged tonal profiles... (p. 377)
Figure 1.9. Profiles of reorderings compared with Cuddy and Badertscher (1987) and replication (Brown, Butler, and Jones, 1994, p. 396).
This description of the tonal hierarchy model lines up fairly well with Browne's (1981) description of pattern matching (discussed below in relation to the intervallic rivalry model). And it points to the need for explanations of position-finding, such as is provided by the intervallic rivalry theory, which yield decisions regarding the initial establishment of tonic and subsequent changes of key:

Rare intervals and their orderings are assumed to operate initially over time to contribute to tonal profiles by fixing a single pitch as a tonal center. Therefore, the strength of the intervallic rivalry model lies in suggesting how rare intervals facilitate discovery of key.

The two models address different aspects of tacit knowledge about tonality.... (Brown, Butler, and Jones, p. 377)

West and Fryer (1990) performed a test of the tonal hierarchy model in response to their own concerns regarding temporal orderings of the pitches in the major diatonic set and listeners' choices of tonic. They noted that contexts for probe tone studies were often ascending or descending scales, or other patterns, in which all possible orderings of their elements were not used to control for possible primacy or recency effects. In their test, the authors presented a context of randomly ordered the seven pitches of the major diatonic collection (in all transpositions) and played a diatonic probe tone. The task was to rate the probe tone for suitability as a major key tonic for the context. The results did not resemble a major key tone profile. Rather,
the tonic, dominant, subdominant, and mediant all received similarly high ratings, showing that temporal order does have an effect on listeners' judgment of tonic.

Cook (1994) generalized several of the criticisms of the tonal hierarchy model in the following manner:

It is ordered structures that are significant: harmonic progressions, melodic patterns. The diatonic set is simply a theoretical abstraction, a generalization from specific harmonic and melodic contexts. It is a pedagogical construct, like Schoenberg's chart of the regions. Tonal hierarchy theory, then, does not arise from the observable phenomena of music. It arises from the attempt to give a psychological interpretation to concepts drawn from music theory. (p. 86)

**Intervallic rivalry**

Richmond Browne's (1981) speculations concerning the relationships of the seven pitches of the diatonic collection (those pitches found in the major scale) form a theoretical basis for the intervallic rivalry theory. Browne proposed that a listener brings two types of "tonal behavior" (p. 4) to bear upon hearing a piece of tonal music: position finding ("Where are we in this piece or key, and how did we get there?") and pattern matching ("Is this the same as what we've heard before, and can it become more or less similar?"). Further, Browne suggested that tonal music contains two properties which the listener uses in position finding and pattern matching: interval content and intervallic context. (p. 5)
Interval content refers to the materials of a collection of pitches. In this case, we are interested specifically in the intervals between the pitches comprising the major diatonic set. This content is expressed by the interval vector \(<254361\>). Browne notes that all interval-classes (ic's) are represented, and that each ic is represented a unique number of times. He suggests that those ic's that occur the least (the "rare intervals"), i.e., the tritone which occurs once, and the minor seconds which occur twice, help with position finding—that by hearing two pitches which form a rare interval, the listener can immediately infer a satisfactory answer to the question, "Where are we?" This notion ties in with context.

Intervallic context refers to the actual position and specific intervallic distances each pitch has in relation to the other members of the set. Browne put it in the following way:

For each scale degree, certain intervals are present as context—and necessary, though not all are equally necessary. And for each degree, certain intervals are not present...

...The distinction between any two degrees always rests on the presence or absence of the rarest interval(s) either possesses—and that quantity is a different one for each pair of closely-similar scale degrees. Thus, between \(\hat{4}\) and \(\hat{6}\) a tritone is at stake. But between \(\hat{1}\) and \(\hat{5}\), neither having a tritone, the minor second below makes the difference.

So we may say that the rare intervals control position finding. The degrees are constantly matched in terms of their presumed contextual patterns. (pp. 13, 14; emphasis original)
Consequently, a listener can determine a key by the use of rare intervals which provide context. For example, the tritone occurs only once within the diatonic collection, so it can be inferred that its presence will establish a key for the listener.

Browne's ideas have been empirically studied and expanded by Helen Brown and David Butler. Brown and Butler first tested Browne's ideas in 1981 and have subsequently found further evidence to support Browne's claims (Brown, 1985, 1987, 1988; Butler, 1989, 1990b).

Brown and Butler (1981) identified several issues regarding Browne's assertions about position finding, pattern matching, and key identification, such as:

- Do rare intervals carry sufficient tonal information that musicians can confidently identify tonal center?
- Do more common intervals elicit similar judgments of tonal center?
- Is tonal structure time-independent, or do ordered relationships of tones influence musicians' tonal judgments?
- With only partial evidence, can listeners identify tonal structure by integrating stated and implied relationships?

To examine these issues Brown and Butler presented listeners with a variety of three-note sets. Some of the sets were univalent "cue-cells" that contained two pitches outlining a tritone plus one other tone (representing a third
pitch-class) and were thus predicted to elicit one tonic, based on Browne's assertions. The remaining sets were multivalent; i.e., they did not contain a tritone and could consequently be interpreted as falling into more than one major key. Subjects were to identify the tonic for each set in any manner that they chose.

In reference to the above questions which Brown and Butler sought to answer, their results showed that rare intervals do carry sufficient tonal information for confident identification of tonal center, while more common intervals do not; time-ordered relationships do influence tonal judgments; and partial evidence is enough for listeners to infer tonal structure.

Specifically, cue-cells produced an overall accuracy of 87%, and for multivalent sets as a whole, accuracy was 97%. As Brown and Butler rightly noted, multivalent sets had more than one "correct" answer, which would greatly increase the chances of being right. It turned out that none of the available correct answers was preferred more than 44% of the time.

Of particular interest to the present study are the results regarding time-ordered relationships and their influence on tonal judgments. Brown and Butler discovered that the order of presentation of the pitches of the tritone affected listeners' choices of tonic. In the three orderings in which ti follows fa (or, in terms of C major, B follows...
F), listeners correctly identified tonic at a mean accuracy rate of 93% and not below 90% for any single time-ordering. Conversely, accuracy was considerably lower for the three orderings in which ti precedes fa (B before F): Mean accuracy was at 81% and not above 85% for any single ordering. Accuracy was highest when ti was the third tone and was lowest when fa was the third tone.

Corroborative results were found by Helen Brown (1985, 1987, 1988) in studies in which she manipulated "pitch strings" of varying lengths and varying degrees of multivalency in order to emphasize different tonics. This was accomplished by manipulating the time-orders of the least common intervals in each pitch string. She found that those pitch strings containing the tritone in the order fa-ti elicited predicted tonic responses over 80% of the time, while other orderings which contained the tritone ordered ti-fa received about 24% of the predicted responses; those with no tritone received about 50% of the predicted responses; and those with two interleaved tritones received about 27%.

These results led Brown to suggest:

If the presence of rare intervals had been the sole determinant of tonal center, then stimuli containing the rarest intervals should have evoked the greatest tonic agreement. But the critical perceptual cues to functional tonal relationships among pitches in these stimuli were supplied not by their presence alone but by the manner in which their intervallic relationships were exploited temporally. The power of intervals rare in the diatonic set to supply critical information about tonal center to listeners so easily can as easily be employed to undermine that information. Although the
rare intervals operate in this way more effectively, both rare and the more common intervals in the set can be manipulated compositionally to either indicate or to obscure tonic choices. (1988, p. 242)

Butler (1989), in addition to the criticisms of Krumhansl and Kessler's (1982) tone profiles, also contributed to codifying the precepts of the intervallic rivalry theory.

The quickness and apparent ease with which key recognition occurs suggests that this act of perceptual orientation must be based on a limited and relatively simple mental process. There is one explanation for this listening behavior that seems most reasonable: a perceptual theory involving a hierarchy of intervals, which takes the dynamic form of perceptual rivalry. A compact statement of this theory would be that Any tone will suffice as a perceptual anchor—a tonal center—until a better candidate defeats it. The listener makes the perceptual choice of most-plausible tonic on the basis of style-bound conventions in the time ordering of intervals that occur only rarely in the diatonic set; that is, minor seconds (or enharmonics) and the tritone.... (p. 238)

In spite of the strength of some of Butler's criticisms against the tonal hierarchy, the intervallic rivalry model does not totally negate the claims of the tonal hierarchy model. Rather, both rely on the intervallic content of the diatonic pitch collection, which is abstract and independent of temporal considerations. However, the intervallic rivalry theory is crucially dependent on the temporal orderings of the notes in real music, i.e. the context, which must be accounted for in any model of an activity that can occur only in time.
Boltz (1989a, 1989b) found evidence of particular interest to the present study to support the intervallic rivalry theory's claims in the absence of the tritone. This study investigated the importance of the leading tone-tonic relationship as a means of marking the end of a melody. She suggested that

The leading tone-to-tonic progression illustrates how temporal order information within a melody's context is used to specify particular functions for an attentive listener. If listeners are in fact sensitive to the role of such information, this implies that music cognition includes representations of various scale degrees and chordal sequences associated with a given tonality..., as well as temporally ordered pitch intervals that are used for particular communicative purposes. (1989a, p. 751)

Boltz found that the leading tone-to-tonic endings were judged to be the most complete, while the reverse ordering was the most incomplete. She also found that the penultimate note of the melody influenced completeness ratings, in that the submediant-to-tonic ratings were significantly lower than those for leading tone-tonic, so that not only the temporal ordering but the pitch content of the pattern was important for judgments of endings.

Boltz (1989a) also found that altering patterns of accentuation in melodies that did not contain a tritone influenced completeness ratings for those melodies. She cited Kidd (1984), who found that when the tritone was
absent, and the melody was therefore tonally ambiguous, rhythm was used to infer the key of that melody.

Unfortunately, very little research has been done on the effects of rhythm on listeners' perceptions of tonal organization. As was noted above (see p. 7), Riemann speculated that rhythm could be used to enhance modulations, but his ideas have not been tested empirically. His ideas were framed within the framework of meter, which in itself has been the subject of numerous studies, but with very little reference to its effects on tonal organization and its perception by listeners in that regard. Meter is beyond the scope of this project, but it is possible to examine the effects of variable durational patterns, without reference to meter, on listeners' perceptions of tonic.

Of particular interest to the present investigation of pitch and rhythm relationships is an informal study which dealt specifically with rhythm's influences on the perception of tonic in tonally ambiguous circumstances, an unpublished paper by William Dougherty, "The Effect of Agogic Accent on Perception of Tonal Center" (1982).

Dougherty's study found evidence to support the hypothesis that the lengthening of a note in relation to two others will cause a listener to "interpret [the three-note sets] differently when they appeared in different rhythmic guises" when more than one choice of tonic is available (p. 5). However, this study was a small informal one in which
strict controls were not placed on several variables. The premise and preliminary results of this study form the foundation of the current project, which uses the necessary controls and procedures by which to achieve statistically valid results.

Dougherty's study was meant to be a project designed to further investigate Richmond Browne's hypotheses and to expand on the findings of Brown and Butler (1981) by introducing a rhythmic element, the lengthening of one note, in an effort to broaden the definition of "context."

Dougherty presented listeners with sixteen different multivalent three-note sets in each of three rhythms: long-short-short, short-long-short, and short-short-long. He found that, generally, while listeners gave a different response for each rhythm, the accuracy rate was fairly high; i.e., one of the several possible tonics for each set was identified (see comments above in discussion of Brown and Butler (1981)).

Unfortunately, as noted above the study was informally done, so that the reliability of the results is somewhat doubtful. The raw percentages for only six of the sets were presented, and the other ten are not shown at all. There is also no indication that any of the same sets were used in different time-orderings, which is a major drawback, especially in light of his reliance on Browne, and Brown and Butler, as the basis for the project. There was no attempt
to relate his findings to the rare interval or temporal order hypotheses. Nevertheless, the premise of Dougherty's study is a logical extension of the rare interval and temporal order hypotheses of the intervallic rivalry model, and it serves as the basis for the present study, particularly with regard to the "importance of time-dependent factors in the musical experience" (Dougherty, p. 8), encompassing both time-order and durational relationships.

Dougherty's study, the intervallic rivalry theory, Boltz's and Kidd's studies, and some aspects of the tonal hierarchy theory are the bases for the current project. Dougherty's small informal study has been the only source that this author could find which has investigated the claims of the intervallic rivalry theory after the method of Brown and Butler (1981), using tonally ambiguous stimuli and different rhythms. Although Boltz and Kidd studied rhythm and pitch effects in light of the intervallic rivalry model, they used complete phrases of musical material, from which responses could have been influenced by factors such as the length of the melody, meter, and registral groupings; consequently, judgments concerning the minimal amount of pitch and durational information required to make correct tonic choices could not be made. The intervallic rivalry model does not currently incorporate aspects of duration or accent. The use of durational patterns can be seen as the next
extension of the intervallic rivalry model, particularly as they may relate to the temporal orderings of the pitches.
CHAPTER 2

THE MUSICAL STIMULI

INTRODUCTION

The issues of key-finding which were raised in Chapter 1 led to the development of two hypotheses regarding the relationships of temporal placement and duration to musical listening behavior and the perception of tonality. These hypotheses and the musical stimuli used in the experiment designed to test them are discussed in this chapter.

HYPOTHESES

The purpose in this study is to provide evidence to support an empirical perceptual theory of tonality by examining tonally enculturated listeners' responses to pitch and rhythmic relationships in short tonal examples. The general hypotheses to be evaluated are:

1) A listener's perception of tonality develops through the awareness of time-dependent relationships among pitches,
including the relative durations as well as the successive order of those pitches.

2) Perceptual cues to functional tonal relationships are provided by the way in which intervallic relationships are used. Rare intervals, especially the tritone, in the diatonic collection provide important information about tonal center; however, other intervals, such as the minor second, can be manipulated to influence a listener's choice of tonic.

To test these hypotheses, musical stimuli were presented to listeners who were able to vocalize their tonic judgments. The stimuli comprised four three-note sets, the pitches and durations of which were manipulated in ways intended to facilitate certain tonal responses. The effects of four different durational patterns—equal durations, long-short-short, short-long-short, short-short-long—were examined to test the effects of relative durations on tonic choice. The pitches of each set were presented in all available successive orders. Consequently, the general hypotheses which were presented above can be stated specifically:

1) In tonally ambiguous three-note sets, the lengthening of one note will influence a tonally enculturated listener's choice of tonic, so that the lengthened note will be interpreted as the tonic.

2) In tonally ambiguous three-note sets, temporal order of the notes will influence a tonally enculturated listener's
choice of tonic, so that tonic choices will vary according to the serial placement of the members of the rarest interval in the set.

DESCRIPTION OF THE MUSICAL STIMULI

So that valid comparisons could be made, restrictions were applied to the individual stimuli and also to their presentation.

First, all sets must be multivalent in two and only two major keys, for statistically valid and uniform comparisons of the responses. Second, the largest interval must be the perfect fourth. The tritone is not permissible because its presence would make the set univalent. Larger leaps could introduce a grouping effect, a variable that is difficult to define and control and is beyond the scope of this project.

These two restrictions reduce the number of "usable" sets to four. In integer notation, these sets are 013, 023, 015, and 045, represented below in Figure 2.1. Note that the common characteristic of all four sets is a half-step, represented as B-C, which can be interpreted in only two ways diatonically within a major key: either as ti-do or as mi-fa, thus allowing the illustrated sets below to fall in the keys of C major or G major, respectively.
Two limitations were also imposed on the presentation of the stimuli: First, all possible time-order arrangements of the notes must be presented. There are six possible time-order arrangements, or permutations (Figure 2.2 on the next page presents all of the permutations in musical notation [for ease of comparison, shown here in the key of C]):

- \( p_1 \) B-C-x
- \( p_2 \) C-x-B
- \( p_3 \) x-B-C
- \( p_4 \) x-C-B
- \( p_5 \) B-x-C
- \( p_6 \) C-B-x

Second, four rhythm patterns were used: equal durations; long-short-short; short-long-short; and short-short-long (hereafter abbreviated sss, lss, sls, and ssl, respectively).
Figure 2.2. Permutations notated for each set.
Set/permutation combinations were presented such that each combination of set and permutation was heard three times in each of the four types of rhythm pattern (sss, lss, sls, and ssl). All transpositions were used equally. The tempo of the examples was s = 66 beats/min.

Rhythm conditions were presented in four counterbalances arranged in a Latin square design in order to prevent order effects based on rhythm:

<table>
<thead>
<tr>
<th>R1</th>
<th>: sss</th>
<th>lss</th>
<th>sls</th>
<th>ssl :</th>
<th>3 times each</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>: lss</td>
<td>sls</td>
<td>ssl</td>
<td>sss :</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>R3</td>
<td>: sls</td>
<td>ssl</td>
<td>sss</td>
<td>lss :</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>R4</td>
<td>: ssl</td>
<td>sss</td>
<td>lss</td>
<td>sls :</td>
<td>&quot; &quot;</td>
</tr>
</tbody>
</table>

Two pitch counterbalances for each rhythm counterbalance were also used, so that the total number of counterbalance orders used was eight.

Each block of each rhythm condition (sss, lss, sls, ssl) contained 24 samples (every permutation of each set, six permutations of four sets). The samples were ordered in a "quasi-random" fashion, according to the following rules in order to prevent carry-over effects between samples related to set, permutation, or key:

The same set and/or the same permutation may not occur in more than two adjacent samples. All potential key interpretations must be equally represented, but adjacent samples may not share one or both potential interpretations of major keys. In addition, neither potential key interpre-
tation of a sample may be a perfect fifth from either key interpretation of an adjacent sample, because the two potential key interpretations of a given sample are a fifth apart.

The presentation of the stimuli and the procedure for the test are described in Chapter 3.
CHAPTER 3

METHOD AND PROCEDURE

SUBJECTS

Because of the nature of this study and the tonal ambiguity of the stimuli, it was necessary to find participants who had an intellectual understanding of the tonal system, sufficient working knowledge of the tonic-do solfège system, and adequate vocal control, such that they and the investigator were confident that their vocalizations represented their desired tonic responses to the stimuli. To meet these general criteria, subjects were solicited who met the following specific requirements: The subjects each had to have 1) successfully completed the first year of aural training in the undergraduate music curriculum (or the equivalent); and 2) successfully completed a pre-test with a 100% pass. The pre-test and a brief discussion of it are presented in Appendix A (p. 128).

Fifty-six subjects participated. Thirty-six were music students associated with The Ohio State University; 16 were music students at West Virginia University; one was a
music student from University of Rio Grande (Ohio); 2 were
music library faculty, and one was a professional church
musician. All had completed at least one year of music
theory and aural training courses. Other information about
the subjects is listed below in Table 3.1.

OSU: 1 soph. 7 jr. 15 sr. 13 grad.
WVU: 5 soph. 2 jr. 6 sr. 3 grad.
other: 1 soph. 3 professional

Gender: Male 35 Female 21

Year in school: Soph 7 Grad 15
Jr 9 Other 4
Sr 21 (B.Mus. or B.Mus.Ed.)

Age: (mean=25.14 yrs)

<table>
<thead>
<tr>
<th>age</th>
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<tbody>
<tr>
<td>18</td>
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<td>22</td>
<td>4</td>
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<tr>
<td>19</td>
<td>2</td>
<td>23</td>
<td>4</td>
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<td>20</td>
<td>10</td>
<td>24</td>
<td>4</td>
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<tr>
<td>21</td>
<td>12</td>
<td>25</td>
<td>2</td>
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<tr>
<td>18</td>
<td>2</td>
<td>26</td>
<td>2</td>
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<td>19</td>
<td>3</td>
<td>27</td>
<td>3</td>
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<td>4</td>
<td>28</td>
<td>4</td>
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<td>29</td>
<td>1</td>
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<td>1</td>
<td>31</td>
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<td>21</td>
<td>3</td>
<td>34</td>
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</tr>
<tr>
<td>21</td>
<td>1</td>
<td>49</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>62</td>
<td>1</td>
</tr>
</tbody>
</table>

Major instrument:

voice 7 trombone 3 double bass 1
flute 4 tuba 1 electric bass 1
oboe 3 percussion 4 guitar 2
saxophone 4 violin 5 piano 9
trumpet 5 viola 2 organ 1
horn 1 cello 3

Average aural training grade:

<table>
<thead>
<tr>
<th>B+</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>12</td>
</tr>
<tr>
<td>B-</td>
<td>2</td>
</tr>
</tbody>
</table>

2 were in programs with no separate aural training courses. Theory grade=A (both)

Table 3.1. Demographic information of the subjects.
APPARATUS

Examples were prepared using Vision sequencing software for Macintosh and a Yamaha TG-77 Tone Generator, and were recorded using a Panasonic SV-3700 DAT Recorder onto 3M R120 Digital Audio Tape for use as master tapes. Field copies were made onto Sony UX-Pro High Bias 90-minute cassettes, using a Sony Digital Audio Recorder PCM-2500 and Kenwood Stereo Cassette Deck KX-32B. Examples were played back through speakers at a comfortable level from a portable Panasonic Stereo Radio Cassette Recorder RX-FW29 and recorded for later independent review onto 3M AVX Professional Audio Cassettes (normal bias) using a portable Panasonic Stereo Radio Cassette Recorder RX-F3.

PROCEDURE

All accepted subjects were tested individually. The experimenter was present to run the test, answer any questions, to write down the vocalized responses, and to tape-record the session.

Each session was conducted in the following manner: The subject was given a demographic information questionnaire to fill out and a consent form to sign (see Appendix B, p. 131). Then the following instructions were read:
For this study, you will hear twelve groups of trials. Each group contains twenty-four trials and is about seven minutes long. Each trial will be a presentation of three notes in a particular rhythm: equal durations; long-short-short; short-long-short; or short-short-long. All groups will be separated by pauses, with longer breaks as you think you will need them. However, a group of trials may not be interrupted once it has started.

Your task is to decide on the MAJOR key which you think each trial best fits in, and to sing (or hum) the tonic note for that trial. You will hear each example twice in the following manner:

The example number will be announced by the experimenter. Then you will hear the example the first time. Approximately three seconds later, you will hear it the second time. Immediately respond by singing (or humming) your choice of MAJOR tonic, because about three seconds after the second time, you will hear a noise in preparation for the next example. The next example will then be announced.

For practice at responding, you will now hear twelve examples. Please respond as just instructed. [Practice examples were played.]

You may vocalize and think out loud as much as you wish. I'd like to have that recorded as well. Again, think in terms of MAJOR keys only.

Are there any questions before we begin?

No musical notation or visual cues were presented to the subjects before or during the test. Subjects were encouraged to comment freely on the task between groups of trials and were asked for final impressions during an oral debriefing at the conclusion of the test. These comments are provided in Appendix C, p. 133.

After all of the data were collected, the tapes were reviewed and the answers tabulated by the author and another independent reviewer who was informed of the nature of the task. Differences between the two tabulations were resolved by a third independent reviewer.
CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the results of the study are presented and their implications are discussed.

RESULTS

Four categories of responses were created for analysis and presentation of the results. Table 4.1 below refers to C major; all responses have been transposed to C for purposes of discussion (see also the description of the musical stimuli in Chapter 2):

1 Most highly predicted C
2 Next most highly predicted G
3 Related, but not predicted D, E, F, A
4 Leading tone/chromatic, not predicted B, C#/D♭, D#/Eb, F#/Gb, G#/Ab, A#/B♭

Table 4.1. Categories of responses.
As was noted in Chapter 2, there are only two major diatonic sets into which the stimuli fall, and for which tonic responses are therefore predicted. These are labeled as categories 1 and 2. In terms of C major, they are, respectively, C major (half-step = ti-do), and G major (half-step = mi-fa). The ti-do interpretation was expected to be the more common response for two reasons: The tonic is present in the three-note set, and harmonically, most tonal music emphasizes the half-step between the leading tone and tonic by means of the prominent placement of the authentic cadence.

Categories 3 and 4 contain the remaining ten pitch-classes and are a means to differentiate between types of "wrong" answers. Category 3 comprises those pitch-classes that stand in a major diatonic relation to C, and category 4 comprises the chromatic pitch-classes plus B (the leading tone). These categories are based on Krumhansl and Kessler's (1982) major key tone profile. In spite of the criticisms of that study offered in Chapter 1, it remains one of the most comprehensive quantitative studies on the tonal hierarchy, and continues to be one of the "yardsticks" by which other quantitative studies of tonal music are measured; as such, it is valuable for the sake of comparison in this project.

The mean number of responses for each set/permutation combination was calculated over the three repetitions of each combination for each subject. These means were then
collapsed across subjects to arrive at a proportion for each category of response in each rhythm. Tables of proportions and corresponding graphs were then generated for examining the possible interactions between temporal order, set content, and rhythm. They will be presented in the following order: 1) permutation and rhythm; 2) set and rhythm; 3) set/permutation combination and rhythm; 4) permutation and set.

**Permutation and rhythm**

Table 4.2 presents the overall percentages of responses in each category, arranged by permutation. Category 1 (C) received a majority (60.58%) of the tonic responses, but it was not as high as music theory might lead one to expect for a *ti-do* interpretation. The rival tonic, G (category 2), received only 17.88% of the responses, also not as high as might be expected, especially from the intervallic rivalry model.

Table 4.2, below, presents the percentages of each category of responses within each permutation. There are noticeable differences between permutations and categories of responses. The highest percentages for category 1 occurred for p2 (CxB), p4 (xCB), and p6 (CBx), while the highest category 2 percentages occurred for p1 (BCx), p3 (xBC), and p5 (BxC).
Table 4.2. Overall percentages of responses in each category, by permutation. (cat1 = C; cat2 = G; cat3 = A,D,E,F; cat4 = remainder; NR = no response)

Table 4.3 shows the proportions of category 1 (only) and category 1 and 2 (combined) responses by permutation and rhythm. Figures 4.1 and 4.2 graphically represent the patterns of those proportions of responses (category 1 responses only, and category 1 and 2 responses, respectively).

It is immediately noticeable that rhythm did not influence listeners' choices of tonic as measured against permutation. However, the variety of responses for permutation is in keeping with the other hypothesis of this study. The proportions of responses for each permutation as they were figured across subjects and rhythms generally follows the outlines of the percentages shown above in Table 4.2. The highest proportions of category 1 responses occurred for p2, p4 and p6, while category 2 responses affected mostly the proportions for p1, p3, and p5. Of particular interest are the relatively low proportions, in
both categories, of the expected responses for p5 (BxC) and the high proportions for p2 (CxB) for category 1. The implications of these results for categories 1 and 2 will be discussed later.

\[
\begin{array}{cccc}
P & R & \text{cat.1} & \text{cat.1 or 2} \\
1 & 1 & 0.4539 & 0.7708 \\
1 & 2 & 0.4405 & 0.7545 \\
1 & 3 & 0.4717 & 0.753 \\
1 & 4 & 0.4345 & 0.7485 \\
2 & 1 & 0.8601 & 0.8914 \\
2 & 2 & 0.8795 & 0.9092 \\
2 & 3 & 0.8438 & 0.878 \\
2 & 4 & 0.8542 & 0.8973 \\
3 & 1 & 0.5387 & 0.8051 \\
3 & 2 & 0.5476 & 0.8051 \\
3 & 3 & 0.5551 & 0.7991 \\
3 & 4 & 0.5521 & 0.8021 \\
4 & 1 & 0.6488 & 0.7753 \\
4 & 2 & 0.6607 & 0.7827 \\
4 & 3 & 0.6786 & 0.7813 \\
4 & 4 & 0.6726 & 0.8065 \\
5 & 1 & 0.4524 & 0.6845 \\
5 & 2 & 0.433 & 0.6815 \\
5 & 3 & 0.4613 & 0.6696 \\
5 & 4 & 0.4554 & 0.6815 \\
6 & 1 & 0.6845 & 0.8036 \\
6 & 2 & 0.6935 & 0.7976 \\
6 & 3 & 0.6384 & 0.7768 \\
6 & 4 & 0.6741 & 0.8155 \\
\end{array}
\]

Table 4.3. Proportion of responses by permutation (separated by rhythm). (P=permutation; R1=sss; R2=lss; R3=s1s; R4=ssl)
Figure 4.1.
Proportion of category 1 responses by permutation (separated by rhythm)
Figure 4.2.
Proportion of category 1 or 2 responses by permutation (separated by rhythm)
Set and rhythm

Although it was not predicted or hypothesized, set also had an influence on listeners' choices of tonic and, again contrary to the first hypothesis of this study, rhythm did not have an influence.

Table 4.4, below, shows the percentages of each category of response in each set. The percentages of category 1 responses are comparable between sets 1 and 2 (013 [BCD] and 023 [ABC], respectively) and are lower for set 3 (015 [BCE]) and considerably higher for set 4 (045 [GBC]). The percentages of category 2 responses were comparable between sets 3 and 4 and were higher for set 1. The relatively high percentages of category 3 responses in set 3 will be discussed later in this chapter.

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<tr>
<th></th>
<th>s1</th>
<th>s2</th>
<th>s3</th>
<th>s4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BCD</td>
<td>ABC</td>
<td>BCE</td>
<td>GBC</td>
</tr>
<tr>
<td>cat1</td>
<td>14.45</td>
<td>14.79</td>
<td>11.79</td>
<td>19.55</td>
</tr>
<tr>
<td>cat2</td>
<td>6.48</td>
<td>4.72</td>
<td>3.13</td>
<td>3.54</td>
</tr>
<tr>
<td>cat3</td>
<td>2.17</td>
<td>3.63</td>
<td>8.45</td>
<td>1.04</td>
</tr>
<tr>
<td>cat4</td>
<td>1.87</td>
<td>1.77</td>
<td>1.59</td>
<td>0.85</td>
</tr>
<tr>
<td>NR</td>
<td>0.03</td>
<td>0.08</td>
<td>0.05</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 4.4. Overall percentages of responses in each category, by set. (cat1 = C; cat2 = G; cat3 = A,D,E,F; cat4 = remainder; NR = no response)
Table 4.5, below, shows the proportions of responses in category 1 only, and in categories 1 and 2, for each set. The proportions of responses for each set as they were calculated across subjects and rhythms generally follows the outlines of the percentages shown above in Table 4.4. Figures 4.3 and 4.4 depict the patterns of those proportions of responses. Note particularly the consistently low proportions of C and G responses in set 3 (015 [BCE]) and the high proportions in set 4 (045 [GBC]). As with the percentages noted above, the proportions of sets 1 and 2 were comparable, while the proportions of set 3 were lower and those of set 4 were significantly higher.

<table>
<thead>
<tr>
<th>S R</th>
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<th>cat 1 or 2</th>
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</thead>
<tbody>
<tr>
<td>1 1</td>
<td>0.5635</td>
<td>0.8393</td>
</tr>
<tr>
<td>1 2</td>
<td>0.5952</td>
<td>0.8413</td>
</tr>
<tr>
<td>1 3</td>
<td>0.5863</td>
<td>0.8234</td>
</tr>
<tr>
<td>1 4</td>
<td>0.5714</td>
<td>0.8492</td>
</tr>
<tr>
<td>2 1</td>
<td>0.5992</td>
<td>0.7857</td>
</tr>
<tr>
<td>2 2</td>
<td>0.5903</td>
<td>0.7817</td>
</tr>
<tr>
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Table 4.5. Proportion of responses by set (separated by rhythm).
Figure 4.3.
Proportion of category 1 responses by set (separated by rhythm)
Figure 4.4.
Proportion of category 1 or 2 responses by set (separated by rhythm)
Set/permutation combination and rhythm

On the next page, Table 4.6 shows the percentages of each category in each set/permutation combination. Note that the percentages of category 1 responses are high for all versions of p2 (CxB), although the percentage for set 3 is relatively lower. Conversely, the percentages of C responses for p5 (BxC) are consistently low across all sets.

S1p1 and s2p1 (BCD and BCA, respectively) were the only two set/permutation combinations to receive more G responses than C responses. It may be that the mi-fa interpretation of the half-step is being reinforced by a dominant interpretation of the D as sol and the A as re.

Table 4.7 and Figures 4.5 and 4.6 present the proportions of set/permutation combinations (separated by rhythm) for category 1 responses alone and categories 1 and 2 together. Once again rhythm showed no effect, but the combination of set and permutation produced some striking results. As was shown above, permutation and set each as a whole produced significant differences in the proportions of the predicted major tonic responses. The differences of permutation within each set are just as pronounced. In both graphs, notice particularly the consistently high performance on p2 (CxB) in all sets, and the especially low performance for s3p5 (BEC). The general pattern of responses is the same across sets—proportions for permutations in which B precedes
Table 4.6. Percentages of each category of response in each set/permutation combination (N=672/comb.)

C tend to be lower than those in which B follows C, with the exceptions of s3p4 (ECB) and s3p6 (CBE) (although they are still higher than s3p5 [BEC]).

The differences in the proportions of the responses within sets and between sets are more pronounced for ti-do interpretations alone (category 1 responses) than when mi-fa interpretations (category 2 responses) are figured in. The
category 2 responses minimally affected the proportions of responses to permutations in which B follows C (which already received primarily ti-do interpretations), but considerably raised the proportions of those in which B precedes C (which generally did not receive ti-do interpretations).

<table>
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Table 4.7. Proportion of responses by set/permutation combination (separated by rhythm)
Figure 4.5.
Proportion of category 1 responses by set/permutation combination (separated by rhythm)
Figure 4.6.
Proportion of category 1 or 2 responses by set/permutation combination (separated by rhythm)
Table 4.8 and Figures 4.7 and 4.8 below show the proportions of permutations by set. These provide a summary of the proportions for each permutation in each set without regard to rhythm. In Figure 4.6, set 4 (GBC) is consistently higher than the other three sets, but still exhibits generally the same profile between permutations. It may be that the set content, GBC, provides an extra sense of the dominant since G and B are sol and ti, although they were not always interpreted that way. S3pl (BCE) has the next highest proportion for C responses, but the remainder of set 3 consistently received the lowest proportion; when G responses are figured in, s3pl's proportion does not increase as substantially as did that of the same permutation of sets 1 and 2 (BCD and BCA, respectively). Generally, the largest differences between set/permutation combinations are found when dealing with C responses alone. This means that the mi-fa interpretation of the half-step is strong for those permutations which received relatively lower proportions of C responses, especially in sets 1 and 4 (BCD and GBC). Sets 2 and 3 (ABC and BCE) remained low even with the addition of G responses, however, indicating a fairly strong presence of category 3 and 4 responses.
Table 4.8. Proportion of responses by permutation (separated by set).

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The significance of the differences in the proportions of category 1 and 2 responses was modeled using logistic regression with subject as a random effect. Two models were created, the first dealing with only category 1 (C) responses, and the second, with category 1 or 2 (C or G) responses (see p. 79, Tables 4.9 and 4.10).
Proportion of category 1 responses by permutation (separated by set)
Figure 4.8.
Proportion of category 1 or 2 responses by permutation (separated by set)
In both models, rhythm did not have a significant effect on listeners' responses, either by itself or when combined with permutation and/or set ($p > 0.1$). Effects of permutation and set, however, were significant, both individually ($p < 0.0001$) and combined ($p < 0.0001$). The effects of permutation, individually and combined with set, were greater for C responses alone than for C and G responses together, while effects of set remained almost the same.

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<td>0.00000</td>
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<td>3.146</td>
<td>0.36968</td>
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<tr>
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Table 4.9. Model 1: Logistic regression of proportions of category 1 responses only

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Table 4.10. Model 2: Logistic regression of proportions of category 1 or 2 responses
DISCUSSION

As can be seen by the figures and tables presented above, the immediate conclusion is that rhythm had no influence on the choices of tonic which were made, at the tempo that was used in this study (short = 66/min.). It remains for further study to investigate the possibilities of faster speeds as influences on choice of tonic in otherwise similar circumstances. However, it is also obvious that the conclusions for the other hypothesis (temporal order) are much different and more complex. Differences between permutations were significant, and although it was not one of the two original hypotheses, the pitch content of each set was found to produce a significant effect in accuracy and consistency of tonic responses. The same was true for set/permutation combination.

As noted above, performance of listeners in selecting the most highly predicted major tonic (C) was very good. However, it is apparent that both the set content and the order of the pitches in the sets determine the likelihood that the listener will choose the ti-do response. By including the mi-fa interpretation (G, the next most highly predicted response), the likelihood of a major key response was further increased, particularly for sets 1 and 4 (013 [BCD] and 045 [GBC], respectively). It is valuable to notice, however, that the influence of permutation lessens dramatically when C and G responses are evaluated together.

80
(Chi-square[model1] = 918.146 vs. Chi-square[model2] = 288.378), while the influence of set content remains virtually the same (Chi-square[model1] = 575.670 vs. Chi-square[model2] = 576.905).

The results for the permutations in this study can be compared with similar results which were found by Brown and Butler (1981; refer to Chapter 1). Just as Brown and Butler found that accuracy was greater for sets in which ti followed fa, the present study also found that the proportion of ti-do responses (C) was greater for those sets in which ti followed do (i.e., B followed C): CxB, CBx, and xCB. This brings to mind Rameau's admonition that the establishment and tracking of the leading tone is of utmost importance for a clear sense of key (see Chapter 1).

However, while the present results for permutation were much like Brown and Butler's results, there was a large difference in the outcomes regarding set content. Brown and Butler found no significant effect for set content, whereas the present study found an effect comparable to that of permutation (see Tables 4.9 and 4.10 [models 1 and 2]).

Brown and Butler took their results for both permutation and set to be

a strong indication that temporal order of cue-cell components influences tonal specificity (or lack of it) more than set membership of the context tone does. In other words, the results indicate that the structural hierarchy of the diatonic set has perceptual validity only when it includes time-order dependencies. (p. 53)
The latter half of this statement is a generalization from the former half insofar as it includes the tritone. But in light of the results of the present study, it may be that the tritone in certain time-orders exerts its unique influence far more strongly than was realized. When it is absent, in contrast to Brown's results (1982, 1988; see Chapter 1), set content has a definite impact, by itself and in conjunction with permutation, although not in the manner that would be expected—i.e., the rival tonic of G was not on an equal footing with C as another preferred tonic. If it had been, the jagged contours of the graphs of the responses would have flattened out in the corresponding graphs that include the G responses. Rather, other tonic interpretations came into play, particularly in sets 2 and 3 (023 [ABC] and 015 [BCE], respectively). These interpretations included minor keys (A and E), mode (Dorian, with a tonic of D), and a secondary dominant application (F), in spite of the explicit instructions to the listeners to give diatonic major key answers (and much to the chagrin of several of the subjects, who insisted that, although the alternative tonics were not major and/or diatonic, they were the only ones that they could "hear"; see comments in Appendix C, p. 133).

The primary impetus behind the following discussion of the unpredicted responses is due to the unexpected and noticeable amount of E responses in the raw data, especially with respect to set 3 (015 [BCE]) and to the listeners'
reactions to its permutations during the test. Proportions of other responses, such as the D in set 1 (013 [BCD]), emerged for scrutiny upon further examination of the results.

**Unexpected responses**

**Background:**

There are very few studies (empirical or otherwise) in which the minor mode and/or chromaticism are discussed in relation to the key-finding (Longuet-Higgins and Steedman, 1971; Longuet-Higgins, 1976; Krumhansl and Kessler, 1982; Bharucha, 1984; Krumhansl, 1990; Brown, 1992; Butler, 1992; Butler and Brown, 1994; Van Egmond and Butler, in progress).

There are difficulties in dealing with the minor mode, stemming from the fact that it comes in three varieties which are often used in combinations with each other: the so-called natural, harmonic, and melodic forms. Longuet-Higgins and Steedman (1971) place the minor mode (harmonic form) on an equal footing with the major mode as simply an alternative mapping of pitch space (see Chapter 1). Krumhansl and Kessler (1982) treat the minor mode only with respect to the harmonic minor form. As was noted in Chapter 1, the tone-profiles for the minor form were derived from the results of ratings of probe-tones in contexts provided by a minor triad and the cadence patterns iv–V–i, ii’–V–i, and VI–V–i. They found that the mediant received higher ratings than the dominant, but otherwise the minor tone-profiles were very
similar to the parallel major tone-profiles (see Figure 1.3 on p. 22). Krumhansl and Kessler also found that the tone-profiles of the relative major and minor keys were similar (see below, Figure 4.9).

As Krumhansl (1990) pointed out, dealing with minor keys is a complicated issue because minor keys are generally considered to be related to two major keys that are themselves not closely related. That is, the relative and parallel major keys for any given minor key are a minor third apart, or three positions away in the circle of fifths. A major key is similarly related to two minor keys which are

![Diagram of tone profiles of C major and A minor]

Figure 4.9. Tone profiles of C major and A minor (Krumhansl and Kessler 1982; Krumhansl, 1990)
themselves not closely related. The use (mixture) of the natural and melodic forms of the minor mode, in addition to the harmonic form, along with the various relations between relative and parallel keys, can also be seen as a fundamental source of chromaticism.

Because the harmonic and melodic minor forms involve different alterations from the major diatonic set (and natural minor), they consequently have different interval vectors. The harmonic minor interval vector is <335442>, and the ascending melodic minor interval vector is <254442> (descending melodic minor is the same as the natural minor and the major). The differences carry influences on the set membership, and consequently the tonal implications, of groups of pitches. This is demonstrated in the ongoing work of Van Egmond and Butler.

Van Egmond and Butler (in progress) discuss the implications of subsets of the diatonic major, harmonic minor, and ascending melodic minor collections (they do not include the natural minor as a separate collection since its interval content is identical with that of the major set). They recognize that sets that are inversionally equivalent in atonal music are not equivalent in tonal music and carry very different and specific implications. For example, in the present study, (013) vs. (023), and (015) vs. (045), are inversionally equivalent pairs; their respective prime forms are (013) and (015). As has been amply illustrated, however,
their tonal ramifications are vastly different. Therefore, it is not appropriate to discuss the four sets in terms of their prime forms. However, it is useful to adopt the convention, when discussing sets, of taking the normal order of a given set and transposing it to begin on pc0. Consequently, the various tonal implications of sets and between sets can still be acknowledged and discussed. This not-quite-prime-form notation of sets is what Van Egmond and Butler term "primitive form." Compare this with Rahn's "Tn-type" (1980, pp. 75-77).

Van Egmond and Butler categorize the key implications of primitive forms by using a system, similar to an interval vector, called a "key-class index." A key-class is an abstract reference to a key according to the pitch-class that represents its tonic, without reference to the mode of the key. The key-class index is a vector-like list with a space for each of the twelve key-classes, each of which contains the number of diatonic sets (of major, harmonic minor, ascending melodic minor) that the indexed set lies in for the given key-class. This allows for comparisons of sets which include both key and mode implications. Below, Table 4.11 summarizes the key and mode for each of the primitive forms used in the present study. (The natural minor form is included here for the sake of comparison.)
Table 4.11. Key/mode implications of each primitive in the present study.

The key-class index provides a more complete integration of minor keys than does Krumhansl's model of key-relations because it takes into account the (ascending) melodic form. It also points to a key-relationship which Krumhansl (1990) only briefly notes, but does not seem to take advantage of: the relationship between the relative minor of the dominant (in terms of C major, this is the relative minor of G major, or E minor). Figure 4.10 is a graphic representation of Krumhansl's tone profiles of C major and E minor, in the same manner as that presented above for C major and A minor.

Bharucha (1984) discussed chromaticism within the context of what he called "tonal schemata" and "melodic anchoring." He defined a tonal schema as the "cognitive structure that incorporates information about a particular tonal hierarchy and uses this information to influence the encoding of music" (p. 486). In other words, a tonal schema...
Figure 4.10. C major and E minor tone profiles (after Krumhansl and Kessler, 1982)

is used by the listener to assess the relative stability of each tone as it is heard. (However, Bharucha did not discuss what it is that "activates" a tonal schema to begin with; he discussed only "unstable" notes in the context of an already active schema.) Generally speaking, a schema sets up the context for each successive note, but what he proposed is that an unstable note is perceptually "assimilated" to the schema according to the note which comes after the one in question. This is the temporal order process which he called "melodic anchoring."

Melodic anchoring calls for the use of the stable tones of the tonal hierarchy as "cognitive reference points" to which unstable tones are resolved. The reference points must be in close proximity (i.e., a half or whole step) for
anchoring to occur and must follow the unstable tone. Bharucha found that in a melody which implies a chord, "a nonchord tone is more easily confused with a chord tone if it is anchored than if it is not" (p. 504). He also found that melodies with "nondiatonic," anchored tones were more easily confused with those containing only chord tones than were melodies with diatonic unanchored tones. He concluded that "anchoring renders nondiatonic tones more stable than diatonic tones that are not anchored" (p. 506).

Bharucha's conclusions seem to be music-theoretically naive. The process of anchoring actually emphasizes the "stable" chord tone by allowing the two notes involved to be grouped together as a unit. This would account for the confusions between chord tone melodies and nonchord tone melodies, and the nondiatonic-anchored vs. diatonic-unanchored differences. The latter case is of particular interest in this study because nondiatonic (chromatic) tones were often treated as temporary leading tones resolving to their appropriate tonics in order to emphasize the tonicized note. Consequently, the chromatic note is not necessarily made more stable; rather, it is perceived as an integral part of a recognizable pattern: that of a leading tone to its tonic, which may be subsequently rendered as a real or temporary tonic by the presence of another note.

Support for this interpretation can be found in Brown (1992). Brown explained that, "chromaticism is assumed to
weaken tonality in studies when discussion includes no incorporation of concepts of mixture and tonicization of scale degrees other than tonic, both of which are chromatic processes common in diatonic tonality that can easily function to enrich and reinforce a single tonal center" (p. 150).

Mixture and tonicization supply the means for such reinforcement by providing upper and lower leading tones to what Meyer (1956) called "substantive tones." Mixture tends to provide the upper leading tones, which resolve to emphasize tonic or dominant; tonicization provides the lower leading tones, which resolve to their respective tonics, which are subsequently interpreted as real or temporary according to the context provided by the notes that come after them (see Figure 4.11).

Figure 4.11. Upper leading tones (a) and lower leading tones (b) with resolutions (after Brown, 1992, p. 151).
The interpretation of a given note as an upper or lower leading tone depends on its surroundings, particularly the notes that come after it. Thus, a descending half-step can be interpreted several ways outside the major diatonic collection: $b^2-1$ (Phrygian); $b^3-2$ (minor, me-re); or $b^6-5$ (minor, le-sol). An ascending half-step can be interpreted as at least a temporary ti-do, to be subsequently supported or changed by the context following it.

Results and discussion of category 3 responses:

To identify and understand the influence of other key interpretations in the context of this study, category 3 responses (A, D, E, F) were analyzed in the same manner as the category 1 and 2 responses. Tables of the percentages of each element of category 3 (A, D, E, and F) are presented along with tables and figures of the proportions of category 3 as a whole, broken down by permutation, set, and set/permutation combination separated by rhythm. Although rhythm did not have an effect, these tables and graphs are presented for comparison with the corresponding items above.

Table 4.12 lists each component of category 3 as a percentage of the total number of possible responses and as part of category 3 responses only.
Table 4.12. Percentages of individual category 3 responses (A, D, E, F), against total number of responses (N=16,128) and category 3 responses only (N=2467).

As can be seen below in Tables 4.13 and 4.14, and in Figure 4.12, the effects of permutation were limited. The most noticeable differences were with regard to p2 (CxB) in general (the low percentages correspond with the dip in the proportions in Figure 4.13), and with regard to p5 (BxC), specifically the extremely high proportion of E responses as compared to the other three responses in the category. E in general was the preferred category 3 response in terms of the effects of permutation alone.

Table 4.13. Percentage of category 3 responses in each permutation (N=2688/perm.)
The effects of set, however, did not result in a general preference for E in category 3. As can be seen in the tables and figures below, as well as the model generated for category 3, set had by far the greatest influence on the variability of tonic responses. This interpretation is borne out by Table 4.15, below, in which it can be seen that set 3 (015 [BCE]) received significantly more category 3 responses than the other sets. Although the proportions for the individual components in category 3 cannot be reflected in the statistical model or the graphs, Table 4.17 shows that similar effects do carry over down to that level. Note that in set 1 (013 [BCD]), D received a higher percentage of responses than E or A (minor key responses), while set 2 (023 [ABC]) relatively more A responses, and set 3 (015 [BCE]) garnered mostly E responses. It seems, then, that there are

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Table 4.14. Proportion of category 3 responses by permutation (separated by rhythm)
Figure 4.12.
Proportion of category 3 responses by permutation (separated by rhythm)
cues within sets that can predispose the listener to choose tonics other than diatonic major key tonics. These cues may be found in the temporal order of the pitches of the set, i.e., set/permutation combination, which was also found to produce significant differences (see Tables 4.15 and 4.16 below and also refer to Table 4.20 [category 3 model]).

\[
\begin{array}{|c|c|c|c|c|}
\hline
& s1 & s2 & s3 & s4 \\
\hline
E & 2.28 & 4.12 & 20.34 & 1.41 \\
A & 1.69 & 8.13 & 7.24 & 0.69 \\
D & 4.12 & 1.31 & 1.46 & 1.12 \\
F & 0.6 & 0.97 & 4.76 & 0.94 \\
\hline
\end{array}
\]

Table 4.15. Percentage of category 3 responses in each set (N=4032/set)

\[
\begin{array}{|c|c|c|c|c|c|c|}
\hline
S & R & cat.3 & S & R & cat.3 \\
\hline
1 1 & 0.0843 & 3 1 & 0.3214 \\
1 2 & 0.0942 & 3 2 & 0.3383 \\
1 3 & 0.1012 & 3 3 & 0.3681 \\
1 4 & 0.0665 & 3 4 & 0.3214 \\
2 1 & 0.1438 & 4 1 & 0.0437 \\
2 2 & 0.1488 & 4 2 & 0.0337 \\
2 3 & 0.1488 & 4 3 & 0.0437 \\
2 4 & 0.1389 & 4 4 & 0.0466 \\
\hline
\end{array}
\]

Table 4.16. Proportions of category 3 responses by set (separated by rhythm)
Figure 4.13.
Proportion of category 3 responses by set (separated by rhythm)
Table 4.17 below shows the percentages of the category 3 responses by set/permutation combination. The patterns of these mistakes support the suggestion that nonmajor and/or nondiatonic responses are influenced by the combination of set and permutation. These will be discussed shortly. Table 4.18 and Figure 4.14 show the pattern of responses made by the category as a whole.

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Table 4.17. Percentages of category 3 responses in each set/permutation combination (N=672/comb.)
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<td>3 2 2</td>
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<tr>
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</tr>
</tbody>
</table>

Table 4.18. Proportion of category 3 responses by set/permutation (separated by rhythm)
Figure 4.14.
Proportion of category 3 responses by set/permutation combination (separated by rhythm)
Table 4.19. Proportion of category 3 responses by permutation (separated by set)

Table 4.20 on p. 102 is a model for category 3 responses as a whole. Note that permutation by itself had a small, but still significant, effect. This can be seen mainly with permutation 2 (CxB), which, as has already been observed, received the highest proportion of category 1 responses (see Figures 4.1 [permutation] and 4.5 [set/permutation combination], pp. 64 and 73). Set, on the other hand, had a very large effect. This can be seen by comparing Figure 4.14 with Figures 4.3 and 4.4 ([set] pp. 68 and 69). The peak in the category 3 responses for set in Figure 4.14 corresponds with the dip in the category 1 and 2 responses in Figures 4.3 and 4.4. There is a similar correspondence between peak and
Figure 4.15.
Proportion of category 3 responses by permutation (separated by set)
dip in the responses for set/permutation combinations;
compare Figure 4.15 (p. 101) with Figures 4.5 and 4.6 (pp. 73 and 74).

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>ChiSquare</th>
<th>p</th>
</tr>
</thead>
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<tr>
<td>Perm</td>
<td>5</td>
<td>64.862</td>
<td>0.00000</td>
</tr>
<tr>
<td>Set</td>
<td>3</td>
<td>400.943</td>
<td>0.00000</td>
</tr>
<tr>
<td>Rhythm</td>
<td>3</td>
<td>1.939</td>
<td>0.58507</td>
</tr>
<tr>
<td>Perm x Set</td>
<td>15</td>
<td>121.005</td>
<td>0.00000</td>
</tr>
<tr>
<td>Perm x Rhythm</td>
<td>15</td>
<td>7.181</td>
<td>0.95244</td>
</tr>
<tr>
<td>Set x Rhythm</td>
<td>9</td>
<td>7.351</td>
<td>0.60058</td>
</tr>
<tr>
<td>Perm x Set x Rhythm</td>
<td>45</td>
<td>27.630</td>
<td>0.98063</td>
</tr>
</tbody>
</table>

Table 4.20. Model 3: Logistic regression of proportions of category 3 responses

In Ch. 2 and earlier in this chapter, the half-step that is common to all of the sets used in this study was explained in terms of the diatonic major key tonics, C and G (ti-do and mi-fa, respectively). The same half-step can also be interpreted as sol-le (scale degrees 5 and lowered 6) in E minor and as re-me (scale degrees 2 and 3) in A minor. In the context of these examples, D can occur as a tonic only in the Dorian mode, which comprises the pitches D, E, F, G, A, B, C (in which B and C are la and te). F is the tonic response when C is interpreted as a dominant in which B is heard as the secondary leading tone in a V/V - V - I progression (B = fi and C = sol). (See Figure 4.17 below.)
Figure 4.16. Solfège interpretations of each set.

Although there were four potential responses identified as members of category 3, it was not expected that they would combine to account for such a substantial amount of the responses (15.3%).

As noted above, D is a modal response in the context of these stimuli. Consequently, the high proportion of D responses in set 1 (013 [BCD]) was unexpected. The particularly high percentages in p3 (DBC) and p4 (DCB) may be accounted for as a primacy effect, or as an effect of contour, or both. Thus, in p3, a D response is a return to the first note through the completion of the pattern B-C-(D). In p4, the A response becomes a more viable choice as a continuation to complete the pattern D-C-B-A (4-3-2-1, or fa-me-re-do); the placement of C-B can also encourage an interpretation as te-le-sol (7-6-5) in E minor.
Set 2 (023 [ABC]) was expected to receive some confusion between the major interpretation, la-ti-do (C response) and the minor response, do-re-me (A response). From this author's experience in the classroom, this seems to be a fairly common problem. This was indeed the case for three permutations—p3 (ABC), p4 (ACB), and p6 (CBA); however, the strength of the E responses for the other three permutations was unexpected.

Set 3 (015 [BCE]) in general proved to be troublesome. As was noted above, it received the lowest proportion of C and G responses and the highest proportion of E responses. As was shown in Figure 4.16, this set can be interpreted as sol-le-do, which is common in music written in the minor mode. The perfect fourth (between B and E) would be ambiguous were it not for the context provided by the third note, C, a half-step from B. This creates what may be an overlearned pattern that the enculturated listener automatically assigns to the minor mode. It is interesting to note, however, that there is a considerably higher proportion of F responses in p1 (BCE), which may be the result of attempts to complete the chromatic pattern, B–C–E–F (fi-sol-ti-do, in which E becomes the leading tone), a common melodic device in the baroque and classical styles. The device also outlines a musically logical secondary dominant application, in which fi belongs to V/V, sol and ti to V, resolving to do.
Set 4 (045 [GBC]) had a very low percentage of mistakes of any type. The proportions of category 3 answers in this set seem to be dependent on permutation. The F response for p1 is similar to that described above for s3p1; the pattern, fi-sol-re-do, outlines a secondary dominant V/V, in which fi resolves to sol, and sol and re resolve to do. The few E responses for p2 (CGB) and p4 (GCB) are mainly the result of B being interpreted as sol, rather than as ti. The relatively high proportion of D responses in p3 (GBC) was totally unexpected. Its modal implications are similar to s1p3 (DBC).

Results and discussion of category 4 responses:

Because there were relatively few category 4 responses (6.09% of the total responses) and because it was established that rhythm did not have an effect on tonic response, this category as a whole was not analyzed in the same manner as the other three categories. However, the six individual responses comprising this category were examined for patterns within permutation, set, and set/permutation combination that might suggest tonally logical explanations for responses that would otherwise be labeled as "mistakes."

Table 4.21, below, shows the percentages of the category 4 responses compared with the total number of responses and within category 4 only. Note the very high proportion of B
responses, in spite of its leading tone position in the half-step. As the only C major diatonic member in category 4, this outcome is predicted to some extent by the tonal hierarchy model but not by the intervallic rivalry model.

<table>
<thead>
<tr>
<th></th>
<th>% of total</th>
<th>% of cat.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>4.31</td>
<td>70.85</td>
</tr>
<tr>
<td>B*</td>
<td>0.51</td>
<td>8.36</td>
</tr>
<tr>
<td>E♭</td>
<td>0.4</td>
<td>6.52</td>
</tr>
<tr>
<td>A♭</td>
<td>0.39</td>
<td>6.42</td>
</tr>
<tr>
<td>D♭</td>
<td>0.27</td>
<td>4.49</td>
</tr>
<tr>
<td>F♯</td>
<td>0.20</td>
<td>3.36</td>
</tr>
</tbody>
</table>

Table 4.21. Percentages of individual category 4 responses, against total number of responses (N=16,128) and category 4 responses only (N=981).

As with the responses categories 1, 2, and 3, category 4 responses exhibit an effect of permutation, again particularly with p2 (CxB) and p5 (BxC). (See Table 4.22, below.) The higher proportions of B in p1 (BCx) and p5 could be due to primacy effects. In the case of p5, some effect of the C being perceived as an upper leading tone (♭2) could also influence the listener to choose B as a tonic.
Table 4.22. Percentage of category 4 responses in each permutation (N=2688/perm.).

The effects of set were such that B was the favored mistake in all sets (see below, Table 4.23), especially set 1 (BCD), and was given about equally in sets 2 and 3 (ABC and BCE), while B♭, although still proportionally far behind B, gained more responses in set 2 than in the other sets. Clues to these proportions lie in the set/permutation combinations (see Table 4.24, p. 109).

<table>
<thead>
<tr>
<th></th>
<th>p1 BCx</th>
<th>p2 CxB</th>
<th>p3 xBC</th>
<th>p4 xCB</th>
<th>p5 BxC</th>
<th>p6 CBx</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>6.66</td>
<td>1.38</td>
<td>1.79</td>
<td>2.79</td>
<td>11.01</td>
<td>2.23</td>
</tr>
<tr>
<td>B♭</td>
<td>1.00</td>
<td>0.11</td>
<td>0.11</td>
<td>0.26</td>
<td>1.34</td>
<td>0.22</td>
</tr>
<tr>
<td>A♭</td>
<td>1.6</td>
<td>0.07</td>
<td>0.15</td>
<td>0.07</td>
<td>0.11</td>
<td>0.33</td>
</tr>
<tr>
<td>F♯</td>
<td>0.3</td>
<td>0.07</td>
<td>0.19</td>
<td>0.04</td>
<td>0.19</td>
<td>0.45</td>
</tr>
<tr>
<td>E♭</td>
<td>0.74</td>
<td>0.22</td>
<td>0.04</td>
<td>0.6</td>
<td>0.41</td>
<td>0.37</td>
</tr>
<tr>
<td>D♭</td>
<td>0.11</td>
<td>0.07</td>
<td>0.37</td>
<td>0.15</td>
<td>0.89</td>
<td>0.04</td>
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</table>
Table 4.23. Percentage of category 4 responses in each set (N=4032/set).

<table>
<thead>
<tr>
<th></th>
<th>s1</th>
<th>s2</th>
<th>s3</th>
<th>s4</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>5.95</td>
<td>4.46</td>
<td>4.94</td>
<td>1.88</td>
</tr>
<tr>
<td>B^b</td>
<td>0.3</td>
<td>1.46</td>
<td>0.2</td>
<td>0.07</td>
</tr>
<tr>
<td>A^b</td>
<td>0.1</td>
<td>0.35</td>
<td>0.25</td>
<td>0.87</td>
</tr>
<tr>
<td>F#</td>
<td>0.15</td>
<td>0.2</td>
<td>0.27</td>
<td>0.2</td>
</tr>
<tr>
<td>E^b</td>
<td>0.84</td>
<td>0.1</td>
<td>0.3</td>
<td>0.35</td>
</tr>
<tr>
<td>D^b</td>
<td>0.15</td>
<td>0.52</td>
<td>0.4</td>
<td>0.02</td>
</tr>
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</table>

An examination of the responses for set/permutation combinations yields some interesting results. Aside from the prevailing B responses—a failure on the part of the listeners either to identify or to accept the given half-step as a leading tone to tonic progression—other chromatic or tonicizing functions appear to have been operating.

For example, in set 1, the next most common mistake is that of the E^b response. In p1 (BCD) and p6 (CBD), this could be due to the listener interpreting the D in the final position as a leading tone. However, this does not explain the E^b response to p4 (DCB). One could call on a sort of primacy effect of the D as leading tone, but this is contradicted by p3 (DBC), which also starts with D and which elicited no E^b responses at all.

Set 2 responses are a bit more clear-cut. B^b as a response to p1 also fits the leading-tone-at-the-end interpretation, as does the D^b in p3 (ABC) and p5 (BAC).
relatively high proportion of \( B^b \) in p5 could be due to a sequential follow-through to complete the pattern B–A–C–B\(^b\), which also allows for A to be interpreted as a leading tone.

\[
\begin{array}{cccccccc}
\text{slp1} & \text{slp2} & \text{slp3} & \text{slp4} & \text{slp5} & \text{slp6} \\
\text{BCD} & \text{CDB} & \text{DBC} & \text{DCB} & \text{BDC} & \text{CBD} \\
B & 8.93 & 0.89 & 2.23 & 7.89 & 13.24 & 2.53 \\
B^b & 0.3 & 0 & 0.45 & 0.15 & 0 & 0.15 \\
A^b & 0.3 & 0.15 & 0 & 0 & 0.74 & 0.15 \\
F# & 0.15 & 0 & 0.3 & 0 & 0.3 & 0.15 \\
E^b & 1.34 & 0.74 & 0 & 1.34 & 0.6 & 1.04 \\
D^b & 0 & 0.15 & 0.15 & 0 & 0.6 & 0 \\
\text{s2pl} & \text{s2p2} & \text{s2p3} & \text{s2p4} & \text{s2p5} & \text{s2p6} \\
\text{BCA} & \text{CAB} & \text{ABC} & \text{ACB} & \text{BAC} & \text{CBA} \\
B & 8.63 & 0.6 & 1.34 & 0.89 & 14.73 & 0.6 \\
B^b & 3.13 & 0.3 & 0 & 0.6 & 4.46 & 0.3 \\
A^b & 0.89 & 0.15 & 0.15 & 0.15 & 0.3 & 0.45 \\
F# & 0 & 0.15 & 0.15 & 0.15 & 0.3 & 0.45 \\
E^b & 0 & 0.15 & 0 & 0 & 0.3 & 0.15 \\
D^b & 0.45 & 0.15 & 1.19 & 0.3 & 1.04 & 0 \\
\text{s3pl} & \text{s3p2} & \text{s3p3} & \text{s3p4} & \text{s3p5} & \text{s3p6} \\
\text{BCE} & \text{CEB} & \text{EBC} & \text{ECB} & \text{BEC} & \text{CBE} \\
B & 5.65 & 2.98 & 2.98 & 2.08 & 11.46 & 4.46 \\
B^b & 0.45 & 0.15 & 0 & 0.15 & 0 & 0.45 \\
A^b & 0.3 & 0 & 0.45 & 0.15 & 0.15 & 0.45 \\
F# & 0.3 & 0 & 0.15 & 0 & 0.15 & 1.04 \\
E^b & 1.19 & 0 & 0 & 0.15 & 0.3 & 0.15 \\
D^b & 0 & 0 & 0.15 & 0.3 & 1.93 & 0 \\
\text{s4pl} & \text{s4p2} & \text{s4p3} & \text{s4p4} & \text{s4p5} & \text{s4p6} \\
\text{BCG} & \text{CGB} & \text{GBC} & \text{GCB} & \text{BGC} & \text{CBG} \\
B & 3.42 & 1.04 & 0.6 & 0.3 & 4.61 & 1.34 \\
B^b & 0.15 & 0 & 0 & 0.15 & 0.15 & 0 \\
A^b & 4.91 & 0 & 0 & 0 & 0 & 0.3 \\
F# & 0.74 & 0.15 & 0.15 & 0 & 0 & 0.15 \\
E^b & 0.45 & 0 & 0.15 & 0.89 & 0.45 & 0.15 \\
D^b & 0 & 0 & 0 & 0 & 0 & 0.15 \\
\end{array}
\]

Table 4.24. Percentages of category 4 responses in each set/permutation combination (N=672/comb.)
In spite of the difficulties listeners had with set 3 (BCE), there were fewer types of chromatic errors in set 3 than in sets 1 and 2 (BCD and ABC). Mistakes clustered around the B, which, in this particular set, is in a particularly strong relation (as dominant) to E, and to which the C could also be misinterpreted as b2 instead of b6. These relationships may hold for the other three sets as well, given that E minor is one of the diatonic collections that all four of the sets fall into (see Table 4.11) and that the B–C relationship is invariant between the four sets, too.

Permutation 1 of set 4 (BCG) contains the only pattern within the category 4 responses in which B is not the prevailing mistake. Here it is A♭, conforming to the leading-tone-at-the-end interpretation.

In general, it appears that when listeners attempt to make a tonic response, on occasion regardless of any "theoretical" accuracy or validity, an effort is made to interpret the last tone heard as having a dominant function—whether ti, sol, or re, a tendency which Brown (1992) identified ("...listeners' tendencies to interpret the last tone heard in a pattern as part of a dominant function, implying continuation" [p. 147]). This tendency to interpret the last tone as a dominant was observed throughout the course of this investigation. As subjects were encouraged to "think out loud," the experimenter was able to note that
subjects often sang the "sol-do," "ti-do," or, less often, "re-do" from the last note.

Thus, in all sets in which B is last, C is the preferred response (B = ti), but E (B = sol) and A (B = re) may also be chosen. When C is last, D♭ may be sung as may F or B♭.

Table 4.25 (below) shows the tonic response that may be elicited by the third note of each set when interpreted as ti, sol, or re.

<table>
<thead>
<tr>
<th>set 1</th>
<th>tonic</th>
<th>set 3</th>
<th>tonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>= ti</td>
<td></td>
<td>= ti</td>
<td></td>
</tr>
<tr>
<td>D = sol</td>
<td>G</td>
<td>E = sol</td>
<td>A</td>
</tr>
<tr>
<td>= re</td>
<td>C</td>
<td>= re</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set 2</th>
<th>tonic</th>
<th>set 4</th>
<th>tonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>= ti</td>
<td></td>
<td>= ti</td>
<td></td>
</tr>
<tr>
<td>A = sol</td>
<td>D♭</td>
<td>G = sol</td>
<td>C</td>
</tr>
<tr>
<td>= re</td>
<td>G</td>
<td>= re</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 4.25. Tonic responses to third note having dominant function.

A comparison of these potential tonics to the responses found in Tables 4.6, 4.17, and 4.24 (set/permutation combinations) reveals some evidence for this behavior, especially when B precedes C in the set, as in p1 (BCx). It may be that the resolution of the B–C relationship allows the listener to perceive the third note as requiring a continuation, or tonic response—a predisposition for a
dominant. See, for example, the high percentage of G responses for s1p1 (BCD) in Table 4.6 (p. 71), and the proportion of Eb responses in the same set/permutation relative to the other nondiatonic pitches in Table 4.24 (p. 109). Likewise, s3p1 (BCE) garnered the highest proportion of F responses in the study (refer to Table 4.17, p. 97). Note that neither C nor G is a tonic option for set 3 when E is interpreted as a having a dominant function. This may have contributed to the confusion that was experienced by a number of the listeners when they encountered this set.

SUMMARY

Table 4.26 below summarizes the overall percentages of the tonic responses provided by the listeners. They are depicted graphically in Figure 4.17.

<table>
<thead>
<tr>
<th>tonic</th>
<th>%</th>
<th>tonic</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>60.57</td>
<td>F</td>
<td>1.82</td>
</tr>
<tr>
<td>G</td>
<td>17.87</td>
<td>Bb</td>
<td>0.51</td>
</tr>
<tr>
<td>E</td>
<td>7.04</td>
<td>Eb</td>
<td>0.4</td>
</tr>
<tr>
<td>A</td>
<td>4.44</td>
<td>Ab</td>
<td>0.39</td>
</tr>
<tr>
<td>B</td>
<td>4.31</td>
<td>Db</td>
<td>0.27</td>
</tr>
<tr>
<td>D</td>
<td>2.00</td>
<td>F#</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table 4.26. Overall percentages of individual tonic responses
The graph in Figure 4.17 strongly resembles Krumhansl and Kessler's (1982) major key tone profile. There are noticeable differences—A was favored over F, and B was given as a tonic more often than D or F and was almost as prominent as A—but the contour is the same.

![Graph of tonic response percentages for all 12 pitch-classes](image)

**Figure 4.17.** Overall percentages of tonic response for all 12 pitch-classes

Since the task in the present study was explicitly to provide tonic responses to the given stimuli, which were tonally ambiguous, the graph presented in Figure 4.17 is more aptly described as a profile of suitability of tonic response, rather than a profile of stability of tonal
function. In this context, Krumhansl and Shepard's (1979) tonal hierarchy, and the representation of it in Krumhansl and Kessler's (1982) tone profiles, is not one of tonal function, but rather a hierarchy of tonic appropriateness, given that the task in the former study was to rate how well each probe tone completed a C major scale, and the task in the latter study was rate the fit of the probe tone in several context patterns. In this regard, ratings by enculturated listeners can provide a valid measure of how well the probe tone fits as a reasonable tonic response or continuation of the given context pattern, even if the resulting profile of a particular context does not match the standard provided by Krumhansl and Kessler (1982).

In this light, seemingly inconsistent results found in other studies, such as Cuddy and Badertscher (1987; see Chapter 1), may be interpreted consistently. In Cuddy and Badertscher's case, either C or F# can be considered as an appropriate tonic response to the ordering of the B diminished triad that they used (B-D-B-F). C is appropriate because of the harmonic implications of the chord in C major; F# is appropriate because F, in its position at the end, could be isolated and enharmonically interpreted as E#, the leading tone of F#. Given the results of various of Brown and Butler's studies, in which the ordering of the tritone influenced listeners' choice of tonic, and given the results of the present study, the strength of F# over C is another
example of the tendency of listeners to interpret the last note heard as having a dominant function, specifically the leading tone, when the musical context demands closure with a tonic response.
CHAPTER 5

CONCLUSIONS

In Chapter 5, the results and discussion are summarized. Conclusions are drawn regarding the relationships found in the responses of the listeners and a proposal is made about the general operation of tonality as a function of the enculturated listener. Pedagogical implications and suggestions for further research are also discussed.

CONCLUSIONS

The patterns of responses in this study have shown that there is a process by means of which tonally enculturated listeners are able to identify tonal center correctly most of the time. The patterns of "mistakes" are also systematic and indicate that this process involves the temporal orderings of the constituent pitches. This process can be termed a tonal schema.

Neisser (1976) defined a schema (in general) as a pre-existing structure that "directs perceptual activity and [is] modified as [the activity] occurs" (p. 14). By this
definition, it is also a process that occurs over time. He further elaborated his definition by describing a schema as internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified. (p. 54)

...The listener continuously develops more or less specific readinesses (anticipations) for what will come next, based on information he has already picked up. These anticipations—which themselves must be formulated in terms of temporal patterns, not of isolated moments—govern what he will pick up next, and in turn are modified by it....All of us have schematic anticipations for the structured sounds of our own language; that is why we hear them as distinct and separate words while the talk of foreigners often appears to be an almost continuous stream. We develop such anticipations in the course of listening to any individual sentence; hence we can identify words far more easily in context than in isolation. (pp. 27-28)

The same could be said for tonal music: A tonal perceptual schema is activated by temporal patterns and creates anticipations for patterns of sounds that enculturated listeners have learned. These anticipations are similar to Jones's (1981, 1982) "expectancy schemes," which are sets of "anticipations about the pitch and timing of future notes. These specific anticipations are time based... An expectancy scheme represents a listener's knowledge of whole groups of future notes... The main function of an expectancy scheme is preparatory" (1982, p. 2). This means that those listeners can recognize what comes next without actually being able to predict exactly what will come next. As Neisser also pointed out:
It would be a mistake to suppose that perceivers constantly formulate highly specific hypotheses about what is coming next and discard them in favor of better ones only when they fail to fit. At any given moment, what has already been picked up predicts the spatial origin and general nature of what will be obtained next, but does not define it precisely. (p. 28)

The tonal schema incorporates both the tonal hierarchy and the intervallic rivalry model. It is general: The present study has not produced any evidence to support the notion that this perceptual schema is key sensitive in terms of actually having 24 major and minor tone profiles somehow stored away. Rather, it appears to be based on recognizable patterns of intervals that are used in stylistically typical (and therefore learnable) ways, so that when it is activated by a tonal stimulus, it orients the listener toward (rather than away from) one or more specific keys during the act of listening. The music itself provides the pitch and temporal cues for expecting certain kinds of continuations. However, expectations in tonal music cannot be accomplished without some background for position-finding and pattern-matching—a mechanism that can exist only if there is some sort of framework set up first or one that can be put up quickly. This in itself requires some sort of forehand knowledge.

The present study, having investigated temporal order influences on tonic judgment in sets containing no tritone, in conjunction with Brown and Butler's investigations of same
in sets with a tritone, provides evidence suggesting that the intervallic rivalry model and some aspects of the tonal hierarchy model are all part of a broad tonal schema. Brown, Butler, and Jones (1994) hinted at this when they suggested that

[The two models address different aspects of tacit knowledge about tonality. Here it is assumed that key discovery precedes tonal reinforcement but that both processes are necessary for a listener to follow tonal music in real time. (p. 377)]

Brown, Butler, and Jones proposed three hypotheses about the role played by intervallic rivalry: 1) primacy, in which listeners understand the first note heard to be the tonic until a better candidate replaces it; 2) rare intervals, in which rare intervals such as the tritone and minor seconds allow listeners to narrow down their key choices because of their positions in the diatonic set; and 3) temporal order, in which the succession of members of the rare intervals implies "goal-oriented harmonic motions commonly encountered in tonal music" (1994, p. 372).

The present study found that temporal order of the entire trichord, not just its rarest interval, the minor second, was an important influence on the tonic responses of the listeners. This study found 1) that the highest number of correct responses were received for the permutations CxB and xCB, in which the leading-tone is in the last position; and 2) that when "mistakes" were made, they were often such
that the last note heard was interpreted as having a dominant function, i.e., as sol, ti, or re. The latter interpretation happened most often in the orderings BxC and BCx, in which the real leading-tone is furthest removed temporally from the position which would favor a "correct" tonic response. These findings corroborate those of Brown and Butler (1981), in which they found the highest number of tonic responses in those sets in which ti occupied the last position. They also support those of Brown, Butler, and Jones (1994), in which the ordering of a C major triad, C-G-E-C, elicited responses of D♭ (see Chapter 1). All three studies show, then, that listeners have a general tendency to somehow perceive a dominant-functioning tone, particularly the leading tone, in order to make a tonic response.

In terms of the operation of the tonal schema, the hypotheses of the intervallic rivalry model comprise a process that activates the schema. Primacy is in essence a perceptual default until more information is received by the listener and put into the schema, where the prior and recent pieces of information, the notes, are immediately compared for content and temporal ordering. As soon as a second piece of information, another note, is sensed, the schema becomes active.

The schema includes knowledge of pitch and interval relationships that are used in particularly controlled ways, such as at cadences, which usually contain stylistic,
formulaic uses of the dominant-tonic relationship and voice-leading, especially leading tone-tonic sequences. Thus, in tasks such as this study was based on, the need for a tonic response generated two main types of responses: 1) the whole three-note pattern was taken into account, and the half-step was interpreted in a diatonically logical way, such as ti-do, mi-fa, sol-le, or re-me, depending to some degree on the third note; or 2) only partial information was used—the last note, which was assigned a dominant function (i.e., it was interpreted as re, sol, or ti).

Considered from the perspective of the present study, Krumhansl and Shepard's (1979) tonal hierarchy and Krumhansl and Kessler's (1982) tone profiles are snapshot representations of the degrees of implication and appropriateness of various tonic responses to specific musical situations. They are a measure of the efficacy of the given stimuli in establishing a particular tonic(s). Once the schema is active, the tonal hierarchy model provides a background or set of expectations which the musical stimulus may or may not match. When they do match, the tonic choice based on primacy, rare interval, and temporal order information is reinforced. If the stimulus does not match the background or expectation, then rare intervals and temporal ordering are engaged once again in an effort to identify a new dominant or leading tone and thus locate the position of the appropriate tonic.

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PEDAGOGICAL IMPLICATIONS

Theory and aural training teachers can take advantage of a schema such as that just described. Characteristic patterns (such as those used in this study) can be manipulated in different orderings to illustrate the effects of progression and voice-leading on the ease or difficulty of keeping track of tonic in sight-singing and dictation exercises. The differences in the functions of the notes given their temporal position in the pattern can be illustrated by "resolving" short patterns to various tonics based on the various major and minor diatonic, as well as chromatic, interpretations of the half-step and of the last note. Melodic patterns that signal tonicization and modulation can also be identified, especially by the uses of notes in dominant functions and the differences in resolutions when the notes are taken as sol, ti, or re.

These kinds of exercises can also help students understand the differences in the uses of enharmonic spellings based on the function of the notes within very specific patterns and how those patterns necessarily change with changes of functions. Blombach (1995) utilizes information of this sort in a computer melodic dictation algorithm with the same purpose as the key-finding algorithms of Longuet-Higgins and Steedman and Krumhansl—to correctly notate any given melody. Her algorithm is superior in several ways (although it still assumes a key signature at
the beginning, which a listener is not usually in a position to know). The most notable strong point is that, on-the-fly, it recognizes local melodic patterns that listeners use to make tonic choices, particularly la-ti-do, and examines half-steps according to their context (what was the key choice prior to the half-step, are both members of the half-step diatonic to that key, and which direction does the half-step move?). This makes it adept at locating and identifying tonicizations and modulations based on local context, without the cumbersome "shift" of key maps or tone profiles, because the patterns are generic: They indicate key without belonging to a particular key.

SUGGESTIONS FOR FURTHER RESEARCH

It still remains to be seen just exactly what kinds of influences rhythm can have on the perception of pitch relations. Relevant questions include:

- What are the effects of tempo on tonic responses in tonally ambiguous three-note sets that occur in various durational patterns?
- Would the degree of multivalency (i.e., placement in three or more keys) of a three-note set in addition to the durational pattern (and tempo) have an effect on tonic response?
• What are the effects of meter on perception of tonic in melodies?
• Does rhythm influence the perception of specific tonal functions such as the dominant?
• Does rhythm influence the perception of modulation?
• Why is there a tendency for listeners to hear an isolated ascending perfect fourth as sol-do in the rhythmic context of anacrusis-downbeat?
SUMMARY

The purpose in this study was to examine the relationships between pitches and between pitch and durational pattern. Most of the theoretical literature that deals with pitch relations is with regard to tonal organization within specific pieces or compositional styles and shows an evolution in the concept of tonality as a hierarchical system of pitch relations revolving around a central pitch, the tonic. The empirical literature has progressed from placing tonal organization as inherent in the sounds of music to placing it in the mind of the listener based on learned patterns. Relations between pitch and rhythm within this hierarchical system have not been extensively studied empirically, although the studies that have been conducted have found that the temporal ordering of the pitches and various patterns of accent and/or duration can influence key choices when tonal cues in the music are ambiguous.

It was found in this study that durational pattern did not have an influence on tonic choices made by listeners, at the tempo that was used. The study did find that pitch relations in a tonal context are rich, and that these
relationships can be described in terms of a general (i.e., not key-specific) tonal schema. This schema is learned by the listener and is activated by the local relations of pitches and the temporal-order patterns in which they occur.

The tonal schema is a broad two-part process that employs position-finding and pattern-matching. Position-finding is manifested in the current model of intervallic rivalry, which suggests that the use of rare interval patterns, the tritone and minor second and their temporal orderings, allows the listener to limit key choices based on the positions of those intervals within the diatonic collection. Pattern-matching is done against a hierarchical template of harmonic functions, enabling the listener to recognize various learned tonal patterns, and is best described by the tonal hierarchy model, which this study found to be a hierarchy of tonal expectations and suitability of tonic response.

The results of this study suggest that rare intervals and temporal ordering are initially employed for the first identification of a dominant-functioning pitch, preferably the leading-tone, which leads to a choice of tonic response. Once the leading tone (or other dominant representative) and tonic have been established, the tonal hierarchy and its attendant expectations are engaged, which the musical stimulus may or may not continue to match. If the stimulus
and expectations do not continue to match, then the position-finding apparatus is engaged again in an effort to identify a new dominant or leading tone and consequently the new tonic. Further research is needed to determine the role(s) of rhythmic elements such as duration and accent within the schema.
APPENDIX A

PRE-TEST

Because the stimuli used in this study were tonally ambiguous, it was imperative to recruit subjects who were able to give reliable tonic responses. The following examples were devised by Helen Brown in 1980 as a pre-test to assess accuracy and competence of vocal production.

Subjects heard the examples played on a piano and were asked to sing or hum the tonic. A 100% pass was required to participate in this study. Note that these examples are not tonally ambiguous, but they do contain varying degrees of emphasis on the tonic: 1) perfect authentic cadence—strongest possible tonic emphasis; 2) imperfect authentic cadence; some subjects sang the soprano, indicating a difficulty in separating the soprano line from root movement; 3) deceptive cadence; a number of subjects had difficulty extracting the tonic from the third of the vi; 4) progression starting on the dominant, containing secondary dominants, and ending with a plagal cadence; the dominant note, E, is extremely prominent in this example—many subjects were not
able to interpret the IV-I motion at the end as a cadence from which to extrapolate the tonic; 5) mildly chromatic, with emphasis on the dominant harmony, ending with a half-cadence (some would perhaps say an incomplete cadence, since the last measure consists of I6 - V7).

1.

2.

3.
APPENDIX B

SUBJECT QUESTIONNAIRE

Information about yourself

Name: ____________________________________ Male Female

Age: ______


Major instrument: ________ Years of study/playing: ______

Other instruments/years of experience:

Voice range (SATB): ______

Average aural training grade (letter grade): ______

Absolute (perfect) pitch:  Yes    No    (circle one)
Consent to this investigation and procedure:

I understand that all of the above information and my responses to this procedure will be kept confidential.

I hereby authorize Rockelle Strader of The Ohio State University to perform the following procedure: to present a number of short series of musical tones and ask that I respond according to the instructions which I will be given. I understand that there will be no excessive or aurally damaging loudness levels, and that all of my responses will be audiotaped for later analysis. This is done as an investigation into the perception of rhythm and tonally ambiguous musical stimuli.

I understand that this procedure is not intended to measure or actually reflect my abilities as a musical performer and listener.

(Instructions will now be explained.)

I understand the instructions, and any questions have been answered to my satisfaction.

Signed: ______________________________ Date: __________

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APPENDIX C

COMMENTS FROM SUBJECTS

Subject

1 Some of them [examples] I know I sang minor tonics instead of major tonics.
   On one set, I was aware of changing what tonic was about half-way through the test regardless of rhythm.

4 [Between blocks of trials:] So if it's in a minor key, I should sing the relative major? Like the last one? [105 (CBE)]
   [After the test:] BCE caused me problems. I wanted to sing F, but I changed it to C even though the other sounded right. I also associated some of these combinations with tunes. The pitch sequence seemed to have more influence regardless of the rhythm.

5 [consistently commented "minor" to 051 (BEC), 105 (CBE), and 501 (EBC)]

7 [After the test:] Sometimes...hearing things right before it [an example] and having my mind in that key, you know—I mean, I think that's the reason you used the all-keys down [the distracting noise between samples], right? But it still didn't sometimes completely erase, you know, what's in my mind...But, I worked that out, I think...I didn't have as much trouble because I started listening more just for the tis. You know what I mean? [sang] ti-do. You know, and after I got to that point, you know, it got a lot easier for me. At least, at the beginning when I wasn't...listening specifically for that, it was—you know, I would hear something in one key and then would jump to another one, and you know, if they were related keys, I would hear that as...I would hear ti as a sol or something...You know what I'm saying? It'd jump around.
[After the test:] I ended up referring to a lot of pieces I know that had that interval structure. And that's how I would determine do, or try to determine do. It was interesting, because I heard Mussorgsky in there, and I heard "Let's go band," and I'd just refer to that. A lot of interval relationship.

You played one—I could tell you played, like, four or five of 'em—same ones over, and I could just tell which ones those were. A lot of 'em were same ones. Two of 'em just stuck in my mind [did not elaborate].

[Between blocks of trials:] I'm always picking the top of the semitone I hear for tonic....You're staying within a fourth or less...There are two available choices—the one you hear at the semitone or the fourth below...

I might have chosen different notes sometimes had I not decided to just stick with the top of the semitone...I'm not really listening to the three tones as a whole and trying to figure out what melodically sounds like it's gonna go to tonic. I'm just picking the top of the semitone all the time.

Pretty many times there's another note—the fourth below the note I sing—might be—like melodically more likely to end up as being tonic, hearing the three notes I just heard. But it's easier to just pick the top of the semitone. So in other words, if I could sing two notes at the same time—like if I was playing an instrument—I might play a fourth as the answer every time—a perfect fourth—the semitone I hear and the fourth below...

I'm sort of obscuring—I'm trying to obscure the effect of rhythm by just listening for the semitone, instead of listening for an emphasis.

[Between blocks of trials:] It's hard to change keys like that. You get one key feeling in your head, then you go to the next one, and it just—like for me that—the key feeling that I get in my head stays there, and when I hear another one, it's just way out there. I mean, it's not even in the way I'm thinking...I gotta totally readjust and say, "Wait a minute. That's not the key of the last one. This is the key of this one." I gotta think of where it is from there.

Like I said before—it's a key feeling. If I'm in—say we have a, you know, [sang 105 (CBE)]. That sounds, like, with that minor second, ti-do, right there. And then we go to a different key, and it may do the exact same thing, you know, but in a different key? And it doesn't even sound anywhere near like ti-do. You know, it just doesn't register. Is that good or bad?
[After the test:] I tell you what: I don't think the rhythms bothered me as much as the changes in key... I'm sure that the rhythms—Some of 'em sounded like—they need completed, if you know what I mean. And some of 'em sounded like they were being completed. If that makes any sense. By the rhythm. That's what it's about, isn't it? The rhythm and...?

[After second block of trials:] Don't you think it has something to do with the contour of the line, too? It obviously does as well as the rhythmic content, so that—I'm sure you've taken that into account. You'd have to.

For me, I'm so aware of melody because I play a lot, and I try to bring it out with these three fingers [3, 4, 5 on right hand], and so I'm conscious of the contour because I have to work it out with three fingers!

The rhythm doesn't necessarily make a difference. It just depends on what—where I'm hearing the intervals. And sometimes it'll appear to make a difference because of the contour of the line [sic], but then in another one it won't because I'm attracted to—the rhythm more than I am to the contour. Does that make sense? The rhythm on occasion outweighs the contour and then at other times, the contour overtakes the rhythm. Okay?

[After the test:] I think I like my sevens emphasized. I mean obviously, the half-step relationship's going to affect you a whole lot.

Some melodies popped in my head and it's hard to think about do. I heard a Dvorak symphony and I think I finally figured out that one [sang 4-5-2-0] I think I finally figured that one out. I think; I'm not sure.

I tried to give you my first impression of do, but some of them may have been fa.

There were some that I could have done other ways, but I seemed to have a pattern and decided to stick with it. I went with the one that I felt best about.

[Between blocks of trials:] There's a couple of minor context ones I can't think of in major, that quickly. I guess I could if I thought about it. Some of these I seem to think that I try to extend the excerpt so that it produces a melody. I think of a couple more notes going on after the three notes and then I can get to a do. And I change my mind between the first and second hearing once in a while. Sometimes I think sol is the note, and then I extend the melody another note down, I go to do.
Some of the ones in minor just beg to be minor. And it's hard because—given a little more time, you could re-orient your thinking. But since you have to respond immediately, it's screaming minor in your mind, and you know that's not the answer you want! But it's the only one I can give you in two seconds or whatever. So I know some of them are wrong for that reason, but...I'm sorry.

Some of 'em I can think chordally, and some of 'em I think scale-wise. And I can feel myself switching back-and-forth. And I think it depends on whether something is major-sounding or minor-sounding, I think—because I'm still thinking about trying to find the major one—so I switch back-and-forth depending on whether it sounds major or minor. I hope that's helpful.

There's some patterns that seem to appeal to the lower, like the bottom tetrachord of the scale, and some patterns appeal to the top tetrachord of the scale. I was thinking how the top one always seems to imply a bass line and the bottom one seems to imply some sort of melody (in my mind).

I'm definitely thinking in terms of either 5-4-3-2-1 or sol-do, listening for sol-ti-do—those tendency tones.

You said no minor keys? I feel like I keep singing do when, like with a minor part—I don't know how to explain it. But, like, I might hear [sang 510 (ECB)] instead of sounding major to me, those three notes, it sounds minor and then my do is relative to that minor-sounding thing, so I don't think I'm doing that right. But I don't know. I'm just singing what I think is do, even though it sounds minor to me, and you said there's no minor. I don't know.

Once in a while I feel like it's going too fast, and I have to just pick one, but that's once in a while. Sometimes it's very obvious, 'cause I hear ti a lot, so then that one's easy. Some I'm just slower on.

I keep hearing the minor. I can't—I'm trying, but I can't translate it, yet anyways.

I wonder if position is important. You know what I mean? Like, which note is first.

I keep hearing the minor! I keep hearing le-sols. And that makes me in minor...

Boy, it does sound different when you play different notes longer, you know? I think it does.

I never got the hang of that major thing.
I think you're likely to hear the first note as do until something comes along that changes your context, that it couldn't be do. That's the way I—or sol...Do mostly, though. Until something changes it, and it doesn't fit that context anymore.

In tonal harmony, of course the order is—I mean, that's the way we hear. And, you know, just like you're supposed to have this come before this, and this come before this. So, of course, it would be important. I mean, that's how we've been taught to hear things. That's all the music that we hear. And I was hearing some tes in there that—it's like probably from pop music influence, you know. Like, I wanted to hear te-do... From pop music, 'cause you hear that all the time.

You know if the fourth is more important...than the half-step—when we studied world music, everybody that we studied has a fourth in their music. You could have really scales [sic] that had a billion notes in 'em or you could have scales that only had 5 notes or something, but everybody uses, like, sol-do, what we would call sol-do. That was the biggest thing that struck me, out of that class, was that [it] seemed like everything we listened to had—So it has to be, to my mind, it has to be something psychological, in our brain—that somehow that is pleasing. Somehow that relationship—because it was in Native American, it was in everything we listened to. I don't know if there were any exceptions at all. In Indian music, I mean, it was—there's something about it. I've often wondered about that sol-do thing, you know....

A lot of times I thought I was hearing re-ti-do. I thought I heard la-ti-do or do-ti-la, but a lot of them in between there were...I couldn't put a solfège to....You gotta know your solfège to do this.

I was really answering in minor, I think, a lot.
I did hear a lot of the same thing, and I heard consistently when [I thought] "What am I going to do with this?", and a lot of consistent ones that I thought "I know just what to do with it."....Some of those ones in there, I thought "Ooh, that doesn't sound major for anything!"

[Between blocks of trials:] Interesting to see how it—how accuracy progresses from—whether it gets better or worse!
[After the test:] [In response to the experimenter's statement about temporal order hypothesis:] Usually the first and last ones [notes] were used more than the second one, I thought. At least, for me, I thought.
I kept hearing Britten's War Requiem intervals in that stupid thing!

[Between blocks of trials:] It's hard to find do! Actually, I felt like a lot of them were minor. I could go to minor a lot easier to find do, for some reason. And I also felt like I was trying to finish out the line, instead of finding do. That's what I felt like doing, at least. I'm sure if I took me longer [sic], I could probably be more accurate, but that's not—I mean, just going through it and finding out in the scale where each pitch is, but I just can't do that, that quickly. [After the test:] I kept changing my technique to figure it out...I must have been in a minor mode or something. Everything sounded minor, or I could apply everything to minor—not everything, but a lot of it. But, I think I tried, first of all, for leading tones, and then—even though—if one of the notes didn't necessarily, I usually said what the leading tone went to...

And any combination of me-re-do, or those intervals, of major second and a minor second—the re would become do or something. You see what I'm saying? I don't know if that works or not, but...At first, I thought it would be sol-fa-mi, and then I would try to find do there, or re-do-ti, and then find do there, But, it could go either way.

[After hearing 105 (CBE) in the fourth block of trials:] Sure these are all major?

[Between blocks of trials:] I seem like I'm just making up, like, the rest of something, or—I don't know. I guess that's what is going on inside my head. Just trying to make up the rest of what it might be. A lot of times I think that "Oh, jeez, this is minor!" But the only thing I can come up with—you said to try to think major, but sometimes I think things that are probably minor. I think, "Oh, no!" But then from there I can't think—that's just the way it would end, I guess.

[After the test:] I thought, "Oh, man!" Some of these are just confidence builders. And the other ones, OK...

[After second block of trials:] About the pitches: If you recognize what the pitches are—if your pitch perception is accurate enough that you know, "Okay, that's a C on the piano, that's a B," whatever—That's a whole other process that's going on at the same time which takes time and can be confusing. I was hearing the actual pitches. And—I don't know—it wasn't
connecting. I wasn't just going on what I heard and put it in a key.

[After the test:] Once you figure out the pattern—that's what does it for you. Some of it's very easy to hear the tonal center, and others of them aren't. I don't know whether the same ones are easy for people or not, but there are ones that are very easy to hear, and others that would be just the pattern that would indicate where do is.

[Between blocks of trials:] Some of those I messed up on! Some of them even though I hear the [imitated distraction noise], you know, I still—I'm still thinking of the last pitch I sang. And, I don't know—it's not intentional. I don't intentionally try to—I'm still thinking about the last one, and we go on to the next one, I'm still thinking of the same do. Maybe that's what might throw me off a couple of 'em.

Number 14 [105 (CBE)], I think I heard sol-le again [in reference to comment during block of trials] and I said something else. I sang something completely off. I heard do-le-sol, I think.

I started to hear sol-le-do again, then I realized that it was—that the half-step was a ti-do relationship, finally!

[After the test:] On 15 on this last series [105 (CBE)], I heard—at first heard le-sol-do. I kept on thinking I was hearing that the whole time, and that one I sang the do which would be the minor do, like le-sol-do. I think that's what it was—I'm not sure—but I heard more of a minor progression. I realized it was the same progression—I mean, it's ti-do, do-ti-mi, or whatever it would be, to slide it into major. That was the tricky one that got me just about every single time it came up until mid-way through the test.

[Between blocks of trials:] I hear dominant or what I think is dominant when I sing the tonic after it...

It gets frustrating. I mean, you hear patterns that you—you can't get something out of your head, even though you know it's probably wrong.

[After the test:] It's just hard. You start second-guessing what you hear in your head and you lose track of it. And some of 'em are just—you hear something, and just keep hearing that over and over, whether it's what it should be or not.

[Between blocks of trials:] Lower register seems to be where I—It takes me longer to decide what should be do—what I want to be do. It's harder to be creative in finding do in the lower register.
I hear a lot of 'em in minor, but I always try and end it in major. So I don't know if I'm actually thinking it in minor and ending [sang] ti-do. I don't know.

When I'm finding do, I like to revolve around sol, la, and ti, sometimes re. These seem to be the best way to get to do, the easiest way to find do, for me.

[After the test:] What confuses me with—I couldn't figure out why I would hear 1-2-minor 3, let's say, or whole step-whole step-half step. Why sometimes I hear it as [sang] la-ti-do, and other times I'll hear it as [sang] do-re-me, and I couldn't figure out why, you know, it should be simple. I'm not sure if it has something to do with the length of one note being longer than the others—is that stressing one particular note which makes me believe that it could, should be minor. That felt true for another interval—something like ti-do-sol. I think that might have been it...I would hear that again and sometimes it would be major and sometimes I'd hear it as minor. And I was wondering, is it because of one of the three is longer than the others? Is it artificially stressing a tonic?

If it's going A-B^-C and sometimes I would just hear A, I couldn't find C as do. I just wanted A to be the do, and it wasn't and that's why I would take long.

51 [Between blocks of trials:] I hear that minor 1-2-3, and I just go "Hmm!" I know it's 3-4-5, I just can't sing 1!

It's so weird, because you hear the same things and then, like when it's—there are certain sequences like 4-3-1 and 8-7-5, where you don't know if, like, should you go for that one, or should—It doesn't really have a lot to do with the rhythm.

[After the test:] It's so weird when you hold the first note long because you try to make everything relate to it. Like if you have 3-4-2; my God, I'm in Phrygian! What can that be?

54 [Between blocks of trials:] There's a combination of pitches that throws my ear off the most, at first. But then once I got used to it; hearing it, I could sort of recognize it—that one pattern in the scale. I think I'm hearing it better than I did at first.

[After the test:] I'm curious if any other subjects have picked out a do that was not actually played.

[After experimenter's remark on composition of the sets, particularly 015 (BCE):] I think, as I heard it more and more, I started thinking of it more as major, but I wasn't sure about that.
[Between blocks of trials:] I assume you want the first thing that pops into my head, right? Sometimes my analytic mind start getting ahead of my—you know, well, it could be this, could be that! Well, you know. But I'm just trying to not think—just saying the first thing that comes into my head. That's what you want, right? Kind of like word association? The most natural tendency, right? And, you only want the major do, right? Those ones that start with a descending major third I sometimes, you know, if that's the longer tone, like [sang 510 (ECB), long on 1 (C)], oh—I mean, my romantic sense just wants to kick right in...That's the only really tricky one that always gets me, I think.

[After the test:] It was just interesting, how powerful the first tone is. In any one of the three settings, seemed more powerful when the first tone was the longer, like [sang 051 (CEB), long on 0 (C)], you know. It seems like you assume that there's a chord tone of where it's going to resolve to. And that everything—most of the examples sort of fit into a—imaginary I-V-I cadence. And I just found myself getting into that rut, intellectually. Just processing this information whether I was doing it with or without thought. So I thought that was interesting, and it's probably the expected response. I don't know, but if you have any—as your hypothesis that would be expected that the first one sets the environment...

The power of the downward third movement—at least all of those—just the sheer power of the chordal movement in Romantic music is what grabs you, you know. It's almost more powerful than the downward fifth in some ways, in some weird sort of way. But it doesn't work on each of 'em because after a while I was kinda looking for that combination, and you know—it would be very interesting to see how that works out with the rhythm—whether it's just that succession of three pitch-classes in the same arrangement or whether rhythm affects that. That'll be fascinating.

So, in each set, were you using the same pitch-classes and just changing the rhythm? I mean, I didn't keep track of it, but I kept hearing certain patterns coming back.

Some of those I could see where they went both ways, where it was like, "pick one" because they're both in my head. But that happened only very rarely, like only once or twice in each set [block of trials]. Most of the time it was just clear as a bell which one to get...And I was trying to think as I was going along, "Well, what is it?"—but I didn't want to think too much—like say, [sang 5-4-3-1 pattern]. But I'll swear the reason why I was responding to some of those things is
because I've got a known melody in mind [sang 3-1-0...]
It's Prokofiev, right? [sang 1-0-3...] From Brahms.
So I don't know how that plays into the variance. You
might want to talk about that, because I was playing
"Name That Tune."
LIST OF REFERENCES


Lipps, Theodor. (1926). *Psychological Studies.* (Herbert C. Sanborn, Trans.). Baltimore: Williams & Wilkins. (Original published in German, 1885).


Van Egmond, René and Butler, David. (in progress). Key and mode connotations of PCsets. Manuscript submitted for publication.

SUPPLEMENTAL BIBLIOGRAPHY


Narmour, Eugene. (1992). The influence of embodied registral motion on the perception of higher-level melodic implication. In M. R. Jones & S. Holleran (Eds.),
Cognitive Bases of Musical Communication (pp. 69-90).


