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Tonal Structure versus Function: Studies of the Recognition of Harmonic Motion

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Two empirical studies identified and tested strengths of dynamic cues that assist listeners in identifying tonal centers. The hypothesis that it is rare intervals, rather than physical properties of tones or static representations such as scales and triads, that play a significant role in a musician's perceptual process of key identification led to the first experimental study of context sufficiency in perception of tonality. Musicians extrapolated tonal centers upon aural presentation of subsets of a major diatonic set with an accuracy mean of 87%. Univalent trichords gave 100% clearer indication of tonal center than did multivalent trichords. The strength of the tonality percept was further explored by examining effects of temporal ordering and by evaluating relationships between formal training and test scores. In a second experiment, listeners judged appropriateness of tonal centers after hearing paired dyads consisting of the rarest intervals in the major set: the tritone and the two minor seconds. Listeners indicated strongest impressions of tonal center when the tritone was heard as a simultaneity. Test performance showed a stronger correlation with listeners' abilities to identify tonal centers in actual music than with listeners' status as musicians or nonmusicians. These results are interpreted as evidence of a widespread cognitive skill that interprets tonality as a system of tonal relations rather than just an abstracted collection of tones or a system governed by the psychophysical attributes of tones.

Introduction

When [the dominant seventh] is heard, there is no doubt of the key; every secret of tonality is revealed by the relationship of this fourth degree with the leading tone.¹

These two notes (*ti*, *fa*) placed in contact, form an attractive harmony, which is able to satisfy the musical sensitivity and intelligence only by

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1. Translation by Kosar (1984).

Lorsque celui-ci se fait entendre, il n'y a plus de doute sur le ton; tout le secret de la tonalité est révélé par le rapport du quatrième degré avec la note sensible. (Fétis, 1844, p. 38)

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*.²

François-Joseph Fétis (1832, 1844) made these assertions in a series of essays that forms the first comprehensive discussion of tonality in music. Although the reader may be put off initially by the apparent hyperbole and oversimplification, even the most skeptical must admit that Fétis's statements invite empirical testing. In this article, we will show that—at least for the major mode—Fétis was correct in identifying the critical intervallic relationships that define the dominant harmonic level and in stating that it is harmonic motion articulating the dominant that, in turn, defines the tonal center. Subsequently, we will report the results of our tests of key assessment, which provide empirical data to support Fétis's statements.

Fétis's treatises on tonality have not been generally available in translation, and his influence on theorists outside France and Belgium has been diminished for that reason. Working largely without access to Fétis's insights, authors of English-language music theory texts have contrived myriad introductions to tonality in music. With few exceptions, these may be distinguished as adhering to one of two theoretical bases: (1) tonality as the musical embodiment of some extramusical entity or event; either the manifestation of physical/psychophysical laws, or the analogue of linguistic, geometric, or mathematico-logical mental processes; or (2) tonality as the result of compositional adherence to a tone set (invariably offered with some rules for the manipulation of the set's "stable" and "unstable" members).

It comes as no surprise that the perceptual models currently enjoying the greatest influence can also be grouped into these same two categories. One who wishes to test empirically either of these theoretical positions on tonality will invariably encounter problems either when attempting to derive testable hypotheses or when trying to design appropriate stimulus patterns. An examination of these two theoretical bases will reveal why this is the case.

The physical-sensory basis of tonality (as presented by, e.g., Helmholtz, 1885; Hindemith, 1945) has gained adherence among some empiricists (e.g., Terhardt, 1978; Mathews & Pierce, 1980; Houtsma, 1981; Wightman, 1981), although it seems that this position can only maintain credibility as long as one makes no real distinction between the psychophysical

2. Translation by Kosar (1984).

Ces deux notes (*si*, *fa*) mises en contact, forment une harmonie attractive qui ne peut satisfaire la sensibilité musicale et l'intelligence que par la résolution de ces mêmes notes sur celles qui n'en sont séparées que par un demi-ton, comme *si* suivi de *ut*, et *fa* suivi de *mi*. . . (Fétis, 1844, p. xxxix)

attributes of sound and the cognitive structuring of music and as long as one is indiscriminate in using such terms as “chord,” “harmony,” “key,” and “tonality.” Historically, a minority among music theorists (e.g., Fétis, 1832, 1844; Cazden, 1954, 1958, 1962, 1980; Poland, 1963, 1971) has argued, in effect, that physical laws exert an influence on music that is at once immense and trivial: music cannot violate physical laws, but sounds can be ordered in so many physically possible combinations that one need not spend much time chafing at the restrictions. Fétis, Cazden, and Poland warned against the slavish acceptance of the natural law position that among other things confuses psychoacoustical “roughness” with musical dissonance. For example, while research relating roughness to critical bandwidth may be valuable to acousticians in determining certain auditory percepts, that research tells us nothing about why the major third was considered a dissonance in the eleventh century but a consonance in the eighteenth. Ultimately, it is impossible to find any significant attribute of tonality that is carried within the psychophysical properties of tones.

An important segment of the empirical literature on musical pitch perception has come to agree with the theoretical position (e.g., Piston, 1978) that music is composed according to “high level” rules of tonality, and that musical listeners possess varying levels of skill at grouping and identifying pitches according to these rules—human conventions removed from, or at least operating freely within the confines of, physical laws and sensory limitations. If the empirical literature has actually come to any consensus on what the rules of tonality really are, it is that tonality is regulated by a hierarchic structure intrinsic to the various precompositional pitch sets: the equal-tempered chromatic scale, various major and minor diatonic sets, and subsets of these (triads, seventh chords, and so on).

Studies attempting to define and measure the structural hierarchy of musical pitch (e.g., Taylor, 1976; Balzano, 1978, 1980; Krumhansl, 1979; Krumhansl & Shepard, 1979; Cuddy, Cohen, & Mewhort, 1981; Krumhansl, Bharucha, & Castellano, 1982; Shepard, 1982) have shared two complementary assumptions. The first is that adherence to a major or minor scale set promotes tonality. The second is that any deviation from strict adherence to the set will weaken tonality. Music theorists who appreciate Fétis’s distinction between the concept of *gamme* (an unordered collection) and *échelle* (an ordered collection, or scale)³ will criticize these two assumptions as simplistic. One can find in the performance literature examples of tonally ambiguous music composed entirely of tones found in a diatonic major scale set. One can also find examples of music, rich in tones foreign to the scale set, that leave no doubt in the listener’s mind as to tonal center.

3. Kosar (1984).

Thus, it is only sensible that one look beyond precompositional pitch sets to the compositional act when trying to identify the indispensable perceptual attributes of tonality in tonal music.

The two studies described below had that objective. In selecting stimulus materials for both studies, our premise was that there must exist some fundamental compositional conventions that guide the selection and ordering of tones so that the composer can convey an unmistakable impression of key center to the acculturated listener (Brown & Butler, 1981; Butler, 1982). This mandated that we devise a perceptual model parsimonious enough, and sufficiently precise, to submit to experimental testing. This, we feel, seems to be the critical point at which perceptual models for tonality are most apt to be found wanting. If it is necessary for the model to incorporate all (or even many) of the possible combinations of tones in a key system—all scale members, all possible triads, all possible seventh chords, and so on—the model would be prohibitively cumbersome. Attempts that have been made to test such models have tended to sacrifice control over stimuli, response tasks, or both.

This problem, of course, has been attacked by those who have argued that certain salient members of the set—the keynote, the triad built on the keynote, or the first, fourth, and fifth scale degrees—serve to inform the listener of the key level of the music. The primary problem with such structural hierarchies lies in their failure to address tonal ambiguities or tonal misinterpretations. We have consistently found that knowledgeable musicians seem to get their tonal bearings immediately and effortlessly upon hearing extremely short segments of tonal music. It is apparently not necessary that the listener hear the beginning of the work, the end of the work, or even a harmonic cadence, although hearing these parts of the music may increase the listener's confidence if asked to identify the key of the passage being heard. Musicians can and will make tonal center identifications quickly and accurately with much less information. The question of sufficiency of tonal information is intrinsically one of context rather than content, since a tone or chord out of context can be given more than one tonal interpretation. For example, the pitch "C" may just as likely be the fifth degree of the F Major scale as the tonic of C. The triad "C–E–G" may just as likely represent the subdominant harmony in G Major as the tonic harmony in C (see Figure 1). Even in a tonal musical composition, the first chord we hear may not be an expression of the tonic harmony, as Norman Cazden has pointed out:

. . . we may remark on the strange logic by which a composition cannot begin on its tonic harmony. The work may be, let us say, in the key of C major, and it may begin with a simple C major chord, but there is no functional relationship as yet that makes us accept that chord as having a tonic role, and the further progress of the composition may easily demonstrate that it is really in another key (Cazden, 1954, p. 25).



Fig. 1. Alternative interpretations of the major triad C–E–G as representing (a) tonic, (b) subdominant, (c) dominant major mode, (d) dominant minor mode, (e) submediant, (f) subtonic, and (g) mediant harmonies.



Fig. 2. Intervals of the major set, shown in the key of C.

What pitch relationships prohibit this sort of guesswork? Browne (1981) offers an attractive solution. Since each interval in the major diatonic set occurs a different number of times (see Figure 2), Browne suggests that a hierarchy of tonal relationships exists in the relative ubiquity or rarity of intervals in the set. For example, since six perfect fourths (or their complements, perfect fifths) are found in the major set, this intervallic relationship will yield six tonal interpretations (*do-fa, re-so, mi-la, so-do, la-re, and ti-mi*). While this commonness may assist musicians in recognizing the perfect fourth as a melodic relation, that very commonness robs the perfect fourth of the power to elicit a confident and accurate judgment of tonal center. On the other hand, the tritone, which occurs only once in the set, should for that reason alone offer the listener the strongest sense of tonal center. Assigning this critical perceptual role to the tritone necessitates reevaluating some prominent perceptual theories of tonal relations (e.g., Siegel & Siegel, 1977; Balzano, 1978) that treat the tritone as a perceptual curiosity more likely to impede our tonal awareness than to enhance it. Although, of course, we can assume Fétis was not thinking in terms of the interval index that Browne relates to position finding in a tonal context, Fétis obviously recognized the rare intervals as indispensable in unlocking the “secret of tonality.”



Fig. 3. Representative stimulus patterns used in Experiment One: (a) cue-cells correctly interpreted in only one major key and (b) multivalent cells, correctly interpreted in two or more major keys.



Fig. 4. Enharmonic relation of the tritone member F (E-sharp) in the diatonic sets for C and F-sharp major.

Experiment One

Method

We tested the rare-interval hypothesis by comparing musicians' responses to two categories of three-tone series, represented in Figure 3. The first (Figure 3a) could be correctly interpreted as having only one major mode tonal center; these patterns are called cue-cells below. In all cue-cells, two of the three tones were a tritone apart; the third tone equally represented all other members of the diatonic set. Although listeners could interpret the tritone as belonging to two different keys through enharmonic equivalence, the third tone in the series necessarily furnished sufficient tonal context that only one tonic could be assigned correctly to the pattern. Any third tone will provide this context, since the tritone member not interpreted enharmonically is the only member that belongs to both sets. All other tones belong to mutually exclusive sets, as is shown in Figure 4.

The second category of tone series (Figure 3b) excluded the tritone but equally represented all other intervallic relationships found in the major set. We will refer to these as multivalent cells. Because their intervallic constitution was limited to intervals that occur from two to six times within the diatonic major set, there were always from two to five correct tonal interpretations for the three tones, the number of interpretations being determined by the rarest interval found within the pattern.

Stimulus patterns were produced on a Steinway grand piano and were recorded on a ReVox model B77 tape recorder. The test was presented to subjects individually in a free sound field on a Marantz SD800 cassette recorder routed through a Marantz PM300 amplifier to Marantz HD440 speakers.

Twenty-two paid subjects were selected on the basis of achieving a perfect score on a key identification pretest. These subjects, all undergraduate students ($N = 11$) or graduate students and faculty ($N = 11$) at The Ohio State University School of Music, were instructed to listen to each stimulus cell and to produce its tonal center. Both categories of stimuli in Condition I were presented with an ascending pitch contour. To reduce the likelihood that direct judgment responses were inhibited by performance limitations, subjects were allowed

to identify each tonal center by vocalizing its pitch, by assigning *solfeggio* syllables to one or more members of the cells, or by identifying the tonal center through a verbal description of its intervallic relationship to any tone in the cell. Subjects' levels of confidence in their judgments were recorded in two ways. First, subjects rated each cell as an ambiguous or unambiguous tonal indicator, using a three-point scale. Second, subjects were allowed to listen to stimuli as many times as they wished. Numbers of repeated presentations were counted, without subjects' knowledge, as an independent measure of tonal ambiguity. Test sessions were recorded on a second tape deck to verify vocalized responses and tabulations of numbers of presentations. To avoid confounding of stimulus patterns through memory carryover, a complex frequency glide of indeterminate pitch was presented after each response.

Condition II was included to test for possible contour effects in stimulus cells. These stimuli differed from those in Condition I only in their equal representation of all possible contour configurations, as illustrated in Figure 3: ascending/ascending, ascending/descending, descending/ascending, and descending/descending. Ten subjects who had scored above the mean accuracy level for responses to patterns in Condition I participated in Condition II; five were sophomores, five were graduate students or faculty.

Results and Discussion

Responses to cells in Condition I clearly indicated that the tonal information picked up by trained musicians from these short patterns was very convincing. Subjects identified correctly the tonal centers for cue-cells with 83% accuracy [$t = 55.48$ (with t reflecting the difference from chance expectation), $df = 11$, $p < .0001$]. Accuracy for identifying one of the alternative correct tonal centers for the multivalent cells was 96% [$t = 59.75$, $df = 11$, $p < .0001$]. Performance on both categories was appreciably better than chance [$t = 58.25$, $df = 11$, $p < .0001$].

Although the added contour variable may have made the task more difficult in Condition II, listeners were even more successful at identifying tonal centers for cue-cells (91% accuracy) and multivalent cells (98% accuracy).

The accuracy of responses to cue-cells in both conditions provides persuasive evidence that the tritone serves as a primary indicator of tonal center. First, the response task was not a two-alternative, forced-choice paradigm where 50% accuracy levels would indicate guesswork. There were 11 possible incorrect responses and only 1 correct response to the cue-cells, which means that accuracy at the chance level would be about 8%. Second, only three tones in succession were heard, and listeners were not provided any harmonic reference or notational cues. Third, although the subjects were trained musicians, the task was quite novel. Finally, the stimulus patterns did not necessarily resemble familiar melodic excerpts, and learning bias in that sense ought to have been minimal.

Approximately three out of four responses in both categories of trichords were given after a single presentation of the stimulus pattern. Subjects did request that cue-cells be repeated slightly more often than multivalent cells, and a few commented that the cue-cells were harder to vocalize. Neverthe-

TABLE 1
Confidence Rankings

		Very Confident	Moderately Confident	Not Confident
a	Cue- Cells	65%	26%	9%
b	Multivalent Cells	44%	40%	16%

less, ratings for confidence on a three-point scale were much stronger for the cue-cells than for the multivalent cells, as is shown in Table 1.

The percentages for confidence levels seem to bear a nearly inverse relationship to accuracy (96 and 98% for multivalent cells in the two conditions, as compared to 83 and 91% for cue-cells in the two conditions). Although the higher accuracy levels for multivalent cells might seem to indicate that they are stronger tonic indicators than are cue-cells, this is not the case, since it must be considered that (1) the probability of being right by chance was much greater, (2) when taken separately none of the possible “correct” tonics for the multivalent cells was chosen more than 44% of the time, and (3) the percentages shown in Table 1 imply that subjects were well aware that their choice was not the only correct choice.

Although subjects made relatively few errors in their responses to all stimulus patterns, there were obvious patterns in those errors. Sixty-nine of the responses to the 530 cue-cells were incorrect. The three most common of those errors, accounting for 63% of all incorrect responses to cue-cells, were the misidentification of: (1) *fa* as *do* (30%), (2) *so* as *do* (16%), and (3) the tone a tritone away from *do* as the tonal center (17%). These errors support Browne’s theoretical model. The tonic and subdominant share five out of six intervallic relationships to other members of the set: both have set members a major second above, a major third above, and so on. The tonic and dominant also share five out of six intervallic relationships, but *fa* and *do* share the characteristic of having the rare interval of a minor second below them. Browne’s hypothesis that rare intervals control position finding is supported by our evidence that these two set members were those most often confused. It is expectable that increasingly similar sets of intervallic relationships would produce increasing potential for confusion. The erroneous response that confounds the tonic with the tone a tritone away, however, is quite inconsistent with responses that might be predicted by perceptual theories of tonality limited to diatonicism. We interpret that these errors, too, support Browne’s model and are a good indication of tonal thinking: if the context tone in the cue-cells were misheard, the listener

would be very likely to interpret the tritone enharmonically, and the expectable response error would be at the tritone. (See Figure 4.)

Varying degrees of formal training and performing experience bore little relationship to subjects' performance in this experiment: accuracy levels averaged separately for the eleven sophomores and the eleven graduate students and faculty in Condition I showed no significant difference in performance between the two groups; nor did averaged accuracy levels between the five sophomores and the five graduate students and faculty in Condition II.

Analyses of variance for accuracy means across the 22 subjects in Condition I indicate that context tone variations appeared to have no significant effect on response accuracy to cue-cells [$F(4,84) = 1.64, p = .172$]. Context tone variations within Condition II yielded similarly weak differences [$F(4,36) = 1.39, p = .256$]. Temporal order variations within cue-cells had a strong effect on accuracy means within Condition I [$F(1,21) = 8.90, p = .007$]. The tone-order effect was not as pronounced for responses within Condition II [$F(1,9) = .069, p = .26$], although the nearly perfect performance in the second condition obviously diminished variance.

Figure 5 illustrates the effect of tone order on response accuracy in each condition. The "x" in the figure represents the context tone (either *do*, *re*, *mi*, *so*, or *la*). Figure 5a shows that when *ti* was heard after *fa* in the cue-cell, the accuracy level was highest. Hearing the context tone last mediated the effect somewhat (Figure 5b). Accuracy levels dropped sharply when *fa* followed *ti* (Figure 5c). The lowest response accuracy levels resulted when *fa* was the final tone of the cue-cell. This finding is provocative in that it offers specific evidence for the relationship between temporal order of tones and tonal specificity. We can surmise that tonal harmonic implications were clouded by a stylistically atypical progression to a subdominant, or that, given the almost identical intervallic context of *do* and *fa* in the diatonic set, *fa* counterfeited quite well for *do*.

The finding that order of stimulus tones employed in this experiment influenced tonal specificity more than context tone did suggests strongly that any structural hierarchy that inheres within the diatonic set has greatest perceptual validity when time-order variables are taken into account; some sequences of tones represent harmonic motion more commonly encountered in tonal music than others do.⁴

Two intriguing questions emerged from this experiment. First, is it possible to define the time-order effect on tonal ambiguity with more precision,

4. A pilot study by Dougherty (1982) indicates that manipulation of rhythmic relationships among components of multivalent trichords strongly affects the listener's choice of tonic.

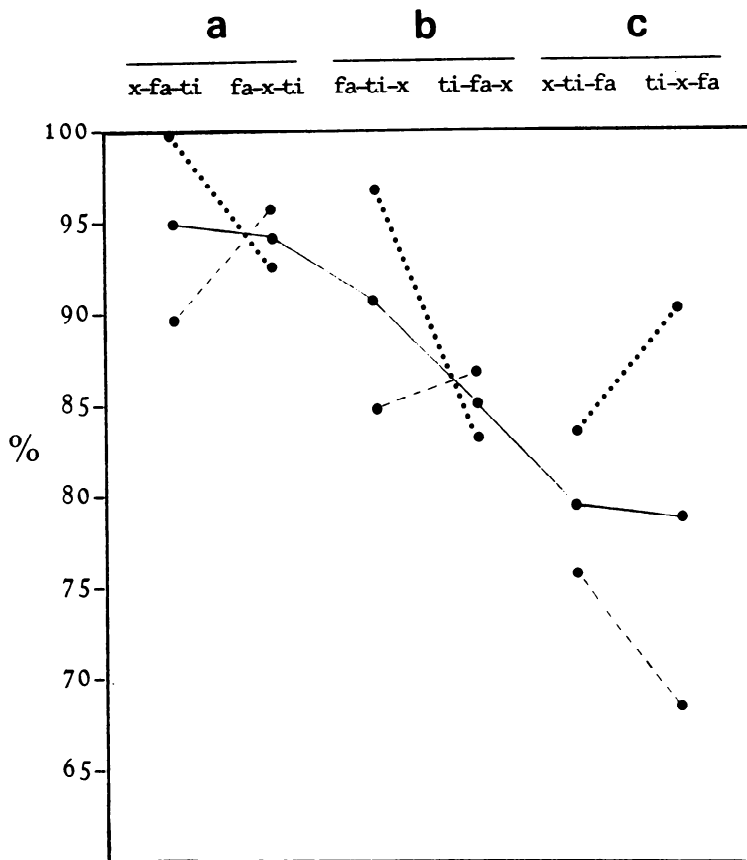


Fig. 5. Order effects within cue-cells as shown by response accuracy percentages for Condition I (broken line), Condition II (dotted line), and averaged for the two conditions (solid line). The symbol "x" represents the context tone *do*, *re*, *mi*, *so*, or *la* added to patterns where (a) *ti* was heard last, (b) the context tone was heard last, and (c) *fa* was heard last.

or was this effect anomalous? Replication and improved definition of this effect would increase support for the hypothesis that the rare intervals of the set, when arranged across time so that they are most easily recognized, will evoke the strongest and most accurate tonic identification response. Second, although the subject population possessed varying levels of training and performing experience, they could be characterized as not representing a broad spectrum of listeners. If similar responses resulted from a test involving a more heterogeneous listener group, an obvious conclusion would be that the ability to recognize key center in a minute quantity of musical sound is a skill not limited to trained musicians but a skill acquired informally, a skill that can be readily applied to new musical experiences.

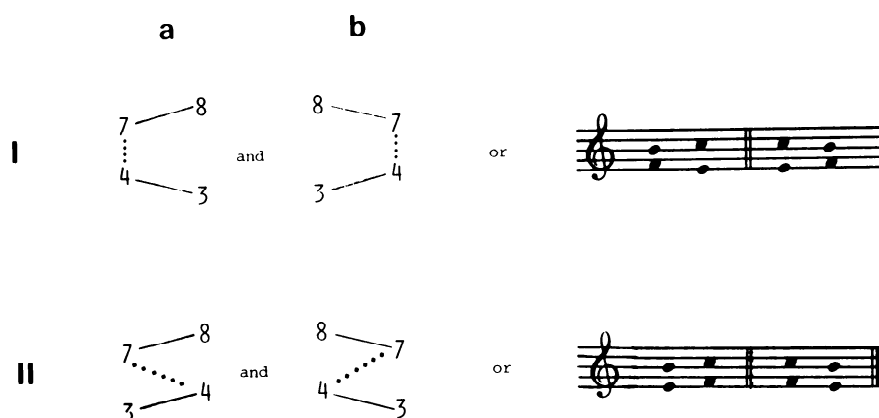


Fig. 6. Temporal orderings of the rarest intervals in the diatonic set. Condition I: *mi*, *fa*, *ti*, and *do* ordered to represent (a) dominant-to-tonic and (b) tonic-to-dominant motion. Condition II: the same set members reordered to avoid dominant/tonic interpretations.

Experiment Two

Experiment Two was designed to test two hypotheses that arose from the first experiment: (1) that temporal manipulations of identical subsets of the diatonic set would have a measurable effect on the perceptibility of their tonal center, as observed in response accuracy levels for identifications of tonic for those subsets; and (2) that this time-order effect would be observable in the responses of both musically trained and musically untrained listeners.

Method

All stimuli for this experiment were composed of the same four-member subset of the major set: *do*, *mi*, *fa*, and *ti*. These form the rarest intervals in the set: *fa* and *ti* comprise the tritone; *ti* and *do*, as well as *fa* and *mi*, the minor seconds. The tones related at these intervals had evoked the most confident and accurate judgments of tonal center in Experiment One. The four tones in each pattern were presented as a pair of dyads, arranged in one of four ways (Figure 6). In the first two arrangements, the tritone was always sounded as a simultaneity (Figure 6-I, a and b). In these orders, called Condition I below, the rarest intervals of the set occur in the closest possible temporal proximity that can be interpreted as the succession of tertian harmonies. In the third and fourth arrangements, called Condition II, the same set members were ordered so that the tritone-related tones never sounded together, nor in the same voice (See Figure 6-II, a and b), but the sequential semitone arrangement was preserved. All major keys were represented an equal number of times in each condition, ordered randomly among trials.

Each pattern was heard twice, with a 1-second pause between the two presentations. Following this, an answer tone was presented. The answer tone was doubled at the upper and lower octaves to minimize the potential for effects of registral difference. All members of the chromatic set were employed as answer tones; these were distributed equally across the stimulus categories and ordered randomly. To check for order effects between trials, trial sequence was reversed for roughly one-half of the listeners.

Subjects were instructed to judge whether each answer tone represented the major tonal center for the stimulus pattern preceding it. This two-alternative, forced-choice response task, rather than the direct judgment used in Experiment One, made it possible to test a more varied subject population. Twenty-four (Group X) of the 47 students at The Ohio State University who served as paid subjects for this experiment were graduate level music students who had accumulated an average of 10.2 years of private music instruction and an average of 13.9 years of performing experience. The remaining 23 subjects (Group Y) were enrolled in a variety of baccalaureate programs other than music, and they had accumulated an average of 2.7 years of private music instruction and an average of 2.7 years of musical performing experience.

All subjects were given a pretest that presented 10 taped excerpts from the eighteenth, nineteenth, and twentieth century tonal music literature.⁵ The response task in this pretest was the same as that in the main study: subjects were instructed to judge whether an answer tone, doubled at the upper and lower octaves, represented the tonal center for the musical excerpt that preceded it. The pretest was administered for purposes of correlation, not screening. All subjects took the test immediately after completing the pretest. Stimuli were presented to subjects in groups. Apparatus for Experiment Two was the same as in Experiment One.

Results and Discussion

Response accuracy levels for the 10-item pretest ranged from 3 to 10 correct. The mean for Group X (9.2) was higher than that for Group Y (6.0), although there was a pronounced overlap in accuracy levels between the groups: the scores within Group X ranged from 7 to 10 correct, and from 3 to 10 correct within Group Y. This overlap indicates that it is not safe to assume a music student will have a stronger sense of tonal center than a nonmusic student. The performance level of this listening skill does not necessarily equate to the listener's extent of musical training and performance experience.

Table 2 shows correlation coefficients across all listeners for the variables of response accuracy for the pretest, response accuracy for the test as a whole, and response accuracy for each of the stimulus categories (refer to Figure 6). Despite the inhibiting effect one may expect on the pretest correlations because of the small number of observations solicited in that measure, correlations among all variables were quite strong, and all were found to be significant at the .01 level or beyond. There is a strong relationship between performance on the pretest and the test as a whole. The relationship between performance on the pretest and Condition I is considerably greater

5. Tape recordings were made of short (12–18 seconds in duration) nonmodulatory phrases arbitrarily selected from these compositions: (1) Copland, *Fanfare for the Common Man*; (2) Mozart, *Sonata in A Minor*, K. 310 (Movement I); (3) Haydn, *Symphony No. 45* (Movement I); (4) Tchaikovsky, *The Nutcracker* (“Trepak”); (5) R. Strauss, *Till Eulenspiegel's Merry Pranks*; (6) Mozart, *Serenade*, K. 525 (Movement I); (7) Beethoven, *Sonata*, Opus 14, No. 1 (Movement I); (8) Brahms, *Intermezzo*, Opus 118, No. 4; (9) Beethoven, *Symphony No. 9*, Opus 125 (Movement II); (10) Haydn, *Mass in Time of War* (“Sanctus”).

TABLE 2
Response Correlations, All Subjects

	Test	Condition I		Condition II	
		ti-do fa-mi	do-ti mi-fa	ti-do mi-fa	do-ti fa-mi
Pretest	.763*	.753*	.727*	.541*	.538*
Condition I					
ti-do fa-mi			.681*	.519*	.522*
do-ti mi-fa				.581*	.570*
Condition II					
ti-do mi-fa					.766*

NOTE. Correlation coefficients across subjects (*N* = 47) are shown for the variables of response accuracy in the pretest, response accuracy in the test, and response accuracy for the separate stimulus and condition categories within the test.
**p* < .01.

than that between the pretest and Condition II. Probability levels for these correlations were significant beyond the .01 level.

These correlations remain quite stable among the variables when responses from Groups X and Y are compared, as in Table 3, although relationships are generally weaker, and levels of significance are greatly diminished for the responses given by Group Y (shown in the lower left) than for Group X (shown in the upper right).

Table 4a shows response accuracy means for the different stimulus categories, with 12 trials per category, figured for Groups X and Y. The means for Group X approach the perfect mark for Condition I and drop noticeably for Condition II. Group Y response accuracy means are sharply lower on the whole, and the condition effect within this group is weak to nonexistent. A three-way analysis of variance was performed on means for Groups X and Y using stimulus categories (See Figure 6a and b) and condition categories (See Figure 6-I and -II) as repeated measures. Differences between group means and between condition means were found to be significant, as is shown in Table 4b. Differences between stimulus means were not significant (Table 4b), indicating that semitone motion itself is not sufficient to articulate the dominant level—the vital information in tonic identification. It does seem clear that musical training and performing experience help listeners recognize intervallic relationships ordered to represent harmonic motion to or from the dominant level.

TABLE 3
Response Correlations, Musicians and Nonmusicians

Listener Group Y (N = 23)	Listener Group X (N = 24)					
	Pretest	Test	Condition I		Condition II	
			ti-do fa-mi	do-ti mi-fa	ti-do mi-fa	do-ti fa-mi
Pretest		.691*	.585*	.674*	.484	.635*
Test	.426		.762*	.786*	.925*	.920*
Condition I						
ti-do fa-mi	.377	.619*		.529*	.627*	.567*
do-ti mi-fa	.465	.630*	.427		.587*	.599*
Condition II						
ti-do mi-fa	.178	.624*	.001	.179		.878*
do-ti fa-mi	.152	.748*	.160	.212	.489	

NOTE. Correlation coefficients are shown for response accuracy in the pretest, test, and separate stimulus and condition categories within the test for music student and nonmusic student listeners.
**p* < .01.

Because earlier informal inspection of responses to the pretest had indicated that some overlap existed in response accuracy levels for the two subject groups, it was sensible to determine whether this overlap extended to the test scores. Accuracy means were calculated by category for those listeners who had obtained a perfect score on the pretest, and these were compared with the means calculated for subjects who had made one or more response errors on the pretest. These means, shown in Table 5a, indicate that pretest scores are better predictors of performance on the test than is knowledge of the extent of the listener's formal music training and performing experience. A three-way analysis of variance was performed on these means using stimulus categories and condition categories as repeated measures. Differences between group means and between condition categories were found to be greater than those for the musician/nonmusician differences, as is shown in Table 5b. Differences between stimulus means were less pronounced than those in the musician/nonmusician comparison. Test results substantiated the hypothesis that variations of time-ordering of identical diatonic subsets would affect the perceptibility of tonal center for those subsets. Patterns that contained a simultaneously sounded tritone elicited significantly higher accuracy levels for judgments of tonal center in

TABLE 4
Response Accuracy Means, Musicians and Nonmusicians

a	Condition I			Condition II		
	(a)	ti fa mi	do mi	ti mi fa	do fa mi	
Music Students (Group X) N = 24 Group Mean = 9.89			11.17		9.29	
	(b)	do mi fa	ti fa mi	do fa mi	ti mi fa	8.58
Group Mean by Condition			10.84		8.93	
Nonmusic Students (Group Y) N = 23 Group Mean = 7.05			6.91		7.04	
	(b)	do mi fa	ti fa mi	do fa mi	ti mi fa	6.22
Group Mean by Condition			7.48		6.63	
Averaged Group Mean by Condition			9.16		7.78	

b					
	Source	DF	SS	F	p > F
	Group X Mean, Group Y Mean	1	376.53	38.51	0.0001
	Condition I Mean, Condition II Mean	1	88.41	23.04	0.0001
	Stimulus (a) Mean, Stimulus (b) Mean	1	3.37	2.03	0.1612

NOTE. (a) Response accuracy means (perfect score = 12) are shown for music (Group X) and nonmusic (Group Y) students; (b) a three-way ANOVA was calculated for these means using stimulus categories and condition categories as repeated measures.

TABLE 5
Response Accuracy Means Compared to Pretest Accuracy

a	Condition I			Condition II		
Listeners with Perfect Pretest Scores (N = 16) Group Mean = 10.72	(a)	ti do fa mi	11.63	ti do mi fa		9.94
	(b)	do ti mi fa	11.38	do ti fa mi		9.94
	Group Mean by Condition		11.51			9.94
Listeners with Imperfect Pretest Scores (N = 31) Group Mean = 7.36	(a)	ti do fa mi	7.77	ti do mi fa		7.29
	(b)	do ti mi fa	8.23	do ti fa mi		6.13
	Group Mean by Condition		8.0			6.71
Averaged Group Mean by Condition			9.75			8.33
b	Source	DF	SS	F	p > F	
	Perfect Pretest Group Mean, Imperfect Pretest Group Mean	1	477.68	63.44	0.0001	
	Condition I Mean, Condition II Mean	1	83.89	20.91	0.0001	
	Stimulus (a) Mean, Stimulus (b) Mean	1	2.43	1.33	0.2553	

NOTE. (a) Response accuracy means (perfect score = 12) are shown for subjects who had accumulated perfect (N = 16) and imperfect (N = 31) scores on the pretest; (b) a three-way ANOVA was calculated for these means using stimulus categories and condition categories as repeated measures.

Experiment Two than did patterns in which the tritone was presented sequentially and obscured by the voice leading. This indicates that—for aural presentation of tonal music—the perception of tonal center is predicated not on a structural hierarchy of pitches, but on a functional hierarchy formed by the perceptual prominence of their intervallic relationships.

Conclusion

A listener's awareness of the relations of pitches within a tonal framework involves the recognition of the rare intervallic relationships among the tones heard. The evidence presented here shows that these relationships, expressed conventionally in musical time, constitute an archetypal harmonic motion in tonal music. Listeners' confusions were greatest when the archetype was not present: in Experiment One, stimuli in which the syllable *ti* preceded *fa*, a sequence that does not represent a common tonal juxtaposition; and in Experiment Two when the dyads were paired so that the tritone was least prominent. Manipulation of tones related by rare intervals can obscure those relationships, thus making the tonal center less obvious. An abundance of tones related by rare intervals can make a passage rich in tonal center cues (Butler, 1980; Browne, 1981), offering the listener a wide array of possible tonics.

While formal training certainly appears to improve performance on this sort of test, it would be imprudent to assert that this sort of listening ability is confined to a highly trained elite group. Inasmuch as response accuracy levels for the pretest in Experiment Two, in which excerpts from the tonal music literature were presented, indicate that a great degree of overlap in proficiency in tonic identification exists between musician and nonmusician groups, we should be aware that "musical" test subjects may occasionally give us surprising listening responses, especially if our tasks are musically sophisticated and our methods for selecting musical subjects are not. Panion (1983) has found that few well-known standardized tests of musical listening abilities make any attempt to isolate and measure the listener's capacity to discern the key level of a musical specimen. Panion also has found some evidence that this ability shows a strong correlation with a listener's ability to recognize and/or reproduce tonal melodies.

The results of both experiments reported here support the theory that tonality, if it is to be perceived unequivocally, must reside in a system of intervallic contexts. These contexts underlie the cognitive awareness of tonal harmonic motion. It should be noted that this harmonic context does not rely solely on chords. In fact, subjects in these studies obviously heard sufficient harmonic context in three-tone series and in pairs of dyads that they were able to make confident and accurate identifications of tonal center.

The perceptibility of tonality results not from a structural hierarchy that obtains within a precompositional set but from the listener's recognition of relationships when tones are arranged in musical time; that is, functional harmonic motion.

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