Rhythm and "good endings": Effects of temporal structure on tonality judgments

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The purpose of the present experiment was to investigate the influence of rhythmic structure on the perception of tonal relationships marking the end of a melody. Musically sophisticated listeners were asked to rate the degree of resolution in a set of folk tunes that varied in their tonal ending and temporal accent structure. The results indicated that melodies ending on the leading tone-to-tonic progression were judged the most complete, while the least complete were those leaving a listener "hanging" by ending on the leading tone note. These ratings, however, were influenced by the temporal accent structure of a tune. The highest degree of resolution was observed for melodies that ended "on time" through an invariant pattern of temporal/melodic accents. Accent structures that led to endings occurring earlier or later than expected resulted in significantly lower resolution ratings. The present results illustrate the need to incorporate dynamic pattern influences into models of tonal perception.

In the natural environment, there are many situations in which an individual must coordinate the onset of one's motor behavior with the offset of another's. And perhaps the most striking feature of such events is the smoothness and continuity with which this interchange of motor gestures occurs. Witness, for example, the smooth exchange of speaking roles in interactive speech or the uninterrupted flow from one lead instrument to another during a concert performance. These phenomena suggest that many natural events contain nonarbitrary endings, and that listeners are able to use the event's unfolding context to anticipate "when" this ending will occur. One purpose of the present research was to consider how rhythmic structure may generate expectancies about the future course of an event, including when in time it should end. A second goal was to examine whether the perception of tonal relationships is influenced by a melody's preceding rhythmic context.

Tonal Relations and Melodic Completion

The study of event completion is well suited to the medium of music since most compositions of Western music (from the past two centuries) end on a leading tone-to-tonic progression. The tonic refers to the underlying key in which a melody is based. For example, the melody shown in Figure 1A is based on the C-major tonal system and thus ends on the note C. Of course, the tonic can and does recur throughout the course of a tune and so to

communicate a true sense of finality, a composer will mark melodic completion in two additional ways. First, the "leading tone" typically precedes the final tonic in time. As its name implies, the leading tone (B in the key of C-major) occurs immediately before the tonic in a diatonic scale and, in the context of a melody, it creates the expectancy that it will lead to the final tonic. Second, the duration of the final tonic is prolonged so that it is longer than any preceding note in the melody. This convention is known as *resolution* and is tacitly understood to communicate melodic completion (Kramer, 1981; Meyer, 1956). A similar phenomenon has also been observed in speech. In declarative statements, a speaker's pitch intonation typically returns to the fundamental frequency at the end of an utterance (Cooper & Sorensen, 1977; Pike, 1945) and the duration of the final syllable is prolonged relative to the preceding context (Cooper, Paccia, & LaPointe, 1978; Lehiste, 1975; Oller, 1973; Scott, 1982). This suggests that there may be a common scheme in the auditory environment for using certain structural invariants for similar purposes.

Recent research (Boltz, in press a) has indicated that listeners are, in fact, sensitive to the structural markers of musical completion. In these studies, subjects were asked to judge the degree of "completeness" in melodic endings that varied in their functional relationship to the tonic. The results showed that melodies ending on the leading tone-to-tonic progression were judged the most complete, more so than those with a final submediant-to-tonic progression. Conversely, melodies ending on the leading tone seemed the most incomplete, to leave one "hanging," because the tonic that invariably follows in traditional music was now missing. The results of a second experiment further revealed that the perception of resolution was influenced by two contextual variables: the presence of the rare tritone interval (i.e., F-B in key of

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C-major) and the rhythmic accentuation of certain pitch intervals. When the tritone interval was present to specify the melody's underlying tonality unambiguously (Brown & Butler, 1981; Browne, 1981), the leading tone-to-tonic progression was deemed significantly more resolved. The presence of the tritone also disambiguated and reinforced the relationship of the tonic to its other tonic-triad chord members, the mediant and the dominant. These latter intervals, by bearing special harmonic relationships to the tonic, often function to resolve phrases within a melody (Kramer, 1981; Piston, 1978; Todd, 1985). Indeed, when these intervals were temporally accented in a regular fashion, they were rated as highly resolved endings to a musical composition. In sum, the overall pattern of results indicates a sensitivity both to the structural markers of musical endings and to the contextual factors that highlight a melody's tonality.

Using different methodologies, other researchers have also found that listeners appear attuned to the markers of resolution. Cuddy, Cohen, and Miller (1979) found that melodies ending on the tonic were more accurately recognized than ones ending with a random sequence of diatonic tones. With respect to resolution within a melody, Bharucha (1984) obtained evidence for melodic anchoring. He found that unstable tones (outside a melody's key) are heard as "dissonant" and "clashing" unless they are immediately followed by a tonic-triad member. Finally, Sundberg, Friberg, and Fryden (1987) demonstrated that listeners prefer melodies ending on a prolonged tonic to those lacking this final temporal prolongation.

From a theoretical perspective, the underlying processes involved in the perception of resolution can be discussed in several ways. One view stems from a model of tonal perception offered by Krumhansl (1979). According to this approach, the perception of melodic relationships is guided by an internal hierarchy of tonal stability based on a melody's underlying diatonic scale. This representation is conical in shape and is anchored by the tonic referent. Other scale members that bear special harmonic relationships to the tonic, namely, members of the tonic-triad chord (e.g., the mediant, E, and the dominant, G, in the key of C-major), are also perceived to be quite stable and are thus represented at the next immediate level. The remaining notes of the scale are found at the third level of the hierarchy, while the lowest level encompasses those notes outside the given diatonic scale. Within this theoretical framework, then, the perceived completeness of various pitch intervals is determined by their psychological distance to the tonic referent. Furthermore, pitch intervals within a given hierarchical level are assumed to be perceptually equivalent since they are equidistant from the tonic anchor. Empirical support for this model has been obtained from several tasks, including the rating of individual tones relative to contexts of ascending and descending major diatonic scales (Cuddy & Badertscher, 1987; Krumhansl, 1979; Krumhansl & Shepard, 1979), minor scales, chords, and cadences (Krumhansl & Kessler, 1982).

Although Krumhansl's model has been very successful in a variety of contexts, it does not acknowledge temporal-order relationships such as those found in musical resolution. Bharucha (1984), however, has recently extended the model to address this issue. In studying the phenomenon of melodic anchoring, Bharucha has noted that dissonant pitch intervals are often inserted into a melody for purposes of melodic embellishment. Furthermore, these intervals seem perceptually resolved if they are immediately followed by a tonic-triad member that is proximal in pitch. Given these findings, one might predict that similar principles may also apply to the perceived resolution of musical endings. However, another study (Boltz, *in press a*) has revealed that this is not the case: perceived completeness does not consistently depend on the pitch proximity of a melody's final two notes. Instead, listeners seem to base their judgments of resolution on whether the leading tone and tonic intervals are both present at the end of a tune and how they are ordered in time.

These results, along with those of Bharucha (1984), led to the suggestion that internal representations of tonality include temporal-order relationships that afford particular communicative functions to attuned listeners (Boltz, *in press a*). Some temporal-order relationships may provide melodic embellishment, whereas others seem to specify a more unique function such as indicating a melody's tonality, phrase endings, or completion. This view, then, attempts to merge approaches that emphasize internal hierarchies of cognitive structure (*à la* Krumhansl, 1979) with those that emphasize the psychological significance of natural event structure (e.g., Gibson, 1979; Mace, 1977; Michaels & Carello, 1981).

The Psychological Impact of Temporal-Event Structure

Effects of temporal-order relationships raise a more general question concerning the potential impact of dynamic pattern context on musical perception. The temporal structure of a melody, arising from the interplay of meter, rhythm, and tempo, may influence the perception of subsequent tonal relationships, as may the preceding arrangement of melodic structure. Yet many contemporary models of tonal perception have ignored this issue and have failed to consider how a melody's unfolding context may affect attending, perceiving, and remembering activities. Indeed, turn-taking behavior in conversations, musical performance, and other interactive events suggest that perceivers can "lock into" an unfolding event to anticipate its future course, including when it will end. What types of structural relationships support such anticipatory behavior, and do variations in an event's preceding context affect its perceived ending?

In the auditory environment, there appears to be multiple levels of structural change that mark the upcoming end of an event. For example, in analyses of musical performance (Gabrielsson, Bengtsson, & Gabrielsson, 1983; Shaffer, Clarke, & Todd, 1985; Todd, 1985), decreases

in loudness and tempo often signal forthcoming closure. Although these kinds of changes may prepare a listener for an ending, they do not contain information for specifying precisely when in time this end will occur. Here it is suggested that it is the rhythmic structure of events, relative to the arrangement of certain pitch intervals, that enables a listener to generate expectancies about the final note of a tune. To illustrate this concept, consider the temporal structure of music and some ways in which timing variations are functionally interleaved with a melody's pattern of pitch change.

Temporal relationships in music are typically described in terms of *meter* and *rhythm* (Apel, 1972). Meter refers to the referent beat of a melody (e.g., a quarter or an eighth note) and the grouping of beats within a mensural framework. Rhythm, on the other hand, refers to the pattern of perceived time changes within the constraints of meter. That is, some notes may receive more or fewer beats than others because their duration is changed by multiples or subdivisions of the referent beat. Rhythm is considered to be psychologically important because it creates a predictable pattern of temporal *accents*. Accents are a perceptual phenomenon in that they represent temporal loci that stand out and capture a listener's attention. On a structural basis, accents arise from several sources. In monophonic sequences, accents tend to correspond to notes that initiate a relatively lengthened interval (Povel & Essens, 1985; Povel & Okkerman, 1981) or to notes with relatively lengthened durations that, in turn, are perceived to end a rhythmic group (Garner, 1974; Vos, 1977; Woodrow, 2009). In isochronous sequences, accents can arise from notes that correspond to changes in pitch contour, pitch interval size, or tonal intervals that are members of the tonic-triad chord (Benjamin, 1984; Berry, 1976; Cooper & Meyer, 1960; Jones, 1987a; Monahan & Carterette, 1985). Despite the fact that accents can arise from either temporal or melodic origins, however, the two tend to coincide in much of Western music to yield a common hierarchy of temporal/melodic structure (Boltz & Jones, 1986; Jones 1976, 1981a, 1981b, 1981c, 1982, 1987a, 1987b; Lerdahl & Jackendoff, 1983; Monahan & Carterette, 1985; Yeston, 1976). One consequence of this convention is that accents can highlight nested levels of temporal organization within a melody (e.g., Handel & Lawson, 1983; Jones 1976, 1981a, 1981b, 1987a; Longuet-Higgins & Lee, 1982; Povel & Essens, 1985; Steedman, 1977; Yeston, 1976) and draw attention to interrelationships among individual but nonadjacent notes (Boltz & Jones, 1986; Jones 1976, 1981a, 1981b, 1981c, 1982, 1987a, 1987b; Lerdahl & Jackendoff, 1983). In addition, others have suggested that rhythm affords a more dynamic function of guiding attending activities over time (Jones, 1976, 1981a, 1981b, 1981c, 1982, Jones & Boltz, in press). Particularly in the case in which rests or lengthened event durations coincide with tonic triad members at phrase ending points (Berry, 1976; Cone, 1968; Piston, 1978), these coupled accents tend to recur after a fixed number of beats to yield a highly predictable melody.

This, in turn, not only allows a perceiver to attentionally track a melody over time but, more importantly, to extrapolate its preceding context and anticipate both the "what" and "when" of future accents. This includes expectancies about the last note because, relative to preceding accents, it too recurs after an invariant beat period and corresponds to the tonic.

Rationale of the Present Experiment

The purpose of the present experiment was to determine whether variations in the timing of rhythmic accentuation may exert a significant impact on the perceived completion of a melody. Musically sophisticated subjects were presented with a set of simple folk tunes that varied in both the pattern of temporal accentuation and the tonal relationships marking melodic ending. The subjects' task was to rate, on a 10-point scale, the degree of "completeness" for each melody.

The tonal endings for each folk tune were of four major types. In two conditions, the leading tone (i.e., B in the key of C-major) preceded a final tonic (i.e., C) or mediant (i.e., E); in the other two conditions, the temporal ordering of these notes was reversed such that the leading tone was preceded by either the tonic or the mediant. Given their different roles in marking musical endings, these various tonal relationships should generate different degrees of perceived completeness and should converge with previous results obtained by this laboratory (Boltz, in press a).

This pattern of ratings, however, is also predicted to be influenced by a melody's pattern of rhythmic accentuation. Consider Figure 1A, which depicts one melodic instance from the present experiment along with its respective variations in temporal accent structure. The first melody, labeled "Invariant," contains coupled accents that always recur after a fixed period of 8 beats. If a listener does, in fact, use this pattern of rhythmic accentuation to guide attending, then his or her expectancies about when the last note should occur will be confirmed. However, consider the melody labeled "Accent Early." This melody conforms to the previous one in its serial arrangement of pitch intervals and the rhythmic highlighting of tonic-triad members. Note, however, that the temporal relationships within accent periods (marked by half notes) have been altered so that the third and fourth accent periods contain not 8 beats, but 10 and 6 beats, respectively. Given the temporal periodicity of preceding accents, a listener should expect the last note to occur after 8 or 10 beats. However, since the last note actually occurs after only 6 beats, the melodic ending occurs earlier than expected and should therefore be perceived as more unresolved than its Invariant counterpart. A similar but somewhat attenuated effect should be obtained with the melody labeled "Accent Late." In this instance, the third period contains 6 beats before the temporal accent, leading a listener to expect the final note to occur after 8 or 6 beats. Since the ending actually occurs after 10 beats, however, the melody ends later than expected and

should therefore yield lower ratings of judged completion. Given that the melody unfolds past its expected ending point, the perceived lack of resolution should be less pronounced here than with the Accent Early melody, but should nevertheless result in significantly lower ratings.

In sum, the view advanced here is that listeners use the pattern of temporal accentuation within a melody to generate expectancies about the "what" and "when" of the last note. If a melody's structure confirms one's expectancies by ending on a "well-timed" tonic, then it should seem highly resolved. However, a sense of incompleteness should arise whenever one or both of these expectancies are violated.

One final issue concerns whether manipulations of tonal ending and temporal accent structure will yield independent or interactive influences upon perceptual judgments. Previous research has revealed both types of findings and, to some extent, this divergency may be attributed to the nature of the task at hand (Monahan & Carterette, 1985; Palmer & Krumhansl, 1987a, 1987b). In tasks that require the recall of melodic sequences, for example, listeners appear to rely on both pitch and rhythm as a unified dimension. Rhythmic patterns that conflict with melodic structure yield a much poorer performance than when the two coincide (Boltz & Jones, 1986; Deutsch, 1980). Studies involving relative duration judgments have revealed similar findings (Boltz, 1985; Boltz, in press b; Jones & Boltz, in press). Independent influences of pitch and rhythm, on the other hand, have emerged primarily in tasks that require perceptual judgments—both structures affect behavior but in an additive, noninteractive fashion (Monahan & Carterette, 1985; Palmer & Krumhansl, 1987a, 1987b). The issue becomes clouded, however, by the conflicting results obtained in melody-recognition tasks. Whereas Monahan, Kendall, and Carterette (1987) have reported evidence for independence, studies by Jones, Maser, and Kidd (1978), Jones, Boltz, and Kidd (1982), and Kidd, Boltz, and Jones (1984) have all reported interactive influences. Thus, although task requirements may play a role in determining the relative impact of pitch and rhythm, other factors also appear to contribute an unacknowledged influence.

Given this backdrop, the present experiment may reveal two potential patterns of results. If completeness ratings converge with the results of other perceptual-judgment tasks, then rhythm and tonal ending should exert independent effects (i.e., main effects but no interaction). Conversely, tonal ending and rhythm may interact with one another such that violations of joint expectancies exert an effect beyond the additive combination of violated single expectancies. That is, the sense of melodic incompleteness may intensify when both the "what" and the "when" of the last note are violated, compared with the effects shown when one or the other is violated alone. Regardless of their additive or interactive nature, however, significant effects of both rhythmic structure and temporal ordering of tonal relationships would demon-

strate the need to incorporate dynamic pattern influences into models of tonal perception. To explore these issues, the following experiment was conducted.

METHOD

Subjects

Twenty-four subjects from an introductory psychology course at Ohio State University participated in the experiment in return for course credit. Each subject had at least 4 years of musical experience within the past 6 years and was currently playing a musical instrument. Twelve subjects were randomly assigned to each of the two counterbalance orders.

Design

The design was a $4 \times 3 \times 3 \times 2$ mixed factorial. Four levels of tonal ending (leading tone to tonic, tonic to leading tone, leading tone to mediant, mediant to leading tone) were crossed with three levels of temporal-accent structure (Invariant, Accent Early, Accent Late) and three melodic instances. Two levels of counterbalance order served as the single between-subjects factor.

Stimulus Materials

Excerpts of three folk tunes were selected from a musical composition book.¹ The titles of these tunes were "Softly Now the Light of Day" by G. Doane; "There's Music in the Air" by G. Root; and "I Don't Want to Play in Your Yard" by H. W. Petrie. To highlight the melody's underlying key, each melody was modified so that (1) the first and last notes were always the tonic, and (2) the rare tritone interval, reported to be a strong indicant of a melody's tonality (Browne, 1981; Butler & Brown, 1984), occurred in both the first and the final accent periods of a tune.

As seen in Figure 1, these melodies represent a somewhat diverse range of music in that they differ in total number of notes (range = 34 to 37), meter (2/4, 4/4); and musical key (C-, G-, F-major). However, all three melodies contain an invariant number of beats between agogic accents (i.e., 8 beats); accents that are members of the melody's tonic-triad chord (i.e., the tonic and mediant); the same event duration and intertone interval for half notes (400 and 200 msec, respectively); quarter notes (i.e., 200 and 100 msec), and eighth notes (100 and 50 msec); and a final tonic whose event duration was always doubled relative to that of a half note (i.e., 800 msec).

The tonal ending of these three melodies was varied to obtain four different experimental conditions. The leading tone acted as the penultimate note for two conditions: in one condition it preceded the final tonic, in the other it preceded the mediant. In the two remaining conditions, the temporal order of the final two notes was reversed so that the leading tone was preceded by either the tonic or the mediant.

The temporal accent structure of this set of 12 melodies was also varied. The three tunes in their original versions all contained an invariant number of beats (i.e., 8 beats) between agogic accents. In the Accent Late condition, however, the temporal structure of the third and fourth accent periods was altered such that the number of beats was 6 and 10, respectively. Conversely, the temporal structure of the third and fourth accent periods was adjusted in the Accent Early condition to contain 10 and 6 beats, respectively. Thus, relative to the preceding accent periods, the final phrase ending within these two types of melodies occurred either "too late" or "too early," despite the fact that all variants were of the same total duration and contained the same total number of beats. The melodies and their respective variants are shown in Figure 1.

By factorially crossing the three melodic instances with the four types of tonal endings and the three levels of temporal accent struc-

A. Excerpt from "Softly Now the Light of Day" by G. Doane

Invariant 8 Beats 8 Beats 8 Beats 8 Beats

Accent Early 8 Beats 8 Beats 10 Beats 6 Beats

Accent Late 8 Beats 8 Beats 6 Beats 10 Beats

B. Excerpt from "There's Music in the Air" by G. Root

Invariant 8 Beats 8 Beats 8 Beats 8 Beats

Accent Early 8 Beats 8 Beats 10 Beats 6 Beats

Accent Late 8 Beats 8 Beats 6 Beats 10 Beats

C. Excerpt from "I Don't Want To Play in Your Yard" by H.W. Petrie

Invariant 8 Beats 8 Beats 8 Beats 8 Beats

Accent Early 8 Beats 8 Beats 10 Beats 6 Beats

Accent Late 8 Beats 8 Beats 6 Beats 10 Beats

Figure 1. The set of folk tunes and their respective rhythmic variants used as experimental stimuli. In Panel A, the melody labeled Invariant illustrates the concept of resolution, in that the melody both begins and ends on the tonic note, C. In addition, this melody displays two other structural characteristics commonly found in Western music: the temporal accentuation (half notes) of tonic-triad members (here the tonic, C, and the mediant, E), and a recurrent periodicity of these coupled accents after an invariant number of beats (i.e., 8 beats). The temporal predictability of these coupled accents allows a listener to generate expectancies about the "what" and "when" of upcoming accents which, here, are reliably confirmed. The Accent Early melody also contains coupled accents, but the timing of accents in the third and fourth periods has been manipulated so that the ending of the melody occurs earlier than expected. Similarly, the temporal regularity of accents in the Accent Late melody has been varied so that the melodic ending occurs later than expected. Similar concepts are illustrated in Panel B (tonic note, G) and Panel C (tonic note, F). (Adapted from *The International Library of Music: Album of the World's Best Home Songs* [pp. 54, 124, and 236] by The Editorial Board of The University Society, 1964, New York: The University Society, Inc.)

ture, a total of 36 experimental patterns resulted. Trials were randomized into two blocks of 36 trials, yielding two presentations of each melody for a given subject.

Apparatus

All melodies consisted of square-wave tones generated by a Wave-tek 159 waveform generator controlled by a PDP-11 microcomputer. A custom-built envelope generator imposed 10-msec rise and fall times on all tones. Tonal frequencies, in Hertz, were taken from the equally tempered scale of International Pitch ($A_4 = 440$ Hz) and were subjectively equated for loudness in the actual experimental context according to the reports of two judges. Sequences of tones, programmed by the microcomputer, were recorded on a Nakamichi LX-3 cassette recorder. During an experimental session, blocks of prerecorded melodies were presented on a Tandberg TCD 310MK II cassette player through AKG K400 headphones at a comfortable listening level.

Procedure

Recorded instructions informed the subjects of pattern presentation details and task requirements. On each trial, a 1-sec warning tone (5000 Hz) preceded a melody by 2 sec. During a 5-sec response interval, the subjects were asked to rate the melody for its degree of "completeness." A complete melody was described as "having a sense of finality because it sounds in fact like it is over." Conversely, an incomplete melody was described as "leaving us hanging because it lacks a sense of closure." Judgments were indicated on a response sheet containing a 10-point scale in which values of 1, 2, or 3 indicated that a melody seemed very complete, and values of 8, 9, or 10 indicated that the melody seemed incomplete. The subjects were encouraged to use the entire range of each rating scale to represent their judgments.

After receiving four practice trials, the subjects were presented with two blocks of 36 experimental trials with a brief rest between blocks. The subjects were tested in small groups of 2-3 individuals, and each entire experimental session was approximately 45 min in duration.

RESULTS

Mean ratings of melodic completeness were collapsed over replication trials and are depicted in Table 1 as a function of tonal ending and temporal accent structure. Means were also collapsed over melody and counterbalance order since both factors contributed negligible effects ($F < 1.00$).

One major prediction of this experiment was that the perceived finality of a tune would vary according to the tonal properties of the final note. A main effect for tonal

ending revealed that this was indeed the case [$F(3,66) = 141.90$, $MS_e = .942$, $p < .0001$]. As predicted, melodies that ended on the leading tone-to-tonic progression were rated the most complete ($p < .01$ for all Tukey post hoc comparisons). Similarly, melodies that ended on the leading tone-to-median progression, which often functions to resolve phrases within a tune, were also judged quite complete and received intermediate ratings ($p < .01$ for all post hoc tests). The most incomplete melodies were those that ended on the leading tone, regardless of whether this final note was preceded by the tonic or the median ($p > .05$).

The results also indicated a significant main effect for temporal accent structure [$F(2,44) = 69.78$, $MS_e = .347$, $p < .0001$]. Overall, melodies in the Accent Early and Accent Late conditions were judged significantly less complete than those with invariantly timed accents ($p < .01$). The most incomplete melodies were those with accent periodicities that led to endings occurring earlier than expected (i.e., Accent Early); this temporal accent structure produced lower ratings of resolution than did the Accent Late condition, in which endings occurred later than expected ($p < .01$ for all post hoc tests).

Finally, there was also a significant interaction between tonal ending and temporal accent structure [$F(6,132) = 2.89$, $MS_e = .411$, $p < .015$]. Relative to invariantly timed accents, noninvariant timing (i.e., Accent Early and Accent Late) exerted a greater impact on melodies ending on the leading tone than on those ending on the tonic or median ($p < .01$ for all post hoc tests). Of the 24 subjects in this experiment, 17 showed this effect. Thus, violations of joint expectancies in both the tonality and the relative timing of the last note led to significantly lower completeness ratings than did violations of each alone.

DISCUSSION

The present experiment indicates that the perceptual markers of musical completion involve at least two types of structural information. One structural determinant is the temporal ordering of tonal relationships at the end of a tune with a regard for the functions that these intervals typically perform in musical compositions. In accordance with their role of marking melody and phrase endings,

Table 1
Mean Rating and Standard Deviation of Judged Completedness for Melodies as a Function of Tonal Ending and Temporal Accent Structure

Tonal Ending and Temporal Accent Structure									
Temporal Accents	Tonal Ending								Mean
	Leading Tone to Tonic		Leading Tone to Mediant		Tonic to Leading Tone		Mediant to Leading Tone		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Invariant	1.40	.45	3.84	.70	5.42	.88	5.15	.96	3.95
Accent Late	2.63	.55	4.43	.71	7.21	.60	6.68	.95	5.24
Accent Early	3.62	.66	5.15	1.04	7.96	.66	7.47	1.36	6.05
Mean	2.55		4.47		6.86		6.43		

Note—Lower values indicate a higher degree of musical completion.

the leading tone-to-tonic progression yielded the highest ratings of perceived completion, followed by the leading tone-to-median endings, respectively. Similarly, a sensitivity to the role of the leading tone in signaling an immediate return to tonicity was reflected in ratings of low resolution when it occurred as the last note of a tune. In short, listeners of Western music appear to be attuned to the communicative functions of certain tonal relationships that occur at particular locations in a tune.

The second structural determinant of melodic completion is a melody's preceding rhythmic context. Melodies were perceived to be the most complete when they ended "on time," with the same temporal periodicity as preceding accent spans. In contrast, melodies were rated significantly less complete when deviations in accent periodicity led to endings that occurred "too late" or "too early." This effect was particularly enhanced for melodies in the latter condition, presumably because their last notes appeared before the expected ending time. However, an equally viable explanation is that notes in the final accent period of these tunes were unfolding at a relatively faster rate toward an end that therefore seemed "abrupt," particularly when the ending of most musical performances is typically preceded by a deceleration in tempo (Gabrielsson, Bengtsson, & Gabrielsson, 1983; Shaffer, Clarke, & Todd, 1985; Todd, 1985). Future investigations may disentangle these two possibilities by equating the tempo of melodies that end earlier or later than expected.

Finally, the significant interaction between tonal ending and temporal accent structure indicates that the effects arising from violated expectancies concerning both the "what" and the "when" of the last note were greater than those predicted from a simple additive combination of violated single expectancies. This finding suggests that listeners perceive a melody as relatively more complete when it ends either on a tonic-triad member or after a well-timed beat periodicity. However, the absence of both structural markers results in a significantly greater lack of perceived resolution. This finding converges with those of other studies showing that behavior is more adversely affected by the violation of joint expectancies than by the violation of single expectancies alone (e.g., Jones, Boltz, & Kidd, 1982; Jones, Maser, & Kidd, 1978; Kidd, Boltz, & Jones, 1984).

These results raise two important issues in the study of music cognition. The first issue involves acknowledging the various functions of rhythm and incorporating these into models of tonal perception. As noted by a variety of researchers (Jones, 1976, 1981a, 1981b, 1987a, 1987b; Monahan & Carterette, 1985; Monahan, Kendall, & Carterette, 1987; Yeston, 1976), perhaps one of the more fundamental roles of rhythm is that it can reveal the particular arrangement of melodic structure. Given that rhythmic structure coincides with melodic relationships, a listener is able to discern the underlying organization of a melody and can relate both adjacent and nonadjacent pitch intervals to a unified, coherent scheme. And given that temporal accents tend to coincide with tonic-triad

members that mark phrase endings, such unified structures will highlight a melody's underlying tonality. Indeed, it has been shown that such accentuation does increase the perceived completeness of melodic endings (Boltz, 1989, *in press a*), and that temporal structures that conflict with melodic arrangements result in significantly lower ratings of phrase completeness (Palmer & Krumhansl, 1987a, 1987b).

Beyond its role of highlighting melodic organization and underlying tonality, however, rhythm appears to perform a more dynamic function in melody perception. In her theoretical model of rhythmic attending, Jones (1976, 1981b, 1982, 1987a, 1987b) has proposed that a common hierarchy of melodic/rhythmic structure allows a listener to "lock into" an event to ensure attentional tracking over time. More importantly, however, such structures provide a basis for preparatory attending since a listener is able to extrapolate the preceding context of an event and generate expectancies about the "what" and the "when" of upcoming tonal relationships. Previous research by Povel (1985) has shown that violations of the "when" increase experienced tension in listeners. In the present study, it was shown that violations of both expectancies have a significant impact on the perceived completeness of melodic endings. Temporal structure thus affects the tonal stability of intervals in the underlying tonality scheme of a melody and the effectiveness of their role in marking melodic completion.

These results ultimately suggest a dynamic model of tonal perception where the unfolding temporal and melodic context of a melody may affect the instantiation of a given tonality scheme, as well as the psychological distance among tonal intervals and the functions they perform in Western music. Although the specifics of such an approach are beyond the scope of this paper, perhaps the most promising route is to envision a dynamic schema of music cognition in which the pickup of information and subsequent remembering activities are influenced by the structure of the event itself. This notion has been previously suggested (e.g., Bharucha, 1987; Dowling & Harwood, 1986; Jones, 1982) but is in need of further theoretical exploration and development.

The final issue that merits consideration involves the additive versus interactive influences of pitch and rhythm. The present study revealed an interaction between the two types of structure, a finding that conflicts with previous research involving perceptual-judgment tasks (Monahan & Carterette, 1985; Palmer & Krumhansl, 1987a, 1987b). In particular, the present findings conflict with those of Palmer and Krumhansl who also examined completeness ratings for melodic phrase endings. One source of this discrepancy may relate to methodological differences and the ways in which pitch and rhythm were manipulated. In the Palmer and Krumhansl experiments, temporal manipulations applied to the entire melodic line of a tune. In contrast, the present experiment varied temporal accent structure only within the final accent periodicities of a tune; pitch and temporal structure always coincided within the initial context of a melody. Thus, this initial

context may have encouraged a reliance on both temporal and tonal accents that continued throughout the course of a melody. Furthermore, in the present experiment all variants were presented in a randomized fashion, in contrast to the blocked format of Palmer and Krumhansl. These differential formats may account for some of the divergency in the results of these studies. Monahan and Carterette (1985), who assessed similarity ratings among melodies, also pointed out several methodological features of their studies that may have contributed to the observed additivity in their results.

However, the fundamental problem remains specifying those situations in which pitch and rhythm will exert additive or interactive influences upon behavior. Perhaps this does depend on processing and capacity limitations, as suggested by Monahan and Carterette (1985) and by Palmer and Krumhansl (1987a, 1987b). Alternatively, it may depend on the way particular event structures and task situations encourage listeners to *actively* use pitch and rhythm. That is, interactive effects may emerge when temporal and melodic structures coincide and allow a listener to generate dynamic expectancies about the future course of an event. Additional research is needed to clarify this issue, which, in turn, may deepen our understanding of the various functions rhythm performs in attending, perceiving, and remembering activities.

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NOTE

1. The original versions of these folk tunes were selected from *The International Library of Music: Albums of the World's Best Home Songs*, prepared under the supervision of the Editorial Board of the University Society, 1964. New York: The University Society.

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