What Is a Cadence?

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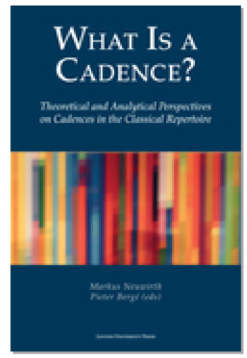

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THE PERCEPTION OF CADENTIAL CLOSURE*

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How does music end? This question has occupied a central position in music scholarship for centuries. The eighteenth-century cadence perhaps best exemplifies this point, as it is a foundational concept in the *Formenlehre* tradition that continues to receive attention and undergo refinement by the scholarly community. Indeed, the revival of interest in theories of musical form over the last few decades has prompted a number of studies that reconsider previously accepted explanations of how composers articulate cadences in the classical period,[1] that classify instances in which cadential arrival fails to materialize,[2] and that situate the concept of cadence within a broader understanding of both tonal and formal closure.[3] Yet despite such intense theoretical scrutiny, it remains unclear how cadential patterns are represented in the mind, how they are perceived and remembered, and finally, how the various features of cadences contribute to the experience of closure. In the pages that follow I will first review the treatment of closure in music psychology and then summarize a study I conducted with William E. Caplin and Stephen McAdams that investigates the perception of cadential closure using examples drawn from Mozart's keyboard works.[4] I will conclude by discussing the impact of musical expertise on the many issues surrounding hierarchical models of cadential strength.

While the systematic study of listening behavior normally rests outside the sandbox of music theory, scholars nonetheless remain highly sensitive to the potential effects of ending formulæ on listeners. Descriptions of cadential arrival as a moment of rest, finality, or repose—terms that abound in the history of theory—imply that closure is inherently *felt* during the act of listening. Heinrich Christoph Koch, a theorist and contemporary of Haydn and Mozart known today for his contributions to the theory of musical form, notably referred to such moments as "resting points of the

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1. Caplin, "The Classical Cadence" (2004), 51–117.
2. Schmalfeldt, "Cadential Processes" (1992), 1–52; Hatten, "Interpreting Deception in Music" (1992), 31–50; Caplin, *Classical Form* (1998), 101–111; Hepokoski and Darcy, *Elements* (2006), 150–179.
3. Anson-Cartwright, "Concepts of Closure in Tonal Music" (2007), 1–17.
4. Sears, Caplin, and McAdams, "Perceiving the Classical Cadence" (2014), 397–417.

spirit," noting that "only feeling can determine both the places where resting points occur in the melody and also the nature of these resting points."[5] By referring to "the spirit," Koch thus implies that closure is not an external property of the sounding stimulus, but instead is determined internally by the listener.

Some two centuries later, many theorists have accounted for the perception of closure by appealing to theories of expectation. Leonard Meyer, attempting to relate emotional experience with listener expectations, considered the classical cadence the quintessential compositional device for eliciting specific expectations. Following the first musical example of his book *Emotion and Meaning in Music* (see Example 1), he writes,

> In Western music of the eighteenth century, for example, we expect a specific chord, namely, the tonic (C major), to follow this sequence of harmonies [...]. Furthermore, the consequent chord is expected to arrive at a particular time, i.e., on the first beat of the next measure. Of course, the consequent which is actually forthcoming, though it must be possible within the style, need not be the one which was specifically expected. Nor is it necessary that the consequent arrive at the expected time. It may arrive too soon or it may be delayed. But no matter which of these forms the consequent actually takes, the crucial point to be noted is that the ultimate and particular effect of the total pattern is clearly conditioned by the specificity of the original expectation.[6]

Example 1: A cadential progression, reproduced here from Example 1 of Meyer's *Emotion and Meaning in Music* (1956), 25

Hence, a cadence, or more precisely, the progression preceding cadential arrival, elicits very definite expectations concerning the melodic scale-degree, the harmony, and the metric position of the goal event. The moment of cadential arrival, on the contrary, elicits no further expectations with respect to these parameters.[7] This absence

5. Koch, *Versuch* II (1787), 342–349 (= *Introductory Essay* [1983], 1–3).
6. Meyer, *Emotion and Meaning in Music* (1956), 25f.
7. Depending on the formal or generic context, however, this point does not preclude the possibility that we may generate expectations for the initiation of subsequently new processes following a cadential goal, such as the prolongation of dominant harmony following a half cadence or the onset of codettas following a perfect authentic cadence. I employ the term 'expectation' rather narrowly in this instance to refer to the musical parameters that characterize a cadential goal, but I acknowledge that the possible types of expectation experienced during music listening are wide-ranging. For a discussion of the diverse applications of the term in music discourse, see Margulis, "Surprise and Listening Ahead" (2007), 197–217.

of expectancy following cadential arrival led Eugene Narmour to describe cadential arrival as a “nonimplicative context,” or, to use Elizabeth Margulis’s expression, as an event that suppresses expectancy.[8] These authors might therefore suggest that terms like rest, finality, and repose result from a desire to characterize the cessation of expectancy following cadential arrival. David Huron summarizes this point nicely: “When there cease to be expectations about what may happen next, it makes sense for brains to experience a sense of the loss of forward continuation—a loss of momentum, of will, determination or goal. In short, it makes sense for brains to experience a sense of repose or quiescence whenever the implications cease.”[9]

But how do such expectations form? The most frequent answer given by theorists and psychologists infers a causal relationship between a statistically probable event and an expected event.[10] Because cadences appear frequently and their underlying harmonic and melodic characteristics remain fairly consistent, listeners learn over repeated exposure to expect these endings. A theory of expectation is therefore appealing to the study of cadence because it provides a direct, causal link between events on the musical surface and the behavioral and neurophysiological responses of the listening subject. Yet since listeners often differ in how they experience a given musical excerpt, the study of closure may benefit from a hybrid approach in which both the music *and* the listener represent the objects of study.

Although the term ‘cadence’ appears frequently in the music psychology literature as a perceptually-relevant concept, little experimental research explicitly investigates the perception of cadential closure. Instead, a vast number of studies employ cadences and other ending formulæ as stimuli under the assumption that the experience of closure during music listening is simply a by-product of more general cognitive processes. Questions as to how listeners store cognitive representations of harmonic, tonal, and rhythmic structure in long-term memory, as well as to how these mental representations affect various aspects of music perception (e.g., the formation of expectations during music listening, the perception of dynamic variations in tension, etc.), continue to resonate with music psychologists, resulting in considerably fewer studies devoted to the perception of closure itself.[11]

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8. Margulis, “Melodic Expectation” (2003), 263. If I may echo Margulis’ sentiment, Narmour’s concept of closure is complex, but his claim is essentially that non-closural events, such as the leading tone, elicit intense and very specific implications, while closural events, such as the moment of cadential arrival, suppress further implications. Narmour, “Analyzing Form and Measuring Perceptual Content in Mozart’s Sonata K. 282” (1996), 265–318.
9. Huron, *Sweet Anticipation* (2006), 157.
10. Although many authors have demonstrated the applicability of invoking statistical thinking in modeling musical expectancy, the relationship is by no means one-to-one. For an apt discussion of the issue, see Meyer, “Meaning in Music and Information Theory” (1957), 412–424.
11. To study expectations in music, researchers typically employ a priming paradigm, which assumes that the processing of incoming events is affected by the context in which they appear. Related events are primed, thus facilitating processing. Harmonic priming studies often employ an authentic cadence

Nonetheless, closure often plays a prominent role in studies otherwise concerned with other aspects of music perception and cognition. Indeed, Bret Aarden has suggested that Carol Krumhansl's highly influential probe tone studies reflect a cognitive representation of the tonal hierarchy that only pertains to phrase endings. In her initial experiment with Edward Kessler, Krumhansl asked participants to rate the goodness-of-fit of each of the twelve members of the chromatic scale following a tonal context.[12] The resulting major and minor key profiles they obtained led the authors to propose that listeners possess a cognitive representation of the tonal hierarchy. Moreover, a comparison of the goodness-of-fit ratings with the frequency-of-occurrence of these scale-degrees in various corpora from Western music revealed a significant correlation, with scale-degrees that occur more frequently receiving higher "fit" ratings,[13] thus leading Krumhansl to suggest that listeners form an internal representation of the tonal hierarchy by internalizing the distribution properties of Western tonal music.[14]

Publications over the past two decades of numerous key-finding algorithms incorporating Krumhansl and Kessler's major and minor key profiles provide convincing evidence for the psychological reality of the tonal hierarchy.[15] Yet a number of authors have since raised several objections both to Krumhansl's probe-tone method and to her interpretation of the results.[16] Aarden, noting a disparity between the distribution of the goodness-of-fit ratings with the scale-degree distributions from tonal music, conducted a reaction-time study in which participants responded to the contour of each event in a short tonal melody.[17] His first experiment was designed to test the assumption that scale-degrees receiving a higher "fit" rating in Krumhansl's tonal hierarchy

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in the expected condition and then recompose the moment of cadential arrival in order to consider the effect of an expectancy violation on response accuracy and reaction time. For an example, see Loui and Wessel, "Harmonic Expectation and Affect in Western Music" (2007), 1084–1092. Many of these studies, however, neglect to discuss harmonic and melodic closure per se.

12. Krumhansl and Kessler, "Tracing the Dynamic Changes in Perceived Tonal Organization in a Spatial Representation of Musical Keys" (1982), 334–368. The profile for the major key is the average rating given to each of the 12 tones of the chromatic scale following either a major chord or one of three progressions (IV–V–I, II–V–I, and VI–V–I); the minor-key profile is the average rating for each of the 12 tones of the chromatic scale following a minor chord or one of the same three progressions.
13. Krumhansl, *Cognitive Foundations of Musical Pitch* (1990), 68f.
14. Ibid., 286.
15. The first model incorporating the Krumhansl-Kessler key profiles was proposed by Krumhansl herself, in collaboration with Mark Schmuckler. For a discussion of the model, see Krumhansl, *Cognitive Foundations of Musical Pitch* (1990), 77–110. Huron and Parncutt have since suggested methods for incorporating effects of echoic memory and pitch salience on tonality perception (Huron and Parncutt, "An Improved Model of Tonality Perception," [1993], 154–171), and Temperley has provided numerous revisions to the Krumhansl-Schmuckler model that improve the mathematical efficiency of the algorithm and address issues related to modulation (Temperley, "What's Key for Key?" [1999], 65–100).
16. For a succinct summary and critique of Krumhansl's methodology and the interpretation of her results, see Aarden, "Dynamic Melodic Expectancy" (2003), 11–26.
17. Although the correlations between the scale-degree distributions of various corpora with Krumhansl's goodness-of-fit ratings are quite high ($r > .80$), several discrepancies remain unexplained, the most

would lead to faster reaction times, yet the results did not support this hypothesis. However, when he asked participants to respond only to the contour of the *final* event of each melody in a second experiment, he observed a close correspondence between participant reaction times and the "fit" ratings of the final events,[18] leading him to conclude that the probe-tone method employed by Krumhansl and Kessler actually encouraged listeners to treat the probe tone as a phrase-final event. Thus, Aarden claimed, Krumhansl and Kessler's major and minor key profiles reflect a cognitive representation of the tonal hierarchy that pertains specifically to endings.[19]

That an internal representation of the tonal hierarchy affects the perception of melodic closure is by no means contentious, though it remains far less clear whether such a representation pertains only to the final event of a phrase, or instead, whether it may pertain to a *series* of events, thereby suggesting that listeners possess schematic representations of various melodic closing formulæ. Marilyn Boltz and David Butler have reported effects of serial order on both the perception of melodic closure and the identification of tonal center respectively,[20] but the issue as to whether listeners store melodic closing patterns in long-term memory remains open. For bass line motion, however, the serial position of the events preceding a phrase ending is fundamental to current definitions of cadential closure; the cadential status of the final tonic in an authentic cadence, for example, is crucially determined by the harmony of the preceding event. Thus, music scholars frequently treat harmonic closure as a temporal process, an idea that has gained acceptance in the experimental literature. To consider the effect of a number of musical parameters on the perception of harmonic closure, Burton Rosner and Eugene Narmour asked participants to judge which of a pair of two-chord progressions seemed more closed; they then quantified variables relating to the position of the soprano and bass voices with respect to the root of each chord, the number of common tones shared between the two chords, and the motion of the soprano voice.[21] In addition to these parameters, they also considered style-specific variables that corresponded to music-theoretic notions of cadential closure, such as the root progression of each stimulus and the position of the final melodic event within the tonal hierarchy. To their surprise, parametric variables such as the soprano position, bass inversion, and the number of shared common tones did not affect the closure preference ratings. Instead, schematic representations of root progressions common to known cadences appeared to play the most prominent role, leading the

noteworthy example being that $\hat{5}$ normally appears more frequently than $\hat{1}$ in the various corpora, yet in Krumhansl and Kessler's key profiles, the tonic receives the highest "fit" rating.

18. Aarden, "Dynamic Melodic Expectancy" (2003), 75.
19. Ibid., 25f.
20. Boltz, "Perceiving the End" (1989), 754; Butler, "Describing the Perception of Tonality in Music" (1989), 234–236.
21. Rosner and Narmour, "Harmonic Closure" (1992), 383–411.

authors to claim that the various harmonic formulæ located at phrase endings result in the formation of schematic representations of harmonic closure. They explain, “when evaluating closure, listeners presumably invoke learned harmonic structures as stylistic schemata. Such schemata come into play when the stimulus displays a sufficient number of featured properties to activate them. This process relies on previously learned stylistic patterns and should be central to closural evaluation.”[22]

That listeners may possess both melodic and harmonic “closing” schemata might also explain why cadences play a prominent role in the perception of tension, a topic that has received a great deal of attention over the past two decades. In a study initially investigating Lerdahl and Jackendoff’s model of tonal tension, Emmanuel Bigand and Richard Parncutt asked listeners to rate their perception of musical tension for each pair of successive chords in Chopin’s *Prelude* in E major.[23] Although they expected Lerdahl and Jackendoff’s model to perform best, they were surprised to find that the simple encoding of authentic and half cadences best explained listener ratings of tension, leading them to conclude that cadences provide important reference points for the perception of tension during music listening.[24]

From an examination of the experimental literature, it appears that cadences play a vital role in the perception of tonal music. Furthermore, that listeners may possess cognitive representations for various ending patterns seems intuitive. But what remains absolutely essential to such a claim is that the strength of the schematic representation depends on a listener’s exposure to the musical style. Unfortunately, the effect either of explicit musical training or passive exposure on the perception of closure remains unclear, with many studies reporting contradictory findings. Boltz asked both musicians and nonmusicians to provide melodic completion ratings on a 10-point scale for several ending patterns, yet she failed to observe a difference between the two groups, leading her to claim that implicit exposure, rather than explicit training, accounts for the perception of melodic completion.[25] Barbara Tillman et al. also reported a similar finding using cadential patterns, in which musicians and nonmusicians provided com-

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22. Ibid., 397f.
23. Bigand and Parncutt, “Perceiving Musical Tension in Long Chord Sequences” (1999), 237–254.
24. Ibid., 254. In a related and pertinent finding to this research, the authors also suggest that listeners perceive tension from within a short temporal window. Accordingly, they claim tension ratings for a given harmonic event remain more or less independent of non-adjacent events. The effect of hierarchy on the perception of both closure and tension is, however, very much in dispute. Lerdahl has since proposed that the results obtained by Bigand and Parncutt reflect a conflation of stability/instability (terms Lerdahl associates with tonal tension) with closure/non-closure. He rightly points out that a highly stable event, such as the tonic initiating a phrase, may nonetheless imply continuation, and thus, non-closure (see Lerdahl, “Modeling Tonal Tension” [2007], 357). The results provided by these studies therefore suggest that the relationship between the concepts of tension and closure crucially depend upon how we define and operationalize these often loaded terms.
25. Boltz, “Perceiving the End” (1989), 753. Like Aarden, Boltz also considered how cognitive representations of tonal structure affect music perception, but in her case she employed an explicit rating task rather than a reaction-time task.

pletion ratings for both half cadences and authentic cadences (in the context of 16-m. minuets).[26] Tillman therefore proposed that participants apply the same perceptual principles when assessing musical closure, regardless of expertise, though nonmusicians may be less efficient than musicians.

Other scholars, however, have noted significant effects of musical expertise on the perception of closure. Michel Vallières et al. asked participants to categorize a series of short excerpts from Mozart's keyboard sonatas as beginnings, middles, or ends; and for the ending excerpts, Vallières selected only perfect authentic cadences. The results revealed a significant difference between musicians and nonmusicians, as the musician group correctly identified these cadences as "ends" with nearly perfect accuracy, while nonmusicians were considerably less accurate, correctly identifying ends roughly 80% of the time.[27] Margaret Weiser also reported an effect of expertise for two-chord cadences (authentic, half, plagal, and deceptive), in which participants were asked to rate the stability of the final chord on a 5-point scale. The results led her to suggest that musical training facilitates flexible voice-tracking, while the absence of such training results in an attentional bias toward the soprano voice.[28] Finally, the findings obtained over a series of experiments investigating the perception of harmonic and melodic cadential patterns led Roland Eberlein and Jobst Fricke to theorize that experienced listeners of tonal music form schematic representations for frequently occurring cadential formulæ. Differences of expertise during the perception of closure therefore result from differences in familiarity with the tonal idiom.[29]

Such contradictory reports as to the role of explicit formal training or implicit exposure on the perception of closure may reflect differences either in the choice of experimental task or in the use of stimuli, as researchers often prefer to use homorhythmic, four-part chorale representations of cadential progressions rather than attempt to find examples of cadences from genuine musical literature. And there are certainly very good reasons for doing so; by eliminating variations in dynamics, tempo, and rhythm, as well as disregarding a number of features that appear fre-

26. Tillman, Bigand, and Madurell, "Local versus Global Processing of Harmonic Cadences in the Solution of Musical Puzzles" (1998), 168.
27. Vallières, Tan, Caplin, and McAdams, "Perception of Intrinsic Formal Functionality" (2009), 23. The correct identification of 80%, of course, is still significantly better than chance, but as Vallières's analysis later revealed, this effect of expertise could not be attributed simply to greater variability between subjects in the nonmusician group, but rather to explicit differences in the way the two groups perceived cadential patterns.
28. Weiser, "Rating Cadence Stability" (1992), 40–46. There has been some empirical support for the claim that nonmusicians appear to privilege parameters related to melodic motion, such as pitch proximity and contour, while musicians attend principally to harmonic factors, such as the size of the interval between two events (see Vos and Pasveer, "Goodness Ratings of Melodic Openings and Closures" [2002], 631–639), a claim that will be pertinent to the results presented here.
29. Eberlein and Fricke, *Kadenzwahrnehmung und Kadenzgeschichte* (1992), 258. Eberlein has also succinctly summarized his theory and proposed a rough model for the effect of familiarity on the perception of closure (see Eberlein, "A Method of Analysing Harmony" [1997], 232f.).

quently in compositional practice (e.g., a trill at the cadential dominant, the cadential six-four, the suspension dissonance at cadential arrival), such abstract paradigms provide greater experimental control and are much easier to alter to satisfy specific experimental needs. But these paradigms also misrepresent the ways in which composers often articulate phrase endings in tonal music (and consequently the ways in which listeners might actually perceive these endings), as they disregard many of the features of cadences that might contribute to the perception of closure. Perhaps worse, such an approach often leads researchers to generalize the behavioral responses elicited by these simple melodic and harmonic formulæ to all tonal music, though the characteristics of closure present in Prokofiev's piano sonatas might differ markedly from those found in Mozart's symphonies.[30] To be sure, the goal of many of the experimental studies employing cadential stimuli is to determine how listeners represent tonal structure in long-term memory. As a result, the examples that they employ serve to probe the various cognitive representations of tonal patterns listeners have abstracted from previous experience. Whether or not a given musical example could actually appear in the repertoire might therefore seem largely irrelevant. But the precision with which we may examine these various representations ultimately depends on a careful understanding of the music to which listeners are consistently exposed. In comparing a listener competent in Mozart's keyboard style with a diverse group of participants, for example, we might find very similar ratings for rhythmically isochronous, harmonic formulæ (and indeed, as a few of the previous studies I have just mentioned can attest, we sometimes do), yet when presented with an excerpt written in that keyboard style, our listener may possess distinctions of a much finer grain than those possessed by the wider group.

The recent revival of interest in the *Formenlehre* tradition has also largely gone unnoticed in the music psychology community, as those studies explicitly examining the perception of closure rarely employ the wider variety of cadential types found in the "common practice" period. Techniques for cadential deviation, in particular, serve an important formal and expressive function in the classical style, but they have yet to be considered in an experimental setting. Indeed, the experimental study of cadential failure could serve to explore rich areas of inquiry in music psychology—the perception of closure, the processing of harmonic syntax, and the generation and violation of expectations—using musical examples that remain ecologically valid.

The study I will summarize here attempted to address these issues directly. While an exploration of the underlying sensory and cognitive mechanisms responsible for the perception of closure in tonal music is the ultimate aim of this research, our initial

30. Indeed, Courtenay Harter has outlined some of the characteristic differences of cadential articulation found between Prokofiev and composers of the common practice (see Harter, "Bridging Common Practice and the Twentieth Century" [2009], 57–77).

approach was more limited in scope, concentrating as it does on a closing pattern that appears frequently in tonal music: the classical cadence. Limiting the initial investigation to cadential closure also afforded the opportunity to consider issues germane to music theory. In the analysis of musical form, the capacity to discern amongst various cadential categories is paramount to the identification of the function of a specific musical passage,[31] and this study provides evidence as to whether expert and non-expert listeners can make such distinctions in real time, without the aid of the score. Furthermore, analysts frequently appeal to a hierarchy of cadential closure, and a few authors have proposed preliminary models of cadential strength (e.g., Janet Schmalfeldt, William Caplin, and, more recently, Edward Latham),[32] though it remains unclear how various cadential categories—perfect authentic, imperfect authentic, half, etc.—may be positioned within the hierarchy, or how the various musical parameters—melody, harmony, rhythm, etc.—contribute to the perception of closure (an issue to which I will return later in the chapter).

As the methods by which composers articulate cadences also vary dramatically both from style to style and from composer to composer, we restricted the selection of stimuli to excerpts from Mozart's keyboard sonatas, which comprise a stylistically unified repertory composed over a period of just 15 years (1774–1789). Due to the lack of experimental evidence concerning the potential effect of musical expertise on the perception of cadential closure, we also considered the impact of explicit formal training. To that end, we recruited 20 participants with musical training equivalent, or superior, to second-year-university level, which comprised the musicians group, and 20 participants with less than one year of training, which comprised the nonmusicians group.

The experimental task was fairly straightforward. Participants were instructed to rate the degree of completion for each excerpt on a 7-point continuous scale. Completion was defined as "the expectation that the music will not continue. A value of 1 indicates that the excerpt would certainly continue, while a value of 7 indicates that the excerpt could end at that moment without the need for anything further." By adopting the more neutral term "completion," we hoped to sidestep any reference to theoretically loaded terms (e.g., cadence, closure) that might complicate the task for nonmusicians and unintentionally bias musicians toward consciously categorizing the excerpts. In addition to the completion judgment, participants also rated both the confidence of their completion rating along with their familiarity with the excerpt on 7-point scales. Finally, to distinguish between those potentially ambiguous excerpts that participants might rate in the center of the completion scale, we also included two

31. In Caplin's theory, a formal function refers to the capacity of a given time span to express its own location in musical time, and he offers five such formal functions: before-the-beginning, beginning, middle, end, and after-the-end (Caplin, "What are Formal Functions?," [2009], 23).

32. Schmalfeldt, "Cadential Processes" (1992), 1–52; Caplin, *Classical Form* (1998), 101–111; Latham, "*Drei Nebensonnen*" (2009), 308f.

statements to which the participants would respond on a 4-point Likert scale labeled from *strongly agree* to *strongly disagree*: "this excerpt could complete an entire work or movement," and "this excerpt could complete a phrase or short passage of music."[33]

Characterizing the excerpts—Caplin's theory of cadential closure

Although the "high classical style" refers to a fairly limited period of music history (ca. 1770–1810), the compendium of cadential terms associated with the music of this period is still enormous. This fact reflects profound disagreement, appearing both in contemporaneous treatises and in recent research, as to the impact of a large number of musical parameters (e.g., melody, harmony, the presence and treatment of dissonance, inversion, texture, dynamics, tempo, timbre, and orchestration) on the perception of endings of varying strengths and for various levels of the structural hierarchy. Thus coming to a consensus as to the procedure by which endings may be identified and categorized remains a tremendous challenge. Attempting to clarify some of these issues, William Caplin classifies every possible cadential category according to two fundamental types: those for which the goal of the cadential progression is tonic (the authentic cadence and its variants), and those for which the goal is dominant (the half cadence and its variants).[34] To these two types he finally adds the IAC, a melodic deviant of the PAC. He refers to these three cadential categories as "the only genuine cadences in music in the classical style."[35]

Borrowing from Kofi Agawu, Caplin further classifies the parameters articulating cadential closure under two headings, *syntax* and *rhetoric*: "in its syntactical aspect, a given cadence represents a particular cadential *type* on the basis of its harmonic-melodic content exclusively. In its rhetorical aspect, that cadence has a unique compositional realization entailing the entire range of musical parameters, including rhythm, meter, texture, intensity, and instrumentation."[36] Thus, Caplin differentiates between the cadential categories common in music-theoretical discourse—perfect authentic, imperfect, deceptive, and so on—strictly according to the syntactic param-

33. A Likert scale is a common psychometric scale typically used in survey research to measure the level of agreement with a given statement. By providing only four possible responses, participants in this study were forced either to agree or disagree with the statement.
34. Ibid., 43. Caplin distinguishes between cadential progressions that feature a final dominant triad in root position—a half cadence—from a final dominant that is inverted or contains a dissonant seventh, which he terms a dominant arrival (see Caplin, *Classical Form* [1998], 79–81).
35. Ibid., 43.
36. Caplin, "The Classical Cadence" (2004), 107. On the rhetorical aspects of closure, see Agawu, "Concepts of Closure and Chopin's Opus 28" (1987), 3–5.

eters specific to each category. Indeed, few scholars have questioned the important role accorded to melodic and harmonic content in establishing cadential closure, particularly for music from the classical style.[37] Distinguishing cadential categories according to their syntactic content therefore provides a suitable starting point for an experimental investigation of cadences. Moreover, the choice to examine cadential categories determined only on the basis of these syntactic parameters greatly reduces the number of potential categories we might study. Nevertheless, by selecting excerpts from the literature (rather than composing stimuli that reflect simple cadential paradigms), the musical examples also differ as a result of the rhetorical content unique to each excerpt. It was therefore necessary to explicitly include these parameters in the design of the experiment.

We presented the participants with 50 short excerpts (average 9 seconds) from Mozart's keyboard sonatas that contained an equal number of perfect authentic (PAC), imperfect authentic (IAC), half (HC), deceptive (DC), and evaded cadences (EV). These categories were chosen both on the basis of their frequency in Mozart's style and on their assumed relevance to scholarship in music theory and music perception. Each excerpt contained at least the entire cadential progression, with some excerpts including music preceding the onset of that progression.[38] Thus, each cadential category differs at the moment of the cadential arrival, which represents the crucial variable distinguishing each excerpt.[39] Finally, to limit the number of variables under consideration, we neutralized performance features such as dynamics and *rubato* and selected a tempo for each excerpt that followed conventional performance practice.

In order to take into account syntactic and rhetorical features not embraced by cadence category membership that occur frequently in Mozart's cadences, we further subdivided each cadential category into two subtypes to consider issues of formal context (in the case of the PAC and HC), the presence of a melodic dissonance at cadential arrival (for the IAC and HC), as well as the melodic scale-degree and harmony at cadential arrival (for the DC and EV, respectively).[40] Table 1 displays the

37. However, many scholars have questioned the subordinate status traditionally accorded to non-syntactic parameters in the perception of closure, in particular for music following the classical period. For an example, see the second analysis of the first movement of Schubert's D. 46 in Hyland, "Rhetorical Closure in the First Movement of Schubert's Quartet in C Major, D. 46" (2009), 120–123.

38. We included additional material preceding the onset of the cadential progression in instances in which we felt the duration of the excerpt was too short to provide a sufficient tonal context.

39. Of course, a number of other parameters within the cadential progression itself might necessarily imply a given cadential category. For example, metrical placement and duration serve to distinguish a dominant harmony in a half cadence from a dominant in an authentic cadence. But for the purposes of the experimental design it was useful to differentiate each cadential category according to a specific temporal event, in this instance the moment of cadential arrival.

40. We also considered a number of other parameters for inclusion as subtypes in the experiment, such as the presence of a surface dissonance at cadential arrival in the perfect authentic cadence category, but the time constraints imposed by the experimental session precluded a design examining more than two subtypes for each category. Moreover, our intent was to select subtypes that reflect the most

cadential categories, the subtypes, and a brief description of the characteristics that define each category.

Table 1: Provides the cadence categories, syntactic characteristics, subtypes, and the number of excerpts for each subtype. [a] ECP refers to an expanded cadential progression; [b] CA refers to cadential arrival.

Cadence Categories	Characteristics	Subtypes	Number
Perfect Authentic	- V and I in root position - Soprano $\hat{1}$	Main Theme	5
		Subordinate Theme (ECP)[a]	5
Imperfect Authentic	- V and I in root position - Soprano $\hat{3}$	Melodic Dissonance at CA[b]	5
		No Melodic Dissonance at CA	5
Half	- V in root position - No 7^{th}	Main Theme	4
		Transition	6
Deceptive	- Ends grouping structure - Typically on vi	Failed PAC at CA	7
		Failed IAC at CA	3
Evaded	- Melody leaps up - Provides no resolution	Tonic Harmony at CA	5
		Non-Tonic Harmony at CA	5

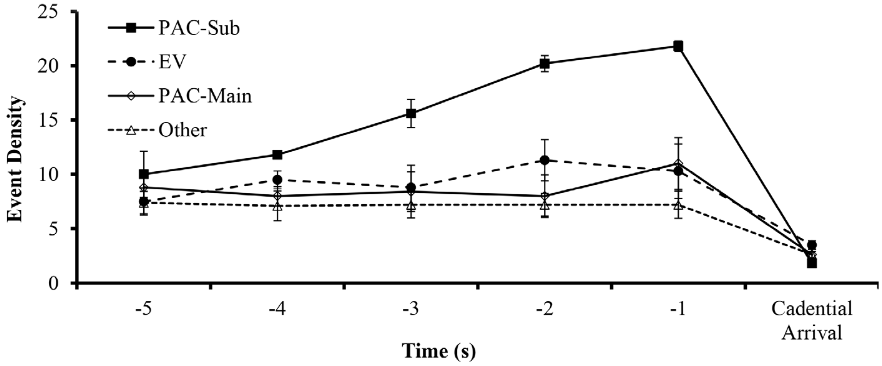
The category of perfect authentic cadences was subdivided according to formal location, selected either from the main theme or the subordinate theme. The excerpts chosen from subordinate themes feature an expanded cadential progression (ECP) (see Example 2a), which, in addition to its longer duration (compared to those cadences selected from main themes), is characterized by a dramatic increase in surface activity, usually resulting from an Alberti bass in the left hand and the appearance of a cadential trill above the penultimate dominant.[41] Indeed, that surface activity may affect the perception of closure has been suggested by Michel Vallières, as he found that higher average event density as well as the sudden decrease in event density at cadential arrival significantly affected the categorization of endings by nonmusicians.[42] Example 3 displays the average event density, calculated as the total number of notes per second, for each of the last five seconds of the two subtypes of the PAC category, the EV category, and finally the other categories aggregated together. Both the PAC subordinate-theme subtype and the EV category feature a significant increase in surface activity in the last moments before cadential arrival, at which point the

prevalent features of Mozart's compositional style. However, in doing so, it should be acknowledged that whereas the features reflected in each subtype may play a prominent role in phrase endings from a number of different style periods, they may also be idiomatic to Mozart.

41. For a discussion of the ECP, see Caplin, "The 'Expanded Cadential Progression'" (1987), 215–257.
42. Vallières, "Beginnings, Middles, and Ends" (2011), 106.

Example 2: Five excerpts representing the five cadential categories. (a) PAC category, Subordinate Theme subtype: K. 309/i, mm. 48–54. (b) IAC category, Melodic Dissonance subtype: K. 330/iii, mm. 39–43. (c) HC category, Main Theme subtype: K. 284/iii, mm. 1–4. (d) DC category, Failed PAC subtype: K. 281/ii, mm. 32–35. EV category, Non-Tonic subtype: K. 279/ii, mm. 1–4

activity ceases almost entirely, while for the other categories, surface activity does not vary within the cadential progression. We therefore hypothesized that PAC excerpts selected from subordinate themes might yield significantly higher completion ratings than excerpts from the other categories.



Example 3: Time Series Plot of the mean event density calculated in a window of 1 second for the two subtypes of the PAC category, the EV category, and the other categories aggregated together

The IAC category was subdivided according to the presence or absence of a melodic dissonance at cadential arrival (Example 2b displays the former case, an accented passing tone embellishing the melodic goal). Although a number of other features might serve to differentiate imperfect authentic cadences, such as the metric placement of cadential arrival (i.e., "masculine" vs. "feminine" endings) or the contour of the melody preceding cadential arrival (ascending vs. descending), etc., the presence of a surface dissonance in the melody at the moment of cadential arrival (defined by the appearance of the final tonic harmony) is a prominent attribute of Mozart's imperfect authentic cadences.[43]

As with the PAC category, half cadences were subdivided according to their formal location, selected either from the main theme (as in Example 2c) or from the end of the transition.[44] As the material within the transition in sonata form typically modulates to the subordinate key, the passages preceding cadential arrival for the

43. Imperfect authentic cadences featuring a surface dissonance typically include $\sharp\hat{2}$ at cadential arrival (see K. 330/i, m. 8; K. 311/ii, m. 32). To prolong the dissonance at cadential arrival, $\hat{2}$ also sometimes appears in the soprano as an upward resolving suspension to $\hat{3}$, with a chromatic passing tone inserted in between (see K. 498a/iv, m. 36; K. 533/iii, m. 26).

44. Unfortunately, the formal location subtypes for the HC category do not contain an equal number of excerpts: the main theme subtype contains four, whereas the transition subtype contains six. However, the surface dissonance subtypes for the HC category contain an equal number of excerpts.

transition subtype are frequently characterized by increased energy (relative to the main theme) and tonal instability.[45] These features serve dramatically to differentiate transition half cadences from those appearing in the main theme. In addition, the ten excerpts from the HC category were also separately classified according to the presence or absence of a melodic dissonance at the moment of cadential arrival.

Whereas imperfect authentic and half cadences remain categorically distinct from the perfect authentic cadence, deceptive and evaded cadences generally do not, as they initially promise a perfect authentic cadence, yet fundamentally deviate from the goal harmony of the cadential progression only at the moment of cadential arrival. The deceptive cadence closes with a non-tonic harmony, usually vi, thus leaving harmonic closure somewhat open, but the melodic line resolves to a stable scale-degree at cadential arrival, thereby providing a provisional sense of ending for the ongoing thematic process.[46] Depending upon the degree of melodic closure, this cadence category has been further subdivided according to whether the melody arrives on the tonic degree ($\hat{1}$), which I will refer to as a failed perfect authentic cadence (as in Example 2d) or on the third degree ($\hat{3}$), which I will refer to as a failed imperfect authentic cadence.[47]

Finally, the evaded cadence is characterized by a sudden interruption in the projected resolution of the melodic line; instead of resolving to $\hat{1}$, the melody leaps up, often to $\hat{5}$, thereby replacing the expected ending with material that clearly initiates the subsequent phrase. Thus, the evaded cadence projects no sense of ending whatsoever, as the event located at the point of expected cadential arrival, which should group backward by ending the preceding thematic process, instead groups forward by initiating the subsequent process. In order to consider issues of harmonic context associated with the evaded cadence, the category has been subdivided according to which harmony appears at the moment of expected cadential arrival—tonic harmony (which is typically inverted, but may sometimes be in root position), or non-tonic harmony (as in Example 2e).

45. Caplin, *Classical Form* (1998), 125; Hepokoski and Darcy, *Elements* (2006), 93.

46. Caplin does not define a deceptive cadence strictly by the presence of the submediant at cadential arrival, but rather by the appearance of a non-tonic harmony that nonetheless ends the grouping structure, thereby providing a provisional sense of ending. Thus, although deceptive cadences in Caplin's typology typically feature vi at cadential arrival, other harmonies may also appear instead, such as I^6 or vii^6/V. Of the excerpts employed in the study, only one did not feature vi at cadential arrival. For more information on the physiognomy of the deceptive cadence and the history of the concept, see the contribution by Neuwirth in this volume.

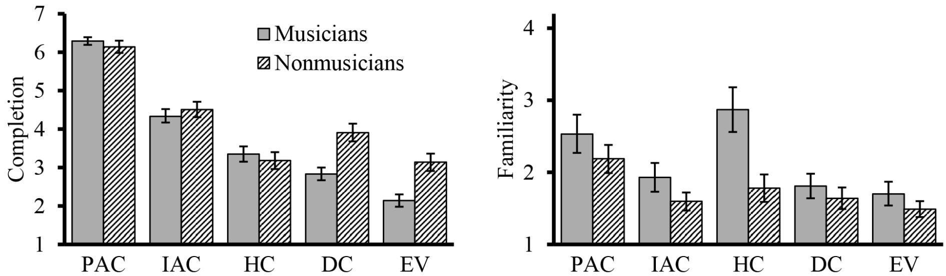
47. Because deceptive cadences occur less frequently in Mozart's keyboard sonatas than the other cadence categories selected for this study, the two subtypes do not contain an equal number of excerpts: the failed perfect authentic cadence subtype contains seven while the failed imperfect authentic cadence subtype contains three.

Example 4: EV category, Tonic Harmony subtype: K. 281/iii, mm. 30–35. Top: From score. Bottom: Recomposed

Unfortunately, the extraction of each excerpt from its surrounding material introduced a number of factors at the moment of cadential arrival that might confound the experimental outcome. To eliminate these unwanted effects while preserving the stylistic integrity of each excerpt, it was necessary to impose a few constraints on the materials appearing at the cadential arrival. First, any chord tones appearing after cadential arrival (e.g., an Alberti bass pattern) were verticalized to the moment of cadential arrival and all subsequent material was removed. This alteration was necessary in order to eliminate differences in surface activity among excerpts, in particular for instances in which the absence of the third of the triad at the point of arrival would have resulted in an unstylistic open octave. Second, we recomposed the duration of the cadential arrival to one full tactus to ensure that differences in duration would not affect the perception of closure. This change still resulted in small variations in the duration of the final event for each excerpt, but these differences were assumed to be too small to significantly affect the completion ratings. Third, because we did not wish to consider the effect of cadential absence—such as when a rest replaces the expected tonic at cadential arrival—in two instances the events following the rest were shifted back to cadential arrival (see Example 4). Finally, any melodic dissonances appearing at the cadential arrival were retained so as not to fundamentally alter the excerpt (for example, in evaded cadences the melodic line frequently features an appoggiatura at the point of the expected cadential arrival).

Results of the experiment

I will first describe the results as they relate to the cadential categories and then discuss differences arising between the various subtypes.[48] The left figure in Example 5 displays the completion ratings in a bar plot for each of the five cadential categories for musicians and nonmusicians.[49] As expected, the musician ratings revealed significant differences between each adjacent pair of categories (PAC–IAC, IAC–HC, etc.), descending from PAC to EV. The membership of each excerpt to a cadential category would therefore seem to significantly affect the completion ratings. Moreover, the descending linear trend from PAC to EV demonstrated in the mean musician ratings suggests a kind of ordinal ranking of the categories according to their perceived strengths, a point I will return to later.



Example 5: Left: Bar plot of the completion ratings for each cadential category for musicians and nonmusicians. Right: Bar plot of the familiarity ratings for each cadential category for musicians and nonmusicians

Like musicians, nonmusicians fully distinguished between the PAC, IAC, and HC categories, which replicates a finding by Tillman et al., in which musicians and nonmusicians did not differ in their ratings of either perfect authentic or half cadences.[50] However, nonmusicians provided much higher completion ratings for both deceptive and evaded cadences than musicians. They also rated deceptive cadences as more complete than half cadences, and surprisingly, their ratings of half cadences

48. For the present purposes, a discussion of the statistical procedures involved in analyzing the participant ratings might obscure a clear presentation of many of the theoretical issues this experiment sought to explore. For a full discussion of the methods and the experimental results, please see Sears, Caplin, and McAdams, "Perceiving the Classical Cadence" (2014), 397–417.
49. A bar plot simply displays the mean responses across all of the participants of each group for each category. The error bars (the vertical lines bounded by short horizontal lines) represent confidence intervals around the mean. Without going into too much detail, a large interval for this error bar indicates that the variability around the mean is quite large, which gives us less confidence that the mean we actually observed will substitute for the mean we would expect to find if we could sample the entire population.
50. Tillman, Bigand, and Madurell, "Local versus Global Processing of Harmonic Cadences" (1998), 166.

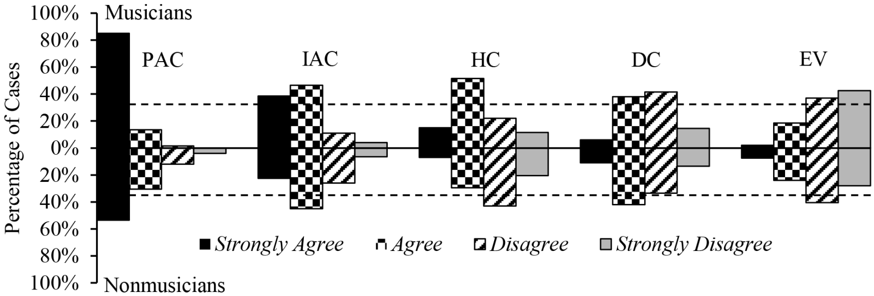
and evaded cadences did not differ significantly. Differences in ratings of deceptive cadences might indicate that nonmusicians privileged the soprano voice in determining the completion of a given excerpt, but differences for the evaded cadence category are more difficult to interpret. There are three possible explanations for this result: first, the completion ratings of the half cadence and evaded cadence categories did not differ significantly for nonmusicians because half and evaded cadences represent the weakest cadential categories for these listeners; second, nonmusicians were simply less comfortable using the entire range of the scale, resulting in considerably higher ratings for evaded cadences; third, this bump in the completion ratings for the evaded category might result from a flaw in the design of the stimuli. Indeed, that each stimulus ends directly following the cadential arrival may have induced an artificial impression of closure, particularly for nonmusicians.[51] To assess the perception of closure for evaded cadences without imposing an artificial boundary would therefore necessitate a new approach to the stimuli, one in which the material directly following the cadential arrival is retained.[52]

The familiarity ratings indicate that both groups rated perfect authentic cadences as somewhat familiar, while the IAC, DC, and EV categories received very low ratings, near the bottom of the scale. Shown in the right figure in Example 5, the familiarity ratings also revealed a surprising effect of expertise. While both groups provided higher familiarity ratings for the PAC category than for the other cadence categories, musicians also rated excerpts from the HC category as somewhat familiar. This effect was specific to musicians, however, as the nonmusician ratings for half cadences did not differ from those of the other cadence categories. The intention behind providing a familiarity scale was simply to determine if previous exposure to a particular excerpt might affect completion ratings. Our assumption was that knowledge of the material following the end of a given excerpt might alter the interpretation of that excerpt's ending, thus affecting the completion rating and confounding the experimental outcome. This effect of expertise on the familiarity ratings of half cadences instead suggests a difference in the degree of exposure to, and subsequent knowledge of, half cadences in general, a particularly compelling finding that we did not observe in the completion data.

So perhaps an explicit completion task alone cannot account for effects of expertise on the perception of half cadences. To resolve this issue, we also asked participants to respond to the statement, "this excerpt could complete a phrase or short passage of music," on a 4-point Likert scale. Example 6 displays a bar plot of the distribution of the percentage of responses for each cadential category, with musician ratings above the x-axis and nonmusician ratings below. The dotted lines represent the minimum threshold necessary to reach significant agreement. Thus, for the 200

51. My reasoning as to why these artificial boundaries only affected nonmusicians will become clear later.
52. My dissertation examines this issue in a subsequent study.

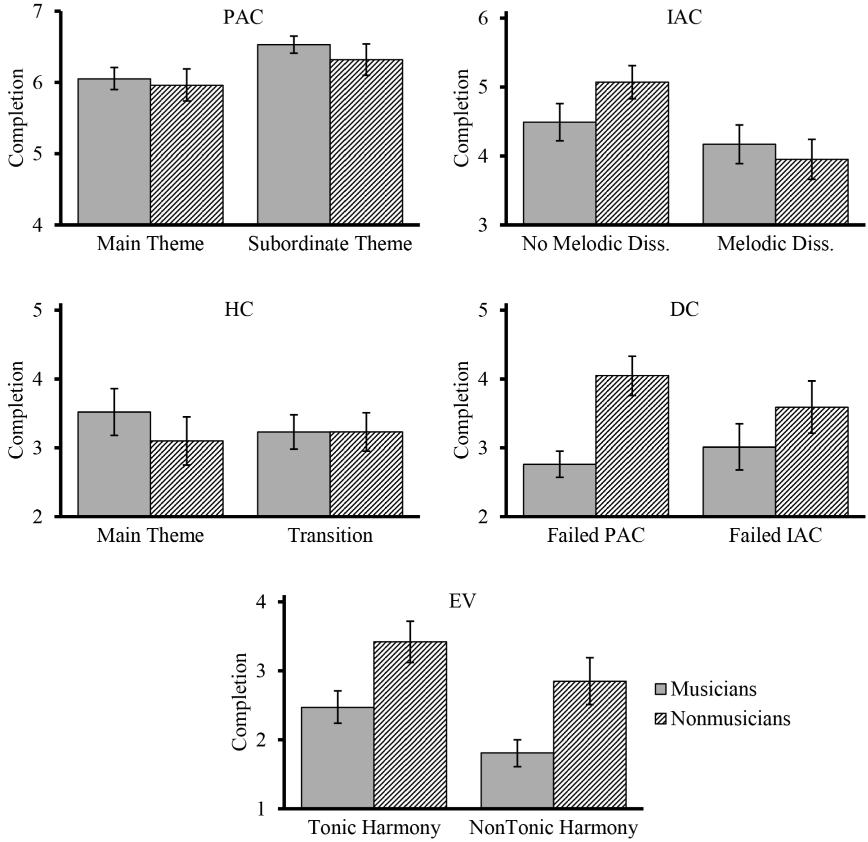
responses provided for each cadential category (20 participants in each group x 10 excerpts in each cadence category), a minimum of 68 identical responses (or 34%) was necessary to reach significant agreement.[53]



Example 6: Bar plot of the distribution of the percentage of responses for each cadential category for the statement, "this excerpt could complete a phrase or short passage of music," with musician ratings above and nonmusician ratings below the x-axis. The dotted line indicates the minimum threshold necessary to reach significant agreement.

Reading from left to right, the first column in the PAC category for the musician group indicates that in 85% of all cases musicians *strongly agreed* that excerpts from this category could complete a phrase or short passage of music. Musicians generally *agreed* with this statement for the IAC and HC categories, while they generally *disagreed* for excerpts from the EV category. The results for the DC category are less clear, as both musicians and nonmusicians appeared to hover between *agree* (40%) and *disagree* (37.5%). Indeed, with the exception of the HC category, the general shape of each distribution appears fairly similar between the two groups, though the nonmusicians were more variable in their responses. However, in 43% of their responses nonmusicians *disagreed* that a half cadence could complete a phrase, whereas musicians *agreed* with the statement in over 50% of their responses. Thus, while the completion ratings did not reveal an effect of expertise for the perception of half cadences, the Likert-scale ratings suggest that nonmusicians generally did not consider a half cadence to be a satisfactory goal.

53. To determine if participants significantly agree in their judgments for a specific category, we compared the distribution of responses for a given category with a flat distribution, in which each of the four possible judgments is equally likely (i.e., 50 responses that *strongly agree*, *agree*, *disagree*, and *strongly disagree* for each category).



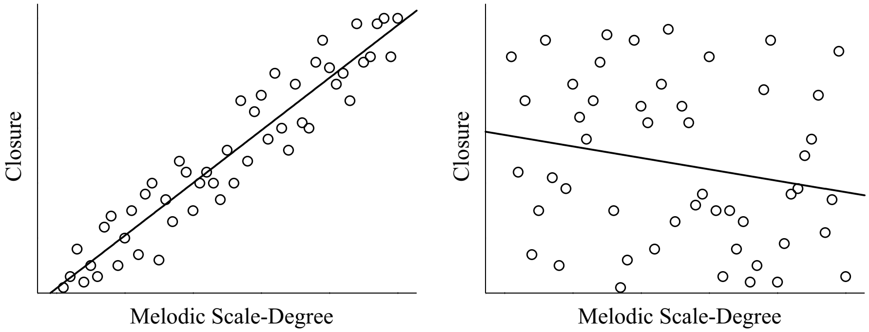
Example 7: Bar plots of the completion ratings for each of the ten subtypes for musicians and nonmusicians

The completion ratings for the ten cadential subtypes, provided in Example 7, reveal significant effects of formal location and surface dissonance as well as the melodic scale-degree and final harmony of the various cadential excerpts. Beginning with the PAC subtypes, the inclusion of formal context significantly affected the perception of completion, with both groups providing higher ratings for excerpts from the subordinate theme. These excerpts exhibit a number of unique characteristics that might explain this result: the expanded temporal duration of the cadential progression resulting from a decrease in harmonic rhythm, the increased surface activity, and the appearance of a trill above the cadential dominant. Without further study, however, it remains unclear precisely how each of these characteristics might contribute to this result.

With respect to the IAC, DC, and EV categories, it appears that on the one hand, nonmusicians attend predominantly to the melody when assessing the completion of a given excerpt, as they provided much higher ratings than did musicians for deceptive cadences, a cadential category that always provides a certain degree of melodic closure. Nonmusicians also appear to be more sensitive to variations in the melody, as evidenced by their lower ratings for imperfect authentic cadences featuring a surface dissonance at cadential arrival. Moreover, differences in the melodic scale-degree in the DC category significantly affected the ratings of the nonmusician group, with melodies featuring $\hat{1}$ receiving higher ratings than those featuring $\hat{3}$, a result that was not replicated by the musician group. On the other hand, musicians appeared to be more sensitive to variations in harmony, as they provided much lower ratings for deceptive cadences, and the harmony replacing the cadential arrival in the evaded cadence category also significantly affected their ratings, with excerpts featuring non-tonic harmony receiving lower ratings. These results might therefore suggest that expertise influences the attending strategy employed by the listener, with melody playing a more prominent role for nonmusicians.

Modeling attention: Melody and harmony

The purpose of this study is to demonstrate the extent to which various cadential categories contribute to the perception of closure. To that end, five distinct categories were selected on the basis of their melodic-harmonic content. But the claim that strategies of attention may differ as a result of musical training necessitates a statistical approach that may determine how melody and harmony independently affect the perception of closure. By encoding the melodic and harmonic information of each excerpt separately, we may model the completion ratings of both musicians and nonmusicians exclusively on the basis of the harmonic and melodic content specific to each excerpt, thus permitting us to abandon the cadential categories proper.



Example 8: Scatter plots of melodic scale-degree and closure. Left: $\beta = .96$, $R^2 = .90$. Right: $\beta = -.21$, $R^2 = .04$

Before going further, a brief explanation of the statistical approach might be useful here. Let us imagine that the melodic scale-degree at cadential arrival for each excerpt will perfectly predict the completion ratings of our participants. Thus, for every excerpt we may calculate a mean completion rating from both our musician and nonmusician groups, and then quantify our melodic predictor according to a set of pre-determined criteria. We may finally place these two variables on a Cartesian plane, assigning our melodic predictor to the x-axis and the completion scale to the y-axis, and then determine the location of each excerpt in the space using the melody and completion values for each excerpt as *xy* coordinates (called a scatter plot). Shown in Example 8, if the relationship between our predictor and our outcome appears to be linear, we may model the relationship using *linear regression*, in which we calculate a best-fit line that minimizes the error between the predicted position of each excerpt on the line with its actual position in Cartesian space. To understand the regression estimates I will describe in the models that follow, R^2 refers to the fit of the model, where a value of 1 indicates that the model accounts for all of the variance in the outcome variable (i.e., a perfectly linear relationship between the predictor and the outcome), and a value of 0 indicates that the model fails to account for any of the variance. In a multiple regression model, in which we may wish to determine the role of a number of predictors on the perception of completion, the slope of the line measured for each predictor, denoted by β, is also a useful estimate for the relationship between the predictor and the outcome, as it will indicate the degree to which the predictor covaries with the outcome variable. The value of β simply represents the change in the outcome resulting from a unit change in the predictor: the larger the value of β, the greater the role of the predictor within the regression model.[54] Hence, the figure on the left in Example 8 presents a best-fit line that significantly predicts closure, while in the figure on the right, the best-fit line provides a very poor fit for the data.

In order to account for the participant ratings of completion, we must quantify each predictor according to a set of criteria. First, a simple and fairly intuitive method might be to evaluate the melodic and harmonic content of each excerpt according to concepts of closure derived from music theory. For the purposes of this experiment, the harmony of each excerpt was assigned a value of 2 for a tonic triad in root position at the cadential arrival, 1 for a dominant triad in root position, and 0 for any other harmony in any inversion.[55] The melody of each excerpt was assigned a value of 2 for

54. In a multiple regression model, each predictor (e.g., harmony, melody, metric position, etc.) may be quantified according to entirely difference scales, so it is important to standardize the β values of each predictor so that we can determine the relative contribution of each predictor in the final model. In the models that follow, one unit of change has been standardized to one standard deviation.

55. Bigand and Parncutt employed precisely this rating system to assess the effect of cadential patterns on tension ratings. See Bigand and Parncutt, "Perceiving Musical Tension in Long Chord Sequences" (1999), 250.

$\hat{1}$ at cadential arrival, 1 for $\hat{3}$, and 0 for any other scale-degree; henceforth I will refer to the estimates obtained from these variables as the *syntax model*.

While this approach is certainly intuitive, it is also glaringly imprecise, as it fails to consider the effect of all of the possible scale-degrees that might appear at the end of each excerpt. In a second approach I assigned the mean goodness-of-fit ratings obtained from Krumhansl and Kessler's major and minor key profiles to the scale-degrees appearing in the soprano and bass line of each excerpt at cadential arrival under the assumption that their profiles signify a cognitive representation of the tonal hierarchy pertaining specifically to endings; I will refer to the estimates obtained from these variables as the *KK model*.

Table 2: Estimates from a stepwise linear regression analysis predicting the mean completion ratings of each excerpt using the Syntax and KK models. Musicians: Syntax R^2 = .42 for Step 1; ΔR^2 = .22 for Step 2. KK R^2 = .48 for Step 1; ΔR^2 = .24 for Step 2. Nonmusicians: Syntax R^2 = .47 for Step 1; ΔR^2 = .18 for Step 2. KK R^2 = .37 for Step 1; ΔR^2 = .35 for Step 2

	Model	β
Musicians	*Syntax*	
	Harmony	.61
	Melody	.47
	KK	
	Bass	.73
	Soprano	.49
Nonmusicians	*Syntax*	
	Melody	.65
	Harmony	.43
	KK	
	Soprano	.65
	Bass	.60

Table 2 displays the estimates of the *syntax* and *KK* models for both musicians and nonmusicians. For the musician group, the *syntax* model selected harmony, with a β of .61, in the first step, accounting for about 42% of the variance in their ratings. The selection of melody in the second step, with a β of .47, significantly improved the fit of the model, which produced a final R^2 of .64. Stepwise selection therefore indicated that the harmony predictor played the most substantial role in accounting for musicians' ratings of completion.[56] Applying the KK predictors improved the fit of the regression model, with the two predictors accounting for 72% of the variance in musicians' ratings. The KK model also produced similar standardized β weights, with the bass-line scale-degree again playing the more prominent role. Thus, as predicted, musicians placed greater emphasis on the bass voice at cadential arrival.

For the nonmusician group, the estimates of the *syntax* model were a near mirror image to those found for the musicians, with the parameters of melody and harmony accounting for 65% of the variance in their ratings, but with melody, with a standardized β of .65, playing a more prominent role than harmony. However, with the addition of the goodness-of-fit ratings in the KK model, the lopsided influence of the soprano voice diminished somewhat, with the bass-line scale-degree playing a more significant role. Thus, it appears that harmonic and melodic content can predict the completion ratings of both groups, and both models indicate unequivocally that musicians privilege the bass voice. With nonmusicians, however, the relative contribution of the two parameters is less clear-cut. In the *syntax* model, melody accounted for a greater proportion of the variance, while in the KK model, regression estimates for the two parameters were nearly identical.

These models support the claim that, in the perception of cadential closure, musicians appear to privilege the bass voice while nonmusicians are more sensitive to subtle differences in the soprano voice. That musical training may indeed influence attention in the perception of closure supports Weiser's claim that training facilitates flexible voice-tracking.[57] Furthermore, a recent study conducted by Psyche Loui and David Wessel showed that, even when presented with a task that explicitly directed participants to attend to the contour of the melody, violations in harmonic expectancy still influenced the behavioral responses of musicians.[58] And because this effect was not observed for nonmusicians, the authors claimed repeated exposure to Western music results in the formation of automatic expectations to harmonic progressions that musicians simply cannot ignore, even when asked to attend to other features of the stimulus. It remains unclear, however, whether attention to bass-line motion in cadential contexts reflects a flexible voice-tracking strategy promoted during explicit

56. Stepwise selection refers to a method for determining the order of input for the predictors. In the first step, the algorithm inputs the predictor that accounts for the highest proportion of the variance in the outcome, then in the second step, the algorithm inputs the next predictor that accounts for the highest proportion of the residual variance (i.e., the variance not already accounted for by the first predictor). Depending on the number of predictors, this process continues either until no predictors remain, or until the remaining predictors no longer significantly improve the fit of the model.

57. Weiser, "Rating Cadence Stability" (1992), 40–46.

58. Loui and Wessel, "Harmonic Expectation and Affect in Western Music" (2007), 1084–1092. In a selective attention task, the authors asked participants to respond to the contour of a melody as they were presented with harmonic progressions that were either highly expected, slightly unexpected, or extremely unexpected. They found that the expectancy condition affected the speed and accuracy of the contour judgment for musicians, but had no effect on nonmusicians.

formal training (i.e., in a pedagogical setting), or an attentional bias formed simply through implicit exposure to Western music.

The distinction between explicit learning through training and implicit learning through passive exposure is admittedly a slippery one. The literature concerning the effect of expertise on musical experience is certainly vast, but it is fair to say both from behavioral and neurophysiological studies that explicit training fundamentally affects aspects of perception and cognition, such as attention, learning, and memory.[59] Yet investigating the potential effects of expertise in an experimental setting crucially depends on the experimenter's sensitive treatment of every aspect of the experimental design (the question(s) of the experimenter, the selection and creation of stimuli, the participant's tasks, etc.). When experimenters employ stimuli with which a trained participant might be highly familiar, for example, the observed results may not reflect differences in expertise, but rather differences in familiarity.[60] To be sure, perceiving and comprehending an auditory stimulus as rich and complex as music places a significant cognitive burden on listeners, and though exposure alone may not account for all of the reported differences between musicians and nonmusicians, the implicit knowledge gained from exposure nevertheless plays a significant role in music listening.

Modeling cadential strength

The previous analysis sought to explain effects of expertise by appealing to differences in the attentional strategies employed during music listening. But perhaps differences in the completion ratings of musicians and nonmusicians might also be explained by taking another approach altogether, one in which we retain the cadential categories and propose a general model of hierarchical cadential closure. Unfortunately, the small number of excerpts employed for this study (50) prohibits a multiple regression model embracing the vast number of musical parameters implicated in the

59. To give two examples, researchers treating musicians as a special population have found differences between the morphology of the musician and nonmusician brains, which suggests that the development of musical expertise, particularly during early childhood, provides a good model for the study of brain plasticity (see Münte, Altenmüller, and Jäncke, "The Musician's Brain as a Model of Neuroplasticity" [2002], 473f.). When expert musicians listen to music played on their own instrument, Margulis et al. also found increased activity in brain regions implicated in the processing of musical syntax, timbre, and sound-motor interactions, suggesting that explicit expertise subsequently affects music listening (see Margulis et al., "Selective Neurophysiologic Responses to Music" [2009], 267–275).

60. Such a conflation of formal training and passive exposure has led Emmanuel Bigand to propose a methodological distinction between tasks intended to investigate explicit formal training and tasks that explore how, simply through exposure to Western music, listeners acquire implicit knowledge of a given style (see Bigand, "More About the Musical Expertise of Musically Untrained Listeners" [2003], 304f.).

articulation of cadences. Nevertheless, the cadential categories themselves provide a starting point for considering a model of perceived cadential strength that might lead to hypotheses to be examined in future studies.

In a model of cadential strength, the perfect authentic cadence represents a good place to begin. From even a cursory glance at the literature, it occupies a central position in music theory, as it clearly represents the *locus classicus* for establishing thematic closure in the high classical period. Indeed, we may speculate that listeners versed in tonal music not only possess a cognitive representation of the tonal hierarchy, but perhaps for those listeners especially familiar with the classical style, a schematic representation explicitly for authentic cadential closure.[61] During music listening, a number of parameters located within the cadential progression may activate our schematic representation of closure in real time, allowing listeners to generate harmonic and melodic expectations concerning the moment of cadential arrival. Accordingly, any deviation on the musical surface would naturally result in a violation of listener expectations, and thus would be experienced as a decrease in the cadential strength of a given excerpt. Deviations in melodic scale-degree and harmony at the cadential arrival thereby result in cadential categories of diminished strength.[62] In this view, the half cadence represents the weakest cadential category; it is marked not by a deviation in the melodic and harmonic content at cadential arrival, but rather by the *absence* of that content. Thus, the half cadence is, as the term suggests, an incomplete cadence.[63]

So according to this view, every cadential context is compared to one essential prototype: the perfect authentic cadence. Henceforth I will refer to this model of cadential closure as the *1-Schema* model. Indeed, this model has received some support from music theorists. Lamenting that "a well-defined hierarchical theory of cadence-types has simply not become established," Janet Schmalfeldt outlined the five cadential types that achieve what she termed *distinct closure*,[64] and of these types, she regarded

61. By this I mean not only a representation for harmonic closure, though such a claim has already been made by Rosner and Narmour ("Harmonic Closure" [1992], 397f.), but rather for a number of potential characteristics—both syntactic and rhetorical—that appear within the cadential progression. However, the question as to whether listeners actually possess such a representation remains open.
62. But such deviations need not only pertain to harmonic and melodic expectations. Hepokoski and Darcy's *attenuated PAC*, in which the moment of cadential arrival is marked by a sudden drop in dynamics or an unexpected shift to the minor mode, provides one such example (see Hepokoski and Darcy, *Elements* [2006], 170).
63. See also the contributions by Poundie Burstein as well as Nathan Martin and Julie Pedneault-Deslauriers in this volume.
64. Schmalfeldt, "Cadential Processes" (1992), 11f. In her model she distinguishes between three essential categories of closure: (1) *distinct closure*, in which the goal event closes a preceding process, (2) *elision*, in which the goal event both closes the preceding process and initiates the subsequent process, and (3) *evasion*, in which the goal event provides no ending whatsoever. She then situates the cadential types—PAC, IAC, HC, and so on—within these three categories.

the half cadence as weakest.[65] Citing Schmalfeldt's hierarchical model of cadential closure, Edward Latham recently proposed a model that identifies and subsequently weighs the criteria deemed necessary for establishing cadential closure on a 10-point scale.[66] He assigns 5 points to tonic harmony and 5 points to the preceding dominant, and he derives these scores from the scale-degrees present in the bass (1.5) and soprano (0.5), from whether the sonority is in root position (1.5), and finally from the presence of particular chord members (0.5) and a contextual feature: whether each sonority serves as a harmonic and melodic goal (1.0). Latham then scores each of Schmalfeldt's cadential types and places them along the scale. According to his criteria, the PAC category receives between 9 and 10 points (depending on whether the cadential tonic is elided), followed by IAC (8.5–9.5), DC (6.5–8.5), EV (3.5–8.5), and finally HC (3.5–5.0), positioned near the bottom of the scale.[67] His model therefore conceptualizes a half cadence as an incomplete authentic cadence.

At the heart of the half-cadence issue is an inherent contradiction: that a dominant, which is the *penultimate* harmony in an authentic cadential progression, can serve as a satisfactory goal. Indeed, many scholars besides Latham envision the half cadence as an incomplete cadence, one in which the expected resolution to tonic simply never appears.[68] And perhaps the results of our experiment reflect this contradiction. Recall that while the two groups did not differ in their completion ratings for the HC category, musicians provided much higher familiarity ratings than nonmusicians. In contrast to musicians, nonmusicians also generally disagreed that half cadences could complete a phrase or short passage of music. Thus, the effect of expertise on the perception of half cadences remains patently unclear. Certainly the very notion of half cadence is a paradoxical one, an instance of what Leonard Meyer famously called "parametric noncongruence," in which a dominant harmony—an active, unstable sonority—achieves the status of a cadential *goal* not by virtue of its melodic-harmonic content alone, but by means of metrical, textural, and rhythmic reinforcement.[69]

William Caplin has posited another view of half cadence, in which a dominant, merely by virtue of its melodic-harmonic content, can represent a harmonic end: "In the half-cadential progression, the dominant itself becomes the goal harmony and so occupies the *ultimate* position. To be sure, this dominant usually resolves to tonic, one that normally initiates a new harmonic progression, but within the boundaries

65. Ibid., 7. At no point, however, does Schmalfeldt explicitly compare the strength of the half cadence with modifications of the perfect authentic cadence, such as the deceptive cadence. Thus her view of the half cadence within the general hierarchy of cadential categories remains unclear.
66. Latham, "*Drei Nebensonnen*" (2009), 308f.
67. His model also positions plagal and abandoned cadences on the scale, and it considers the effect of cadential elision, an issue that has received very little treatment in experimental studies of closure.
68. See, for example, Hepokoski and Darcy, *Elements* (2006). They describe the half cadential dominant as an active dominant (24), one that necessarily implies resolution to an existing or implied tonic (*xxv*).
69. Meyer, *Explaining Music* (1973), 85.

of the half-cadential progression itself, the dominant possesses enough stability to represent a harmonic end."[70] Moreover, recall that Caplin distinguishes the half cadence—one of the genuine cadence categories—from the deceptive and evaded cadences, which represent failed attempts to achieve authentic cadential closure. We may therefore postulate an alternative to the *1-Schema* model, in which listeners may possess schematic representations for each of the genuine cadences, which I will call the *Genuine Cadence* model. Accordingly, we may rank the strength of cadential closure beginning with the PAC category, followed by IAC and HC, followed by the syntactically weaker cadential categories: the DC and EV categories.

Table 3: Estimates from a linear regression analysis predicting the average completion ratings for each excerpt using the *Genuine Cadence*, *1-Schema*, and *Latham* models as predictors

	Model	Cadential Strength	β	Model R^2
Musicians	*Genuine Cadence*	PAC>IAC>HC>DC>EV	.84	.84
	1-Schema	PAC>IAC>DC>EV>HC	.76	.56
	Latham		.77	.59
Nonmusicians	*Genuine Cadence*	PAC>IAC>HC>DC>EV	.74	.53
	1-Schema	PAC>IAC>DC>EV>HC	.80	.63
	Latham		.79	.61

By ranking each cadential category, we may compare the two models with the completion ratings. Given that Latham has provided a method for quantifying closure, I have also calculated the strength of closure for each excerpt using Latham's criteria, which I will refer to as the *Latham* model. Table 3 provides the estimates for each model. For the musicians, the *Genuine Cadence* model accounts for 84% of the variance in their ratings, while the *1-Schema* and *Latham* models were less successful, accounting for between 55-60% of the ratings. However, for the nonmusicians, the *1-Schema* model provided the best fit, accounting for approximately 63% of the variance in their ratings.

What are we to make of this result? The *1-Schema* model assumes that, when presented with a cadential excerpt, listeners have no knowledge of the future, and thus, of the material that may follow cadential arrival. Yet for a listener familiar with the classical style, the material that follows instances of cadential failure often differs considerably from the material following genuine cadential closure. By thwarting the expected moment of cadential arrival, theorists typically conceptualize cadential deception and evasion as a kind of derailment. And in order to attain the cadential closure initially promised, the subsequent passage typically features a continuation

70. Caplin, *Classical Form* (1998), 29 (emphasis in original).

of an earlier process, sometimes even a direct repetition of the previous cadential progression itself, a compositional procedure Schmalfeldt refers to as the "one more time" technique.[71] Thus, Caplin refers to the PAC, IAC, and HC categories as *genuine* specifically because they are the only categories that can achieve thematic closure.

What these results may suggest, however, is that the PAC, IAC, and HC categories also achieve *genuine* status by virtue of the material *following* cadential arrival. A genuine cadence therefore not only provides sufficient closure to permit the introduction of new initiating material, but the perceived strength of such a cadence is also crucially influenced by the function of the material following cadential arrival; or more generally put, the surrounding context may be crucial to determining the strength of a given cadence.[72]

So perhaps during music listening (and particularly during a first listening), the 1-*Schema* model is the default for determining the strength of closure of a given ending, but the material following each cadence subsequently compels listeners to retrospectively re-evaluate their earlier impression, and thus, to adopt a model that embraces a theory of *genuine* cadential closure. Given enough exposure to the style, however, listeners may apply a model of genuine cadential closure even to excerpts presented out of context, which would explain why musicians and nonmusicians disagreed as to whether a half cadence could complete a phrase or short passage of music. But to consider this claim in an experimental setting would nevertheless require stimuli that include the material following cadential arrival, an approach that our experimental design did not permit. Furthermore, many aspects of the perception of closure—the effect of cadential elision, variations in timing and dynamics surrounding cadential arrival, schematic representations of closure for other style periods—remain largely unexplored in music psychology.

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71. Schmalfeldt, "Cadential Processes" (1992), 1–52.

72. This claim is, in fact, essential to Hepokoski and Darcy's concept of *essential expositional closure* (EEC), the moment when the subordinate theme attains the first satisfactory PAC in the new key that proceeds onward to differing material (Hepokoski and Darcy, *Elements* [2006], 120). And it is precisely this "differing material" that distinguishes the EEC from any other PACs appearing in the subordinate theme. Indeed, if what follows the PAC is immediate thematic repetition or variation, then the EEC is deferred to the next PAC in the subordinate theme (123). The authors emphasize, however, that the EEC should not be psychologically privileged as the strongest cadence in the exposition; stronger cadences (i.e., cadences featuring expanded cadential progressions, trills above the cadential dominant, etc.) very often occur in the closing section as reinforcement-work: "One should not determine an EEC on the basis of what one imagines an EEC should 'feel' like in terms of force or unassailably conclusive implication. [...] The first PAC closing the essential exposition is primarily an attainment of an important generic requirement—nothing more and nothing less" (124).

Concluding remarks

As a first step, this particular study took a deductive path, beginning with the categories identified in Caplin's theory of cadential closure and then working down to the parameters at the musical surface that characterize those categories. But this is not to say one could not have taken an inductive approach, whereby the musical parameters dictate the number and position of the categories within the hierarchy. Indeed, my choice here was to engage experimental methods with models of cadential strength advanced in music theory to examine whether, and to what degree, these models might be consistent with the behavioural ratings of participants. But in doing so, this study did not consider those musical passages that defy ready categorization in traditional theories of cadential closure, but that nevertheless elicit an ending percept. By abandoning the cadential categories entirely, we might therefore consider the entire range of musical parameters responsible for the perception of closure without recourse to theories of cadence that attempt to reveal the procedures by which composers articulated closing patterns in the classical style, but which do not always directly correspond with the listening habits, attending strategies, and behavioral responses of listeners. Indeed, what is essential for a theory of cadence may not always be tenable for a psychological theory of closure.[73] Certainly, empiricism provides a method for applying constraints to our theoretical models, weeding out the impossible from the possible, but the concept of closure advanced in theories of cadential closure need not dispense with an examination of compositional procedures in favor of exclusively explaining how listeners perceive and process closing patterns.

However, the desire to explain or clarify how we *experience* musical endings can provide common ground for further cross-disciplinary work. To be sure, terms relating to closure may have a long history in music theory, but closure has emerged only recently in music-psychological research as a relevant perceptual and cognitive concept.[74] The application of experimental methods in future studies may therefore offer researchers the opportunity to gain a more complete understanding of the underlying sensory and cognitive mechanisms responsible for the perception of closure in music.

73. Nicholas Cook makes the same point in reference to the perception of tonal closure (Cook, "The Perception of Large-Scale Tonal Closure" [1987], 205).
74. It is difficult to determine the precise origins of the term in the history of psychology, but Wertheimer's application of closure in visual perception provides one well-known early example (Wertheimer, "Laws of Organization in Perceptual Forms" [1938], 83).

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