8-2011

Cognitive Processes for Infering Tonic

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COGNITIVE PROCESSES FOR INFERRING TONIC

by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Music

Major: Music

Under the Supervision of Professor Stanley V. Kleppinger

Lincoln, Nebraska

August, 2011

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University of Nebraska, 2011

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Research concerning cognitive processes for tonic inference is diverse involving approaches from several different perspectives. Outwardly, the ability to infer tonic seems fundamentally simple; yet it cannot be attributed to any single cognitive process, but is multi-faceted, engaging complex elements of the brain. This study will examine past research concerning tonic inference in light of current findings. First I will survey the recent history of experimental research in cognitive functions for memory retention and expectation as they relate to the recognition and learning of musical schemas. Then I will discuss distributional theories associated with the tonal hierarchy of major and minor key profiles and compare them with functional aspects of the intervallic rivalry model and 4/5 opening rule in order to demonstrate how they are not mutually exclusive for the inference of a tonic pitch. This will be followed with suggestions for instructors of music theory and aural skills in light of findings concerning cognitive aspects for inferring tonic.

To

Nathaniel, Eric, and Kathy

Thanks for all your support

Acknowledgments

I would like to express my gratitude to my committee: Dr. Kleppinger, Dr. Foley, and Dr. Becker.

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CHAPTER 1

INTRODUCTION

The last several years have shown remarkable advancements in our knowledge of cognitive function, making way for deeper understanding of the way we think about music. As instructors of music theory and aural skills, it should always be important to reevaluate our pedagogical practices in light of current knowledge obtained from studies and experiments in music perception. Doing so will allow us to refine and restructure the methods we use to assist our students with the mind/body connections they need to make in order to better accomplish their musical goals.

When babies enter the world, they experience a barrage of information through their senses. It is necessary to sensibly arrange this information in ways that are beneficial for survival and interaction with the world around them. In order to effectively communicate audibly, cognitively received sound signals must be logically organized for efficient and quick learning. Such a process must be able to organize the sound signals differently according to the intended form of communication. For example, the communicative intent for language expression is different than that for musical expression, and will result in different cognitive organizational structures for each. Yet, the brain is able to organize sound signals according to the manner in which it is perceived and utilize elements of this same process for different responsive expressions that effectively communicate an intended meaning and purpose. In an attempt to understand some of the numerous elements relating to this perceptual organization of musical sounds, a focus on the subject of tonic inference will provide a small glimpse into the cognitive functions needed for mental musical organization.

It is important to distinguish terminology that relate to the process of inferring tonic. Using aspects of Leonard B. Meyer's definition for tonic tone, in Western diatonic music, "inferring tonic" is the recognition of a single tone of "ultimate rest toward which all other tones tend to move" and around which a diatonic key is established.[1] This process is sometimes described as "discovery of pitch/key center" or simply "discovery of key." The term "key perception" refers to mental representations of the entire key, in addition to the tonic pitch class. It is necessary to understand that the inference of a single pitch class as the tonic entails a specific concept, whereas key perception is a more general term that involves tonic inference as well, or apart from, other distinguishing characteristics of key defining elements that could also be used in establishing a key profile. The term "key profile" specifically refers to the rating

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[1] Leonard B. Meyer, *Emotion and Meaning In Music* (Chicago: University of Chicago Press, 1956), 214.

results of an experiment conducted by Carol Krumhansl and Richmond Shepard.[2] This experiment confirmed a relationship between tones and their varying levels of stability. Meyer explains the concept of stability along these lines.

> Some of the tones of the system are active. They tend to move toward the more stable points in the system—the structural or substantive tones. But activity and rest are relative terms because tonal systems are generally hierarchical: tones which are active tendency tones on one level may be focal substantive tones on another level and vice versa. Thus in the major mode in western music the tonic tone is the tone of ultimate rest toward which all other active melodic tones relative to the tonic, join the tonic as structural tones; and all the other tones, whether diatonic or chromatic, tend toward one of these. Going still further in the system, the full complement of diatonic tones are structural focal points relative to the chromatic notes between them.[3]

The subject of tonic inference is a subtopic associated within studies of key perception, a larger topic that has significantly contributed to the growing body of music perception research. At the deepest level, inferring tonic involves a process of recognizing and comparing (audible) pitch frequency events with learned schemas such as key profiles, tonal hierarchies, tonal distribution, musical syntax, and rare intervals. These schemas provide a simultaneous array of competing auditory representation from which the listener makes statistical observations to form predictable expectations leading to the designation of a tonic pitch.

On a biological level, inferring tonic involves intricate mechanisms from both hemispheres of the brain, and has been traced to the auditory cortical system. In fact,

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[2] Carol Krumhansl, *Cognitive Foundations of Musical Pitch* (New York: Oxford University Press, 1990), 20.

[3] Meyer, *Emotion and Meaning In Music*, 214-215.

studies of melodic perception involving brain-lesioned individuals who showed damage to either the right or the left auditory cortical systems have demonstrated that while there was a noticeable change in speed of performance decisions concerning pitch recognition, they were still able to adequately perform tonic recognition tasks with accuracy.[4] This implies that though musical perception can change based on modifications made to the auditory cortical system, the region for inferring tonic is not limited, but extends to other parts of the brain. As will be shown, tonic inference is not relegated to any single perceptual task, but involves a complex integration of several different cognitive functions.

Research shows that the music and language sound systems share many overlapping cognitive processes. While direct comparisons between language and music may not reveal many similarities, a common cognitive background can enlighten our understanding of shared learning mechanisms between both. This, in turn, can lead to a better grasp of musical structures derived from the mental framework of learned sound categories. When we learn a sound system, as Aniruddh Patel says, "…it leaves an imprint on our minds. That is, it leads to a mental framework of sound categories for our native language or music …[which] helps us extract distinctive units from physical signals rich in acoustic variation."[5]

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[4] Robert Zatorre, "Neural Specializations for Tonal Processing," in *The Cognitive Neuroscience of Music* ed. Isabelle Peretz and Robert Zatorre (New York: Oxford University Press, 2003), 232-236.

[5] Aniruddh D. Patel, *Music, Language, and the Brain* (New York: Oxford University Press, 2008), 9.

Although acoustical signals are physical, the language and music units derived from them are psychological. Patel explains this phenomenon with the following summarized example by comparing fundamental aspects of DNA with fundamental elements of acoustical recognition. The building blocks of DNA are chemically structured and the brain has only one response to each chemical combination. However, the building blocks of music and speech vary "in physical structure from token to token and as a function of context. The mind must find some way to cope with this variability, separating variation within a category from variation that constitutes a change in category."[6] The brain takes acoustical signals and organizes perceived information according to learned sound categories. In cognition research, it is necessary to extract measurable data from psychological entities. The results can often make perception research difficult to interpret, and is fraught with conclusions that must be continuously refined and reevaluated against growing empirical knowledge.

With these considerations in mind, this study will examine past research concerning tonic inference in light of current findings. First I will survey the recent history of experimental research in cognitive functions for memory retention and expectation as they relate to the recognition and learning of musical schemas. Then I will discuss distributional theories associated with the tonal hierarchy of major and minor key profiles and compare them with functional aspects of the intervallic rivalry

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[6] Ibid., 11.

model and 4/5 opening rule in order to demonstrate how they are not mutually exclusive for the inference of a tonic pitch. This will be followed with suggestions for instructors of music theory and aural skills in light of findings concerning cognitive aspects for inferring tonic.

CHAPTER 2

COGNITIVE ASPECTS: RECOGNITION AND EXPECTATION

In order to understand tonic inference as an aspect of key perception it is necessary to begin by exploring the cognitive processes of recognition and expectation and how they relate to key perception. From an evolutionary perspective these processes developed as a way to increase preparedness for something unexpected. Those with the ability to anticipate future events are more likely to avoid danger and benefit from positive prospects. In order for the brain to successfully predict future events, its adaptive motor functions need to accurately assess and respond to the incoming stimuli from the senses in the most efficient and effective manner possible.[7] This necessarily involves three important aspects of cognition: memory retention, recognition, and cognitive expectation.

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[7] David Huron, *Sweet Anticipation: Music and the Psychology of Expectation* (Cambridge: Massachusetts Institute of Technology, 2006), 3.

This discussion's primary focus is on the complex mechanisms of cognitive expectation; however, it is important to understand that the interactive nature with all of these cognitive features is integral for the adaptation to environment, social norms, and expected behavior. Such functions allow for the cultural assimilation of expected musical events that are recognized by the statistical regularity of hierarchically occurring sound stimuli within a musical setting.[8] As David Huron says, "listeners must be enculturated into specific auditory environments where some events or patterns are more predictable than others.…it is the learned schemas that provide the templates that enable the fast-track brain to make predictions, and in some cases, to be surprised."[9] These learned schemas also allow us to quickly predict a probable tonic note and establish a mental key profile through which the expected tonal center will eventually be confirmed with certainty.

The development of implicitly learned schemas begins early in life through mere exposure to natural structure within a given environment.[10] The passive exposure of the brain to regularly recurring events or patterns in an environment is implicitly acquired and has significant influence in cognitive learning. This is partly the result of the brains tendency for statistical learning.

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[8] Krumhansl, *Cognitive Foundations of Musical Pitch*, 285-286. For a more in-depth discussion of the cognitive functions of expectation, see chapters 1-2 of Huron's *Sweet Anticipation*.

[9] Ibid., 36.

[10] Barbara Tillman, Jamshed Bharucha, and Emmanuel Bigand, "Implicit Learning of Tonality: A Self-Organizing Approach," *Psychology Review* 107, no. 4 (2000): 885.

Statistical learning is a shared cognitive process for sound category learning in both speech and music, and involves two separate principles.[11] The first entails sensitivity to how often various stimuli tend to occur in any given environment such as the frequency of occurrence of patterns. An example is the dominant-to-tonic harmonic implication that regularly occurs both at the opening and closing of phrases, which marks a progression from instability to stability. This is common in many of America's folk songs and hymns, such as the opening and closing harmonies of "Home on the Range," or "Amazing Grace." The second principle involves the statistical likelihood of accurately predicting a probable outcome by using information that is gleaned from the first principle in the form of an array of recognized mental representations that have been shown to regularly occur within specific environmental situations. For example, the fact that we repeatedly hear dominant-to-tonic progressions in music of the Western culture implicates this progression as a statistically learned musical sound schema. The musical patterns that imply dominant-to-tonic function in "Home on the Range" allow us to make predictions about the existence of dominant-to-tonic functions of similar musical patterns in new music. It is not necessary for the individual to be aware of the duration or how often they are exposed to the stimuli for learning to occur.[12] Statistical learning is a crucial process for establishing probable expectation from learned tonal schemas, which is an important part of the cognitive process of inferring tonic. Indeed, in the establishing of

[11] Patel, *Music, Language, and the Brain*, 84.

[12] Huron, *Sweet Anticipation*, 63.

most auditory related cognitive structures, statistical learning seems to play a significant role.

Competition among various, simultaneous predictions complicates matters. According to the theory of competing expectations, dubbed "neural Darwinism," mental representations vie successfully or unsuccessfully for "cortical resources."[13] Huron explains it well.

> Those representations that prove most useful in predicting future events are preserved and reinforced, while less useful representations atrophy. Such neural competition is possible only if more than one representation exists in the brain. That is, in forming expectations, the normal brain would maintain multiple concurrent representations. Relying on a single representation would mean either that the brain had achieved near perfection in forming predictions about the world, or that the representation is genetically ordained, or that the brain has become pathologically structured.[14]

When learning music, the listener hears an array of competing representations in the form of recognized schemas, such as harmonic progressions from dominant to tonic or melodic progressions from the leading tone to tonic. The brain must quickly recognize similarities and choose the most comparable representation for adapting to the new stimuli.

In any given cognitive event, there are multiple alternative mental representations that are engaged in generating expectation.[15] For the process of inferring a tonic note this means that there are multiple mental representations from

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[13] Ibid., 108.

[14] Ibid., 109.

[15] Ibid.

which the selection of a single pitch must be inferred. The brain is able to make a prediction of the expected tonic note based upon differing mental representations spawned from the musical stimuli. While the process is certainly more complex than has been laid out here, the point must be made that there currently is no singular theory regarding tonic inference that is able to adequately explain the process. This is because theories generated thus far uniquely embody different perspectives of alternate mental representations that may all make a contribution, which when combined, assist in the processes of inferring tonic. The importance of understanding processes of cognitive mental expectation is an integral element for developing workable theories of tonal profiles and tonic inference, but such theories considered individually are imperfect models of the tonal-inference process.

When considering key perception, one of the important elements is recognition of a tonic note. In the key of C major, how is it that we are able to infer C as the note of greatest importance? The process by which this is accomplished seems simple, but involves complex elements such as memory of culturally assimilated scale-degrees associated with recognizable musical events. These musical events take on the form of perceived tonal schemas that are recognized through the cognitive processes of expectation, which involve statistically anticipating the probabilities for correct outcomes between competing concurrent mental representations known as neural

Darwinism.[16] In order to have a clearer understanding of these elements of musical cognition, it will be helpful to trace some of the history of their development.

[16] Ibid., 108.

CHAPTER 3

KEY PROFILES AND TONAL HIERARCHY

Modern study of key perception begins with the groundbreaking research conducted by Krumhansl and Shepard (K-S) in 1979. They approached this research with the attempt to discover parallels between the cognitive organization of musical domains and known cognitive principles of organization in non-musical domains. They needed to find a way to test the idea that movement towards points of stability that are recognized as musical structures, are also "psychological reference points."[17] These reference points form the foundation for hierarchical levels of musical functions between related tones in a diatonic scale.

Their experiment used a probe-tone method that asked subjects to rate on a seven–point scale how well a given probe-tone, completed a melodic stimulus. The

[17] Krumhansl, *Cognitive Foundations of Musical Pitch,* 20.

stimulus consisted of the first seven notes of an ascending or descending scale followed by a pause, after which a randomly chosen member of the chromatic scale was sounded as a probe tone. Probe tones are randomly generated pitches taken from the twelve tones of the chromatic scale and sounded without reference to the octave in which the stimulus was played. In this experiment, a single probe tone was heard and rated for its completion of the previous context. For example, if the key of C is used, the stimulus consists of an incomplete ascending diatonic scale starting on C4 and stopping on B4, followed by a pause, after which the probe tone sounds. The participant then rates the probe tone according to their perception of how well it completed the scale. The intent of this method was to "quantify the hierarchy of stability" within a tonal context and thus achieve a measure against which other experiments could be conducted.[18]

The results revealed the pattern shown in Figure 1 below that clearly shows a preference for the notes of the diatonic scale over non-diatonic (chromatic) notes with the tonic rated as the most preferred. These patterns show "goodness" ratings, which disclose a tonal hierarchy that is useful for measuring elements of the perceptual and cognitive processes. The notes receiving a "good" rating would be more easily remembered and subject to fewer distortions than less "good" notes.[19]

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[18] Ibid., 21-24.

[19] Ibid., 18.

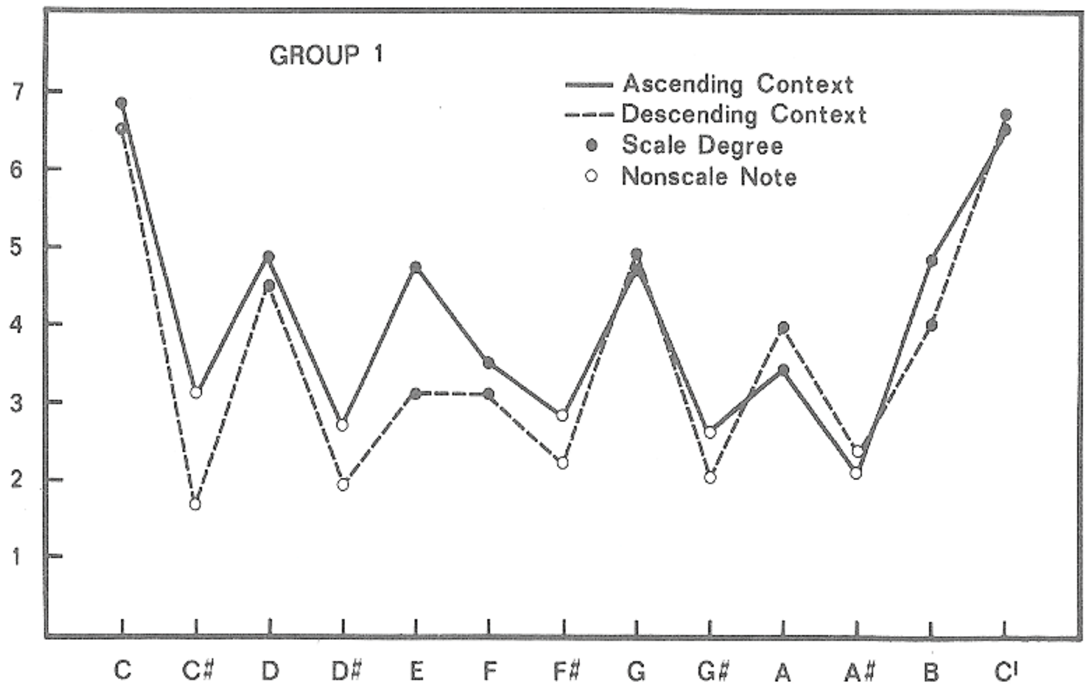

Figure 1. Average goodness ratings for probe tones following a C major scale as stimulus (Krumhansl and Shephard's figure 2.1 from Carol Krumhansl, *Cognitive Foundations of Musical Pitch*, 23.)

K-K KEY PROFILES

An additional experiment undertaken by Krumhansl and Kessler (K-K) replicated the K-S experiment but made changes to provide multiple contexts for the stimuli. Rather than leave out the final note of a scale, the complete scale, with starting and ending tonic notes, was included in the context. In addition, four more contexts were used in both major and minor keys, and consisted of arpeggiated root position tonic triads or three different chord cadences using progressions of IV-V-I, VI-V-I, or II-V-I.

The K-S experiment used three different test groups made up of participants with differing levels of musical experience. However, the K-K experiment only used subjects who had at least five years of musical experience with minimal music theory training. In order to avoid potential confusion associated with differences in pitch height between contextual stimuli and the probe tone, Shepard's tones were used to sound all pitches. The pitch frequencies of these artificial tones are manipulate in such a way that it becomes impossible to associate fundamental tones with their corresponding octave, thereby creating octave equivalency. Similar to the K-S experiment, the participants listened to one of the musical contexts from the group of possible stimuli, followed by a pause and then the sounding of the probe-tone. This time however, the participants were asked to rate the probe-tone according to how well it fit with the previously heard context. The same rating system as in the K-S experiment was used.[20] The resulting graphs, shown in Figure 2 below, became known as diatonic major and minor key profiles and have had significant influence in subsequent music cognition studies and experiments.

[20] Ibid., 26.

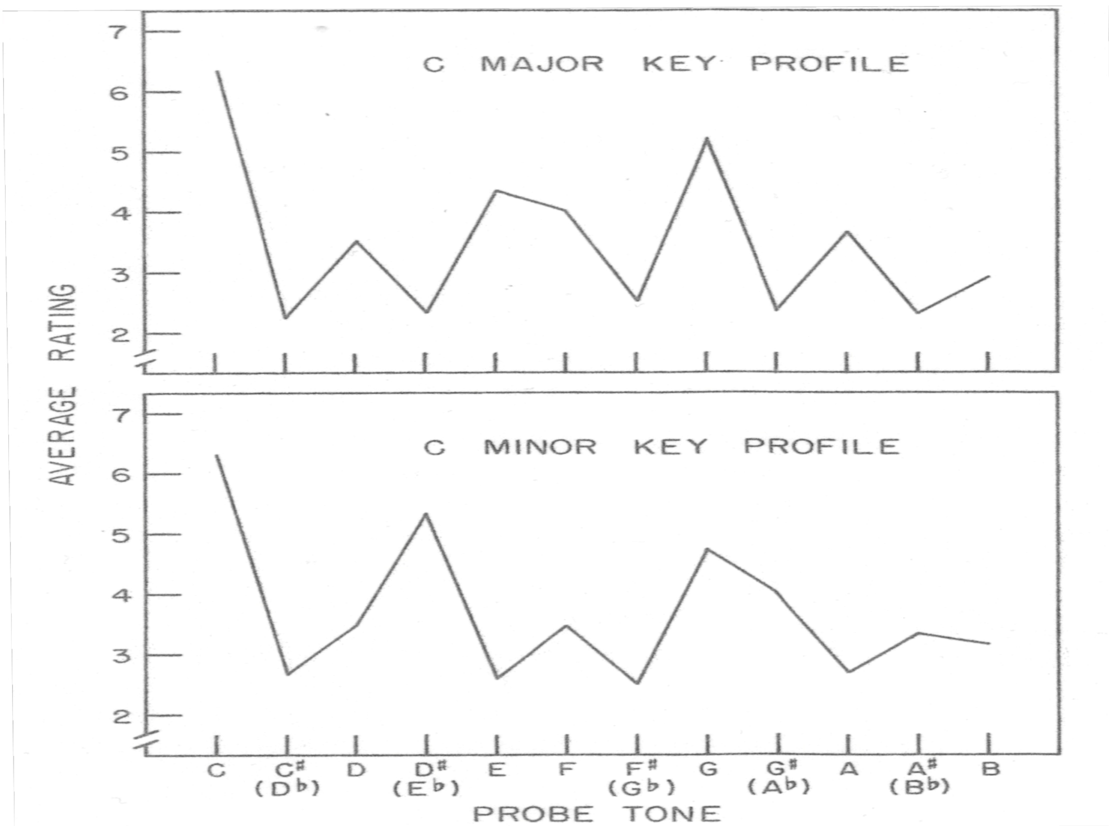

Figure 2. Probe tone ratings of the major key profile (top) and the minor key profile (bottom) with all tones of the chromatic scale shown in relation to the scales of C major and C minor. (Krumhansl and Kessler's figure 2.3 from Krumhansl *Cognitive Foundations*, 31)

TONAL HIERARCHY

Krumhansl and Kessler interpreted the key profiles as a tonal hierarchy that is represented by the participant's perception of the most frequently occurring pitches. As Krumhansl wrote, "what does seem striking is that this information about frequency of occurrence is represented so accurately in hierarchies of tones and chords that they can be used to generate a very regular and interpretable spatial representation of musical keys."[21] They went on to apply this key profile to a harmonic hierarchy, and show a multidimensional relationship between scale-tones and keys in the form of a conical vertex, as seen in Figure 3. The tonic note appears at the point of the vertex with the next-highest rated notes extending outward from the vertex and the lowest rated residing farthest from the tonic note.[22] Krumhansl and Kessler also created a key-finding algorithm using the quantified fitness rating to reinforce the conception of tonal hierarchy as a measure of stability and finality.[23]

Krumhansl also concluded that listeners' sensitivity to the frequency of occurrence supported learning from exposure. "Listeners appear to be very sensitive to the frequency with which the various elements and their successive combinations are employed in music. It seems probable, then, that abstract tonal and harmonic relations are learned through internalizing distributional properties characteristic of the style."[24]

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[21] Ibid., 285-286.

[22] Ibid., 128.

[23] Ibid., 124.

[24] Ibid., 286.

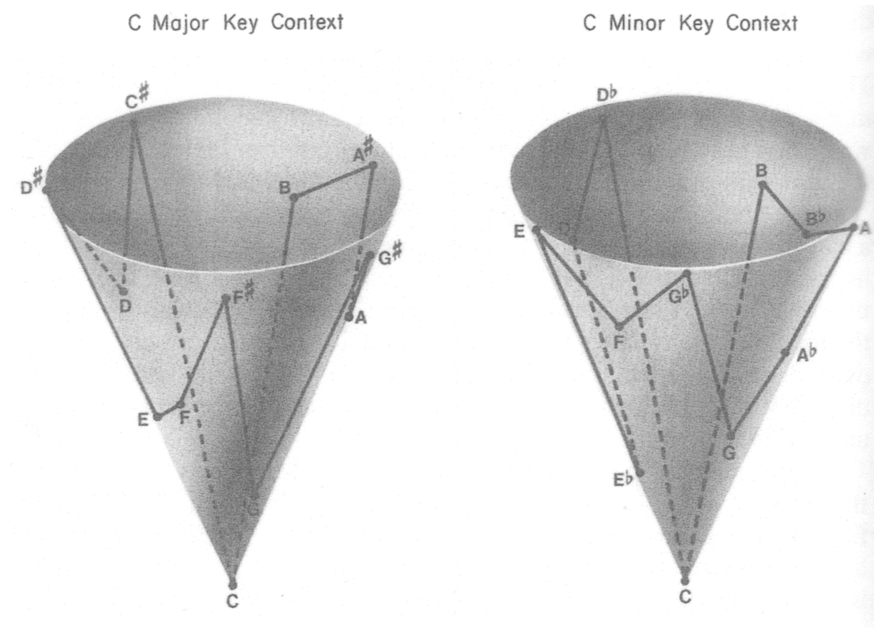

Figure 3. Multi-dimensional depiction of major and minor key profiles with the tonic note located at the vertex of the cone and scale related tones extending outward. (Krumhansl and Kessler's figure 5.7 *Cognitive Foundations*, by Krumhansl, 128)

The idea that key profiles represent a frequency of occurrence suggests that in order to arrive at a particular key profile and tonic note, listeners subconsciously record statistical summaries of the occurrence of each pitch. For cognitive psychologists, this line of reasoning is not far from the theory of statistical learning. The theory that listeners subconsciously collect a statistical distribution of tones throughout a portion of composition became known as the distributional theory of a tonal hierarchy.

The primary detractors to this theory were David Butler and associates who disagreed that this theory could stand alone as the method used most by listeners to infer tonic. They thought it unlikely that listeners regularly compared all the possible pitch groupings and rejected unlikely matches. Though this may be partially attributed to a misunderstanding of the implicit nature of the theory of statistical learning, additional objections pointed to the theory's inability to account for both the role of musically structured cues, and the ordering of tones through time.[25] In order to explain these concepts they formulated objections to the distributional approach with experiments that showed how the intervallic rivalry model provided alternative ways for inferring a tonic pitch.

These objections led to a series of dialogues documented in a variety of papers between supporters of the Krumhansl and Butler models, in which several studies were conducted with the intent to clarify understanding of either view.[26] Although various methods were employed, most experiments failed to satisfactorily prove or disprove either argument. Nevertheless, several relevant arguments were expounded and are worth a brief examination.

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[25] David Butler, *The Musician's Guide to Perception and Cognition* (New York: Schirmer Books, 1992), 121.

[26] See Helen Brown, David Butler, and Mari Riess Jones, "Musical and Temporal Influences on Key Discovery," *Music Perception: An Introductory Journal* 11, no. 4 (Summer 1994): 372; Lola Cuddy and Betsy Badertscher, "Recovery of the Tonal Hierarchy: Some Comparisons Across Age and Levels of Musical Experience," *Perception and Psychophysics* 41, no. 6 (1987): 609-620; and David Temperley and Elizabeth West Marvin, "Pitch-Class Distribution and the Identification of Key," *Music Perception: An Interdisciplinary Journal* 25, no. 3 (Feb. 2008): 193-212.

PROBE-TONE PROFILES

Lola Cuddy and Betsy Badertscher conducted a study using probe-tone profiles in which they considered an important element of the intervallic rivalry model, the rare-interval hypothesis. This hypothesis first proposed by Richmond Browne suggested that in the process of determining a tonal center, listeners relied more upon the rare intervals of a tonal system to infer tonic. The rare intervals of a scale are the least frequently occurring intervals, such as the tri-tone and minor seconds in a major scale. Browne's proposal suggests that, because these intervals are heard most often in specific contexts, whenever listeners hear these intervals they expect them to follow the usual patterns in which they are most commonly heard. More details concerning rare intervals and their place in tonic identification are discussed in Chapter 4 in regards to the intervallic rivalry model.[27] Cuddy and Badertscher interpreted their findings as negative evidence for this intervallic rivalry model.[28]

Butler et al. responded by replicating their probe-tone profiles in consideration of a new idea: the temporal-order hypothesis. It proposed that when listeners relied on rare intervals they were "more accurate in detecting a correlation between a rare interval and the key of the musical event containing it when the pitches that outline the rare interval appear in a temporal order implying goal-oriented harmonic motions

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[27] Richmond Browne, "Tonal Implications of the Diatonic Set," *In Theory Only* 5 (1987): 3-21.

[28] Cuddy and Badertscher, "Recovery of the Tonal Hierarchy," 618.

commonly encountered in tonal music."[29] Butler maintained that completion ratings, such as the K-K key profile, provides partial evidence for tonic inference and works in conjunction with the intervallic rivalry model.[30] More concerning intervallic rivalry will be discussed below.

An experiment by David Temperley and Elizabeth West Marvin showed the likelihood of participants determining a key from listening to distributions of randomly chosen pitch-classes void of recognizable tonal structure was greater than chance, but fell far short of being the single cause for key recognition.[31] "The fact that only slightly more than half of our participants' key judgments matched the predictions of the distributional view suggests that there is much more to key identification than pitch-class distribution. It seems clear that structural cues of some kind – cues relating to the ordering and temporal arrangement of pitches – play a role in key perception."[32] While this experiment did not entirely discount the distributional approach, it did show that more is needed to adequately explain the cognitive processes behind key perception and tonic inference.

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[29] Brown, Butler, and Jones, "Musical and Temporal Influences," 372.

[30] Ibid., 401.

[31] Temperley and Marvin, "Pitch-Class Distribution," 209.

[32] Ibid., 210.

FREQUENCY OF THE DOMINANT

Along with its inability to account for time related orderings and structural cues, another problem with the distributional view is that the K-K key profiles do not match with the distributional frequency of pitches in actual music. A study done by Brett Aarden in 2003 found that the most commonly occurring pitch in a survey of European folk tunes is the dominant pitch, not the tonic.[33] In major keys, the next frequently occurring pitch is the mediant followed by the tonic pitch. In minor keys the tonic is the most frequently occurring pitch after the dominant, but is very closely followed by the mediant pitch. The Krumhansl key profiles, on the other hand, show that the most frequently occurring pitch is the tonic. The differences between these two findings can be seen by comparing the key profile graphs, Figure 2, with the provided graphs of distributed pitches in actual music, Figures 4 and 5.

[33] David Huron, *Sweet Anticipation*, 148-149.

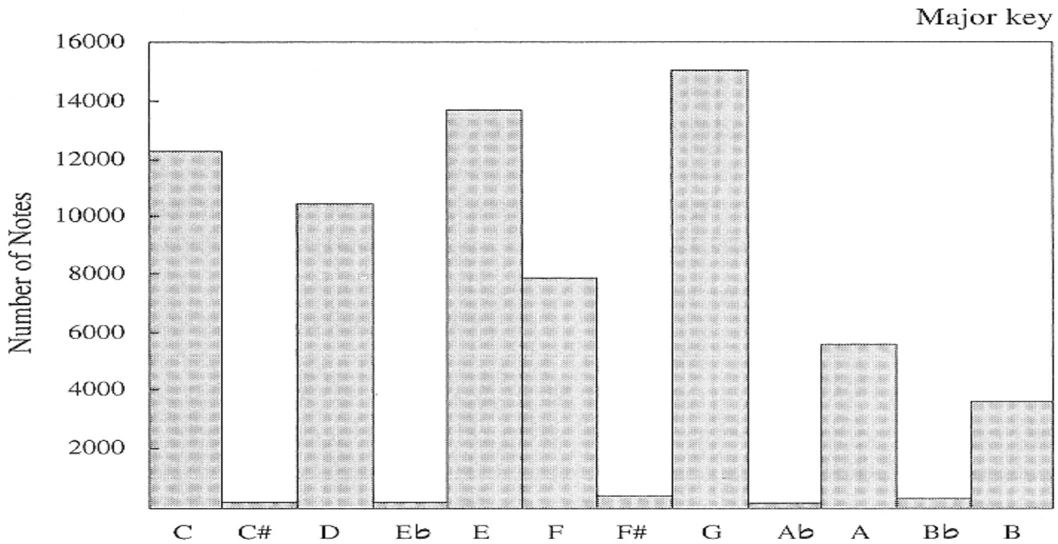

Figure 4 Distribution of scale tones for a large sample of melodies in major keys using more than 65,000 notes. All works were transposed so the tonic pitch is C; all pitches are enharmonic. Modulating passages were excluded. (Huron's Figure 9.1 *Sweet Anticipation*, 148)

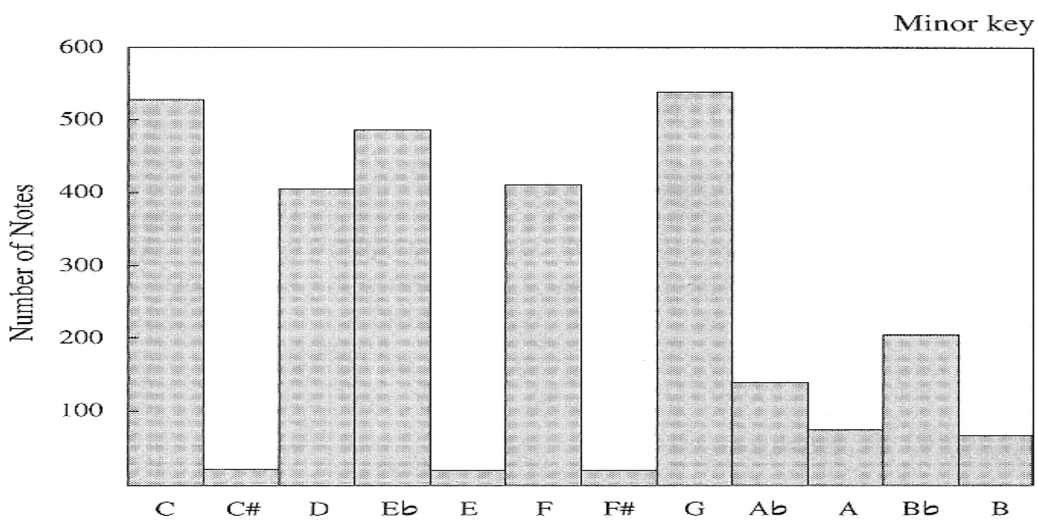

Figure 5 Distribution of scale tones for a large sample of melodies in minor keys using more than 25,000 notes. All works were transposed so the tonic pitch is C; all pitches are enharmonic. Modulating passages were excluded. (Huron's Figure 9.2 *Sweet Anticipation*, 149)

The premise of the distributional view is that the most frequently occurring pitch will receive the highest ratings in a probe-tone profile. Initial interpretations of the K-K key profiles viewed the profiles in light of the distributional views, thereby concluding that the most frequently occurring pitch was the tonic. However, the interpretation of the K-K key profiles according to the distributional view is flawed, because the most frequently occurring pitch in music is the dominant pitch, not the tonic, as shown by Aarden.

PHRASE-FINAL PROBABILITIES

Rather than viewing K-K profiles from the distributional view, it is more likely that participants of the K-K experiment were responding to contextual stimuli as though they were rating probe tones according to expected phrase closings. In order to show that what participants heard and rated in the K-K experiment were actually "phrase-final probabilities", Aarden set out to achieve similar results through different methods, such as his experiment testing musical expectancy with speed response. In doing so, he was able to closely replicate the K-K key profiles.[34]

[34] Bret J. Aarden, "Dynamic Melodic Expectancy" (Ph.D. diss., The Ohio State University, 2003), 69-72.

Using speed response as a measure of expectancy, the experiment tested participant's response to expected closures in music.[35] The contextual stimuli consisted of musical phrases from eighty-two different folk songs. Each phrase ended with one of the seven possible scale-degrees, and was preceded by a key establishing chord progression. See Figure 6 for examples.

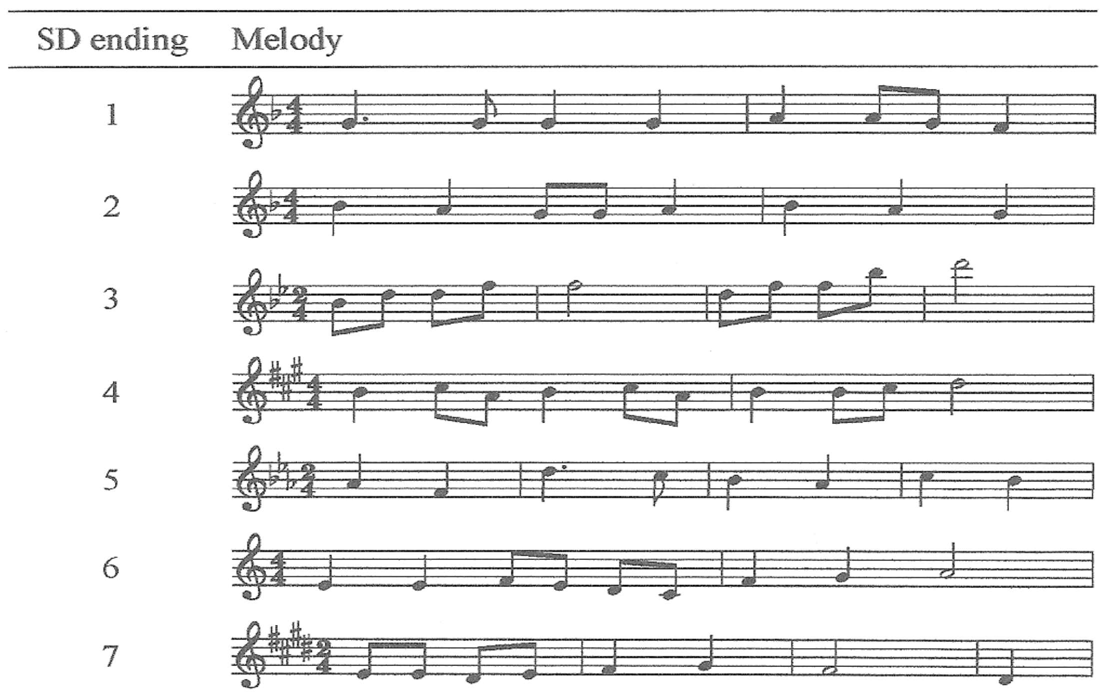

Figure 6. Example of the contextual stimuli used by Aarden using the speed response method. (Aarden's Figure 5.1 "Dynamic Melodic Expectancy" 71)

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[35] The Hick-Hyman law of psychology has shown that the speed response method can be used to provide empirical evidence for cognitive expectation. See Huron, *Sweet Anticipation*, 63.

By quickly pressing one of two buttons, subjects indicated their expectation of whether the note would move up or down shortly after the last note was heard. The speed with which they responded shows the degree to which they expected the destination of the final note of the phrase. As the music progressed through the phrase, participants were able to see a countdown of the remaining notes from an on-screen counter. This helped them recognize the closing note of the phrase, and was also necessary in order to replicate the pause followed by the probe-tone in the K-K experiment that implied phrase closings. The resulting measurements were interpreted as "scale-degree weight estimates in log reaction time," with the tonic note showing the fastest reactions times, followed by the mediant and the dominant.[36]

Figure 7, which compares Aarden's results to the K-K key profile, shows that they are strikingly similar. Aarden interpreted the results as evidence that the "key profile is learned from the distribution of scale degrees at phrase endings," and would be more fittingly recognized as a profile of expected tonal closures rather than the hierarchical distribution of tones throughout a composition.[37]

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[36] Ibid., 78.

[37] Ibid., 96.

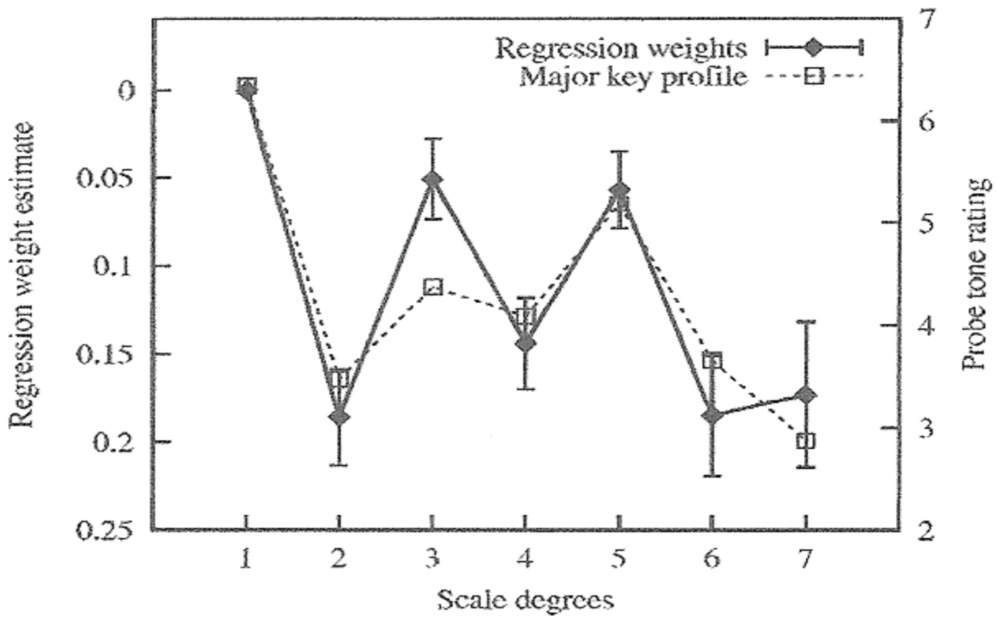

Figure 7. Comparison between the Aarden speed response method and the K-K key profile. (Aarden's Figure 5.6 "Dynamic Melodic Expectancy" 78)

These results provide a new perspective of the process by which scale degrees are aurally perceived. The stimulus for statistical learning is the habitual exposure to phrase-final contexts rather than the general distribution of tones throughout a phrase. This strengthens the Krumhansl hypothesis that a tonal hierarchy is assimilated through statistical learning. Because the key profile does recognize a single pitch as the most stable note, the listener is likely to recognize the phrase-final schema that is most stable and from that infer the tonic note. While recognition of stability degrees may not definitively lead to the inferred tonic, the cognitive predictability for correct outcomes is sufficiently satisfied in assuming a single pitch when hierarchical relationships with contextual notes of the key profile are recognized.

When considering the results of these studies in light of current knowledge about cognition, some interesting conclusions about inferring tonic begin to form. The process of inferring a tonic is not accomplished by a single cognitive task. When listeners hear music, they rely on sound patterns and tonal schemas that they have already learned in order to form musical expectations. Some of these patterns like the K-K key profile are statistically learned through cultural assimilation at a young age of about four to five years.[38] The cognitive comparison of musically generated expectations with learned schemas is a simple process involving statistically predictable outcomes for arriving at the most likely candidate around which a key profile is made. It is probable that by relying upon the learned tonal schemas, listeners are able to quickly recognize the most tonally stable note in a musical phrase. Ultimately the tonal hierarchy model is supported by cognitive theories about expectation, statistical learning, and neural Darwinism.

[38]Kathleen A. Corrigall and Laurel J. Trainor, "Musical Enculturation in Preschool Children: Acquisition of Key and Harmonic Knowledge," *Music Perception: An Interdisciplinary Journal* 28, no. 2 (Dec. 2010): 195.

CHAPTER 4

INTERVALLIC RIVALRY AND THE 4/5 OPENING RULE AS FUNCTIONAL SCHEMAS

The intervallic rivalry model and the 4/5 opening rule are theories taken from studies that investigate time-ordered tonic-defining schemas. Both of these theories focus on mental expectations formed from recognizable musical patterns that imply dominant-to-tonic harmonic function both melodically and harmonically. This function is easily distinguished from most other musical functions, and is one of the simplest concepts to teach beginning music theory students because it is so readily recognized. In actual music, dominant-to-tonic harmony is one of the more frequently occurring progressions, especially when approaching moments of structural stability, making it a likely candidate for adoption as one of the recognizable mental representation that make up our repertoire of recognizable tonal schemas. As these studies show, the overwhelming recognition of the dominant-to-tonic harmonic function plays a crucial role in quickly defining a single pitch as the tonic.

The intervallic rivalry model is the result of several different studies conducted primarily by Brown and Butler.[39] As was previously mentioned, in 1994 they conducted experiments using probe-tone profiles in response to Cuddy and Badertscher's negative findings concerning the rare-interval hypothesis. As a point of departure for their experiments, Butler proposed three hypotheses from which to view the intervallic rivalry model. They are known as the primacy hypothesis, the rare-interval hypothesis, and the temporal order hypothesis.

The primacy hypothesis suggests "listeners are biased to assume that the first note in a musical event is the tonal center, until a better candidate replaces it." The rare-interval hypothesis proposes that for determining the tonic pitch, listeners rely more on the unambiguously correlated rare intervals of a diatonic set than on the common intervals of that set because they provide more reliable key information. Listeners are most accurate "…when the pitches that outline the rare intervals appear in a temporal order implying goal-oriented harmonic motions commonly encountered in tonal music." This is known as the temporal-order hypothesis.[40]

PRIMACY HYPOTHESIS

The primacy hypothesis resembles the concept of neural Darwinism in that it suggests, cognitively speaking, that there is always a fluctuating evaluation and

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[39] This study has been summarized in Brown, Butler, and Jones, "Musical and Temporal Influences," 371-375.

[40] Ibid., 372.

assessment of heard stimuli. An important distinction, however, lies in this theory's assumption that the first tone heard is the tonic note. Musical openings most often feature tonic harmony. However, there are many different melodic opening patterns that do not start on the tonic note, but instead start on a different note of the tonic chord. The opening patterns almost always quickly affirm movement to the tonic note before moving away toward mid-phrase material. Neural Darwinism suggests that from a cognitive perspective, these different melodic patterns form an array of competing mental representations that pinpoint the tonic note. The inconsistency of starting notes in a musical opening warrant diverse expectation concerning the first note heard. Even so, the regular presence of supporting tonic harmony assists in quickly recognizing the tonic note. If statistical learning were to be considered as a factor, the tonic does not receive the highest rating for distribution frequency, but is third after the dominant and mediant.

An experiment seeking to ascertain participant's expected tonal openings in music would be useful for clarification. Though such and experiment is not yet available, a study by Piet Vos assembled similar information by analyzing an assortment of openings from classical music, folk music, and national anthems composed in the Western music tradition. Vos proposed that if a "composition opens melodically with an ascending fourth or descending fifth (4/5 opening), then the second tone is the tonic of the composition's key, and the first tone its dominant."[41]

[41] Piet G. Vos, "Key Implications of Ascending Fourth and Descending Fifth Openings," *Psychology of Music* 27, (1999): 4.

One-fifth of all melodies analyzed started with the 4/5 opening, with ninety-four percent of those opening as ascending fourths. If just the folk tunes are considered, the number of 4/5 openings increase to around one-third of all studied melodies. For determining expected openings, it seems prudent to consider the dominant note as a possible choice for a starting pitch.

The 4/5 opening rule proposes that the second note of such openings is the tonic note. This necessarily establishes a dominant-to-tonic cognitive representation that begins a significant number of pieces. It is clear that exposure to these kind of openings occurs frequently enough in commonly heard music to consider it a likely candidate for statistical learning as a possible opening tonal schema. Because it is the opening of a phrase, it is also the first recognizable representation for statistical learning, making repetitions of this schema more easily recognized in middle and ending contexts. For tonic inference, the recognition of 4/5 opening context and their similarities to most closing context that end with dominant-to-tonic harmonies implicates a likely prediction for fulfilling tonic expectation. This makes the 4/5 opening rule a significant opening tonal schema that immediately indicates a tonic pitch. Similar studies would be helpful in establishing other musical patterns that are common to musical openings.

RARE-INTERVAL THEORY

The rare-interval hypothesis proposes that in a diatonic collection, the rarest intervals are the best indicators for determining a tonic note. A central point to the rare-interval hypothesis is the cognitive recognition of differences between information conveyed by commonly occurring intervals and rare intervals. Rare intervals are those intervals with a relative frequency of .10 or less, as can be seen in Figure 8.[42] In a major key, there are only three possible rare intervals, two minor seconds and one tritone. In a minor key the number of rare intervals can more than double, and is likely to fluctuate according to the raising and lowering of the sixth and seventh scale degrees depending on the minor context that is used.

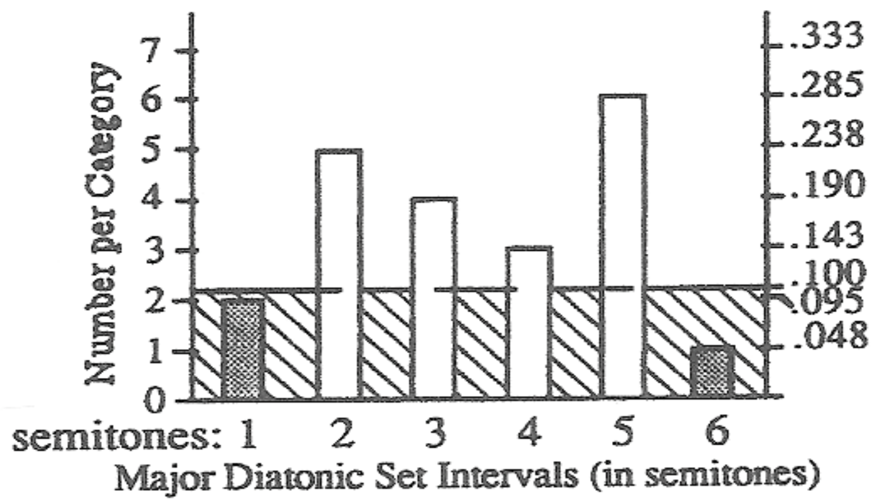

Figure 8. Graph showing the rarest intervals in a major key. Dark-shaded bars represent rare intervals. (Brown, Butler and Jones's Figure 1, "Musical and Temporal Influences on Key Discovery," 372)

An initial problem with the rare-interval hypothesis is that it places greater importance on the least frequently occurring intervals. From a cognitive perspective this would seem to conflict with the research on statistical learning, which would

[42] Brown, Butler, and Jones, "Musical and Temporal Influences," 374.

prefer the most frequently occurring stimulus over the less frequently occurring stimulus. If rare intervals occur less often shouldn't listeners expect to hear more frequently occurring intervals in a given stimulus? Not if rare-intervals form stimuli that are regularly associated with specific types of musical environments, like phrase endings. Rare intervals occur more repeatedly in tonic defining structurally stable contexts such as phrase-ending cadences, whereas more frequently occurring intervals tend to form the phrase body between the starting and ending structural contexts. Therefore, rare intervals are more often associated with ending contexts over the more frequently occurring intervals, which tend to support tonal functions that serve as reinforcement mechanisms for the overall key perception within the framework of the anchor pitch.[43] This necessarily establishes a perceptual recognition of rare-interval functions in developed expectations of tonic inference because the tonic note is so closely associated with closing contexts.

The moment that provides the greatest sense of stability is almost always associated with the phrase-ending arrival on the tonic pitch. The fact that many people are able to perceive the impending arrival of the close of a phrase shows that recognizable representations begin well before the actual cadence occurs.[44] This also shows that there are expected ways to approach a cadence. In the context of a modulating composition, tonal expectation would also include recognized schemas that lead to an expectation of key change in which rare intervals would play a crucial

[43] Ibid., 377.

[44] Aarden, "Dynamic Melodic Expectancy," 79.

role. These schemas would likely entail recognizable representations of tonal instability leading to the arrival of an anticipated sense of stability found in the new tonic. The sense of structural stability is most easily recognized by the functional order of rare intervals leading to the tonic of the new key.

Rare intervals are not necessary for the cognitive assumption of a pitch center. However, they do play a definitive role in evaluating the accuracy of an expected outcome for pitch center recognition, which has significant ramifications for aural skills teachers. Butler et al. show that the well-ordered rare intervals are more influential indicators for a single pitch as the tonic pitch when compared to the common intervals of a key. Nevertheless, it is also likely that throughout the duration of a musical phrase the average listener focuses attention on the increased tension generated by the departure and return between moments of stability and instability, and associate a hierarchy of solidity, such as the ultimate solidity provided by the arrival of the tonic note, to phrase-closing cadences, like the perfect authentic cadence. Aural skills teachers sometimes fail to recognize that students may not be identifying tonic pitches but instead distinguish between differing degrees of instability. For the average listener this is not a problem, but for musical students wishing to attain proficiency, it is expected that they learn to recognize specific pitch functions. The aural instructor must be able to assist the student in refining their hearing from simple recognition of instability and stability to the simple recognition of distinct musically functional processes.

TEMPORAL ORDER HYPOTHESIS

The temporal order hypothesis suggests that listeners are sensitive to the order of tones, and specifically the order in which rare intervals are used. According to Brown and Butler, in the Cuddy and Badertscher experiment the ordering of tones accounted for the results that seemed to discount the rare-interval theory. Temporal order necessarily implies ordering tones in a manner that implicates goal-oriented functional relationships. For example, certain arpeggiated notes can be used to imply the motion of a dominant-seventh chord resolving to the tonic, even though not all notes of these chords are immediately present.[45] If the ordering of notes does not reflect functional motion, the listener is less likely to recognize an intended goal, and consequently will struggle identifying a tonic note. An example of this can be seen when comparing the arrangement of the stimuli used in the Cuddy and Badertscher experiment to the arrangement of the stimuli used in the Brown and Butler experiment.[46] In figures 9 and 10, the stimulus is shown first followed by a rectangle that indicates the point at which probe tone that was heard.

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[45] Brown, Butler, and Jones, “Musical and Temporal Influences,” 375.

[46] Ibid., 385.

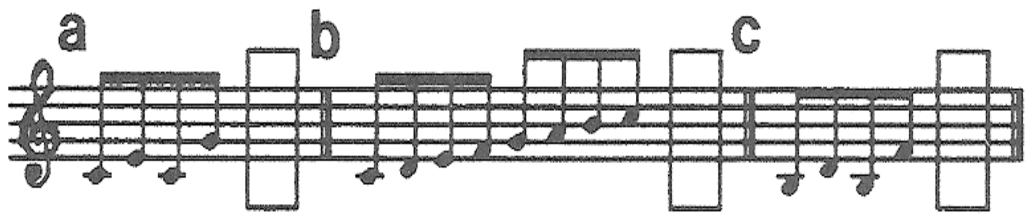

Figure 9. Three original stimuli (a, b, & c) used in the Cuddy and Badertscher experiment that do not follow the principles of the temporal order hypothesis. (Brown, Butler, and Jones's Figure 5, "Musical and Temporal Influences on Key Discovery," 382)

In figure 9, stimuli "a" and "c" show an arrangement of the tones that does not clearly support goal-oriented functional motion, rendering them ambiguous for tonic inference. In figure 10, stimulus "a" is reordered in order to hear the tonic note at the beginning and end of the stimulus. Stimulus "b" is reordered to better reflect randomized musical sequences of the two minor seconds. In stimulus "c" goal-oriented functional motion toward the tonic is more clearly implied by re-ordering the stimulus so that the diminished triad context implies the voice leading expected for a dominant-to-tonic progression.

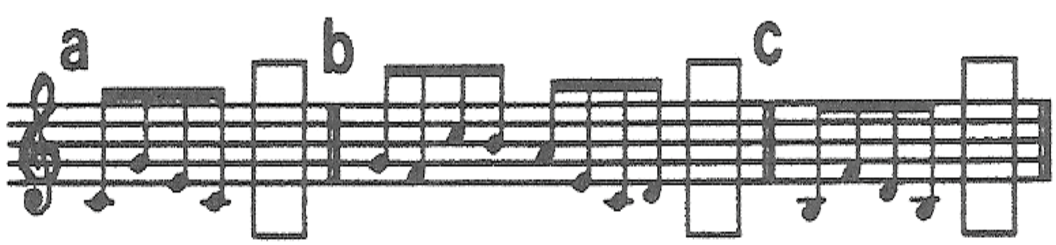

Figure 10. Stimuli a, b, & c reordered according to principles of the temporal ordered hypothesis. (Brown, Butler and Jones's Figure 8, "Musical and Temporal Influences on Key Discovery," 392)

Brown and Butler replicated the Cuddy and Badertscher experiment using the same order of tones for the stimuli, and then reordered the tones to reflect goal-oriented functional motion in a second experiment. The resulting probe-tone profiles reflect all three results and are shown in Figure 11. In probe-tone profile “a,” the reordered stimulus shows similar expectations for the tonic, the subdominant, and the dominant, with the subdominant receiving the highest rating. At first it might seem odd that the subdominant pitch was selected as the highest likely tonic considering that it was not even heard in the preceding stimulus. However, it is likely that listeners heard a dominant-to-tonic relationship in which the stimulus outlined a dominant chord and the subdominant probe tone was heard instead as the tonic note. This strongly implies that listeners rely on dominant-to-tonic schemas for inferring tonic.

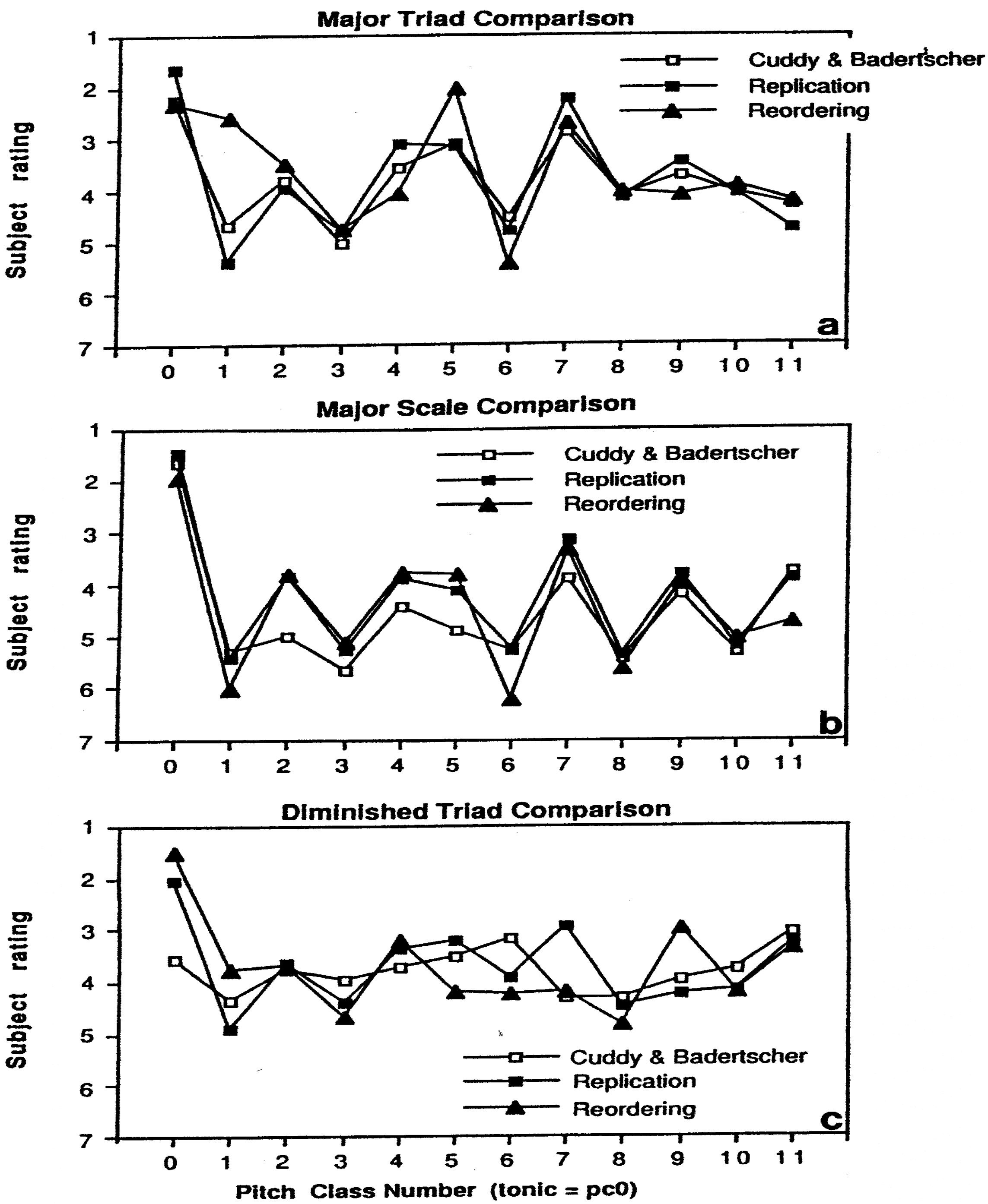

Figure 11. Probe tone profile results showing to the original ordering of stimuli by Cuddy and Badertscher and the replicated and reordered results by Brown, Butler, and Jones. (Brown, Butler, and Jones's Figure 9, "Musical and Temporal Influences on Key Discovery," 396)

The reordered probe-tone profile in the box marked “c” clearly implicated one note as the most likely candidate for tonic. It is striking that the remaining notes rated far below the tonic and did not significantly imply any form of tonal hierarchy. For conclusively determining the tonic pitch, it appears that well-ordered rare intervals reflecting dominant-to-tonic voice leading are remarkably accurate.

The temporal order hypothesis shows that listeners are sensitive to tonal ordering. However, much research remains to be done in order to clearly ascertain the effect ordering has on all tonal relationships. This has implications in relating the intervallic rivalry model to syntactical sequences in music, which is outside the scope of this study.

The intervallic rivalry model suggests that the ordering of tones effects the way listeners perceive the tonal relationships within a given key profile. The hierarchical order of tones in one key can be manipulated by borrowing shared tones from another key and reordering their hierarchical values to reflect those of the new key. The recognizable representations cognitively perceived do not necessarily need to change even though there is a difference in pitch. However, it is probable that an array of conflicting key representations will preside until schemas consisting of well-ordered rare intervals are recognized. The brain is able to recognize the shift of hierarchy from one key center to another key center using time-ordered elements that reflect familiar schemas. In addition, the consistent use of these processes within a modulating context could invoke statistical learning and the development of recognizable modulating schemas.

OVERVIEW OF TONIC INFERENCE EXPERIMENTS

The various key-perception models described above must be considered in light of fundamental concepts of cognitive perception in order to clearly grasp listener's ability to organize musical sounds. Cognitive expectation and related learning processes such as statistical learning and neural Darwinism provide unique insight into possible ways the brain functions when interacting with music. Significant to this research is the process of recognizing and retaining multiple perceptual representations for correctly predicting accurate outcomes. The process for inferring tonic involves many different possible representations presented together in order to arrive at the best possible choice.

The K-K key profile is the quantification of a tonal hierarchy that is implicitly learned from regular exposure at an early age to phrase-closing schemas. These closings become part of a familiar array of recognized tonal schemas from which predictable expectation are formed. In addition, throughout their listening life, listeners rely on these learned schemas as recognizable representations for predicting expected outcomes in new musical experiences.

For tonic inference the K-K profile represents a hierarchy of tonal stability from which the listener is able to asses maintained tonal relationships. By comparing the tonal hierarchies represented by the K-K key profiles with functional tonal schemas, such as those suggested by the intervallic rivalry and the 4/5 opening rule, the listener is able to infer a tonic note. In the absence of these schemas, accurate predictions for a tonic note are possible by recognizing hierarchies of tonal stability.

The intervallic rivalry model suggests that well-ordered rare intervals are accurate determiners of tonic because of their regular use in functional relationships. As time-ordered functional schemas both the intervallic rivalry model and the 4/5 opening rule are appealing for their ability to imply dominant-to-tonic functional harmony. This is a regularly occurring function that commonly appears in beginning and phrase-final musical contexts. Because of statistical learning, regular exposure to this function is likely to develop some form of recognized mental representations that assist in determining a key profile and consequently the tonic pitch class.

CHAPTER 5

PEDAGOGICAL IMPLICATIONS

The cognitive mechanisms used for inferring tonic have multiple applications in all areas of music. Nevertheless the importance of tonic inference is somewhat dubious. As Butler points out, “although key relationships often help define form in tonal music, tonality usually is the vehicle rather than the payload. We attend to tonal music in a key, and not vice versa, unless a conscious effort is made otherwise.”[47] The process for inferring tonic is simple and part of implicit cognitive functions. In passive listening, tonic inference has fewer applications, but seems to be important in more advanced explicit cognitive functions, such as aural analysis, composition, and improvisation.

[47]Butler, *The Musicians Guide*, 123.

The cognitive elements learned from understanding the process of recognizing a key profile and inferring a tonic pitch have ramifications in all areas of musical pedagogy. A variety of teaching methods and styles on a given musical topic should be used instead of highlighting one method, for not every student recognizes the same array of multiple musical representations, A large classroom is likely to have students with diverse expectations of how sound categories are musically structured. In order for the instructor to assist the student in making relatable cognitive connections to the subject being taught, the instructor must be sensitive to applying multiple effective representations to a single topic. It is imperative that teachers incorporate flexible alternatives into their lessons in order to effectively involve active participation in music. One idea might be to simply dividing the class into smaller groups for a class period and allowing each group to collectively work on a musical analysis or the identification of recognizable schemas in a musical example. The class would collectively hear these examples and discuss the way the schemas functioned in the music. Another strategy could small groups working on composing short passages of music with the intent to use musical schemas in their most expected function. The results could be discussed in class and the different compositions could be compared for similar or irregular uses of schemas.

Cognitive research shows that musical sound structures begin assimilation at an early age. The music that we are exposed to throughout our childhood and teenage years has a significant impact on the way we perceive and organize music. Much of the popular music we listen to will shape the way we think about music. Aspiring music students who begin their studies and find certain aspects of their training to be difficult could be struggling because of lack of exposure to the style of music being taught.

If common practice period music is going to be the basis from which theoretical aspects of music will be taught, music students must be familiar the with music of this style. Students with minimal exposure to common practice period music who have been mostly exposed to popular music or even twentieth century art music will likely have a cognitive orientation towards the music of greatest exposer rather than common practice period music. This creates a pedagogical predicament and an unnecessary hardship for the beginning student. As William Brandt et al. wrote, “no instruction in music can be valid unless it constantly relates intellectual understanding to aural experience”[48]

If students enter their theory programs finding it difficult to relate their instruction to aural experience, they may be inadvertently set into a learning process that causes them to retain abstract concepts without truly understanding their musical and aural significance. While they will be able to relate certain elements of theory to what is already a part of their cognitive musical representation, unfamiliar aspects will not be comprehended and will be less relatable to the way they have cognitively organized music. Attempts to grasp abstract concepts that make explicit cognitive connections will fail to connect with implicit cognition, which is widely considered to

[48] William E. Brandt, *Basic Principles of Music Theory* (New York: Harper and Row, 1980), 3.

be the most important purpose of musical training. Teachers should be aware of the importance of simply listening to music. Most of all aural-related cognitive structuring is accomplished through implicit learning. Much of the music instructor’s goal relies on making cognitive connections between implicitly learned musical knowledge and explicit musical practice.

In aural skills training, it is necessary for students to rely upon their learned sound organizations for guidance. Teachers who refine the methods used in aural skills teaching to reflect recognition of the most commonly used sound schemas will assist students with their aural recognition. It is true that many of the principles of the common practice period are addressed beyond a fundamentals level of training. Nevertheless some students find it difficult to hear differences between music from the common practice period and musical elements of modern popular styles. It is imperative that students become aurally familiar with common practice period music before aural training begins. It may be beneficial to teach a fundamentals class that primarily emphasizes listening while introducing theoretical elements that generally apply to music. Students should be made aware of their need to be exposed to this style of music so that they take it upon themselves to listen to recommended music.

Instructors might provide students with an assessment tool that focuses on their musical background and provides a qualitative assessment of the student’s understanding of common-practice-period music. Questions might ask about the genre of music that students have most listened to throughout their life. They could also list a few of their favorite artists and songs. The type of instrument they play or voice part they sing might reveal additional information about their musical background. All things being equal, students who play certain instruments such as piano or violin are more likely to be exposed to common-practice-period music than instrumentalists whose pre-college repertoire tends to live outside of the common practice period such as trumpeters and saxophonists. Vocal and jazz students whose repertoire primarily consists of modern music are also likely to be less familiar with music of the common practice period. These questions and more would be helpful in understanding students' aural exposure to pertinent musical styles.

A questionnaire, similar to the music background survey shown in Appendix A, could benefit the student, the theory teacher, the student's applied instructor, and the whole music department. Program administrators might be faced with making decisions concerning a separate class intended to accommodate a large body of students, or instead rely on individual teachers to make appropriate adjustments to course instruction. This survey could be used as part of the orientation process for new students, and is a form students could fill out on their own time. It is necessary, however, for instructors to compare these results with those from other standard music assessments in order to recognize potential areas for improvement. In any case, in order to improve student comprehension, both instructors and administrators should consider the problems associated with lack of regular exposure to the musical schemas commonly associated with the common practice period and find ways to make necessary adjustments in instruction.

CHANGES IN PHILOSOPHY

Cognitive research supports a philosophical change in theoretical thought. Music theory pedagogy needs to integrate aspects of cognitive theory that reflect statistical learning of musical schemas. Traditionally, theory pedagogy has relied on principles that govern music from the common practice period. Numerous textbooks have been written with different methodological approaches. While, different methods are useful and assist instructors in applying a variety of approaches to a particular subject, with variety comes the risk of confusion over the intent of the instruction, unless the teacher has carefully prepared and thought through the approach.

A fundamental interest to music theory is the musical structure behind all forms of music. However, prevailing instruction centers primarily on music of the common practice period. This is partly due to long-standing tradition in reflection of the general agreement that functions and principles of the music from this period represent general characteristics found in much of the music of Western culture. Consequently music theory instruction is primarily based on principles of this period. There have been attempts to revamp and modernize music theory by incorporating popular music into the curriculum. Nevertheless, comparisons to principles of the common practice period are not uncommon and can imply that music from this period sets the standard by which all Western music is compared. While musical standards are grounded on principles of their particular era, as our understanding of cognitive musical function grows it becomes evident that the mind is not bound by these principles. Instead, the human brain develops rules and expectations based on regular exposure to environmental stimuli.

The fundamental concepts underlying music theory instruction needs to include teaching the principles of a particular style (e.g., the common practice period) from the perspective of cognitive musical processes. This does not suggest a significant change in current instructional methods. However, it does change the perspective from which musical instruction is approached. The view shifts from relying upon principles of a style as the basis of instruction, to relying on scientific principles established from known cognitive musical research. With this knowledge, an instructor would be securely grounded in their fundamental understanding of a given topic, but would be flexible in the application of the principles by being able to choose from several different musical styles to illustrate the principle.

For example, on the topic of phrase endings, an instructor would explain the process of a closing cadence in light of the temporal-order hypothesis of the intervallic rivalry theory, without necessarily referring to these concepts by name. To accomplish this, the instructor would show students the difference between the melodic ordering of scale degrees and how their implied harmonic functions result in different conclusions. Refer to Figures 9 and 10 for examples. Students would then relate the musical patterns to real music.

Recognizing musical elements that are applicable regardless of style and time period, allows flexibility for incorporating analysis of recent musical styles into instruction. Changes in expectation of musical progressions can be freed from the tethers that link them to common practice period music and would instead be linked to the cognitive mechanics and structures that form learned sound categories. Common practice period progressions would be analyzed along with accepted modern progressions and differences explained as a result of changes through the years to psychological perceptions in music. Significant portions of principles from the common practice period would remain a part of instruction, and more pertinent musical elements could be incorporated to reflect current musical styles.

In order to implement these cognitive musical concepts into teaching, significant musical analysis and research needs to be done that extracts regularly recurring musical structures and identifies them as musical schemas. For example, mi-re-do descending by step is a frequent melodic pattern at the end of phrases that implies a cadential I6/4 – V close. An example is shown in Figure 12. A possible study showing middle-ground reductions of many different songs from a mixture of genres and styles will likely reveal this pattern to be a regularly recurring closing structure. Instructors would show this to students as one of several types of closing schemas.

Figure 12. An example of a phrase-ending schema showing stepwise descent from mi to do with an implied harmony of a cadential I6/4-V cadence.

A middle-ground reduction would also be useful in comparing other regularly recurring patterns and analyzing their function across different musical styles. This should be done in a large and diverse body of music in order to compare fundamental similarities.[49] These studies and more can be done as cognitive research for music processing provides empirical data for identifying these musical structures, such as the data provided by the tonal hierarchy model, the intervallic rivalry model, and the 4/5 opening rule. The theory instructor would then be able to categorizing these schemas according to their musical function and teach them.

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[49] Such research has already been started in studies presented here and in other studies like the analysis of works by Mozart in Robert Gjerdingen's *A Classic Turn of Phrase: Music and the Psychology of Convention* (Philadelphia: University of Pennsylvania Press, 1988).

Cognitive research reveals much concerning our understanding of music and the way it is organized and retained. Our understanding of the cognitive process for inferring tonic is just a small glimpse into the way music is perceived. Nevertheless the need to reevaluate instruction in light of cognitive findings is necessary and will benefit both instructor and student.

APPENDIX A

MUSIC BACKGROUND SURVEY

The following survey is intended to help professors develop an understanding of your musical interests and background in order to more fully assist with your instruction. The following form will not be graded. Please answer completely and to the best of your ability.

Name ____

Instrument/Voice Type ____

Number of years of formal study ___________

Name of instructors you have studied with ____________________________

____

____

On a scale of 1-5 please rate how familiar you are with the following composers, with 5 being most familiar.

____ Handel	____ J.S. Bach	____ Vivaldi	____ Schubert
____ Gluck	____ Mozart	____ Brahms	____ Webern
____ Schumann	____ Bernstein	____ Schoenberg	____ Ravel
____ Beethoven	____ Dvorak	____ Debussy	____ Liszt
____ Rachmaninoff	____ Copland	____ Tchaikovsky	____ Ives

Rank the following musical styles according to your *familiarity* with them through performance and listening to those styles. (This is not a rating of your favorite or least favorite styles!)

____ Classical (Mozart, Haydn, etc.)

____ Baroque (Bach, Handel, Corelli, etc.)

____ Jazz

____ 50s/60s Rock 'n' Roll (Elvis, Beatles, etc.)

____ 70s/80s Disco/Dance

____ Current/Pop

____ Renaissance/Medieval

____ Broadway

Rank these musical elements (1 through 5) according to their significance as they appear to you when listening to music.

____ Rhythm

____ Melody

____ Words

____ Harmony

____ Texture

____ Dynamics

____ Counterpoint

____ Instrumentation

____ Articulation

List five styles of music you listen to in order of preference. Include some of your favorite artists and songs from that style.

Example: Style *Pop*
Artists/Songs *Adele, Rolling in the Deep*

1. Style __________________________

Artists/Songs ____

____

____

2. Style ___________________________

Artists/Songs ____

____

____

3. Style ___________________________

Artists/Songs ____

____

____

4. Style ___________________________

Artists/Songs ____

____

____

5. Style ___________________________

Artists/Songs ____

____

____

In several phrases, sentences, or a paragraph, describe the kinds, types, or styles of music you love and/or know well. Think about the music you've performed, but also about the music you grew up listening to, the music you hear the most in the car, in your home, etc. There are *no* "wrong" answers to this question!

GLOSSARY

auditory cortical system. The portion of the cerebral cortex known as the auditory cortex and its related parts used in the processing and organization of sound information.

inferring tonic. The recognition of a single tone of ultimate rest toward which all other tones tend to move and around which a diatonic key is established.

key perception. A general term used to describe mental representations of an entire key that includes tonic inference as well as, or apart from, other distinguishing characteristics of key defining elements that can be used in establishing a key profile.

key profile. The rating results from an experiment that confirmed a relationship between tones and their varying levels of stability.

statistical learning. A shared cognitive process for sound category learning that involves sensitivity to frequency of occurrence of stimuli in a given environment making it possible to accurately predict probably outcomes.

neural Darwinism. A theory that suggests mental representations compete successfully or unsuccessfully for cortical resources.

probe tone. Randomly generated pitches taken from the twelve tones of the chromatic scale and sounded without reference to the octave in which a stimulus is played.

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