Review

Huron, David. *Sweet Anticipation: Music and the Psychology of Expectation*. Cambridge, MA: MIT Press, 2006.

Temperley, David. *Music and Probability*. Cambridge, MA: MIT Press, 2007.

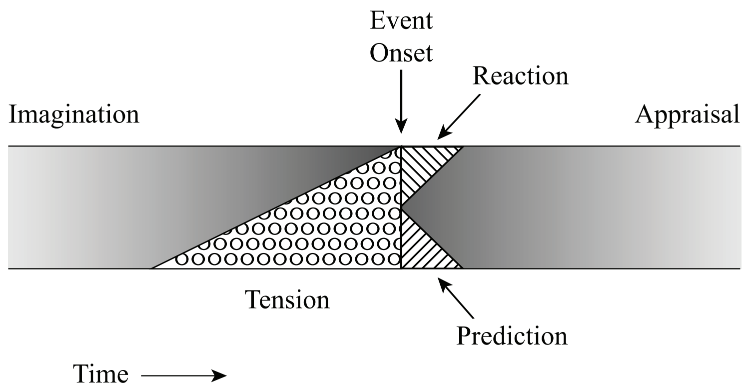
Reviewed by Daniel Shanahan

When news broke of Leonard Meyer's passing in late 2007, Professor Robert Gjerdingen of Northwestern University informed the musical world through the e-mail list of the American Musicological Society, and included a quote from Shakespeare's *All's Well That Ends Well*: "Oft expectation fails, and most oft there, Where most it promises." (Act II, Scene 1) The quote seemed quite apt, as one of Meyer's central theses was that through the fulfillment or denial of expectation in music comes emotion. Over fifty years later, the rapidly growing field of music cognition has two in-depth studies of the role expectation plays in music. David Huron's work, which focuses on the role of prediction, expectation, and reaction in music, offers the student a starting resource for the entire field of music psychology. Covering a great deal of independent research from various fields in an attempt to create a wide-ranging theory of expectation, Huron succeeds at explaining very difficult concepts in a manner that is easily understood by the any reader. The work of David Temperley, which in many ways overlaps with that of Huron, strives to explain the benefits of Bayesian probability when quantifying musical expectation. As both Huron and Temperley explain, musical information can be conveyed by instances with varying degrees of probability. The study of probability is therefore a necessary step in understanding musical expectation.

Huron's Theory

In *Sweet Anticipation: Music and the Psychology of Expectation* David Huron proposes the "*ITPRA*" *theory*, in which expectation is divided into five types of responses. The first two, which are classified as "pre-outcome" occurrences, are imagination ("I") and tension ("T"). Emotion is first triggered by the listener imagining various outcomes of a specified event. As the event approaches, there is usually an increase in the amount of tension for the listener. This feeling is soon overtaken by prediction ("P") once the event has occurred, as the listener evaluates whether or not the previous assessment of the situation was correct. In fact, Huron goes so far as to say that psychological rewards and punishments arise solely as a response to the accuracy of the expectation. This is reminiscent of Meyer's original claim that emotion is evoked solely through the affirmation or denial of expectation. Huron explains that, as a biological fact, expected outcomes are generally positive, even if the outcome predicted was a negative one.

In Huron's theory, a prediction is then followed by a reaction response, which could be classified as two separate responses. A sudden response (for instance, a "knee-jerk reaction") is experienced after an event, whether it is expected or not. This sudden reflex reaction ("R") gradually subsides in favor of appraisal ("A"), which is a prolonged reevaluation of the instance. Whereas a reaction response is sudden, an appraisal takes place over time. The five parts of Huron's theory are a significant contribution to the theory of musical expectancy, and the first systematic classification of the different types of emotion that a subject experiences during an event.



Example 1. Huron's schematic diagram of the "ITPRA" theory of expectation (Huron, Figure 1.1, p. 17).

Temperley's Methodology

In *Music and Probability* David Temperley provides computational models for the perception of key and meter in musical examples from the common-practice era. Like Huron, Temperley begins with certain basic assumptions concerning musical perception, the first being that "perception is an inferential, multileveled, uncertain process." (Temperley, 3) The author assumes that some specific patterns are more probable than others to the listener. Musical certainty or uncertainty cannot simply be classified in termsof fulfilled or unfulfilled expectations, but should be considered a graduated system of various levels of probable occurrences. The second assumption is that probabilities are shaped by the experiences of the listener. People of different cultures expect different things to occur in a musical work. The third and final assumption is that probability affects the composition, improvisation, and performance of a piece. In fact, Temperley dedicates his final two chapters to the role of probability in the shaping of compositional practice as a form of "communication."

Temperley's models all revolve around what is known as Bayesian probability. Bayes's rule states that the probability of the occurrence of an event or state (A) given a certain underlying assumption (B) is equal to the likelihood of B given A, multiplied by the prior probability of A and divided by the probability of B. More generally, Bayes's theorem allows one to infer the nature of an underlying structure given certain observable traits. Temperley considers the hidden variable in music to be the *structure* while the "observed variable" is called the *surface* (Temperley, 11). He applies the theorem thus:

$$P(\text{structure} \mid \text{surface}) = \frac{P(\text{surface} \mid \text{structure})\, P(\text{structure})}{P(\text{surface})}$$

Since musicians are usually concerned only with the most likely structure given the surface, P(surface) can be ignored, and the formula simplified to:

$$P(\text{structure} \mid \text{surface}) \propto P(\text{surface} \mid \text{structure})\, P(\text{structure})$$

This may be read: the probability of the structure given the surface is *proportional* to the probability of the surface given the structure multiplied by the probability of the structure. More simply, the structure that maximizes the value for the right-hand side of the expression will be the most probable structure for the given surface. This idea transfers quite well to musical applications. Temperley describes the perceptual process as follows:

> Listening to a piece involves more than just processing a pattern of surface events. Rather, it involves inferring *structures* from those events, structures which then guide our expectations and interpretation of future events. Our perception of a sequence of pitches, for example, is very much influenced by knowledge of the key; we infer the key of the piece from the pitches already heard, and this conditions our expectations for subsequent pitches. The key of the piece may then change, changing our pitch expectations accordingly. The identification of the underlying key structure and the interpretation of surface events form a complex, intertwined perceptual process. (Temperley, 21)

Thus, if the surface is known (such as certain pitch-classes), then the structure (or the underlying key) can be deduced. Although Temperley obviously favors Bayesian probability for *many* of his models, he utilizes a similar concept—that of the hidden Markov model—on a number of occasions. His polyphonic key-finding model, for example, relies heavily on HMMs, which have been usedquite effectively in the past for transcription and style recognition purposes.[1] Temperley's monophonic key-finding model utilizes this example of probable surface/structure relationships. By determining an underlying structure (the likely key) each tone is analyzed as a surface manifestation in the Bayesian equation. While relationship is most evident in his monophonic model, it is also present in the polyphonic key-finding and metric models, which I will come back to shortly.

Temporal Expectation

Both authors view the temporal nature of expectation as a foundational concept in their theories. Huron investigates the hierarchical nature of temporality, as well as the underlying causes for the listener's preference for the downbeat. Jones posited the notion that listeners focus more attention on strong metric positions.[2] Huron argues that this preference is due to the prediction response. Listeners focus on the periodic nature of meter, and expect the strength of the downbeat (both metrically and tonally) to function accordingly. Echoing a central theme of the book, Huron notes, "pleasure is evoked via predictability." (Huron, 184) This, however, is not the only form of rhythmic expectation. Listeners expect a temporal structure that is predictable, but it does not necessarily have to be periodic. As Huron demonstrates with the example of a bouncing ball, rhythms may accelerate or decelerate, and still remain predictable. Thus Huron's primary argument, that temporal perception is a matter of predictability, not periodicity, is supported by various studies, most notably that of Moelants (1999).[3]

Huron explores the nature of temporal expectation as a branch of a larger scheme of musical expectation when discussing poetry. He notes that readers "tend to prefer poems that have a rhyme scheme and regular meter" (Huron, 197), as they are easier to predict and, therefore, to process mentally. The distinction between expecting *what* will happen and expecting *when* it will happen is also discussed by Temperley. While the two notions are often connected, they sometimes operate independently. This notion obviously has particular importance in the study of temporal expectation in music, and both writers treat rhythmic expectation as an independent parameter.

Huron then discusses recent experiments concerning the ability to discern rhythmic differentiation among both musicians and non-musicians. One particular example from Desain, Honing, et al. found that listeners were more likely to be able to discern a rhythm that was relatively common in music.[4] For example, a quarter note followed by two eighth notes was easily recognizable, while a sixteenth followed by an eighth and a quarter note was relatively uncommon and therefore difficult to identify. The relationships between the rhythmic perception and the familiarity, as well as the reproduction of the rhythm were then connected through the use of Bayesian probability. Temperley's model uses similar concepts to deduce metric probability, but Desain and Honing's use of quantized melodies with perfect timing differs from Temperley's use of realistic performances.[5]

In the third chapter of *Music and Probability*, Temperley introduces his model for determining rhythmic and metric probability. He departs from existing methodologies concerning the perception of meter in that he advocates a generative process. The meter is first divided into three "levels." The primary level is that of the tactus, which Temperley refers to as "level 2" (Temperley, 31), while levels 1 and 3 are assigned to the lower and higher positions in the metric hierarchy. Beats and note-onsets are only assigned to "pips," a series of timepoints that occur every 50 milliseconds. In this generative model, the original tactus interval (labeled T1) dictates the location of the second beat. This process is then continued as needed, and a tactus is created through a constant reexamination of the underlying duration. Once this is achieved, metric qualities on a higher level (or "level 3"), and finally the lowest level ("level 1") can be defined. Temperley then uses these levels to determine the most likely metric grid using the given rhythmic information. This model is then tested by comparing the calculations for 65 monodic passages from the Essen Folk Song Collection. While the method proves to be somewhat flawed at the lower and higher levels, its accuracy rating on the tactus level is quite good. Temperley notes that on this level in "many of the songs, the model's output is essentially perfect." (Temperley, 44) Earlier models of metric perception discussed by the author, such as that of Raphael (2002), take the input of notes as a given for discussing score-times, while Temperley's treats the "pips" as a means for inferring the placement of notes.

It is interesting to note how Huron and Temperley both relate theories of expectation in music to that of linguistics. Huron discusses temporal expectations in terms of contingent events that occur within a certain temporal proximity. For instance, he notes that in English "the letter 'q' tends to constrain subsequent letters—increasing the likelihood of an ensuing letter 'u.'" (Huron, 181) This constraint is then related to the analysis of note-dependencies in music. He remarks that the strongest contingencies are quite close to each other in temporal arrangement. An analogous study concerning dependency locality theory was done by Gibson,[6] who illustrates how syntactical comprehension of a sentence is reliant upon temporal placement of certain words of varying strengths. For example, "The man went to the shop" is perceived much more easily than "The man who was wearing a black jacket and blue shoes went to the shop." As Patel notes, "[dependency locality theory] uses a linear measure of distance rather than a hierarchical one, and thus does not depend on the details of any particular phrase structure theory."[7] Huron also states that some musical works have statistical dependencies that do not rely on contiguous relationships, and questions whether or not the expectation of the listener is affected by the temporal distance of related tones as well as if new expectations can be formed that are unique to the musical events at hand. Temperley's models, which are influenced by hierarchical theories such as those of Lerdahl and Jackendoff (as well as Bod), nevertheless treat musical syntax as a linear object, consistently changing the outcome of the forthcoming events. The generative elements of the metric model, as well as the key-finding models, rely on a dependency between the notes on the immediate level.

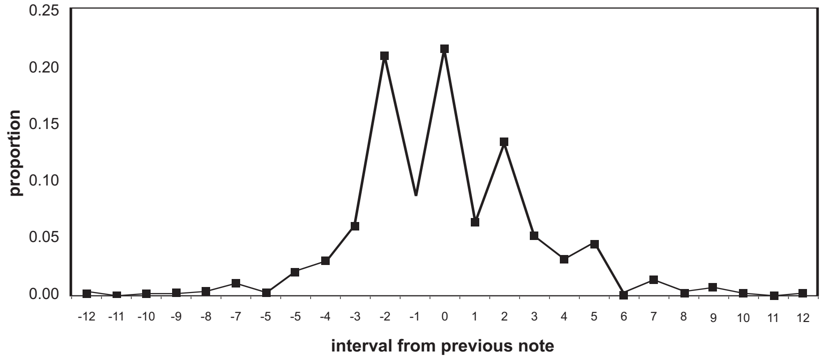
Both authors address the connections between musical and linguistic syntax when discussing the "garden path" phenomenon. This occurs when a situation must be retroactively re-analyzed to be understood correctly. Temperley uses the example of "The old man the oars."[8] At first the reader perceives the subject to be "The old man," yet upon the arrival of "the oars" the reader must reassess the word "man" to in fact be a verb. Huron notes that probabilistically, "old man" is much more likely to be an adjective-noun sequence than a noun-verb sequence (Huron, 280). Temperley explains that an example from Beethoven's Piano Sonata op.14, no.2 is analogous to a garden path structure in that listeners are originally led to perceive a duple meter, rather than the actual $\frac{3}{8}$ (see Example 2). Huron argues that this type of surprise evokes a certain sense of frisson from listeners, which is a vital part of expectation. Temperley, however, who discussed this at length in previous publications, neglects to address this in *Music and Probability*, choosing instead a generative model which does not allow much room for such Husserlian views on temporal perception. Unfortunately, theories that address such ideas as rhythmic projection[9] and Lewin's "well-formed context"[10] are not discussed by either author.

Example 2. The "garden path" phrase of Beethoven's Piano Sonata op.14, no. 2 (Huron, Figure 14.7, p. 280).[11]

Measuring Melodic Expectancy

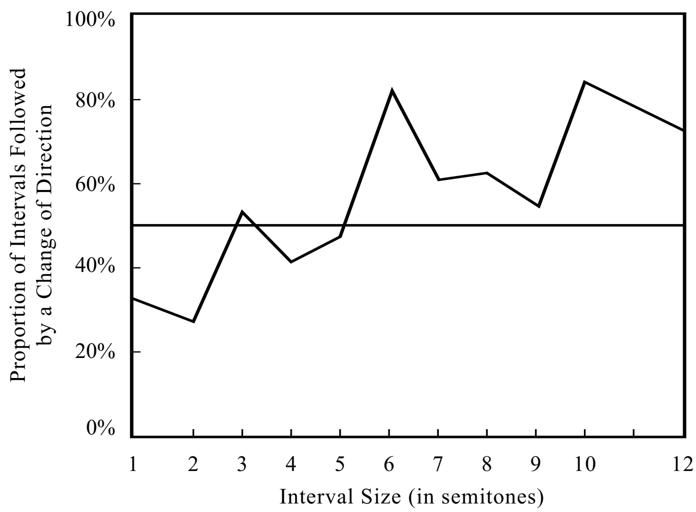
In the chapter entitled "Statistical Properties of Music" Huron discusses the nature of one of the most studied aspects of music perception: melody. Most of the research that has focused on melodic expectation has relied quite heavily on the work of Meyer and Narmour. Huron, however, begins by noting the work done by cognitive psychologists concerning pitch proximity, and notes that many studies[12] found that listeners were more easily able to understand melodic patterns if the notes were in stepwise motion. Huron points out that most stepwise melodies are, in fact, descending, yet listeners expect stepwise motion in both ascending and descending directions. Research done by Paul von Hippel, which took random twelve-tone sequences and asked subjects to predict a thirteenth note, showed that listeners were most likely to expect a stepwise melody to continue, regardless of direction.[13] This symmetrical "step inertia" is credited to the fact that while most stepwise melodies are descending, an ascending melody could move by either stepwise motion or a leap. The fact that listeners are rewarded when they correctly expect descending melodies to be stepwise causes them to "overgeneralize" (Huron, 78) ascending melodies to be stepwise as well. Temperley addresses this somewhat with his monophonic pitch model, which uses a "range × proximity" method and favors stepwise motion in both directions (Example 3).

Huron also offers an explanation for what is known as "post-skip reversal," or more commonly "gap-fill." He believes that the occurrence of "reversal" is in fact nothing more than a "regression to the mean." (Huron, 80) Large intervals are followed by smaller intervals simply because the odds of two large intervals in a row is relatively small. He uses the analogy of rolling a ten with a pair of dice, and observes that "the likelihood is that the next roll will be lower than ten."



Example 3. The distribution of intervallic motions from the Essen corpus illustrates a predilection for stepwise motion in either direction (Temperley, Figure 4.6, p. 58).

(Huron, 80) Since most large intervals are part of an effort to move to the extremes of the range of a melody, it is only natural that it would be followed by a regression toward the middle of the range. A 1924 study by Henry Watt supports this thesis; analyzing intervallic direction in Schubert lieder, Watt found that larger intervals were more likely to be followed by reversal (see Example 4). Regression towards the mean also plays a large part in Temperley's models. In his monophonic pitch model, he uses a "central pitch profile" (Temperley, 57), which is then employed to construct a series of pitch-classes in a certain range and generate a probable melody. This connection is a testament both to the accuracy of Temperley's model and to the viability of Huron's theory.



Example 4. Watt's analysis of intervals in Schubert lieder (Huron, Figure 5.3, p. 81).

Tonality

In the fourth chapter of *Music and Probability*, Temperley lays out his model for a key-finding algorithm when dealing with monophonic music. Previous attempts at devising a sufficient algorithm were "distributional" in that they focused solely on the frequency of the pitches "without much regard for their temporal placement or the patterns they form." (Temperley, 55) Temperley's, however, could be considered a more generative model as it determines a key (which he refers to as "structure") from a sequence of pitches depending on how the pitches are produced from the structure. First, a "central pitch profile" is established to ensure a relatively normal allocation of tones. This is followed by the creation of a "range profile," which favors pitch classes within a given probable range, and a "proximity profile" which determines a conditional probability of a pitch given its relative distance from a previous one. In addition to these, Temperley uses a "key-profile" which determines the appropriate pitch classes for a given key. The combination of the range, proximity, and key profiles (which Temperley terms the RPK profile) are used in conjunction with the central pitch profile and the key probability as parameters in the pitch model.

Temperley's method of calculating the key of the melody by using the range, proximity, and key-profile uses a principle similar to the one found in the generative metric model discussed above. Many previous models, such as that of Longuet-Higgins and Steedman14 eliminate any unlikely keys as the melody progresses and characteristic pitch classes present themselves. Their analysis of all of the fugue subjects from Bach's *Well-Tempered Clavier* proved to be quite accurate, although examples from later centuries contained more ambiguities. A model with a similar process is that of Krumhansl (1990),[15] who establishes a likelihood of scale-degree based upon tests (most notably that of Krumhansl and Kessler[16]) in which listeners were given a tone and told to demonstrate on a scale of 1 to 7 how well it fit within the content of a previously established key. This reliance on music perception allows the Krumhansl "probe tone" algorithm to have a degree of practicality which is somewhat lacking in Temperley's model. Although Temperley's method is more accurate than Krumhansl's (the former had an accuracy rating of 83.3% while the latter achieved only 66.7%), it still struggles with certain melodies. In particular, tunes that might be considered modal rather than tonal as well as certain minor-key melodies prove to be somewhat difficult. Nevertheless, Temperley succeeds at proposing a likely method for a Bayesian analysis of melody, which would be of vital importance to any study of musical information.

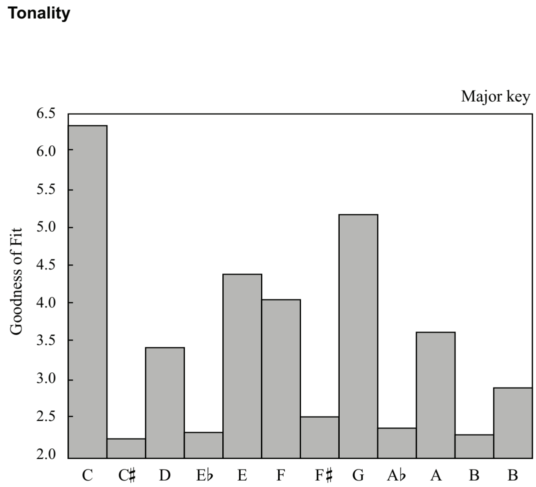
When proposing his model for polyphonic key-finding, Temperley abandons many of the concepts introduced in his monophonic method that emphasized unordered sequences and occurrences of pitch-classes. A piece can very obviously be in the key of C despite there being few if any occurrences of the actual pitch-class. Additionally, range and pitch proximity are no longer considered to be essential and are also disregarded, as they proved to be misleading. Temperley begins by classifying certain pitch-classes as simply "present" or "absent." (Temperley, 80) The polyphonic key-finding model is in fact quite similar to a hidden Markov model, in that each segment is divided into a series of variables, some of which are observable (such as specific pitch-classes) and others of which may be inferred (such as the key). Temperley explains that there are a number of benefits when dividing each piece into smaller segments. Most notably, it allows for the possibility of modulation.

Like both the metric and monophonic models, Temperley's polyphonic key-finding model is generative. It begins by calculating a series of possible keys for each short key segment, but treats remaining in the same key as the previous segment as the most probable: the author assigns the value of .8 for the home key, thus leaving .2 to be distributed equally throughout the remaining twenty-three major and minor keys (Temperley, 84). Once this structure has been determined, the model then calls for generating a surface within the structure, which in this case consists of likely pitch-class sets. Through Bayesian inference, Temperley is then able to establish a series of probable keys and pitch-class sets throughout the piece.

One issue that continued to plague the model, however, was that of modulation. From the outset, the probability of a non-modulating segment was assigned the value of .8. One can be left wondering why this value was not explained in more depth. As Temperley's model then assigns the remaining value (.2) to the remaining twenty-three keys, despite the obvious fact that some modulations are much more probable than others, it is no wonder that the modulation aspect of the model performed the most poorly. As Temperley notes, "it sometimes modulated at points where the correct analysis did not, or failed to modulate when it should have." (Temperley, 93)

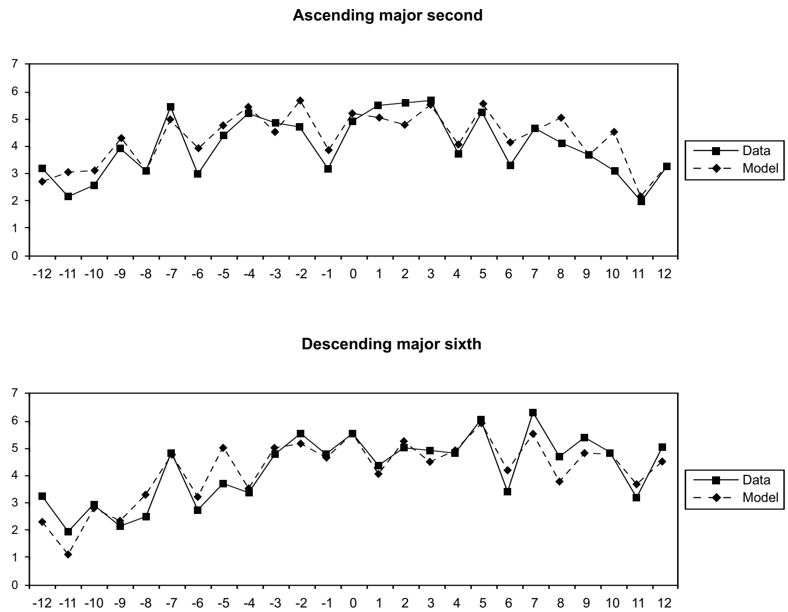
At this point, Temperley points out that the model may have little correlation to key perception and that a more accurate model might include the idea of the perception of a hierarchical key structure. The author avoids this idea, however, as "the hierarchical key aspect of key structure has barely been studied, either in music theory or music psychology." (Temperley, 98) While the probabilistic aspect of tonal hierarchies may have received little attention thus far, there have been tests concerned with the modulatory aspects of phrases. Two studies—one by Cuddy, Cohen, and Miller, the other by Cuddy and Badertscher—both focused on the perception of tonal hierarchies,[17] and there is no doubt that this research could have contributed to Temperley's pursuit of a probabilistic key-finding model which involves multileveled processes like those of his metric model.

Like Temperley, Huron is influenced by the Krumhansl-Schmuckler and the Krumhansl-Kessler experiments when referring to the perception of tonality. This theory considers tonality to be a hierarchy of tones that are learned "from sustained exposure to the music of some culture." (Huron, 172) In fact, both Huron's and Temperley's chapters on tonality share a number of theoretical positions. They both use the Krumhansl-Schmuckler and Krumhansl-Kessler models as foundations for their probable key-finding methodologies. In addition to this, both authors treat melodic tendency as a prime factor for generating probable melodies and keys. For instance, Huron takes samples from "several thousand Germanic folk songs" (Huron, 158) and finds that the most likely melodic transition is that from the third scale degree to the second. He notes that this transition is likely to happen once in every twenty transitions. Huron then measures the melodic tendency by assigning certain scale tones (those which would have many possible transitions) a higher information value (Example 5). This scaling of probable melodic tendency differs from Temperley's generative approach, but does not offer the methodology for analyzing melodic probability in as rigorous a manner as Temperley does.



Example 5. The Krumhansl-Kessler "key profile" for the major scale (Huron, Figure 9.3, p. 151).[18]

Temperley then engages with Raphael and Stoddard's use of hidden Markov models in their own harmonic system.[19] It is interesting that while Temperley himself avoided both a "rule-based" approach (similar to that of Bod) and the use of hidden Markov models (with the exception of a minor discussion when applied to his polyphonic key-finding model), he explains the benefits of each system quite thoroughly. In the book's preface Temperley notes that his purpose is to "present [his] own ideas in this area and also survey work by others." (Temperley, x) This is a prime example of his success in achieving the latter goal. Temperley is very able to engage with multiple influential studies that provide the reader with a starting point for further research in this developing field. In chapters 5 and 7, Temperley focuses on musical expectation and tension, and tests his models in a number of different circumstances. He begins by examining the nature of pitch expectation, and briefly explains previous experimental studies dealing with the perception of melodic expectation. Temperley focuses on a study done by Cuddy and Lunney[20] in which listeners were given an implicative interval followed by a "continuation tone" (Temperley, 66) which was then rated on a scale from 1 ("extremely bad continuation") to 7 ("extremely good continuation"). Temperley then compares the data of the Cuddy and Lunney experiment with the output of his monophonic pitch model and finds them to be strikingly similar (see Example 6). This idea of continuation and closure is part of the foundation of cognitive musical theory,[21] and its correlation to Temperley's model of melodic probability is one of the book's strongest aspects. While this similarity between the author's algorithmic model and Cuddy and Lunney's experiments with actual listeners strengthens the author's argument, a comparison of the model with more tests concerned with pitch expectancy[22] would have been useful.



Example 6. Cuddy and Lunney's intervallic expectation data compared with Temperley's model (Temperley, Figure 5.2, p. 70).

Temperley then tests the polyphonic key-finding method with equally interesting (if not quite as concrete) results. By considering the surface probability of certain pitch-classes after determining the likelihood of each key with the model, probable transitions and tonalities are determined. The probable tonal occurrences are then compared to a series of pieces, each of which has a distinct modulatory scheme. Of particular interest was the comparison of the model to Schumann's *Papillons*, No. 1, which adequately displays the probability scheme of each tonality. This probability would be the inverse of the degree of (new) information being perceived by the listener, and a multi-parametrical approach (including metric, tonal, and melodic probability scales) would be a major step forward in the study of information retrieval and music perception. Temperley notes that "the musical tension of a passage is more than just a simple function of its pitch-class content; all kinds of melodic, harmonic, and rhythmic factors undoubtedly play a role." (Temperley, 115) Despite this, no such analysis is performed on the *Papillons* example. As with the monophonic study, the fact that the model so closely resembles the perception of an actual listener is only a testament to the viability and advantages of such a methodology.

A difficulty that continually plagues the study, however, is the aforementioned perception of tonal hierarchies. For example, the polyphonic key-finding model perceives a modulation as a fairly improbable occurrence. Yet, when the piece returns to the original key, it treats this modulation as an equally improbable occurrence. Although it doesn't seem to cause a major difficulty in the effectiveness of the model tests, Temperley admits that this disparity between human perception and the results of the model is a problem. The subject then turns to musical ambiguity, a topic that has been discussed at length by Meyer.[23] It is generally assumed that asymmetrical structures (such as the major scale) lead to feelings of closure and continuation in music, while symmetrical structures (such as the whole-tone and octatonic collections) lead to feelings of ambiguity. Temperley discusses this, but fails to provide anything more than a rationalization for their use. While the tests in this volume as a whole are quite strong, this tangent, and the lack of any meaningful conclusion, tends to stray from his overall thesis.

Composition as Communication

Both authors address connections between expectation and the compositional process. Temperley's focus shifts in chapters 9 and 10 to the testing of the model alongside Schenkerian theory; he also discusses how "communicative pressure" influences the musical choices of many composers. The author explains how probabilistic models might lead to an increased understanding of linear progressions, as well as how effective these models are in the understanding of metric placement in higher levels in a Schenkerian analysis. Similarly, Huron finds that melodic tendency often favors many of Schenker's key concepts, such as that of the *Urlinie*, which listeners have perceived to be most probable (Huron, 160).

In chapter 11 of *Sweet Anticipation* Huron focuses on the role of compositional schemas in music perception. He notes that a full understanding of a composition cannot take place unless the listener has a complete grasp of the context in which it was written. For instance, a person well versed with post-tonal music will be more comfortable discerning certain tendencies and idiosyncrasies in this repertoire than someone who primarily listens to pop music. Huron observes that "music heard most frequently by a listener occupies a highly differentiated central position in the listener's personal stylistic taxonomy." (Huron, 217) While the very notion of schematic differences among listeners might seem to create difficulties in a study of musical expectation, Huron treats it as a foundation for a larger study of compositional communication.

In his penultimate chapter entitled "Expecting the Unexpected" Huron explores how expectation is created in the music of Wagner, Schoenberg and Stravinsky. Wagner, whom Huron terms a "contracadential" composer (Huron, 334), takes advantage of the psychological need for a cadence by postponing cadential closure for extended periods of time. Similarly, even Schoenberg's "contratonal" twelve-tone works are influenced by tonal music quite heavily, in that many of the rows strive to avoid the implication of a tonal center. In fact, Huron compares actual twelve-tone rows composed by Schoenberg with random generations, and shows that the random rows were statistically more tonal than Schoenberg's, thus illustrating the intentional avoidance of such behavior. Huron terms Stravinsky a “contrametric” composer, in that great efforts are made to deny rhythmic or metric closure. These examples illustrate the nature of expectation as a compositional construct, rather than as something only of importance to perception.

Conclusion

Temperley and Huron take two separate approaches to discussing many similar issues. Temperley is concerned with creating a viable methodology that proves to be quite accurate in determining the probable outcomes for predicting key and meter in selected music. By doing so, he quantifies likely expectations and opens the door for more detailed studies of probabilities affecting various musical parameters. Huron, however, favors more generalized discussion about musical expectation rather than specific instances or analytical systems, in an attempt to explore musical probability. While both authors cover similar research in a still growing field, the books complement each other to the point that any study of music cognition would be incomplete without both volumes close at hand.

NOTES

1. Christopher Raphael and Joshua Stoddard, “Functional Analysis Using Probabilistic Models,” *Computer Music Journal* 28, no. 3 (2004): 45–52.

2. Mari R. Jones, “Attending to Musical Events,” in Mari R. Jones and Susan Holleran, eds., *Cognitive Bases of Musical Communication* (Washington, D.C.: American Psychological Association, 1992), 91–110.

3. Dirk Moelants, “Perceptual Analysis of ‘Aksak’ Meters,” in Marc Lemen, ed., *New Techniques in Ethnomusicology: Proceedings of the 11th Meeting of the FWO Research Society on Foundations of Music Research* (Ghent: IPEM, University of Ghent, 1999), 3–26.

4. Peter Desain and Henkjan Honing, “The Formation of Rhythmic Categories and Metric Priming,” *Perception* 32, no. 3 (2003): 341–365.

5. Temperley notes that other Bayesian rhythmic models (such as the work of Cemgil, et al.) test only very simple rhythmic patterns, while his method is applicable to many types of rhythmic examples.

6. Edward Gibson, “Linguistic Complexity: Locality of Syntactic Dependencies,” *Cognition* 68 (1998): 1–76.

7. Aniruddh Patel, *Music, Language, and the Brain* (New York: Oxford University Press, 2007), 277.

8. David Temperley, *The Cognition of Basic Musical Structures* (Cambridge, MA: MIT Press, 2001), 210.

9. Christopher Hasty, *Meter as Rhythm* (New York: Oxford University Press, 1997).

10. David Lewin, "Music Theory, Phenomenology, and Modes of Perception," *Music Perception* 3 (1986): 327–92.

11. Quoted from Temperley, *The Cognition of Basic Musical Structures*, Figure 8.3, p. 211.

12. Most notably Diana Deutsch, "Delayed Pitch Comparisons and the Principle of Proximity," *Perception and Psychophysics* 23 (1978): 227–230.

13. Paul von Hippel, "Melodic-expectation Rules as Learned Heuristics," in Catharine Stevens, Denis Burnham, Gary McPherson, Emery Schubert, and James M. Renwick, eds., *Proceedings of the 7th International Conference on Music Perception and Cognition* (Adelaide: Causal Productions, 2002).

14. Christopher Longuet-Higgins and Mark J. Steedman, "On Interpreting Bach," *Machine Intelligence* 6 (1971): 221–241.

15. Carol L. Krumhansl, *Cognitive Foundations of Musical Pitch* (New York: Oxford University Press, 1990).

16. Carol L. Krumhansl and Edward J. Kessler, "Tracing the Dynamic Changes in Perceived Tonal Organization in a Spatial Representation of Musical Keys," *Psychological Review* 89 (1982): 334–368.

17. Lola L. Cuddy, Annabel J. Cohen, and Janet Miller, "Melody Recognition: The Experimental Application of Rules," *Canadian Journal of Psychology: Human Perception and Performance* 7 (1979): 869–883; Lola L. Cuddy and Betsy Badertscher, "Recovery of the Tonal Hierarchy: Some Comparisons Across Age and Levels of Musical Experience," *Perception and Psychophysics* 41 (1987): 609–620.

18. Taken from Huron, 151; originally printed in Krumhansl and Kessler, "Tracing the Dynamic Changes," 334–368.

19. Raphael and Stoddard, "Functional Analysis Using Probabilistic Models."

20. Lola L. Cuddy and Carol A. Lunney, "Expectancies Generated by Melodic Intervals: Perceptual Judgments of Melodic Continuity," *Perception and Psychophysics* 57 (1995): 451–462.

21. Leonard B. Meyer, *Emotion and Meaning in Music* (Chicago: University of Chicago Press, 1956) and Eugene Narmour, *The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization Model* (Chicago: University of Chicago Press, 1990).

22. Carol L. Krumhansl, “Music Psychology and Music Theory: Problems and Prospects,” *Music Theory Spectrum* 17, no. 1 (1995): 53–80 and Glenn Schellenberg, “Expectancy in Melody: Tests of the Implication-Realization Model” *Cognition* 58 (1996): 75–125.

23. Leonard B. Meyer, *Explaining Music* (Berkeley and Los Angeles: University of California Press, 1973).