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Communicative Pressure and the Evolution of Musical Styles

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Music functions, at least in part, to convey certain structures to the listener via a surface of notes. For communication to occur successfully, the structures must be recoverable from the surface. I argue that this consideration has been an important factor in the shaping of musical styles, and sheds light on a number of phenomena: the greater degree of syncopation and lower degree of rubato in traditional African music and rock versus common-practice music; the extensive use of rubato in pieces with consistent repeated patterns (e.g., much Romantic piano music); the rise of swing tempo and the higher degree of syncopation in jazz as opposed to ragtime; and the greater variety of chord-tones and lower tolerance for chordal inversion in jazz as opposed to common-practice music.

STYLE, as the term is generally used in musical discourse, refers to what is common or consistent across a corpus of music. Styles are generally associated with a particular historical period and geographical region, but this is not essential; it is perfectly possible for someone living in Hong Kong in 2003 to write something in Baroque style. In this essay, I examine the question: Why are musical styles the way they are? What factors can be identified in the evolution and development of musical styles? Up to now, most attention to this question has come from historical musicology and ethnomusicology, and has focused on the way musical styles are shaped by their aesthetic, intellectual, social, and economic contexts.[1] This approach

1. Most often, claims about the influence of cultural context on music are only implied rather than explicitly stated. To take one example from a well-known source, Grout in his *History of Western Music* (1980) may not directly claim that Romantic-period composers were influenced by the larger intellectual and aesthetic climate of the era, but his discussion of this context, and the ways that Romantic music reflected it, certainly suggests such reasoning. For a more overt attempt to explain stylistic change in cultural terms, see Meyer, 1989.

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is certainly valid and sometimes very revealing. However, the premise of the current study is that much can be learned by focusing on musical communication as a self-contained system, shaped—at least to some extent—by its own internal forces and processes.

The central idea of the current essay is a simple one. Music functions, at least in part, to convey certain structures to the listener via a surface of notes. (The "surface" may also be defined in other ways, as I will explain.) The communicative process relies on mutual understanding between producers (composers and performers) and listeners as to how surfaces and structures are related—what might be regarded as the "rules" of the style.[2] For communication to occur successfully, the structures must be recoverable from the surface. A situation where, given the rules of the style, it was impossible for the listener to infer from the music which structure was intended would not be very satisfactory from the communicative point of view. I will argue that this principle, which I call *communicative pressure*, acts as a significant force on the evolution of musical styles. I hasten to add that communicative pressure is not claimed to be the only factor, or even the primary factor, in the development of styles. Even if the explanatory value of the communicative-pressure idea is found to go far beyond what is claimed in this article, it is surely only one of many factors involved in the evolution of music in its many and diverse forms. But it is, I believe, a very important one.

Communicative Pressure in Rules of Voice-Leading

A good place to start in exploring communicative pressure, and the primary inspiration for the current study, is the work of David Huron (2001) (though Huron himself does not use the term "communicative pressure"). Huron attempts to relate the conventional rules of voice-leading to principles of auditory perception. He argues that many of these rules—as well as other regularities not captured by traditional rules but reflected in musical practice—can be attributed to a fundamental compositional goal:

> The goal of voice-leading is to create two or more concurrent yet perceptually distinct "parts" or "voices". Good voice-leading optimizes the auditory streaming. (Huron, 2001, p. 32)

An example of Huron's approach is his explanation of the rule forbidding parallel perfect intervals (perfect fifths and octaves) (Huron, 2001, p. 31). Perfect consonances naturally tend to fuse into a single perceived pitch;

2. The term "rule" is not intended to imply something inviolable or hard-and-fast; rules might, for example, be probabilistic in nature, as I will explain below.

pitches that comodulate (move by the same interval) also tend to fuse. Thus the danger of fusion should be especially strong with two voices that are related by a perfect interval and comodulate; and this is exactly the situation forbidden by traditional voice-leading rules. A second example is the general avoidance of small harmonic intervals (close chord spacing) in low registers—a well-known compositional principle that has also been empirically confirmed in studies of musical corpora (Huron, 2001, pp. 14–18; see also Huron & Sellmer, 1992). This is compositionally advantageous, Huron argues, because small harmonic intervals in a low register tend to produce auditory masking (due to the interference between partials of the two tones that are within the same critical band).[3]

Consider these findings in light of the idea of communicative pressure. The composer conceives of certain patterns or configurations of notes, and wants those notes to be correctly identified by the listener. (In this case, then, the pattern of notes is actually the structure; the surface is the auditory signal itself.) This can be facilitated if the composer avoids parallel perfect intervals; if two notes are fusing into one, that presumably means that one of the notes is not being heard as a note (or perhaps neither one is, and both are being heard as overtones of another "virtual pitch"). Similarly, avoidance of small harmonic intervals in low registers reduces auditory masking, which might hinder the identification of notes in another way. Thus some important aspects of compositional practice seem to be attributable to composers' desire to facilitate pitch identification.[4]

Another illustration of communicative pressure from Huron's work concerns the avoidance of part-crossing (Huron, 2001, pp. 24, 35). It has been shown experimentally that listeners are reluctant to hear crossing voices; two lines crossing over one another in an X pattern are more likely to be heard as a "V" containing the upper notes and an upside-down "V" containing the lower ones (Deutsch, 1975). Thus, if composers wish the intended structure of polyphonic lines to be perceived, they would be well advised to avoid crossing voices; here again, this is reflected in compositional teaching, where voice-crossing is generally discouraged.[5] Huron (2001, pp. 22–26) makes a similar argument regarding the preference for small

3. As Huron points out, the avoidance of small intervals in low registers might also be attributed to the avoidance of sensory dissonance.

4. The clarification of pitch structure may also account for other phenomena not addressed by Huron; one example is "melodic lead." In studies of performance timing, it has been found that performers tend to play melody notes slightly earlier (20-50 ms) than other nominally simultaneous notes. Palmer (1996) has suggested that this tendency may have evolved to facilitate identification of notes, as slightly asynchronous notes tend to be identified more easily than perfectly synchronous ones. (This raises the possibility that performers, as well as composers, may be affected by communicative pressure—a point that will be important in following sections.)

5. See for example Gauldin, 1998, p. 35. Huron (1991) has also found evidence for the avoidance of voice-crossing in compositional practice.

melodic intervals. Listeners prefer intervals between successive notes in a melody to be small; for example, a pattern of two alternating notes is more likely to be heard as a single line if the notes are close together in pitch. This perceptual tendency is mirrored in compositional practice; a variety of studies of different musical styles have observed a preponderance of smaller melodic intervals. Note that the issue here is not the identification of notes, but rather the grouping of notes into lines. The surface is now a pattern of notes; the structure is a grouping of those notes. But the basic principle remains the same. Listeners make certain assumptions about the nature of structures: in particular, they assume that voices do not cross and that melodic intervals will generally be small. If composers wish for their intended structures to be recovered, it is advantageous for them to respect these rules.

The focus of Huron's study is on common-practice Western music. He does find support for some of his claims from styles outside common-practice music; for example, the prevalence of small melodic intervals has been observed in a variety of musical idioms. However, Huron makes no claims for the universality of such phenomena. As he points out, we would only expect composers to facilitate pitch identification (or the grouping of pitches into lines) if the communication of this information is one of their goals; in some music, it may not be a goal. A composer might, by contrast, deliberately create ambiguity and obscurity as to the pitches of the piece, or the entire dimension of pitch might be irrelevant to the composer's communicative aims.

Huron's work on voice-leading provides a compelling demonstration of the explanatory power of communicative pressure. In what follows, I will consider some other applications of this idea, broadening its scope in two fundamental ways. First, while Huron is primarily concerned with the identification of notes themselves, or the grouping of notes into lines, I will focus on other kinds of structures that are inferred from note information: meter, harmony, and key. Second, while Huron's focus is primarily on common-practice music, I will suggest that communicative pressure provides a powerful tool for explaining differences between styles. In particular, the communicative-pressure idea suggests that certain theoretically independent aspects of styles may be correlated, in ways that seem to agree remarkably well with the empirical facts.

Communicative Pressure in Meter: The Syncopation-Rubato Trade-Off

Metrical analysis is the process of inferring a metrical structure—a hierarchical structure consisting of several levels of beats of varying strength—from a pattern of notes.[6] Although a wide variety of models of metrical

6. This section builds on ideas put forth in Temperley (2001). For an overview of research on metrical analysis, and many citations, see pages 27–30.

analysis have been proposed, there is general agreement about certain basic principles. First, beats tend to be regularly spaced; if we have heard a series of beats 600 ms apart, we expect the next beat to occur roughly 600 ms after the last one. Second, notes (specifically onsets of notes) tend to coincide with beats, especially strong beats; and accented events are more likely to coincide with beats than unaccented ones. ("Accent" is used broadly here to mean anything that gives emphasis to an event, such as a long note, a loud note, a chord, or a change of harmony.) For present purposes, it will be useful to formalize this simple model of metrical perception a bit further, along probabilistic lines. The listener's goal is to infer the most probable structure (a metrical framework) given a surface (a pattern of notes). Using Bayes' rule, we can relate the probability of a structure given a surface to the probability of the surface given the structure:

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

Note that p(surface)—the overall ("prior") probability of the surface—is the same for all possible structures. Thus, for a given surface,

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

Since these two quantities are proportional, we can maximize the quantity on the left by maximizing the one on the right. To determine the most probable structure given a surface, then, we must know—for each possible structure—the probability of the surface given the structure and the prior probability of the structure. These two terms nicely incorporate the two assumptions stated above. The probability of a structure corresponds to its regularity; more regular structures are more probable. The probability of a surface given a structure depends on the alignment of events (especially accented events) with beats; a more probable surface is one in which accented events and strong beats are well-aligned. (For a more fully developed model of metrical analysis along Bayesian lines, see Cemgil, Desain, & Kappen, 2000a; Cemgil, Kappen, Desain, & Honing, 2000b.)

Let us now consider two important rhythmic phenomena: syncopation and rubato. Syncopation refers to some kind of nonalignment between accented events and strong beats; for example, if an event occurs on a weak beat with no event on the following strong beat (see Figure 1B). Rubato refers to some kind of expressive fluctuation in tempo—for example, if two beat intervals of 600 ms are followed by one of 800 ms (Figure 1C). Both syncopation and rubato affect the perception of meter. With a syncopated pattern, the intended structure will be assigned lower probability (relative to a perfectly regular pattern like Figure 1A) because the probability of the surface given the structure is low. If rubato is present, the probability of the structure will be relatively low because the structure itself is irregular (and

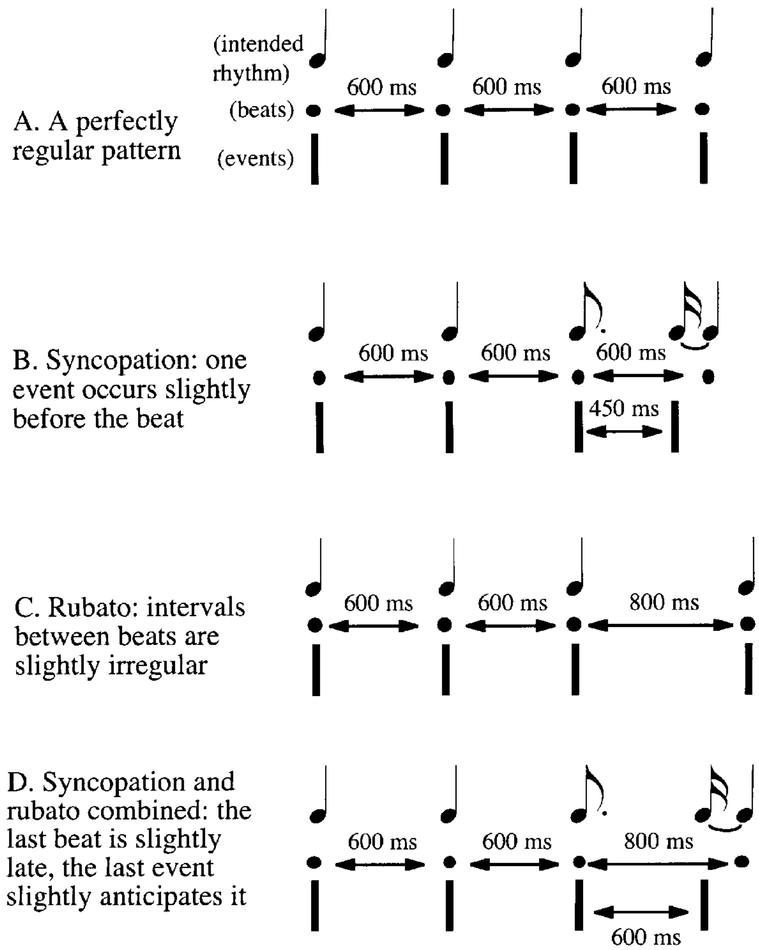

Fig. 1. Four metrical-rhythmic patterns.

hence low in probability). Nonetheless, the intended structure in a case such as Figure 1B or 1C may still be the most probable one overall and thus the one inferred by listeners. (Clearly, we are able to correctly infer metrical structures even in the presence of some syncopation or rubato.) What is of interest here, however, is the effect of these two phenomena in combination. Consider a pattern that involved both syncopation and rubato, such as Figure 1D; the last beat is delayed, but the last event is slightly before the beat. In this case, the actual pattern of events is the same as in Figure 1A (the last event maintains the regular pattern of 600-ms intervals), and the perfectly regular metrical structure of Figure 1A is surely what would be inferred, rather than the intended rhythm shown in Figure 1D. The intended rhythm would therefore be misunderstood. In short, there appears to be a complementary relationship or "trade-off" between rubato and syncopation. Although some degree of syncopation is clearly tolerable, as is some degree of rubato, the combination of the two might well leave the listener unable to correctly infer the beat. Or, to put it another way, the more syncopation is present, the less rubato can be tolerated, and vice versa.

How well is the predicted trade-off between syncopation and rubato borne out by reality? Although general cross-stylistic conclusions are hardly warranted at this point, the evidence from several well-studied styles offers considerable support. To take two styles in which rhythmic structure has been the focus of particular attention, it is clear that traditional sub-Saharan African music features a much higher degree of syncopation than common-practice Western music. Although most traditional African music features metrical grids of the kind familiar from Western music, it is also characterized by frequent metrical conflicts—patterns of accentuation that go against the underlying meter. (This has been observed by numerous commentators; see Jones, 1959; Chernoff, 1979; and Agawu, 1995, as well as Temperley, 2001 and citations therein.) It has been observed—though less widely—that traditional African music features a strictness of pulse far beyond that of common-practice Western music (Jones, 1959, p. 38; Chernoff, 1979, p. 97). Certainly the deliberate, noticeable fluctuations of pulse—rubato—characteristic of common-practice music are rarely found in African music. As another example, rock music features a great deal of syncopation, but also an extremely strict tempo with little expressive fluctuation. Indeed, in much recent popular music, human musicians have been replaced by drum machines and other electronic music sources capable of superhuman rhythmic regularity, without much noticeable loss of expressivity (at least as far as most listeners are concerned)—further evidence that fluctuation in tempo is not a very important source of expression in rock. In comparing common-practice music with traditional African music and rock, then, we find some encouraging support for the syncopation-rubato trade-off: styles with a high degree of syncopation tend to have a low degree of rubato, and vice versa.

The syncopation-rubato trade-off points to a more general prediction: The latitude for expressive timing will be greater in idioms where the meter is more strongly reinforced by the notes. (In Bayesian terms, when p(surface | structure) is high, p(structure) may be lower.) This principle is interesting to consider with regard to stylistic variations within common-practice Western music—generally defined as Western art music from about 1600 to 1900, and embracing the Baroque (c. 1600–1750), classical (1750–1830), and Romantic (1830–1900) periods. It is generally accepted, first of all, that the use of rubato varies considerably from one period to another; in particular, it is used much more extensively in Romantic-period music than in the music of earlier periods. This is true historically, in that the use of rubato among performers seems to have increased as the classical period gave way to the Romantic; Czerny, writing in 1847, lamented the (as he regarded it) excessive use of rubato "in recent time" (Rosenblum, 1991, p. 383). With regard to modern performance practice, the greater use of rubato with Romantic-period music as opposed to that of earlier periods is readily apparent in modern piano performances, and is generally affirmed and approved in pedagogical treatises on performance expression (Barra, 1983, pp. 119–121; Lampl, 1996, p. 56). (I will limit this discussion to piano music; this is the largest and most important solo repertoire, and solo performance provides the most scope for expressive timing, unhindered by considerations of ensemble coordination.) Two authors suggest that Chopin's music is especially appropriate for rubato (Stein, 1962/1989, p. 39, Matthay, 1913, pp. 64–65); Matthay mentions Chopin Nocturnes in particular.

Does the current approach shed any light on why Chopin Nocturnes, and other similar pieces, might be especially well-suited to the use of rubato? Figure 2 shows two fairly typical openings of Chopin Nocturnes. Communicative pressure suggests that the opportunity for rubato would be greatest in cases where the meter is very strongly established and reinforced, so that the probability of the metrical structure given the notes is high. Certainly, there is very little syncopation in these passages—accented events (e.g., long notes in the melody) generally occur on strong beats—but this is generally true of common-practice music of all periods. I wish to draw attention to another aspect of these passages: they feature strong repeated patterns in the left hand. The patterns do not always repeat exactly, but they are at least repeated in terms of their general shape or "contour;" in both cases, the pattern continues throughout the entire piece with only slight variations. Theorists have generally agreed that repeated patterns are an important cue to meter (Steedman, 1977; Temperley & Bartlette, 2002); once we have identified a certain position in the pattern as metrically strong, we expect subsequent strong beats to be similarly placed. This—as well as the very consistent alignment of accented events with strong beats—means that the meter of each passage is very strongly reinforced. Repeated patterns such as these are found pervasively throughout the piano music of Chopin as well as other Romantic composers (Schumann and Mendelssohn, for example); they are less prevalent in classical-period music. Consider Figure 3, the opening of a Mozart sonata. We do find some repeated patterns (such as the left-hand pattern in mm. 3–5), but they are relatively fleeting; the short passage shown in Figure 3 arguably contains three quite different textures.[7] In this important respect, one could say that the meter

7. Ratner (1980, pp. 26–27) cites frequent shifts of texture and mood as a hallmark of the classical style. (Ratner actually refers to "topics" rather than to textures per se, but it is clear that topics are often associated with contrasting textures.) In Romantic-period music, by contrast, uniformity of texture has been cited as a characteristic feature: speaking of Romantic music generally, Grout (1980, p. 559) notes that "long sections, even entire movements . . . may continue in one unbroken rhythmic pattern."

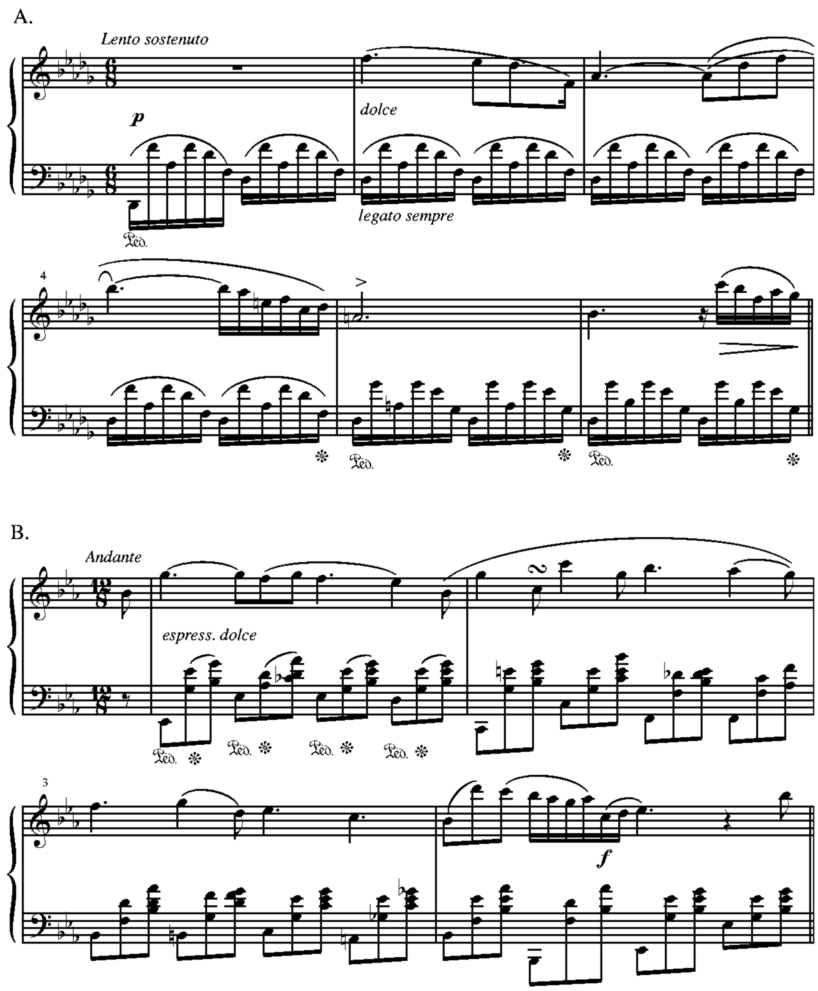

Fig. 2. Two openings of Chopin Nocturnes: (A) Opus 27 No. 2, (B) Opus 9 No. 2.

is asserted and maintained more strongly in the Chopin passages than in the Mozart.

Because of the extreme rhythmic clarity of the Chopin pieces, one can see how they could be played with considerable freedom without obscuring the beat; in the Mozart, by contrast, while perception of the beat in a fairly strict performance would be unproblematic, a substantial degree of rubato might cause confusion. (An analogy could be drawn here with the simple patterns in Figure 1.) Thus, the construction of the Chopin passages seems to inherently allow for more liberties in tempo than the Mozart. This reasoning may explain why Romantic piano music—and especially a particular type of Romantic piano music, involving repeated patterns in the

Fig. 3. Mozart, Sonata K. 309, first movement, mm. 1–9.

left-hand—seems more well-suited to rubato than much other (e.g., classical-period) music.[8]

Another case of interaction between compositional practice and expressive timing is seen in the transition from ragtime to jazz. Figure 4 shows two performances of excerpts from the "Maple Leaf Rag"—the first by Scott Joplin, recorded in 1918; the second by Jelly Roll Morton, recorded in 1938.[9] Both performances feature a good deal of syncopation—long (and hence accented) notes on weak eighth-note beats, such as the E♭ on the fourth eighth-note of the right-hand in the second measure of Joplin's performance of Excerpt 1. But the Morton performance is notably more syncopated than the Joplin, particularly with regard to the left hand. In the Joplin, left-hand events are perfectly aligned with beats (all notes longer than an eighth note occur on strong eighth-note beats), whereas in the Morton, several long left-hand events in both excerpts occur on weak eighth-note beats, with no event on the following strong beat. Thus the Morton performance creates a certain degree of metrical instability. Another significant difference between these performances—not shown in the tran-

8. There are, of course, exceptions to these generalities. Some classical-period pieces feature a left-hand pattern repeated throughout an entire section or movement—this is not uncommon in slow movements, such as that of Mozart's Piano Sonata K. 332. Conversely, Schumann and Brahms are known for sometimes using quite extreme syncopations (see Krebs, 1999, for a thorough study of this aspect of Schumann's style). These exceptions do not fundamentally weaken the argument that, in general, Romantic piano music reinforces the meter more strongly than that of the classical period. They do, however, suggest a further prediction—that, even within the music of a particular period, performers should play pieces in which the meter is more strongly reinforced with more rubato. This prediction remains to be tested.

9. Both of these recordings can be heard on the Smithsonian Collection of Classic Jazz (AS 11892). In Morton's performance, Excerpt 2 actually begins the piece, and is followed by Excerpt 1, but the correspondence between the excerpts in Morton's and Joplin's performances seems indisputable.

Fig. 4. Two excerpts from "Maple Leaf Rag," as performed by Scott Joplin (1918) and Jelly Roll Morton (1938), transcribed by the author.

scriptions in Figure 4, but readily apparent from hearing them—is that the Morton performance features a "swing" tempo whereas the Joplin does not. "Swing" refers to a mode of performance in which the first half of each quarter-note beat is longer than the second half; or, to put it another way, events on strong eighth-note beats are longer than those on weak eighth-note beats.[10] (Swing can be approximated by a 2:1 ratio, though a true swing feel is more variable than this.) The Morton performance is decidedly swung, whereas the Joplin features a perfectly "straight" tempo.

Is there a complementary relationship between these differences? If we think of swing as a kind of expressive timing, analogous to rubato, this might seem to be a counterexample to the current argument, as the Morton performance features both more swing and more syncopation. However, I suggest we view swing in a different way. Notice that one effect of swing tempo is to provide a constant reminder to the listener of where the strong eighth-note beats are (since the strong eighth-note beats are longer than the weak ones). But this is exactly the information that is somewhat obscured by the left-hand syncopations (long notes on weak eighth-note beats) in Morton's performance. Thus Morton counterbalances the destabilizing effect of his syncopations by reinforcing the meter in another way. These two performances in themselves may prove little, but they reflect well-documented broader developments in the transition from ragtime to jazz. The shift from the "even-note" rhythms of ragtime to the swing feel of jazz is well-attested (Schuller, 1968, pp. 67, 217), as is the increase in the degree and complexity of syncopation over the same period (Waterman, 1974, p. 47; Sales, 1984, pp. 28–29). The "communicative pressure" idea may offer an explanation for the roughly contemporaneous occurrence of these changes.

The preceding discussion reminds us that performers as well as composers play an essential role in the communicative process. In many styles, of course, the division between performers and composers assumed in common-practice music is problematic in any case. In traditional African music and in jazz, the extensive use of improvisation blurs this distinction. In rock, too, the composer-performer distinction is often questionable; many performers write their own songs, and the members of a band (the drummer, for example) may well have composed their own parts. In any event, the important point is that the final musical object results from the activities of one or more creators—composers, performers, improvisers—and the behavior of all of these may be affected by communicative pressure.

Another issue arising here concerns possible differences in perception between styles. I have suggested a probabilistic model of meter whereby

10. The word "swing" is defined in many different ways in jazz, and is often simply characterized as some kind of undefinable "feel" (Ulanov, 1952, p. 5). But the sense assumed here—referring to an uneven long-short division of the beat—is one widespread use of the term (Megill & Demory, 1983, pp. 230–231).

listeners infer a metrical structure using assumptions about the regularity of beats and the alignment of beats with accented events; and I have suggested that styles differ in the amount of syncopation and rubato that they employ. But it seems reasonable to suppose that these differences between styles are internalized by listeners, so that—for example—a listener accustomed to traditional African music may have a higher tolerance for (i.e., assign a higher probability to) syncopation and a lower tolerance for rubato. These differences might in turn lead listeners from different cultural backgrounds to assign different structures to the same input. And what about listeners who are familiar with more than one style—do they learn and apply different rule systems for different styles? These are huge and difficult questions, but they do not seem to pose any serious problems for the claims I make here. Thus we will continue to bypass the issue of differences in perception across styles, interesting and important though these may be.

Other "Trading Relationships"

The syncopation-rubato trade-off is an example of a "trading relationship"—a term due to Joseph Swain (1997, pp. 141–167), who introduces it in a discussion of the similarities between musical evolution and linguistic evolution. In the evolution of languages, Swain notes, one change in a language sometimes seems to arise as a way of restoring information lost due to another change. For example, in middle English, the case of nouns (subject or object) was indicated by word endings, but word order was relatively free; when these endings began to drop out, word order became more fixed (with the subject preceding the verb and the object following it), thus indicating case in a different way. (The role of communicative pressure in language is discussed further below.) Swain suggests an analogous case in music as well, relating to cadences. In the Renaissance, the standard authentic cadence was defined as a complex of rhythmic and contrapuntal features; a typical example is shown in Figure 5. As the common-practice tonal system took shape, these rhythmic-contrapuntal features became less rigid and were replaced by the more general V-I harmonic pattern, which takes a wide variety of rhythmic and contrapuntal forms in tonal music.

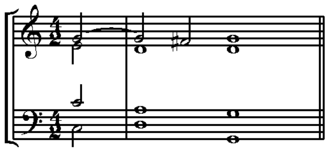

Fig. 5. A typical Renaissance cadence.

It must be said that Swain's cadence example is not entirely convincing, or is at least not fully explained.[11] Still, the general idea of trading relationships is an extremely suggestive one and relates very directly to the idea of communicative pressure. The function of any communication system, linguistic or musical, is to convey certain types of information: for example, syntactic relations in the case of language. If the source of this information is lost (e.g., case endings in middle English), some other means must be found of conveying it (fixed word order). Another causal pattern may occur as well: if a kind of information, already present in the language in one form, is introduced in another form as well, the initial form of the information becomes redundant and may drop out. (That is to say, case endings in middle English may have dropped out *after* the rise of fixed word order because they were no longer needed.) But this second mechanism, too, may be explained as a consequence of communicative pressure; if we assume that the need to convey information may motivate the rise of certain features in the system, it follows naturally that such features may drop out when they become informationally redundant. In short, one may reasonably invoke the idea of communicative pressure without being certain of the exact cause-effect relationships involved. Consider the earlier argument regarding the shifts in compositional practice and performance practice between the classical and Romantic periods. Did an increase in expressive timing among performers exert pressure on composers to increase their reinforcement of the meter (e.g., by writing repeated left-hand patterns), or

11. Swain's example is in some ways a very promising one, and perhaps can be strengthened. In both Renaissance and common-practice styles, cadences are vitally important, partly as cues to segmentation (indicating the ends of phrases and sections) but also indicating the establishment of a tonal center. (We can speak of "tonal centers" in Renaissance music, even though the idea of key is not yet really applicable.) Thus it would not be surprising if the need to communicate cadences significantly affected the evolution of Western music. What needs to be explained, however, is the apparent fact that the common-practice style allows more freedom in the construction of cadences than the Renaissance style. Is there some way in which cadences were more clearly—less ambiguously—identifiable in common-practice music, thus allowing more flexibility in their contrapuntal features? One possible answer lies in the emerging tonal system. In Renaissance music, an entire piece generally uses a single pitch collection (usually the C major scale); there is no modulation from one scale to another, except for the chromatic alterations at cadences. For this reason, the only thing really indicating a tonal center is often the cadence itself. This also means that numerous different cadences on different tonal centers might possibly occur at any time. In common-practice music, by contrast, a cadence is generally prepared by a shift to the key of the cadence (indicated by a shift to the corresponding scale) in the preceding measures; a cadence can only occur in the key of the preceding context. Other things being equal, then, if the same cadence formula was used in both styles, the proportion of possible pitch patterns interpretable as cadences would be much higher in Renaissance music—perhaps unacceptably high, so that cadences would often be perceived where they were not intended (or composers would be prevented from writing what they wanted to write by the need to avoid unwanted cadences). The stricter definition of cadences in the Renaissance style avoids this problem, or (conversely) the contextual constraints on cadences in common-practice music allows them to be more loosely defined in their intrinsic features.

did the use of metrically obvious and uniform textures by Romantic composers allow greater leeway for expressive timing by performers? I will not attempt an answer to this question; it could perhaps be answered through close study of the chronological relationship between the two phenomena (the rise of repeated left-hand patterns and the rise of rubato), and perhaps through consideration of other causal factors. For example, if there is reason to believe that the rise of rubato resulted from extramusical forces—perhaps from the Romantic era's fondness for spontaneous personal expression—then it may seem more probable that the rise of rubato triggered the change in compositional practice rather than the other way around.

Swain restricts "trading relationships" to cases of historical change within a style, where loss of information in one form is compensated for by added information in another. The complementary changes in composition and performance between the classical and Romantic periods would be one example of this; the increase in syncopation and rise of swing tempo in early jazz would be another. However, the term might also be applied in any case where the same information is conveyed in different ways in different styles. This is essentially the case with the syncopation-rubato tradeoff observed between common-practice music generally and traditional African music. Let us consider two other examples of trading relationships between styles.

In both common-practice music and jazz, an important kind of information conveyed is harmonic structure; pitches are grouped into harmonic segments, each one associated with a harmony. An essential part of perception is the identification of the harmonies implied by the pitches. The details of this perceptual process do not concern us (for one recent model, see Temperley, 2001), but essentially, for any given set of pitches, a root must be chosen such that all of them, or as many as possible, are chord-tones of the root. (Some tones may be regarded as non–chord-tones—not part of the chord—but the use of these is generally highly constrained.) For example, the pitches G-B-D are all legal chord-tones of the root G (G is 1 of G, B is 3 of G, and D is 5 of G); therefore G is a possible root. In common-practice music, the set of possible chord-tones is very limited: for the most part, only 1, 3, 5, ♭3, and ♭7 are used, though certain others (like ♭5 and ♭9) may be found under limited circumstances. In jazz, by contrast, a much wider variety of chord-tones is used beyond those allowed in common-practice music, sometimes known as "extensions": 9 (or A above a root of G), ♭9 (A♭), ♯9 (B♭), 11 (C), ♯11 (C♯), ♭13 (E♭), 13 or 6 (E), and the major seventh (F♯) are all commonly found in jazz. (Not all combinations of these chord-tones are usable, and there are naturally many other constraints on how they may be used appropriately [Dobbins, 1994; Grigson, 1988]; but that does not affect the present point.) However, there is another very significant difference between jazz and common-practice harmony as well. In common-practice music, roughly speaking, any registral ordering (or "inversion") of the pitches in a chord is allowed; a C dominant seventh may be spaced with any of its notes—C, E, G, or B♭—in the bass. (There are, again, constraints on the use of inversions; second-inversion triads are particularly restricted in their use.) In jazz, however, such chordal inversions are quite rare; the vast majority of chords are in root-position, that is, the root is in the bass. Thus while common-practice music has a more limited set of chord-tones, it is less restricted in terms of which chord-tone may occur in the bass. It can be seen, once again, that these differences are complementary. Suppose a style allowed both a wide variety of chord-tones and considerable freedom of inversion. This might lead to severe problems of ambiguity, because any chord would have multiple possible roots. To take a simple example, the chord in Figure 6A would be interpretable as A minor seventh with C in the bass (Am6/5) or as C major with an added sixth. As a more complex case, the chord in Figure 6B—a common chord in jazz—would normally be interpreted as C9♭13; but if inversions were allowed, it could be interpreted as an inversion of B♭9♯11 (Figure 6C). In short, it seems to be no coincidence that jazz, which allows a greater variety of chord-tones than common-practice music, also has less tolerance for chordal inversion.

The claims put forth above—that chordal inversions are more frequent in common-practice music than in jazz, and that chordal extensions are less frequent—will, I hope, seem intuitively correct to those familiar with both styles. However, it seemed prudent to subject these assumptions to an empirical test. For common-practice music, the Kostka-Payne corpus was used—a sample of 46 excerpts from the common-practice repertoire, provided in the workbook to Kostka and Payne's harmony textbook along with harmonic analyses by the authors (Kostka & Payne, 1995; Temperley, 2001). The jazz corpus was taken from *The New Real Book* (Sher, 1988)—a collection of lead sheets (showing melodies and chord symbols), spanning a range of jazz styles, created primarily from the composers' original lead sheets and from transcriptions of jazz performances. The first 50 songs in *The New Real Book* constituted the jazz corpus used in this test (the songs are arranged alphabetically). In each corpus, I counted the total number of chords, the number of chords in inversion (i.e., not in root position),

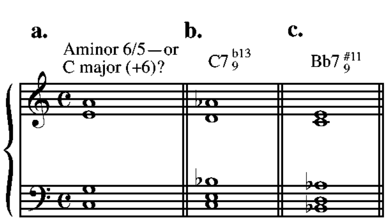

Fig. 6.

and the number of chords using extensions—defined as any chord-tone other than 1, ♭3, 3, 5, or ♭7.[12] Table 1 shows the results. It can be seen that, indeed, the proportion of inverted chords in common-practice music (36.9%) is much higher than in jazz (13.8%), while the proportion of extended chords is much lower (10.8% in common-practice music versus 48.7% in jazz). Thus the trading relationship hypothesized above seems to be borne out.

In some cases, the value of the trading-relationship idea may be in posing new questions, rather than in explaining already observed facts. My final example is a case in point and concerns the communication of key or tonal center. The means whereby listeners determine the key of a piece or passage in common-practice music is a well-studied problem, and a variety of models have been proposed (Bharucha, 1987; Butler, 1989; Krumhansl, 1990; Leman, 1995; Longuet-Higgins & Steedman, 1971; Temperley, 2001). Nearly all models, however, rely heavily on the idea that each key is associated with a certain scale, such that notes within the scale of the current key can be assumed to occur much more than other notes. Informal evidence for the role of scale collection in key-finding comes from "pan-diatonic"

TABLE 1
Inverted and Extended Chords in Two Corpora

Corpus	Number of chords	Number of chords in inversion	Number of "extended" chords (using chord-tones other than 1, ♭3, 3, 5, and ♭7)
Kostka-Payne corpus (46 excerpts)	866	320 (36.9%)	94 (10.9%)
New Real Book (first 50 songs)	2521	347 (13.8%)	1228 (48.7%)

12. One might question my definition of "extensions." By my rule, the ♭5 degree is counted as an extension; thus diminished triads (and diminished or half-diminished sevenths) are counted as "extended chords." This is contrary to the usual understanding in common-practice theory, where the ♭5 of a diminished triad is regarded as an essential part of the chord, substituting for the perfect fifth (and altering the function of the chord). On the other hand, the ♭5 scale degree in jazz often *is* used as a true extension (most often spelled as ♯11)—an elaborating tone added above a dominant seventh chord (see Figure 6C). So there was really no way of classifying this tone that would be true to its usage in both styles. (The vast majority of "extended" chords found in the common-practice corpus were, in fact, diminished triads or seventh chords built on them.) One might also question the labeling of the major seventh as an extension. But in any case, the current argument does not depend on whether a particular tone is considered an extension or not. The point is that, in any style where a large number of chord-tones above the root are allowed (whether they are extensions or essential tones), the widespread use of inversion as well may result in frequent ambiguities; so we would not expect to find these two conditions in combination.

music (such as some of Stravinsky's and Copland's music), in which the notes of a scale are used but in haphazard or unconventional ways; even in the absence of conventional melodic and harmonic structures, the mere use of a scale collection can establish a key quite convincingly. The relationship between keys and scale collections also emerges very clearly from actual musical practice, where it has been shown that scalar pitches are consistently much more frequent than nonscalar ones in both major and minor keys (Temperley, 2002). (Incidentally, the idea that the scale collection in use provides the main cue to the key of a passage is only tenable if we assume the harmonic minor, rather than the natural minor, as the primary scale collection in minor keys. If the natural minor were assumed, then every major key would have the same scale as some minor key—C major and A minor, for example—so it would be impossible to distinguish between them using scale information alone.)

If scale collections are the primary cue to key in common-practice music, this raises a question for so-called "modal" styles of music. The term "modal" generally refers to styles in which the diatonic (major) scale is used, but where the "tonic" position of the scale assumed in common-practice music is not necessarily the tonal center; for example, a modal piece using the C major scale might have a tonal center of D or E. Styles commonly characterized as modal in this sense include Gregorian chant and some types of Anglo-American folk music. Another example is rock music, whose modal character has been attested by several authors (Moore, 1993; Stephenson, 2002; Temperley, 2001); for example, a rock song using the C major scale might have a tonal center of C (Ionian mode), but the tonal center might also be D (Dorian), A (Aeolian), or G (Mixolydian). Clearly, then, the tonal center of rock songs cannot be conveyed by scale collection, since any major scale is ambiguous between at least four tonal centers. How, then, are tonal centers conveyed in rock? One possibility, suggested independently by Stephenson (2002) and myself (Temperley, 2001), is that the hypermetrical placement of harmonies may be an important source of key information: in particular, the tonic harmony tends to occur at hypermetrically strong points. "Hypermeter" refers to meter above the level of the measure; a four-measure phrase typically has the hypermetrical structure STRONG-weak-medium-weak, so that the strongest measure is the first. In rock, then, there is a strong tendency for the first measure of a four-measure phrase to present tonic harmony. The importance of this factor in key-finding is clearly shown in cases where the same chord progression is found in different hypermetrical contexts, affecting the tonal implication. Consider the progressions E-A-D-A and A-D-A-E (Figure 7); the two progressions are essentially the same, if one imagines them repeating indefinitely. Both of these progressions are commonplace in rock: "What I Like About You" by the Romantics is an example of the

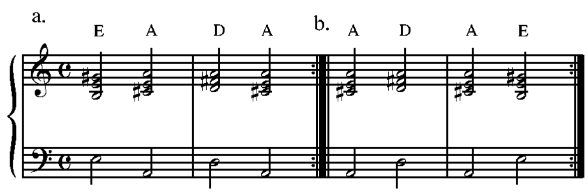

Fig. 7. Two common rock progressions.

first, "Rosalita" by Bruce Springsteen is an example of the second. Yet in the first case, E major is hypermetrically strong, asserting E as the tonal center; in the second case, the hypemetrical context gives priority to A major. In rock, then, the potential ambiguity of key resulting from the modal system may be counterbalanced by a strong preference to use the tonic harmony at the beginning of phrases. This is only a preliminary suggestion; the study of rock harmony and tonality is in an early stage, and there may well be other factors in tonal implication in rock besides the hypermetrical placement of harmonies. The point is that, to the extent that rock music conveys tonal centers and is modal in its pitch organization, we should expect to find other cues to tonal center besides pitch collection.

Low-Probability Events in Constrained Contexts

In this section, we consider a rather different application of communicative pressure. I will introduce the idea by using a simple nonmusical example. Assume that you take a commuter train every day; every day the conductor makes a series of announcements, including either "The cafe car is open" or "The cafe car is closed," but 99% of the time the cafe car is declared to be closed. We assume, also, that there is some probability of the message being mistransmitted (due to noise on the public address system, for example), so that the intended word "closed" might be misheard as "open" or vice versa. In this situation, it might be difficult for the message "The cafe car is open" to ever be communicated. From the perceiver's point of view, if the word "open" is perceived, it may seem more likely that it is really a distorted version of the word "closed," given the very low prior probability of "open." From the communicator's point of view, the problem may be solved by adding extra information: by saying, for example, "And here's something very unusual: The cafe car is open." The extra information (assuming it is provided every time the rare message is read) provides a context that is associated with the rare message; the context increases the prior probability of the rare message from the perceiver's perspective, making it more likely to be perceived as intended. More generally, the communication of a low-probability event can be facilitated if the event is consistently accompanied by some kind of context that is associated with the event and increases its prior probability.

How might this principle apply to music? Let us return to the domain explored by Huron, the compositional rules of common-practice music, though here our focus will be more on the rules of harmony than counterpoint. At the level of notes, one kind of "rare event" is chromatic notes, or notes outside the scale of the current key; as observed earlier, the vast majority of notes in common-practice music are within the scale of the current key. The principle put forth earlier predicts that chromatic notes would occur only in highly constrained contexts, and this is indeed true. For the most part, chromatic notes occur as non–chord-tones, resolved by a half-step and usually prepared by half-step motion as well—so-called chromatic neighbor tones and passing tones (Figure 8). (Chromatic tones may also occur as part of chromatic harmonies—such as augmented sixth chords—but even then they are almost invariably resolved by half-step.) By the current logic, the rarity of chromatic notes combined with the imperfect process of note transmission (notes may be misheard, misplayed, played slightly out of tune, and so on) means that chromatic notes run the risk of being misidentified. The restricted context of a chromatic tone increases its prior probability: if we hear a ♯1 scale-degree (like the C♯ in Figure 8), we may not be sure we heard it correctly, but if scale-degree 2 follows, the probability is greatly increased. A similar argument could be made for secondary dominants—chords, normally outside the current key, which function as dominants for a chord within the key. Again, these chords are presumably low-probability harmonic events (and also involve low-probability pitches, i.e., pitches outside the scale); but they also occur in highly constrained contexts, as they are almost invariably followed by their corresponding tonic chords.

It must be admitted that this explanation is somewhat counterintuitive and goes against the traditional thinking about chromatic tones and secondary dominants. It suggests that the stepwise resolution of chromatic tones arose as a way of facilitating their perception. Traditionally, however, chromatic tones have been regarded as a way of elaborating the following diatonic tone, or filling in the space between two diatonic tones

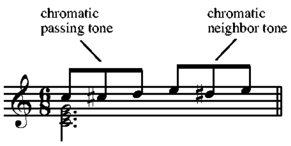

Fig. 8. Chromatic non–chord-tones.

(see, e.g., Aldwell & Schachter, 2003, p. 13). By this conventional reasoning, it is the diatonic tone that motivates the chromatic one rather than the other way around. (A similar point could be made about secondary dominant chords.) Still, these two explanations may not be mutually exclusive. Even if we allow that chromatic tones arose as, and function as, elaborations, there are many conceivable ways that one tone might elaborate another. The communicative pressure idea predicts that patterns of elaboration will be favored in which the context of the chromatic tone is highly constrained.

In the case of both chromatic tones and secondary dominants, the essential context of the rare event follows the event rather than preceding it. (Chromatic tones are usually preceded by stepwise motion as well, but this is not as consistent as their stepwise resolution.) This is not a fatal problem for the current argument. Consider the commuter train example: The conductor might say "The cafe car is open, yes, you heard me right," but this subsequent contextual reinforcement could function to increase the probability of the previous rare message as well. Still, this seems less desirable from a communicative point of view; if the subsequent context of an event is crucial to its identification, this means one can only be certain of the event after it has occurred. In the case of secondary dominants, for example, recognition of the chord would presumably be easier if the resolution chord (the corresponding tonic) preceded the dominant rather than following it; in this case, the probability of the secondary dominant occurring would be raised by the event before it, thus facilitating its identification when it occurred. (Presumably, the tonic of a secondary dominant chord is generally a fairly probable event—even when not preceded by its own dominant—because it is usually a diatonic chord within the key of the larger context.) The fact that the supportive contexts of rare events in common-practice music usually seem to follow the events is a challenge for the communicative-pressure theory that requires further consideration.[13]

Conclusions

I have suggested that a number of phenomena in musical styles can be explained by the idea of communicative pressure. The idea is reflected in the work of Huron, showing that a number of rules and regularities in compositional practice can be seen as strategies to facilitate the identifica-

13. This phenomenon relates to the "anchoring principle", posited by Bharucha (1984), which states that unstable events tend to be followed by more stable and referential events. But no explanation has been given for why events should tend to precede, rather than follow, their anchors.

tion and grouping of pitches. Communicative pressure also accounts for a number of complementary differences between styles (what Swain calls "trading relationships"): the greater degree of syncopation and lower degree of rubato in traditional African music and rock versus common-practice music; the particular appropriateness of rubato in pieces with consistent repeated patterns (e.g., much Romantic piano music); the rise of swing tempo and the higher degree of syncopation in jazz as opposed to ragtime; and the greater variety of chord-tones and lower tolerance for chordal inversion in jazz as opposed to common-practice music. Finally, the idea that low-probability events occur in constrained contexts may account for certain rules of common-practice harmony, such as the highly constrained treatment of chromatic tones and secondary dominant chords.

As noted earlier, Huron's claims regarding the facilitation of pitch and voice perception are not put forth as universals; rather, they depend on the goals of the composer. In some cases, a composer might wish to discourage the perception of clear pitches and lines; in such cases, the composer might well use large melodic intervals, dense low-register harmonies, and so on. The same applies to the claims made here. It has been suggested that the need to communicate metrical structure can exert pressure on composition and performance—as reflected, for example, in the amount of syncopation and rubato. But this applies only in cases where the communication of meter is among the composer's and performer's aims. Some music, at least according to conventional wisdom, simply does not have meter, in the sense of an underlying hierarchical structure of regular pulses. Examples include Gregorian chant, recitative in opera, and some kinds of traditional African music. This actually raises a problem for the whole communicative-pressure idea. The theory predicts that, in music where the communication of meter is a goal, we should not find both a high degree of syncopation and a high degree of rubato. But if we were confronted with such music, we might simply assume that such music did not have any intended meter—because we did not perceive one—and thus that the prediction did not apply; there is, then, a danger of circularity. While this is a problem, it is not a fatal one. There are often external cues as to whether a metrical structure is intended in a kind of music: notation, for example. One reason for thinking that no metrical structure is involved in Gregorian chant or recitative is because none is included in the way the music is notated.[14] Still, the possibility of circular reasoning is a real danger that we should bear in mind when applying the communicative-pressure theory.

14. Another kind of relevant evidence—though not unimpeachable—is the testimony of composers and performers regarding their aims. The fact that some twentieth-century composers have disavowed the presence of key (or tonal centers) in their work indicates fairly strongly that they are not trying to convey tonal centers; see for example Schönberg, 1950, pages 103–105.

One might suppose that the communicative-pressure idea would be applicable to communication generally, not just music. As suggested earlier, communication generally functions to convey information from a sender to a receiver via some kind of "surface"; if the information is not recoverable from the surface, the communicative process fails. It is natural to wonder if this principle applies in revealing ways to the other primary system of human communication, language. As noted above, Swain points out several interesting examples of "trading relationships" in language, such as the contemporaneous loss of case endings and rise of fixed word order in Middle English. He also discusses examples from phonology: for example, the loss of final stop consonants in Chinese coincided roughly with the rise of tone distinctions in vowels, suggesting that some kind of informational trade-off may have been involved (Swain, 1997, pp. 143, 153). However, exploration of the large literature on language change and evolution reveals surprisingly little discussion of trading relationships and communicative pressure generally. Trading relationships of the kind mentioned by Swain are for the most part mentioned only briefly, and communicative pressure is usually put forth only cautiously, and often skeptically, as an explanation (Danchev, 1991; Kiparsky, 1982; Labov, 1994; Pyles, 1971). A few studies have investigated the role of communicative pressure more directly. One active area is the study of syntactic choices—where there is more than one way of expressing something: for example, in an embedded clause, people can either include the complementizer *that* or not ("I said I would go" / "I said that I would go"). In such cases, we might wonder if communicative pressure were involved; do people include the complementizer in cases that would otherwise be ambiguous? While some have found evidence for the role of communicative pressure in syntactic choice (Elsness, 1984; Temperley, 2003), others have cast doubt on this idea (Ferreira & Dell, 2000; Wasow & Arnold, 2003). At present, then, the whole idea of communicative pressure holds a rather marginal status in the study of language—as evidenced by the fact that there is no widely accepted term for it (the term "communicative pressure" is, again, my own invention).

If linguists are reluctant to make strong claims as to the causal role of communicative pressure in language change, this may be because such claims are so difficult to confirm or disprove. And indeed—as already noted—the problem of confirmation is a difficult one that should concern us in the musical case as well. To some extent, the theory has been put forth to explain already observed facts—such as the greater syncopation and greater strictness of tempo in African music as opposed to common-practice music. As such, it inevitably has a somewhat post hoc character—like any theory put forth to explain an existing body of evidence, such as a historical theory, or for that matter the Darwinian theory of evolution. On the other hand, such a theory may still explain the existing facts so elegantly and powerfully that it seems to prove itself on that basis alone; the theory of evolution is a case in point (though I would not claim the same degree of explanatory power for the communicative pressure theory!). The communicative pressure theory may also generate new predictions that can then be examined or tested. For example, it predicts that musical styles (at least musical styles with meter) may have a high degree of syncopation or a high degree of rubato, but not both; this prediction awaits testing in many styles beyond the ones considered here. Similarly, it predicts that modal music, in which the tonal center cannot be conveyed through scale collection alone, will feature other reliable and consistent indicators of tonal center. Such predictions point to further empirical questions to investigate and may lead us to a clearer picture of the theory's empirical validity.[15]

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