Time Warps in Early Jazz

FERNANDO BENADON

Expressive timing can be viewed as a process whereby a rhythmic template is transformed into a new rhythm that departs from the underlying metric grid. In this paper I examine two types of transformation within the context of 1920s jazz. The *Flux* (F) transformation distorts the original rhythmic template by molding it into an acceleration, a deceleration, or a combination of these. The *Shift* (S) transformation changes the global tempo of the template. At the heart of these operations lies the concept of an *anchor*, an on-the-beat synchronization point between soloist and accompaniment that metrically grounds the transformation. Soloists use F and S—often in conjunction—to shape their rhythms and to control the level of tension/resolution in relation to the underlying beat.

Keywords: jazz, rhythm, microtiming, improvisation, transformation, rubato, Louis Armstrong, Bubber Miley

INTRODUCTION

By most accounts, jazz rhythm is elastic and adventurous. Attacks are displaced, phrases are laid back, time is stretched, subdivisions are blurred, and beats are turned around. Young Louis Armstrong was renowned for "cutting entire phrases afloat from the beat," and Coleman Hawkins could "assert his [rhythmic] conception over that of the accompanying rhythm section, in fact completely ignoring it" (Gushee 1998, 308; Schuller 1989, 433).[1] Beyond such anecdotal descriptions, music theoretic studies that unravel and formalize these phenomena are scarce.[2] Some writers have approached the topic by addressing specific features such as metric displacement (Downs 2000/01; Haywood 1994/95; Kofsky 1977; Waters 1996) or the algorithmic modeling of rhythmic kernels (Johnson-Laird 2002, 431–36). Still, these discussions rely almost exclusively on standard notation and thus miss out on many of the nuanced temporal dimensions critical to jazz rhythm. Other writers have made headways by dwelling on the small-scale temporal phenomena collectively known as "expressive timing" (or "microrhythm" or "microtiming"). These studies seek to explain the properties of sub-beat rhythmic activity, whether it be performing behind-the-beat (Collier

1 As early as 1917, a listener remarked that a "highly gifted jazz artist can get away with five notes where there were but two beats" (quoted, among other similar accounts, in Collier and Collier 2002, 280). See also Hudson (1994), who notes that Virgil Thomson described jazz's "simultaneous use of free meter with strict meter" (404).

2 Certainly, the topic of rhythm plays an important role in some treatises on jazz. At 81 lines, "rhythm" is by far the bulkiest index entry in Paul Berliner's *Thinking in Jazz* (1994). Gunther Schuller (1968; 1989) also underpins the larger framework of the jazz art form with frequent excursions into the mechanics of rhythmic invention and innovation.

and Collier 2002; Folio and Weisberg 2006), "swing" eighth-notes (Benadon 2006; Friberg and Sundström 2002), rhythm section asynchrony (Prögler 1995), ballad rubatos (Ashley 2002), or the inner makeup of grooves (Butterfield 2006). In these scenarios, there is a slight but perceptible departure from a prescribed or expected rhythm, and the new rhythmic interpretation is viewed in terms of its magnitude of deviation. Hence what these studies have in common is an understanding of expressive timing as a deviation from an idealized—often metronomic—template: the eighth-notes are swung because they are not isochronous, the downbeat is rushed because it is played slightly earlier than the transcription indicates, and so on. However, the deviations are almost always viewed as discrete local events, ostensibly independent of the preceding and subsequent notes. The idea of an underlying transformative process lurks behind these analyses but it rarely takes center stage.

This article furthers the discussion of jazz rhythm and expressive timing by placing the concept of temporal transformation at the fore. I present two transformations: *Flux* (F) and *Shift* (S). F distorts a basic rhythmic template into an acceleration, a deceleration, or a combination of these; S replaces the tempo of the template. These operations convert a metrically gridded (quantized) sequence of durations into one whose subdivision grid is either in flux, related to the original subdivision grid by some ratio, or distorted in less systematic ways.[3]

This approach enables us to move away from the myopic note-by-note interpretation of microrhythm by allowing transformative processes to encompass (slightly) larger windows of time. The coming pages will illustrate these processes with musical examples drawn from the 1920s jazz discography.[4] The choice to use examples exclusively from the early jazz period is mainly reflective of this author's current predilections. Analogous examples exist in the decades that follow the 1920s, almost certainly in even greater abundance. Yet, providing hard proof that sophisticated layers of microrhythm already existed in the music's earlier days can only enrich our understanding of its historical development. More broadly, I hope to show how a variety of seemingly unrelated rhythmic and microrhythmic devices may be explained as consequences of a single larger force.

two transformations: flux and shift

We begin with the opening melody of "Crawdad Blues," played by Lamar Wright during a 1923 recording session with Bennie Moten's Kansas City Orchestra.[5] The group has been described as "rhythmically stiff beyond belief," playing an "unvaried and heavy" beat (Schuller 1968, 283–84).[6] But Wright's rhythmic freedom is a clear exception. The eighteen-year-old cornetist continuously reshapes a recurring motive that consists of three eighth-note triplets followed by a series of roughly isochronous D♭s and a final descent to B♭ (in one case C in order to accommodate the underlying change in harmony). Example 1 provides five iterations of the motive. The self-similarity among the motive forms suggests that they are derived from a common prototype. We cannot say for sure which one of the five versions represents

3 The concept of time warping from "score time" to "real time" originates with computer music. Roger Dannenberg (1997) describes two such operations: "shift" displaces an event to an earlier or later point in time, and "stretch" (equivalent to my shift and flux transformations) alters the tempo.

4 All of the examples contain palpable rhythmic deviations and were selected on the basis of hearing. Audio files are available on www.redhotjazz.com.

5 Articulation markings, chord symbols, and dynamics are left out of the transcriptions to preserve visual clarity.

6 To be fair, the band had big shoes to fill. Only a few months earlier, the traveling makeshift studios of the Okeh label had recorded the legendary sides of King Oliver's Creole Jazz Band. See Rice 2002 for details on the 1923 Bennie Moten sessions.

EXAMPLE 1. *Lamar Wright (cornet), "Crawdad Blues" (0:11–0:34). Four transformations (a–d) of a source template (e). Numbers above the staff denote millisecond delays (→) and anticipations (←) with respect to the accompaniment's beat; on-the-beat anchors are marked with vertical arrows.*

the unaltered, original motive; perhaps it is never actually heard, or perhaps it does not exist.[7] It does not matter. For now, we are interested in analyzing the transformative process itself regardless of whether we are able to identify the source object or the direction of the transformation.

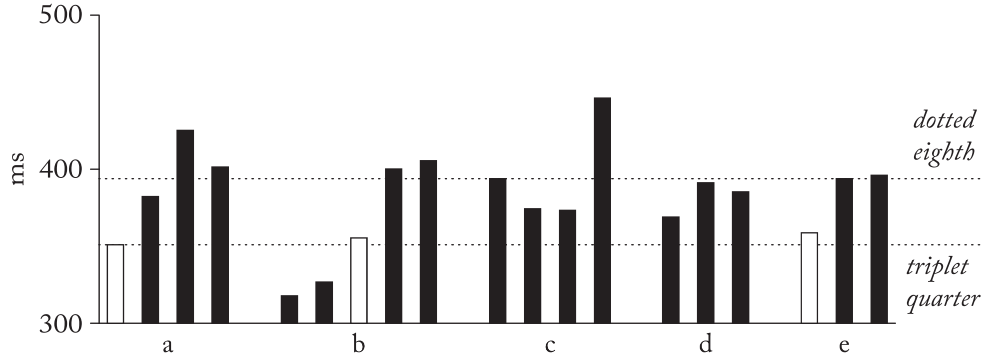
Suppose that the source pattern is (e), and that the other four versions are transformations of it—we can say that they are *reducible* to it.[8] Some of these transformations are visible in the transcription. In (a), for instance, the motive is displaced to the right by one beat, and the chain of D♭s is slowed down (dotted eighths instead of quarter-note triplets) and extended by one additional repeated note. In (b), not only is the entire motive played off the beat, but it is also extended by two D♭s which in turn are lengthened at the end. Versions (c) and (d) are likewise varied. Since the note values employed by the transcription are but rough approximations of the performance's audibly flexible durations, more precise timing information is displayed above the transcription.[9] Millisecond values appear above the horizontal arrows denoting delays (→) and anticipations (←) with respect to the underlying beat. Vertical arrows mark the presence of *anchors*: on-the-beat synchronization points between soloist and accompaniment that metrically ground the phrase. Although microrhythmic delays and anticipations are sometimes local and independent occurrences, I will show that often they are the end results of more overarching rhythmic transformations. But first let us illustrate and define the two kinds of temporal transformation that form the essence of this article.

Example 2 shows the durations of D♭s—excluding that of the motive's final D♭ to B♭ descent—for all iterations of the

7 Not hearing the original form does not necessarily preclude the listener from forming a mental category of it; see Desain and Honing 2003. See also Posner and Keele 1970 for evidence of prototype formation given visual stimuli consisting of distorted dot patterns.

8 This would mean that the non-transformed version of the rhythm occurs after its variations have already been presented. Harker (1997) notes that, in the case of Louis Armstrong, such developmental nonlinearities counter "traditional assumptions that jazz variations move from the familiar to the abstract" (68).

9 I made these measurements with the audio editing software Peak. I use the term "duration" to mean inter-onset interval (IOI), the time-span between onsets of two adjacent notes irrespective of articulation. Measurements are rounded off to the nearest one-hundredth of a second (10 ms). This might seem an excessive liberty for a microtiming study, but the approximations should be excusable on two grounds. First, the magnitudes in question are generally large as far as microtiming goes, generally ranging between 50 and 250 ms. On this scale, worrying about differences of a handful of milliseconds seems pointless. Second, the exact onsets—particularly those in the rhythm section—are often fuzzy and difficult to situate with precision.



example 2. *D♭ durations (IOIs) in "Crawdad Blues." Only three notes (unfilled columns) retain the quarter-note triplet duration; all others are stretched or compressed. These duration patterns can be described as Flux (a–c) and Shift (d–e) transformations.*

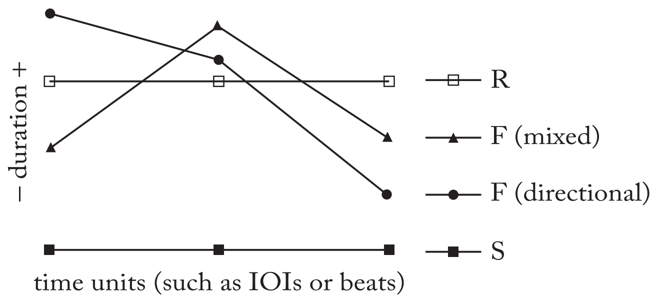
"Crawdad Blues" motive. The graph confirms an audible trend: most D♭s, far from being equidurational, are often in a state of temporal fluctuation well beyond what one might expect from the unintentional motor noise of human performance. The timing pattern in (b) spells out a clear deceleration. Unlike (b), the fluctuation patterns in (a) and (c) are non-directional, revealing instead more of a give-and-take in the case of (a) and a take-and-give in the case of (c). These are flux (F) transformations: conversions from metrically subdivided durations into unmetered ones.

The graph also shows that Wright frequently inflates the durations of the D♭s. While there are some clear-cut triplets (shown with unfilled columns), most are augmented into dotted eighths and other less easily defined values. The supposed quarter-note triplets of our designated prototype (e) are too slow, as are those in (d). Perhaps these triplets are slow because they are being played at a slower, substitute tempo. The quarter-note triplets may be slow at the original tempo of 114 bpm, but given an alternate tempo of 105 bpm, they are mostly in time. In fact, both of these quarter-note triplet groups—(d) and (e)—are equal in total duration almost to the millisecond, possible proof that the rate of slowness cannot be coincidental. These are shift (S) transformations: augmentations or diminutions of original durations by some fixed proportion.[10]

An important consequence of S is that it affects the soloist's placement in relation to the underlying tactus. In the above "Crawdad Blues" example, the slowness delayed the soloist's beats: (e) began on the beat but ended 100 ms behind, and (d) began only slightly (50 ms) behind the beat but ended almost one third of the beat behind (150 ms). Hence, one advantage of conceiving timing deviations as byproducts of momentary tempo substitutions is that we can formalize and objectively quantify intuitive concepts such as rushing and laying back.

Example 3 illustrates F and S in general terms. Let a given rhythm R contain an ordered set of deadpan durations such as {2, 2, 2}. This rhythm can be transformed by F in two ways: it can undergo a directional change, for example

10 The reason for not using the terms augmentation and diminution here is that these usually connote a transformation that can be explained by the underlying pulse subdivisions. The S transformation is more general because it is not constrained by simple metric ratios.



EXAMPLE 3. *Flux and Shift transformations of a rhythmic template R.*

by starting off slowly and accelerating gradually to become something like {2.3, 2.1, 1.5}, or it can mix directions so that its values lie about the original durations forming no discernible pattern, such as {1.7, 2.2, 1.8}. Alternatively, the rhythm can be sped up or slowed down instantaneously and proportionally by S, for example to {1.2, 1.2, 1.2} through a multiplicative transformation of 3/5.

As we will see, not only can F and S act simultaneously, but they can also be related to each other in straightforward ways. For example, S may further undergo F to yield a tempo substitution that contains some fluctuation in its note durations. It is also possible to embed S within F, as follows. Suppose that each F point in Example 3 represents not the duration of a single note but that of a larger unit of time, such as a beat. In this way, each point becomes an S transformation in itself, since low-lying points denote fast/short beats and high points denote slow/long beats. Now the overall F trend describes a chain of S transformations.

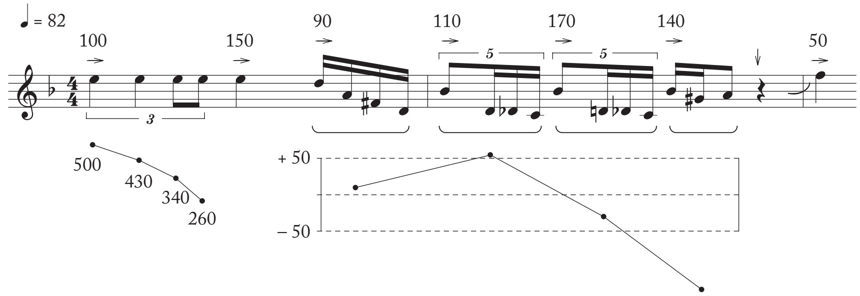
MILLESCONDS IN CONTEXT

Before continuing, a brief discussion of method is needed. The microscopic dissection of phrases is a delicate matter, and it is important to place the measurement magnitudes in context before jumping to conclusions. Statisticians speak of two types of error when assessing the significance of one's findings. One can either fail to detect a trend that really does exist (a false negative), or claim to have discovered one when it is actually nonexistent or attributable to chance (a false positive). In this study, we must be especially mindful of the latter to prevent an over-reading of potentially noisy data. Perception thresholds, though far from universally established, play a key role. Imagine a scenario where three successive notes have duration values of 190, 185, and 180 ms. Are we justified in claiming that this group of notes is gradually accelerating? Absolutely not, for two reasons: the differences are small enough to arise through measurement error, and more importantly, it is highly unlikely that a listener will be able to perceive such small scale acceleration. Furthermore, auditory cognition often interprets durations in ways that differ from their physical reality, as in the time-shrinking illusion whereby two short durations are deemed equal even when the first is shorter than the second (ten Hoopen et al. 2006).[11]

We then face the question of what constitutes a perceivable timing discrepancy, for example between two otherwise isochronous durations or between a downbeat and a displaced attack. Since the answer depends on a multitude of factors too complex to address here,[12] I now state the rule of thumb that acts as this study's analytical filter: measurement magnitudes are significant only when they serve to support and articulate a "by ear" explanation of the passage. This approach is purposely permissive of subjective interpretations of rhythm. Its logic rests on the understanding that an analysis which purports to explain expressive effects is fundamentally suspect if its measurements do not reflect appreciable sonic manifestations.

11 The article also provides a comprehensive overview of categorical rhythmic perception, the process by which listeners convert complex durational ratios into simpler ones. See also Desain and Honing 2003.

12 London (2004, 27–47) provides a review.



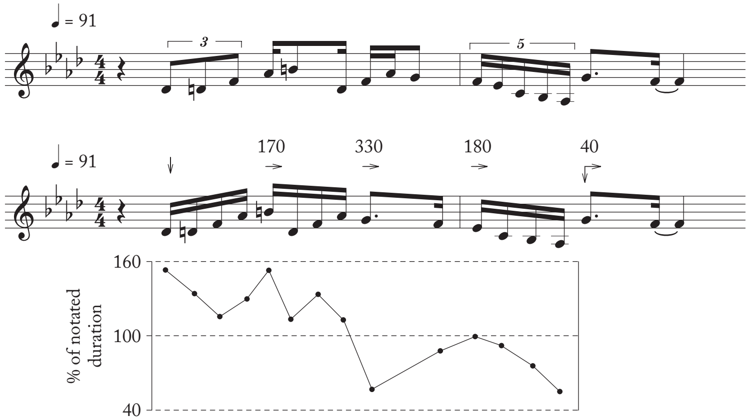
EXAMPLE 4. *Louis Armstrong (trumpet), "Two Deuces" (1:55). The graph on the left shows note durations. The one on the right shows durations for Armstrong's beats as compared to the rhythm section's (dashed line). Throughout the phrase, F controls the degree of temporal offset between soloist and accompaniment.*

Throughout this paper the reader may want to use 50 ms as a measuring stick. To my ears and in these examples only, timing deviations are evident and intentional-sounding at this magnitude and above. Two types of deviations arise: between the beat and the soloist's onset (such as a delayed downbeat attack), and between an expected note value and the performed duration (such as an elongated eighth-note).

FLUX AS EXPRESSIVE TIMING

We have seen how S transformations can produce behind-the-beat playing. Example 4, an excerpt from Louis Armstrong's trumpet solo on "Two Deuces," shows how F can regulate the size of the delay in a phrase that is already displaced in its entirety behind the beat.[13] The phrase contains not a single aligned onset between soloist and tactus. There is always a temporal disconnect between the two—or rather a relegation, since Armstrong's beats, like persistent shadows, consistently lag behind the accompaniment's by big margins. The opening Es are not only delayed but also gradually compressed: F decreases the durations of the first four notes in almost perfect linear fashion from 500 to 260 ms. The remainder of the phrase also finds Armstrong's beats trailing those of his bandmates, a gap that is widened even further after Armstrong stretches his beat one by 50 ms. The bit of ground that he regains by slightly shortening his second beat—an exact restatement of the first—is nowhere near enough to bring him back to par, so that the arrival of beat three finds him a hefty 140 ms behind. In order to realign himself with the rhythm section, he would need to intensify this rushing tendency through the third beat. This he does briefly, since the first half of his third beat is only 300 ms, about 60 ms shorter than the tempo's correct duration. But rather than continue this accelerating trend into the beginning of the fourth beat, Armstrong stops short halfway through the third. Harmonically, he already reached his destination on the upbeat of the third beat, where the recalcitrant B♭ appoggiatura finally gave way to the D^7 chord's fifth degree, rendering further motion superfluous. Following seven beats of temporal differences between

13 Large scale delays are frequent in jazz. Performers often shape these in individual ways that help to define their own expressive profiles. See Folio and Weisberg 2006.



EXAMPLE 5. *Coleman Hawkins (tenor saxophone), "One Hour" (1:37). The top transcription is more accurate but it conceals the pre-transformed template as shown in the lower transcription. The overall acceleration can be thought of as an F curve. Equally valid is the perspective of an S-chain containing two beats of 72 bpm followed by two beats of 124 bpm.*

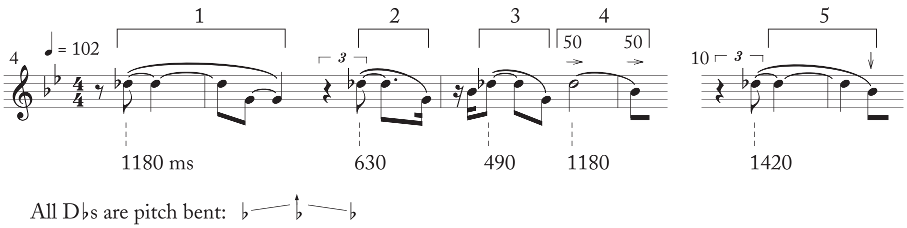
soloist and accompaniment (and preceding yet another laid back attack on the downbeat of the subsequent measure), Armstrong seizes the opportunity and allows the accompaniment to articulate a reassuring anchor as he rests on the fourth beat. With a Zen-like stroke, he grounds the entire phrase by sounding out a metrically firm silence. This is not to say that anyone who plays off time need simply rest for one beat in order to stabilize the phrase. But Armstrong's compensating acceleration through beats two and three suggests that, had he played on, he might have arrived on target either on beat four or on the ensuing downbeat.

VARIABLE PERSPECTIVES

Example 5 provides an excerpt from Coleman Hawkins's classic 1929 solo on "One Hour." The passage illustrates one aspect of the relationship between F and S. The top transcription shows a fairly literal interpretation of the passage, but a more accurate reflection of its inherent rhythmic structure appears in the lower transcription.[14] Even though the phrase undergoes a noticeable departure from isochrony, its temporal looseness is securely held in place by two anchors, one at the beginning and one near the end.[15] Sandwiched between the two anchors is a four-beat tempo curve. By the end of the first measure, Hawkins has leisurely fallen behind the beat by one full eighth-note (330 ms). He changes gears

14 The top transcription resembles Schuller's (1989, 432), who uses triplets for the first three beats. It is widely acknowledged that jazz transcriptions often vary depending on how much detail the transcriber is willing to convey. Hence, although it is often remarked that music notation fails to capture certain rhythmic realities, the opposite is also true: when the notation represents note placements and durations too accurately, essential—that is, pre-transformed—rhythmic properties may be obscured. See DeVeaux 1997, 82 and 100.

15 The second anchor is not a perfect resynchronization. But given the magnitudes of the previous delays, it is heard as a convincing realignment.



EXAMPLE 6. *Bubber Miley (trumpet), "Ponchatrain" (1:35–1:52). The tritone goes elastic.*

again halfway through the phrase, now by rushing to close the delay gap and reach the second anchor.[16] This slow-fast trend is shown below the transcription, which plots the percentage amount by which each note in the performed version differs from its notated equivalent. During the first two beats, all durations are too long. During the next two, they are too short. This points to an overarching F transformation, since the durations first exceed and then fall under the transcription's note values.[17]

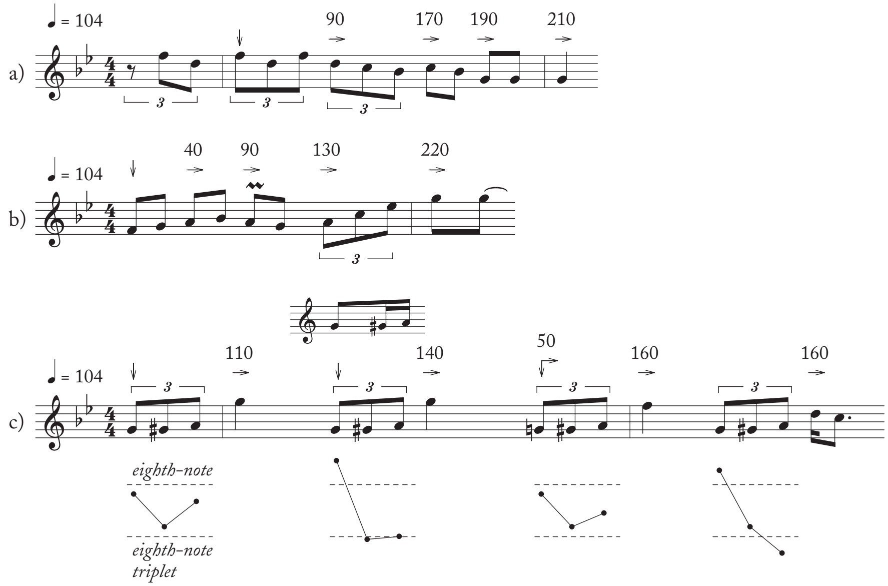
Rather than frame Hawkins's temporal diversions on a note-by-note basis, we can assess the phrase's trajectory more globally (though still locally with respect to the entire solo). We have already mentioned the slow-fast breakdown over the phrase's four beats. Let us divide the phrase evenly into two regions of two beats each. The first region spans 1667 ms, equivalent to two beats at 72 bpm. The second one is almost half as long at 968 ms, equivalent to 124 bpm. (As one would expect, the sum of both regions, 2635 ms, equals four beats at the excerpt's tempo of 91 bpm). We now have a metric that describes the timing behavior of the phrase as a succession of tempo substitutions: two beats at 72 bpm followed by two beats at 124, then anchoring on 91, the song's tempo. Hence, it is sometimes possible to explain a passage from either transformational perspective: S (this paragraph) or F (previous paragraph). In the example, F directs our attention to the overall curve from slow to fast; S provides a middle-ground metric for assessing the components of that curve.

SHIFT AS EXPRESSIVE TIMING

Rhythmic elasticity is especially striking when it appears side by side with more rigid rhythmic renditions. Such stylistic contrasts were regularly featured during the early decades of jazz, when the music was still an amalgam of marches, blues, ragtimes, and dances hot and sweet. The first two choruses of Jelly Roll Morton's 12-bar blues "Ponchatrain" feature a trumpet solo by Ward Pinkett and a clarinet solo by either Ernie Bullock or Jerry Blake. Their rhythms are laden with on-the-beat attacks and almost quantize-perfect triplet subdivisions. Rhythmically, these solos stand in stark contrast to the two that immediately follow. Trumpeter Bubber Miley and guitarist Bernard Addison stretch time, blur barlines, and continuously thwart metric regularity. Miley's bluesy descending motive is heard five times. Example 6 shows how the motive's opening D♭ is twice intact, twice compressed, and once stretched out. It is also continually displaced, saving the anchor until the end of the final iteration.

16 The placement of both anchors on the second beat of each measure—rather than on the downbeat—adds yet another level of metric fluidity.

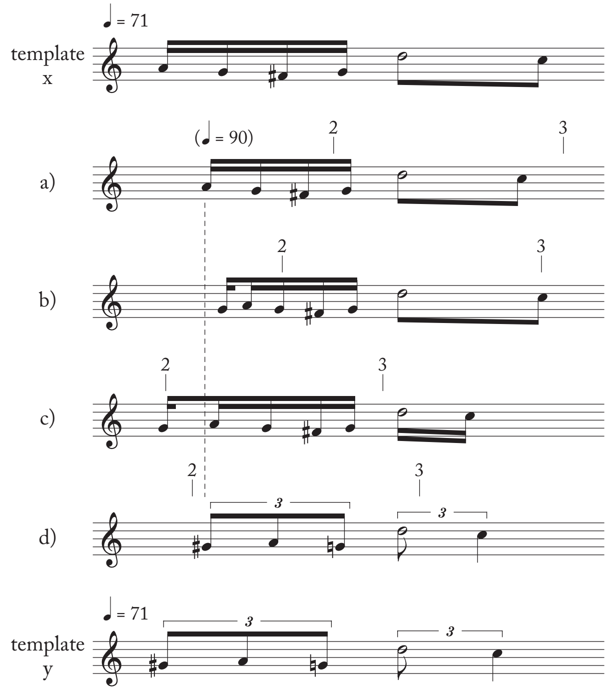
17 Note also how, on a more local level, Hawkins inserts slight agogic accents on the first note of each group of four sixteenths.



EXAMPLE 7. *Bernard Addison (guitar), "Ponchatrain" (1:54–2:17). (a) The triplets are played at 91 bpm, creating a substantial delay of 170 ms by mid-measure. The eighth-notes are played faster at 101 bpm (but still slightly slower than the real tempo) in order to contain the rapidly growing delays. (b) Addison's tempo of 95 bpm generates a 220 ms delay by the next downbeat. (c) The delayed quarter notes are compressed to ensure anchor-ready triplets.*

But we are mainly focused here on the various S transformations in Addison's guitar solo, which follows suit. He also distances himself from the underlying metric grid, mostly by way of gradual and ever present decelerations. Example 7 shows three distinct instances of this trend. In (a), a series of firmly grounded triplets quickly loses momentum to become languid eighth-notes, all the while increasing the beat delay such that Addison's final downbeat is late by more than one third of a beat. S is the reason. Even though the song's tempo is currently 104 bpm, the triplets are played at 91 bpm, causing a significant delay of 170 ms halfway into the measure. It is hard to imagine how Addison might maintain this rate throughout the entire measure. Doing so would place him almost two thirds of the beat behind the rhythm section at the ensuing downbeat, possibly an acceptable margin within a more rhythmically amorphous context such as a ballad but unusual at this moderate tempo. To restrain the snowballing lag and prevent an overly delayed downbeat, Addison speeds up the eighth-notes in the second half of the measure to 101 bpm, although this tempo is still slightly slower than the band's. This resembles the series of S transformations we saw earlier in the Coleman Hawkins example. Another systematic lag, seen in (b), occurs five measures later when Addison's slower tempo of 95 bpm again peels off from the band's tempo. In (c), the effect is shrunk and cycled. While the beginning of each two-beat motivic cell attacks on the beat,[18] the triplets unfold too slowly, consistently delaying the quarter-note so that it lands about 65% of the way—rather than halfway—from one low G to the next low G. These delays in turn require that the quarter-notes be shortened by about 35% in order for the next group to attack on the beat. The triplets are not only slow but also occasionally distorted by F, as illustrated by the small graphs below the transcription. The horizontal dashed lines provide a reference by showing where the eighth-note and the eighth-note triplet values would lie given the accompaniment's tempo of 104 bpm.

"Sobbin' Hearted Blues" contains similar S transformations. Here, Louis Armstrong fills the spaces between Bessie Smith's vocal lines with interspersed, rhythmically loose phrases.[19] One of these, an ascending fourth (G–C) ornamented with a turn and a long appoggiatura, appears four times in various rhythmic guises. The horizontal spacing between notes in Example 8 mirrors their precise duration as played by Armstrong, such that slower notes are visually farther apart than faster notes, which are notated closer together. The top and bottom templates, respectively labeled *x* and *y*, provide a metronomic reference for comparing the timing of Armstrong's rhythms. The pitch D, a registral peak, sounds like an arrival point and was therefore chosen to act as the transcription's vertical axis of alignment. It is important to keep in mind that this peak appears in various positions within the measure, never landing on the beat, let alone a downbeat. As the small beat-number tick marks show, the motive floats freely around beats two and three of the 4/4 measure, indifferent to the accompaniment's beat and its subdivisions. The first statement of the motive, (a), closely resembles template *x* but it is uniformly compressed.



EXAMPLE 8. *Louis Armstrong (cornet), "Sobbin' Hearted Blues" (1:06, 1:19, 1:43, 2:34). With the exception of (b), Armstrong's fills conform to 90 bpm templates.*

In fact, the only difference between the two versions is their tempo: playing template *x* at 90 bpm yields iteration (a). Iteration (b) is compressed even more; it could be explained as an S transformation at 120 bpm, but the extremity of the squishing suggests a more traditional ornamental diminution rather than a tempo substitution. The prepended pickup G appears again in (c), which operates under the same tempo as (a). This kinship is confirmed by the dashed line joining their aligned beginnings. In (d), the grouping is modified to resemble triplets (compare with template *y*). How fast are

18 The third group is about 50 ms late, but this is a small amount compared to the 100+ ms delays exhibited by the quarter-notes.

19 Givan (2005) shows how Armstrong uses rhythmic diminution in the sung melody of "All of Me" to create spaces for interjected "mmmm"s and "oh baby"s.

EXAMPLE 9. *Louis Armstrong (voice), "Lonesome Blues" (1:52, 2:04). The two transcriptions at the top are accurate but they counter the accentual pattern of the text. Below, the rhythms are re-notated to place speech accents on the beat. The delays caused by these interpretations disappear if we apply tempo substitutions (in parentheses).*

these "triplets"? Just as iterations (a) and (c) can be conceived as 90 bpm S transformations of template *x*, so is (d) template *y* at 90 bpm, as the dashed line again confirms.

Whether Armstrong really switched tempos in his mind to enact the hasty lead-ins to the D cannot be known. The important point is that certain rhythmic transformations can be explained in precise analytical terms—in these cases, from the perspective of a brief tempo shift. We could conceive this as the rhythmic equivalent of "playing out" harmonically, a technique whereby the soloist briefly superposes an alternate harmonic framework over the underlying one. The harmonic dissonance usually resolves much like an anchor re-latching a rhythmic dissonance.[20]

Another piece by Armstrong, "Lonesome Blues" adds a dimension not considered in the other examples: that of sung words. Of the many rhythmically intriguing phrases found in this song, two in particular stand out.[21] Literal transcriptions of these passages are shown at the top of Example 9. Their

20 Morgan (2000/01) provides a study of Herbie Hancock's use of harmonic superposition.

21 The words are not very clear in the second phrase. This is my best guess.

accuracy is undermined by the fact that we learn little about the phrases' fundamental structure. The versions shown at the bottom are probably more indicative of how the rhythms were conceived by Armstrong before he transformed them. Words are grouped according to their natural speech patterns, to which Armstrong mostly adheres through accentuation. According to these less literal interpretations, Armstrong falls further and further behind the beat before closing the rift with a final anchor. The longer of the two phrases is especially sluggish, persistently accruing a temporal deficit that ultimately reaches almost 50% of the beat. For this reason, it is difficult to hear the phrases—especially their latter part where the delay is most pronounced—as described by the given transcriptions. As we discovered earlier, consistently increasing delays are a giveaway for S transformations. Replacing the given tempo markings with slightly slower ones offers better fits for the durations as actually performed. These alternate tempos, shown in parentheses, would erase the delays.

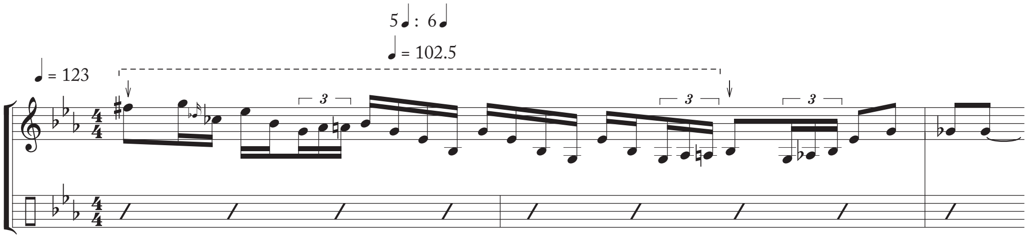
SHIFT AS POLYRHYTHM

Tempo substitutions can be disguised within a rubato-like give and take, as discussed thus far, or they can be blatant usurpers of the main tempo, if only for a few moments. Such superposition of alternate clocks in jazz performance has been noted elsewhere. Cynthia Folio's (1995) analyses of improvised polyrhythms in bop and free jazz reveal simultaneous tempos related not only by fixed ratios such as 7:6 and 7:4, but also by variable proportions. Schuller (1968) illustrates how in 1923 Jelly Roll Morton "experiments with a bimetric and birhythmic independence of the two hands, . . . trying to bifurcate the music into separate tempo levels" (172–73), and how the "polymetric organization" in a 1947 solo by Stan Getz results from "the overlay of 'irregular' meters upon the 'regular' 4/4 beat" (23). Jeff Pressing (2002) also uses the term "overlay" to describe a rhythmic device that "subverts the meter by temporarily establishing a rival accent or phrase structure not congruent with the metrical structure, before eventually returning to it. [This creates] complete independence from the ground meter, as in displays of vocal rubato" (301).

Nowhere is the superposition of tempos in jazz examined more closely than in Hao Huang and Rachel V. Huang's (1994/95) study of Billie Holiday's singing style. According to the authors' "dual track time" theory, "there are two beat systems functioning simultaneously, one governing the accompaniment and the other regulating the vocal line" (188). Instead of coinciding with the accompaniment's beat or its basic subdivisions, Holiday's note placements can be matched well to the beats and subdivisions of an alternate, "recitation" tempo. The authors cite two examples (although only one is supported by a transcription). In one song, Holiday's average tempo stands in a 6 to 5 ratio to the rhythm section's tempo; in the other, the ratio is 7 to "almost" 5. Generally speaking, the dual track time effect is equivalent to the S transformation proposed here. The principal difference lies not in the theory but in how the concept is applied analytically. In Huang and Huang's approach, the soloist's tempo—in their case Holiday's—must be inferred over the course of a performance, since "rarely does she accommodate us with a series of equal-length notes" (193). Here, S can accommodate a variety of time spans, an approach that lets us adapt to specific musical situations in different parts of the solo.

Given certain tempo ratios between soloist and accompaniment, the S transformation is sometimes maintained long enough for the soloist's beat to realign with the accompaniment at the end of the cycle. This ties S to the classic view of polyrhythm, in which two or more rhythmic strands dissonant to each other come together when the cycle defined by their composite ratios is completed.[22] Consider the rhythm of Rex Stewart's flourished E♭ arpeggios in "Easy Money," provided in Example 10. Unhurriedly, he fills two 4/4 measures not with eight beats but with seven. Especially noteworthy about this temporal escapade is Stewart's surgical re-entry

22 See Folio 1995, 103–07 and references therein.



EXAMPLE 10. *Rex Stewart (trumpet), "Easy Money" (2:21). This substitution is in a (low-order) 5:6 ratio to the original tempo, allowing the soloist to complete a full phase from anchor to anchor within a handful of beats.*

into the original tempo via an anchor. The exact location of this point of return is far from premeditated (or at least so it sounds). Stewart's slower tempo gradually recedes his beats in relation to those of the rhythm section, so that the further he falls behind, the closer he comes to a realignment. In other words, the rhythm section "laps" him as the phase relation comes full circle. A quick calculation of their respective tempos tells us where the beat realignment should occur. Stewart's 102.5 bpm stands in a 5:6 ratio to the rhythm section's 123 bpm. Thus, the two come together again on the accompaniment's seventh beat, which is marked with an anchor in the transcription. The seamlessness of this juncture results from Stewart's split-second reaction. He detects the realignment and instantly merges with the original tempo to cap the phrase. The gateway between real and warped times is as subtle—the difference between the two tempos' beat duration is less than one tenth of a second—as it is crucial to the equilibrium of the phrase. This delicate symbiosis between rhythmic dissonance (S) and resolution (↓) is essential to shape the sense of spontaneity in jazz improvisation.[23]

Armstrong's scat vocal on "Hotter Than That" offers another example of a polyrhythmic-style S. Critic Gary Giddins (1988) notes that the scat chorus's "devious cross-rhythms [are] a stunning example of a musician superimposing one rhythm over another" (91). Such a "polymetric structure," concurs Schuller (1968), is the result of Armstrong "improvising essentially in 3/4 time against [guitarist Lonnie] Johnson's 4/4 background" (112). Both authors refer to the uninterrupted sequence of 24 dotted quarter-notes sung by Armstrong, the type of 3-against-2 metric disorientation prevalent in much jazz. An even more stunning demonstration of rhythmic superposition, however, occurs ten measures earlier. The top of Example 11 provides a transcription of this puzzling four-measure passage. It is evident from one's hearing, much more so than from the notation, that Armstrong has momentarily discarded the accompanying guitar's tempo of 216 bpm in favor of another of his own choosing. Voice and guitar are together on the opening beat but quickly part ways. The E♭ quarter-note in the last measure is the unmistakable resynchronization anchor, followed by two other firmly grounded quarter-notes that confirm Armstrong's return to *tempo primo*. If the phrase could be extracted from its accompaniment, heard in isolation, and notated, it would closely resemble the one in the lower transcription. At the alternate tempo of 180 bpm, Armstrong's "eighth-notes" are elongated and his "quarter-notes" are compressed, but overall this alternate tempo provides an excellent fit.

23 Anchoring also plays an important role in jazz ballad performances. Ashley (2002) shows how soloists employ "cadential anchoring" to clarify the structural organization of ballad melodies.

example 11. *Louis Armstrong (scat vocal), "Hotter Than That" (1:30). Another 5:6 tempo substitution.*

It is worth noting that the two tempos in Example 11 stand in a 5:6 ratio, as was the case with Rex Stewart's earlier example and with Huang and Huang's aforementioned analysis of a performance by Billie Holiday. According to Huang and Huang (1994/95), this ratio is expressively useful because it is not as obvious as a 3-against-2 or a 4-against-3, which can be more easily heard in the context of the original tempo (192). Most likely, the soloist is not deliberately thinking of a specific ratio or alternate tempo. Rather, the idea is to create rhythmic interest by abandoning the tonic tempo, preferably prompting a temporal relationship that is sufficiently dissonant.

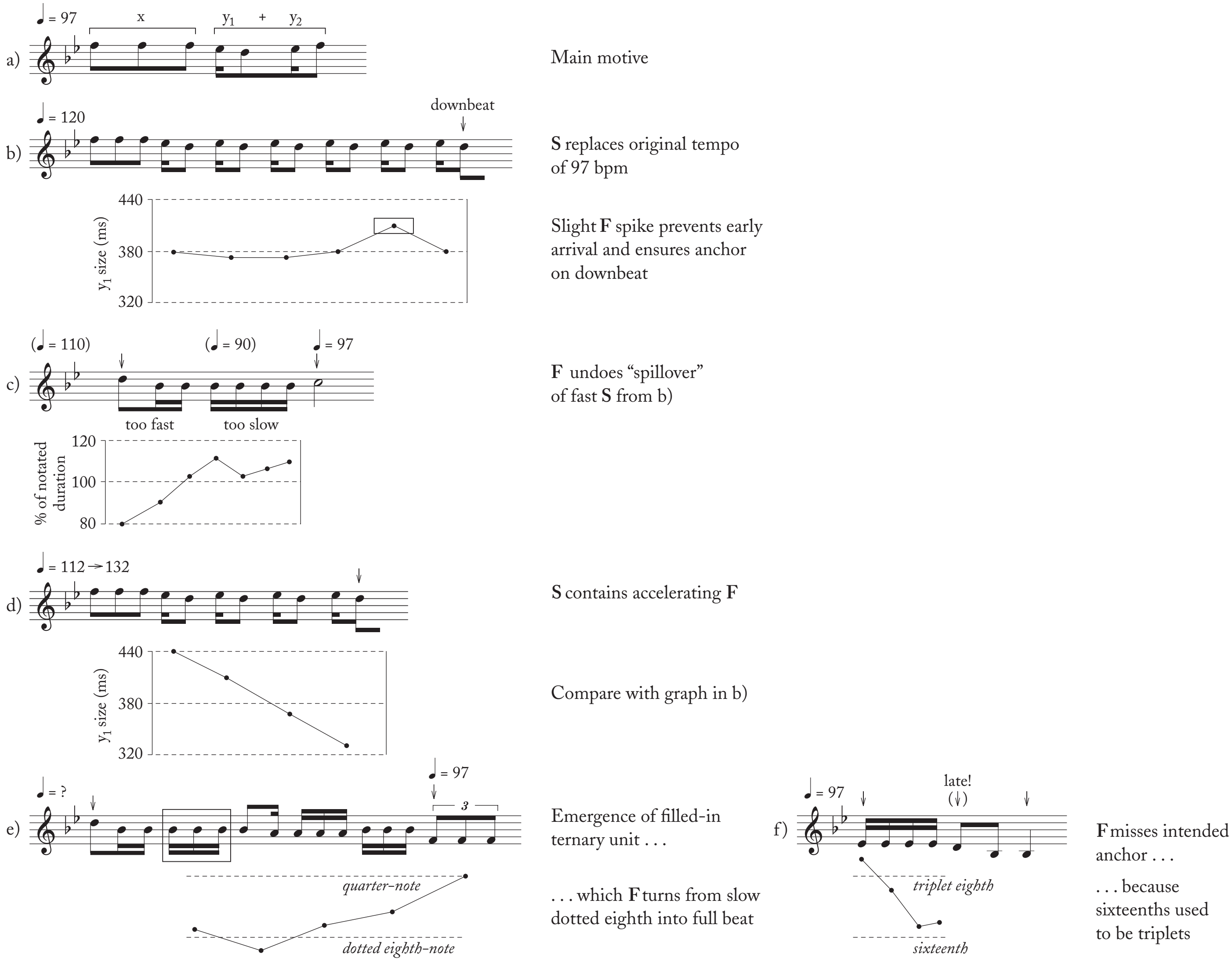
shaping a solo

Bubber Miley's 1927 "Creole Love Call" trumpet solo serves as a good example of how flux and shift can interact to shape the development of a rhythmic motive. Example 12(a) shows the opening *x*-*y* motive that serves as the main rhythmic building block. The motive is stated twice. The third iteration, given as (b) in the example, is compressed by S from the original 97 bpm to 120, as y_1 is looped a total of six times. As we saw on more than one occasion, such tempo divergences eventually resolve by way of an anchor. This occurs here as well, but not without some slight tweaking on Miley's part. Cycling y_1 at Miley's faster rate would land him at the imminent downbeat too early. Sensing this, Miley gently pulls the reins on the next-to-last repetition of y_1, extending its duration just so in order to ensure that the last repetition of y_1 anchors the next measure's downbeat. The graph shows how: each sixteenth-eighth pair (y_1) lasts roughly 380 ms, which is about right at 120 bpm. But there is a clear spike in the next-to-last one. We can say that this S transformation contains a small dose of F.

The downbeat anchor marks a noticeable rhythmic resolution but it does not signal Miley's return to the original tempo. The quickness of his alternate tempo carries through the next beat—so much so, that he must, as shown in (c), slow down the beat after that in order to place a clear anchor on the half-note, thereby settling back into the original tempo. The next four bars (not shown) provide a rhythmic respite.

At (d) Miley then revisits the earlier method of extending the motive by looping y_1. Again the motive is played at a faster tempo (now 112 bpm), and again S contains an F. But whereas last time F affected only one of the *y*'s, this time F sweeps them all. This acceleration is confirmed by the graphed diminishing durations of consecutive y_1 repetitions, which begin at 440 ms and shed 30–40 ms per repetition to reach 340 ms. The motive's conclusion is again capped by an anchor.

To end the solo, Miley begins with an exact restatement, almost to the millisecond, of the eighth-sixteenth-sixteenth figure shown earlier in Example 12(c). This time he groups



EXAMPLE 12. *Bubber Miley (trumpet), "Creole Love Call" (0:31–1:00). F and S transformations of a basic motive.*

EXAMPLE 13. *Bubber Miley, complete "Creole Love Call" solo. The 12-bar blues form alternates rhythmically stable (A) and unstable (B) phrases. The various "ex. 12" labels point to the corresponding segments in Example 12.*

the sixteenths into three's, churning out a chain of rhythmically wavering quasi-monotones (Example 12[e]). Multiple readings of this segment are possible, all of them as problematic as they are illuminating—illuminating, because they all engage the notion of temporal transformations cadencing on an anchor; problematic, because they all explain the passage equally well (or poorly), casting doubt on each interpretation's analytical superiority. According to the interpretation presented here, Miley truncates the beat into the ternary mold of y_1, which is now for the first time in the solo filled in with its three subdivisions. (Note that these are not triplets, but sixteenths grouped in three's.) As the dashed lines indicate, initially the group of three sixteenths adds up to a little more than a dotted eighth-note, with subsequent repetitions further increasing the total duration of each three-note group until the triplet value is reached at the anchor. This is of course significant because the ternary division of the beat has transitioned from an unstable metric relationship to a stable one in which the beat contains three triplets rather than three sixteenths. (We might also view the notated triplets suspiciously, preferring instead to think of them as a brief excursion into the boundaries of fluxed sixteenths.) Not content to rest on this newfound metric stability, Miley immediately reverts to the sixteenth-note value with a clear acceleration. The passage appears in Example 12(f). The good thing about this little acceleration is that it gets Miley back to the neighborhood of proper sixteenth durations. The bad thing is that he does not accelerate quickly enough, causing him to overshoot the intended anchor on the tonic downbeat by a margin of 80 ms. The "error" is rectified in subsequent beats, which are sparse and metronomic.

Example 13 provides a standard transcription of the entire solo.[24] The 12 measures are held together by an ABABA structure where predominantly metronomic passages

24 Compare with Tucker's (1991, 240) transcription, which is somewhat more literal.

(A) alternate with marked digressions from the underlying beat and its basic subdivisions (B).

THE ROLE OF TEMPO

Most of the excerpts we examined thus far are in somewhat slow tempos. (About half of them are slow blues.) It might be tempting to consider this tendency towards slower tempos as a general feature of 1920s jazz, but doing so would be a mistake. Although it is true that super-fast performances emerged in earnest during the swing and bebop years, early jazz boasts its share of up-tempo, 200+ bpm performances. The reason for the prevalence of slow tempos found in this study is that slowness lends itself well to expressive timing and fastness does not.

Picture a straight line of finite length marked on a stretch of grass, as in Example 14(a). Along this line we dig four evenly spaced holes of equal size. If a raindrop were to fall somewhere along the line, how likely is it that it will fall inside one of the holes? The answer depends on two factors: the length of the line and the diameter of the holes. Wide holes on a short line are more likely to catch the drop than narrow holes on a long line. One might imagine how a short enough line with wide enough holes would catch every drop that rained along the line, since the edges of the holes would be touching each other. Knowing the length of the line and the diameter of the holes allows us to predict the probability of a random raindrop landing in a hole.

In Example 14(b), the line is a beat, the holes are its metrical subdivisions, and the raindrop is a note onset. The grassy area can be thought of as a *rubato zone* (*r.z.*): the portion of a beat where a note onset is perceived as non-metronomic because of its sufficient distance from a subdivision.[25] Notice that the vertical subdivision lines are enveloped by shaded areas of width b, as in *buffer*. In order for a note onset to be perceived as deadpan, it need not occur exactly on the beat or one of its subdivisions. Given a small enough timing discrepancy, the nominally displaced attack will be absorbed—that is, quantized—by the nearest subdivision slot, and the result will be perceived as a metronomic onset. Turning to Example 14(c), we see that just as a larger hole catches more raindrops, increasing the size of the buffer gives each subdivision greater "pull" and reduces the overall size of the rubato zone. A faster tempo—a shorter beat—also brings the shaded areas closer together, thereby decreasing the potential for rubato (Example 14[d]).

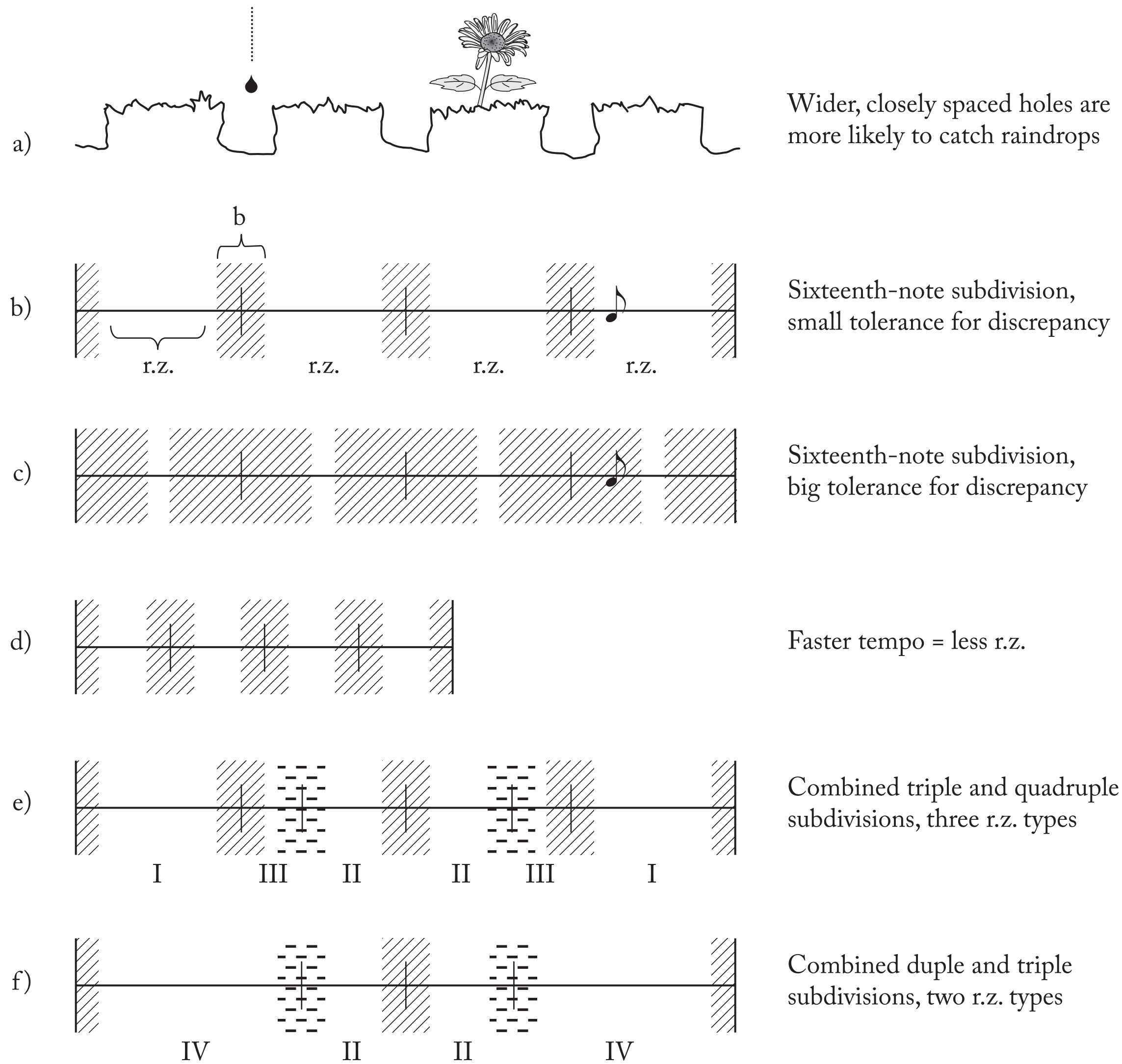
These illustrations assume a beat subdivision of four sixteenth-notes. But, depending on context, a listener might be engaging either a triple, duple, or quadruple subdivision mode. Hybrids such as quadruple/triple or triple/duple, in which two subdivision modes operate simultaneously, are also conceivable. Example 14(e) shows the 4/3 hybrid. Notice that this combined subdivision paradigm gives rise to three different r.z. types, labeled I (large), II (medium), and III (small). These are the beat's nooks and crannies in which an expressively timed onset might reside.[26] The 3/2 hybrid is given in Example 14(f). There are now two r.z. types: type IV (the sum of I and III) is new and type II is retained from the previous model.

Different subdivision models yield different rubato zones. Example 15 plots the relationship between tempo and total rubato zone for different subdivision models given a 50-ms level of tolerable discrepancy on either side of the subdivision line, or b = 100 ms.[27] The y-axis plots the total portion

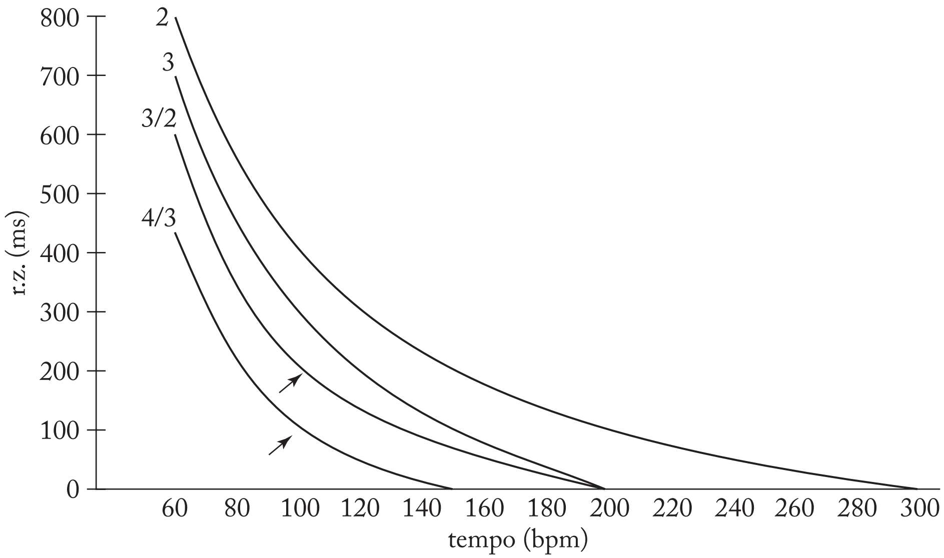
25 "Rubato" is usually understood as a temporal fluctuation that governs the entire musical surface. Here, as in most jazz microtiming studies, the term refers to a temporal fluctuation in the melodic line while the accompaniment's tempo remains steady.

26 Type III is rarely operational; its adjacent triple and quadruple subdivision buffers overlap unless the tempo is extremely slow (50 bpm or less if b equals 100 ms).

27 I informally chose this value because it is roughly the magnitude of perceptible discrepancy I encountered in this study. The value of b may be smaller or greater depending on musical context and listener differences, but this variance does not hinder the forthcoming observations.



EXAMPLE 14. *Surface area distribution for rubato and metronomic onsets.*



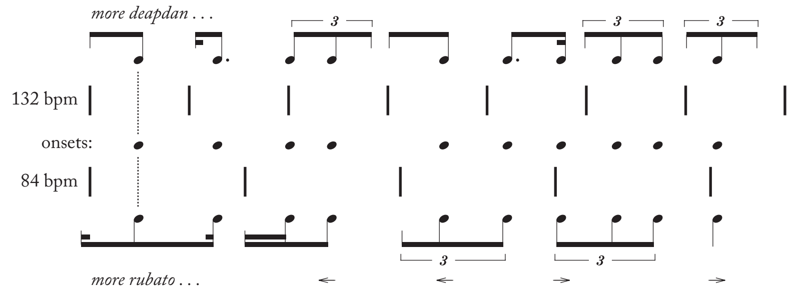
EXAMPLE 15. *Rubato zone amounts per beat at different tempos given a 100-ms subdivision buffer and different beat subdivision models. The arrows in the hybrid lines indicate overlap of subdivision buffers.*

of the beat that qualifies as a rubato zone. As the graph shows, larger rubato zones occur at slower tempos because their longer beats have widely spaced subdivisions. The total "beat surface" available for rubato onsets decreases steeply and more or less steadily as tempos increase. Each mode is maxed out once it reaches the shortest allowable subdivision value of 100 ms.[28] For instance, the 4/3 model is divisible up to 150 bpm because beyond that tempo the sixteenth-note is shorter than 100 ms. The arrowed kinks in the hybrid lines at 100 bpm mark an important boundary beyond which r.z. type II becomes inactive. The reason is that at 100 bpm, the discrepancy buffers surrounding type II are close enough to begin to overlap, erasing type II and leaving active only type I in the 4/3 model and type IV in the 3/2 model.

Some of the above claims can be illustrated aurally with a simulation that plays randomly generated interonset intervals (within the range 100–400 ms) over a steady beat moving at either a slow or fast tempo.[29] The random rhythms sound surprisingly expressive at the slower tempo of 84 bpm, where the majority of onsets can be heard as flexible triplets

28 Interonset intervals shorter than roughly 100 ms sound blurred and arrhythmic. See London's review (2004, 34) for further discussion on how the 100-ms limit affects the relationship between subdivision, beat, and meter.

29 The audio demonstration is available from the author.



EXAMPLE 16. *Given a framework of basic beat subdivisions (duple, triple, quadruple), randomly placed onsets sound more flexible at slower tempos.*

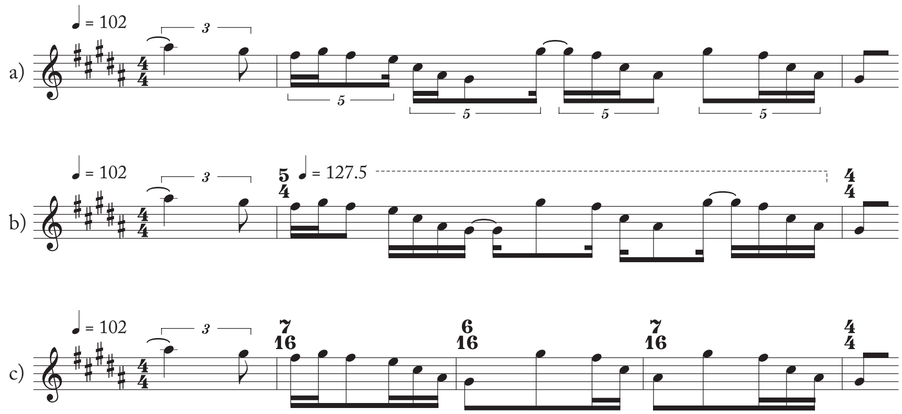
or sixteenths. At 132 bpm the random durations also sound like triplets and sixteenths, but they feel much more metronomic. The sense of rubato found in the slower example is minimized in the faster one, as the earlier graph predicts. Example 16 provides a visual sense of this effect.

I do not presume with these graphs to provide an ironclad model for assessing jazz rubatos. Such a model would have to take into account a myriad of parameters not considered by this one, which is indifferent to many of the realities of rhythm perception and cognition. For instance, this model assumes that if an onset is late enough to land on a subsequent subdivision, the onset is considered metronomic, when in fact this is not always true. Given the right context, an attack may be perceived as microrhythmically delayed even if technically it lands on a subdivision slot. In addition, the model only considers single isolated onsets without paying heed to grouping effects instigated by such features as contour or articulation.

ON RHYTHMIC REDUCIBILITY

In the foregoing pages I have attempted to explain intricate and flexible rhythms as transformations of original and at times hypothetical forms. The need for such a mapping is not always apparent. We might encounter a rhythm that could be represented equally well as a template or as a transformation. For instance, Johnny Hodges's dizzying use of syncopation in "The Blues with a Feelin'," provided in Example 17(a), is satisfactorily captured with quintuplets without undue orthographic complexity. To make the argument that this rhythm is a transformation, we could propose Example 17(b), which suggests that a tempo substitution has taken place, or Example 17(c), which indicates that there is an underlying metrical conglomerate that cuts through quadruple time. It is probably impossible to know, in this example as much as in most others, which if any of these frameworks guide the performer's creative intent. Given multiple and equally descriptive explanations, the analyst may wish to discard the more complicated ones in favor of the one which rests on the fewest assumptions. From this perspective, it seems that the top explanation of Johnny Hodges's passage has an edge over the other two.

I suggested earlier in connection with Example 12(e) that the rhythm at the end of Bubber Miley's solo could feasibly be reduced to more than one source template. Because of its gridlessness, this rhythm was deemed a transformation, and the challenge lay in reducing it to one of several competing source templates. Let us explore the

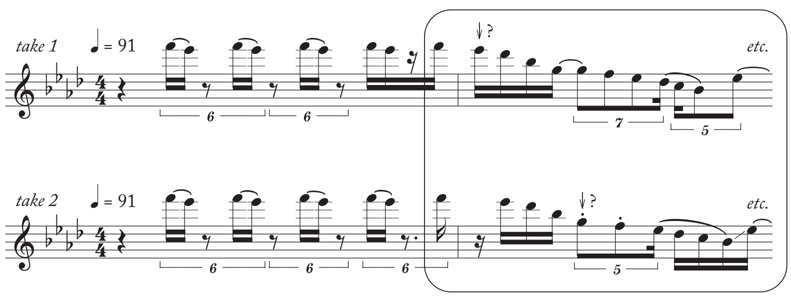


EXAMPLE 17. *Johnny Hodges (soprano saxophone), "The Blues with a Feelin'" (1:01). Three views of a lick: (a) non-transformed, (b) as a tempo substitution, (c) as a polymeter substitution.*

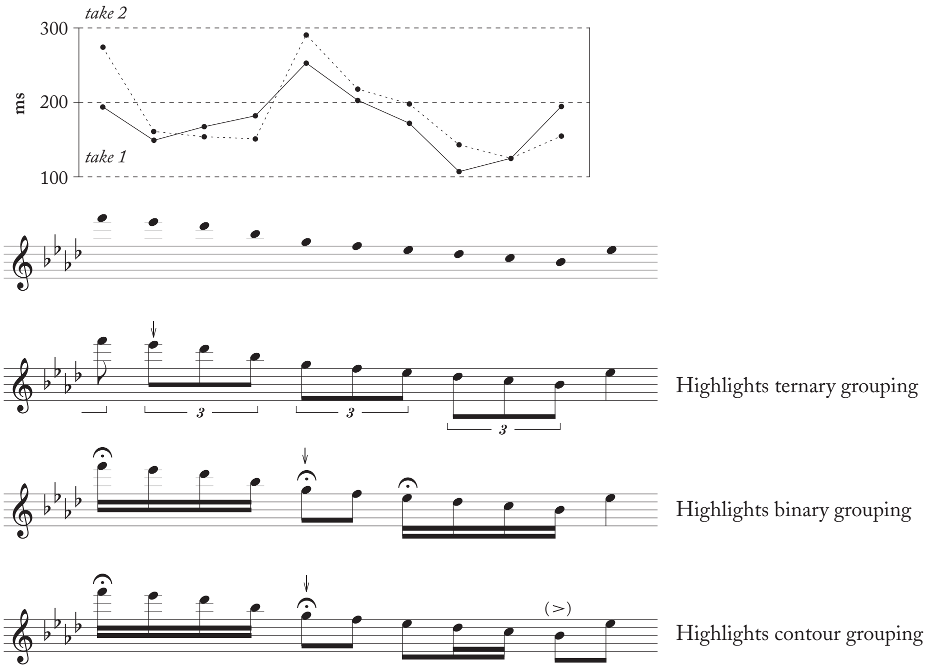
idea of competing templates more thoroughly by turning to another example.

Example 18 gives the beginning of Albert Nicholas's clarinet solo on both takes of "Blue Blood Blues." The rhythmically ambivalent melody that emerges from the initial hemiolic kernel presents a rhythmic enigma, in great part because of the absence of clear anchors. The timing graph in Example 19 shows how closely the two versions co-vary, encouraging us to find a common source template from which these two versions are derived.

Below the graph are three feasible templates for take 1. Weighting different features of articulation and microtiming



EXAMPLE 18. *Albert Nicholas (clarinet), "Blue Blood Blues" (0:31 both takes).*



EXAMPLE 19. *Timing data and possible templates for take 1 of "Blue Blood Blues." Only the middle template is supported by the phrasing of take 2, as seen is Example 18.*

promotes different template candidates. The top template profits from a downbeat anchor by treating the first note as a pickup; the three-note slur at the end (cf. Example 18) provides further evidence in favor of this triplet-based conception. The middle template is supported by micro-agogic accents on the first note of each beat (visible in the graph), but the slight temporal separation between the last two notes casts doubt on the arrival strength of the final E♭. The bottom template honors that separation by treating the low B♭ as the arrival point of a long descending line. David Lewin (1986) warns us against falling "into the position of voting for a slate of candidates . . . as we respond to music" (359). Indeed, with minimal effort a listener can mold his or her perception of take 1 into any of the three templates shown here. (Others are also imaginable.) Our present goal, however, is to trace the acoustic object to a structural model employed by the performer. To help us cast that vote, we turn to take 2 for additional hints.

In contrast to take 1, take 2 contains a rupture between the first two notes, weakening the pickup view we had advanced in the triplet-based top template. Also at odds with the triplet grouping is the four-note slur at the end of take 2. This discards the top template. Take 2's seamless glissando connecting the last two notes, their temporal proximity, the anchor on G, the two staccatos: all point to the middle template as the likely common source.

How drastic must a distortion be before we are unable to reveal the phrase's rhythmic origin? The above analytical successes notwithstanding, extreme time warps might conceivably erase all traces of a rhythm's lineage. It is also not unreasonable to doubt whether such an original form exists, in other words, whether the rhythm is inherently irreducible: a complex rhythmic entity in its own right rather than an expressive distortion of a simpler form. The initial motivation for this paper was to provide examples of supposedly irreducible rhythms and to prove their irreducibility. As I began to analyze my initial collection of found rhythms one by one, F and S gradually took shape and nullified my original arguments. But it remains unclear whether F and S can successfully decode all non-metronomic jazz rhythms beyond those presented here. These kinds of questions seem worth exploring in the future. For now, I hope to have added a useful method of analysis to the theorist's repertoire and a new layer of meaning to our listening perspective.

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