

McDonough, J., H. Danko, and J. Zentz. (2007). Rhythmic structure of music and language: An empirical investigation of the speech cadence of American jazz masters Louis Armstrong and Jelly Roll Morton. In L. Wolter and J. Thorson (Eds.), *University of Rochester Working Papers in the Language Sciences*, 3(1), 45-56.

RHYTHMIC STRUCTURE OF MUSIC AND LANGUAGE: AN EMPIRICAL INVESTIGATION OF THE SPEECH CADENCE OF AMERICAN JAZZ MASTERS LOUIS ARMSTRONG AND JELLY ROLL MORTON

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Jelly Roll Morton and Louis Armstrong, acknowledged innovators of American jazz, were born in New Orleans and made historic recordings (1920s) that profoundly influenced that genre's practices and traditions. Both also had distinctive speaking styles, using spoken word as part of their performances: in rhythmic patter, stage introductions, interviews and storytelling. As part of an investigation of rhythmic structure in music and language, examples of speech in storytelling and in introductions were taken from recordings made in 1938 (Morton) and 1962 (Armstrong). These recordings were segmented, analyzed using a normalized pairwise variability index (nPVI) and, as an alternative to linguistic (metrical grid) notation, marked using musical rhythm notation. These examples illustrate the challenges of relating rhythm and phrasing in improvised speech events to parallel elements in music, and the complex relationship of metric phrasing in language and music.

1. Introduction

1.1 Background

The relationship between the rhythmic structures of music and speech has interested research communities in both fields. Musicologists and linguists have borrowed tools from each other to investigate and describe these structures (Daniele and Patel 2004). Most recently a body of work has arisen examining the somewhat elusive relationship between so-called stress- versus syllable-timed languages and the classical music culturally associated to these languages, using an algorithm (PVI) that measures the relative duration of adjacent units in a stream, comparing musical notes and inter-syllabic units (Grabe and Lowe 2002; Patel and Danielle 2003). Languages with higher PVI's (pairwise variability index) have more variability between units, i.e. canonically, the syllables of English are more uneven than those of French. This PVI analysis has been extended to musical analysis; types of classical music associated with these languages have been argued to tend to exhibit the same rhythmic patterns (Patel and Iversen, et al. 2006). However, there are interfaces between music and language in which speech and music are more closely bound and thus, we believe, are more likely to yield insight into this relationship. One of the most obvious is found in the development of American jazz in the early 20th century, which arose out of an oral tradition of both music and speech in the African-American culture of New Orleans and other locations. The orthography of written English does not capture the nuances and characteristics of these speech communities, and at that time the music from those cultures was not widely recorded, if at all.

Another issue arising in this discussion relates to the appropriateness of the inter-syllabic average (PVI) as a measure of the rhythm of an utterance. We refer to this utterance or conversational rhythm as 'speech cadence' and suggest that it is an integrated part of both an individual's and, by extension, a speech community's identity. Speech cadence, like music, has a strongly expressive role in human communication; it is part of the performance event. In this

paper, we attempted to capture the expressive aspects of speech performance by turning around an existing methodology. Instead of using aspects of linguistic structure (syllables and stress) as a measure of difference in music, we used rhythmic musical notation (without melody) to attempt to capture rhythmic patterns in speech in two individuals from a culture in which speech and music are closely aligned. One further advantage of this technique is that it allows us to examine and notate actual speech and music events, rather than a written transcription of the events, since in oral cultures, performing and composing are considered to be simultaneous events with their own structure (Lord 1960, Rubin 1995, Kiparsky 2006).

In this paper, which is a preliminary study of this approach, we investigate a unique set of data, the speech of Louis Armstrong and Jelly Roll Morton. Both men had distinctive speaking styles, and used the spoken word as part of their performances: in rhythmic patter, stage introductions, interviews and storytelling. We did a PVI analysis of the speech, which yielded interesting results that emphasized the differences in their individual rhythms. We also tried an alternate method, using rhythmic musical notation to investigate patterns in their speech cadence, to attempt to gain insight into differences in their speech styles.

1.2 Morton and Armstrong

Morton and Armstrong were among the first to document their musical innovations on recordings. Significantly their major musical contributions predate the formal study of jazz improvisation with its emphasis on adaptations of western classical harmonic theory. Both men are known to use thematic paraphrasing and melodic variation as their basic strategy for improvising. The relationship between their distinctive speaking and singing styles and their instrumental performances reflects this in a natural manner that is common to African-American music traditions in the period of their formative years.

Louis Armstrong, born August 4, 1901, in New Orleans, played the cornet and trumpet, forging new ground as an instrumental and vocal soloist, and became a world-famous jazz ambassador during his lifetime. He grew up in the uptown black district of New Orleans and left permanently by 1920. He died on July 6, 1971, in New York. The speech example used was taken from a radio broadcast from 1962 taken from an archive in the Jazz Studies Department at the Eastman School of Music.

Jelly Roll Morton, born October 20, 1890, in New Orleans, was a pianist, composer, and arranger who became famous in the late 1920s, but died in relative obscurity in California on July 10, 1941. He was of French Creole ancestry and grew up in downtown New Orleans in the Creole district. In contrast to Armstrong, Morton's first language was French as spoken in the New Orleans Creole dialect at the turn of the century. He left New Orleans first in 1907 and permanently by 1915 to travel and disseminate his music. The spoken word example used was taken from the Library of Congress recordings from 1938 (Morton, from the Lomax Collection, 2006).

2. Methods

Sections of these archived recordings were searched to find instances of the speech of Louis Armstrong and Jelly Roll Morton. In particular we avoided instances of rhythmic stage patter as well as lyric and scat singing, but looked instead for straight conversational style in storytelling and song introductions. A short section of speech of Louis Armstrong was taken from a broadcast of Armstrong acting as a DJ in <audio_file_3>. Short sections of speech from Jelly Roll Morton were chosen from the Lomax CD's (Lomax Collection 2006). In these sections Morton is sitting at a piano being interviewed by Lomax. He is playing while he is speaking, i.e.

he is storytelling over his piano playing <audio_file_1 and 2>. The speech of both men was transcribed into standard written English (for reading ease) and the IPA, and marked at the utterance level for primary and secondary stress. For Morton, the notes and measures in the music were also notated on separate tiers. For both men, the IPA is a more accurate transcription of their speech than the standard written English. A transcription of the Armstrong speech used in this study follows:

(1) Armstrong

ə 'tun ,hiə ðæt (pa) 'dʒækŋə dɪd æt ðə (pa) ə: 'taʊn ,həl 'kɑnsə't (pa)
 ŋə: (pa) ɪ wɛnoʊə 'ɹil ,swɛl ɪ wəz 'ɪn ə: 'vɪktə ,ʔælbəm (mumble) (pa)
 ɪtsə (pa) 'dɪɛt ðæt ,wi ,pled (pa) ,
 kəl (pa) 'ouʔ 'ɹɑkən ,tʃeə

A tune here that Jack and I did at the, uh, town hall concert.
 And, uh, it went over real swell. It was in a Victor album.
 It's a duet that we played
 called "Old Rockin' Chair."

A transcription of Morton's speech used in this study follows:

(2) Morton

a mɪst 'goən tðə 'seɪn ,lʊɪs ,ɛkspə'zɪʃən (pa)
 tə'getnə 'pjænə ,kɑntəs (pa) wɪtʃ wəz 'wɒn (pa)
 bə 'ʔælfɪəd ,wɪlsən əv ,nuə'linz (pa)
 ,aɪəz 'vɛɪ mʌtʃ dɪs'gʌstəd bɪ,kʌz a ,θər aɪ ,ʃʊdəv 'gɒn (pa)
 a ,θɒt ,tɒni 'dʒæksən wəz gənə ,bi ðeɪnəv ,kɒs ðæt ,kaɪnə 'fɹaɪʔn mi (pa)
 bərə 'nu a ,kʊdəv ,teɪkənə ,ʔælfɪəd 'wɪlsən

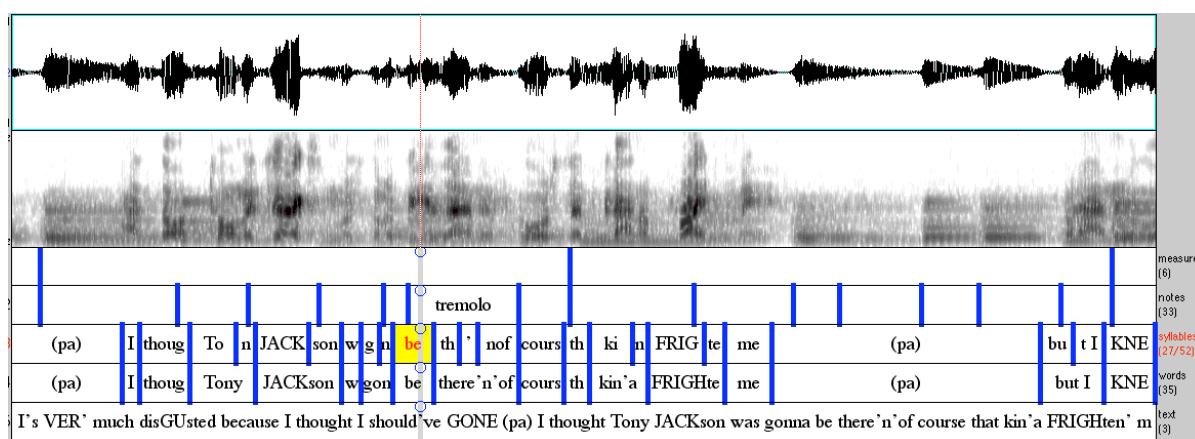
I missed going to the St. Louis Exposition
 to get in a piano contest which was won
 by Alfred Wilson of New Orleans.
 I was very much disgusted because I thought I should've gone.
 I thought Tony Jackson was going to be there and of course that kind of frightened
 me. But I knew I could've taken Alfred Wilson.

2.1 Mark-up and notation conventions

Jelly Roll Morton's speech was segmented using a five-tiered TextGrid in Praat software (Boersma and Weenink, 2007). Three tiers were used to mark intervals of speech: at the syllable, word, and utterance level (Figure 1). The syllables were marked from the beginning on the onset consonant to the beginning of the next consonantal onset. The duration of the syllable was the unit used in the PVI analysis. Morton's speech was chosen in part because he was playing the piano casually while he was talking. We used this as an opportunity to examine the relationship between his playing and his speech. The text in the figure aligns the speech with the music. For instance, the second measure begins during the word 'exposition'. The speech and music were marked on separate tiers on TextGrids in Praat.

The notes he was playing on the piano were segmented using one tier (Tier 2) to mark the measures and another (Tier 1) to mark the interval between the notes. An example follows of the Praat window with 4 of the 5 TextGrid tiers, including the two music interval tiers (1 and 2). Of interest is the lack of any systematic alignment between either the notes or the measures with the speech, which we see an example of in Figure 1. In this section there is an alignment of the last note in a measure with the word [kɔs] ‘course’ in ‘of course’ and the measure ends in the middle of the reduced word ‘that’ in ‘n’of course that kinda frightened me’. A beat falls towards the end of the stressed syllable in the word ‘frightened’. But there is no systematic or structured alignment of text with measure or beat in these passages; there is not tendency for instance for notes to be struck in the middle of stressed syllables, or to align stressed syllables with particular places in the rhythm of the music. They exist independently of each other.

Figure 1 The sound file for the 1938 Morton recording with spectrogram and 5 tiered Praat TextGrid.



The following figure represents the full notation of the piano playing of Jelly Roll Morton used in this study. The piano part was then transcribed rhythmically, using standard musical notation in Sibelius software on a PC (Figure 2). A two-voice, one-stave layout was chosen for readability (the upward-facing stems represent the right hand; the downward-facing stems represent the left hand). Although Morton probably thought of the meter as 4/4, his performance is more accurately represented by 12/8, where the triple subdivision of each of the four beats is clear.

To look for rhythmic structure in Morton's speech, phrasal utterances were delineated by pauses, resulting in six phrasal groups, each one ending with a pause. We included pauses as part of the speech performance. We then transcribed these utterances in rhythmic musical notation in Sibelius software on a PC. An example of the notation is in Figure 3.

Figure 2 The musical notation of Jelly Roll Morton's piano playing with the speech superimposed over the melody line.

3 a mist 'gəʊn tðə 'seɪn ,lʊɪs ,ɛkspə'zɪʃən tə'getŋ ə 'pjænə ,k

5 antes wɪtʃ wəz 'wʌn bə 'ʔælfɪəd ,wɪlsŋ əv ,nuə 'lɪnz

7 aɪəz 'veɪ mʌtʃ dɪs'gʌstəd bɪ,kʌz ə,θər aɪ ,fʊdəv 'gʊn

9 ə ,θət ,tɒni 'dʒækŋ wəz gənə ,bɪ ðeŋəv ,kəs ðət ,kænə 'fɪaɪʔŋ mi bæra

11 'nu ə ,kudəv ,teɪkŋə ,ʔælfɪəd 'wɪlsŋ

We made a decision to use the shortest syllable in the speech as a base unit for the algorithm. The shortest syllable (58 ms) in the Morton speech stream was rounded up and used as a base of notation and used as the unit of conversion ($60\text{ms}=1/16$ note) for Morton's transcriptions. Since 4/4 is by far the most common meter in music, we made it the basis for our transcription, using the equivalent form 16/16, allowing 16 beats per measure (to avoid assuming 4 beat measures). All syllable durations in the speech were divided by 60 to give a unit number to that syllable, and assigned a rhythmic notation. The phrases were divided into 16 beat measures. Thus a syllable duration of 111ms was given a unit number of 1.85 ($111/60$) and rounded to rhythmic notation where $1 = 16\text{th}$ note: $1.85 = 2 = 1/8$ note (2 16ths). The syllables were rounded both up and down by hand to avoid a high or low end bias.

Measures of irregular meter ($1/16$, $3/16$, $13/16$, $19/16$) were adjusted to allow for any extra beats. in phrases that did not fit exactly into 16/16 measures. In Figure 3, the phrase is off a 4mm beat by a 16th note, which is part of the pause at the end of the phrase. The number in parenthesis in the boxes in Figures 2 and 3 indicates the audio files associated with the figures <audio_files_2 and 3>. The ties under the notes mark the syllable units. Thus 'missed' [mɪst] is represented by a grouping of an 1/8 note and a dotted 16th, which is equal to 210ms. The actual duration is 212 ms. Note that some syllables ['dʒækŋ 'Jack' span a measure's boundary. Each phrase's total duration in musical notation was then matched to the total duration in time. Table 1 presents the actual durations in ms and notated measures and durations of those measures of each of the phrases.

Figure 3 The rhythmic transcription of Morton's speech: 4mm + 1/16 note (1 = 60 ms). The ties indicate syllable units.



For Armstrong, a TextGrid with three tiers was used for marking the speech: syllable, word, and utterance levels. Data from the syllable level segmentation was used in this study. The procedures outlined above for transcribing Morton's speech were followed for Armstrong. Armstrong's shortest syllable was 104 ms; this figure was rounded to 100 ms and used as the conversion unit (100ms = 1/16 note). Armstrong's pauses were also used as marks of phrasal groups, resulting in 4 phrasal groups (Table 2).

As with Morton, measures of irregular meter were implemented to account for the places where the phrases do not fit exactly into 16/16 measures. Figure 4 is the phrases in the Armstrong speech. The initial syllable is 104 ms long (the shortest syllable) and is assigned a 16th note. This phrase falls exactly into 3 measures, including the pause (Table 2).

Figure 4 Armstrong's speech in rhythmic transcription (1 = 100 ms).

2.1 PVI Analysis

A nPVI (normalized Pairwise Variability Index) measures the variability of syllable duration in speech. The PVI has been used to distinguish between so called stress versus syllable timed languages. The classic examples in the literature of stress versus syllable timing is English versus French (Grabe and Lowe 2002). The nPVI gives a running average ratio of all the adjacent units in an utterance by taking the difference in duration between each pair of intervals and dividing this result by the mean duration of each pair. This number is an indication of how much variation in length is present between the units measured. A high PVI indicates larger differences between the measured intervals than a lower one. More stressed-timed languages have stressed syllables that are longer in duration than the surrounding unstressed ones; they will have larger PVI's than syllable-timed languages. In the formula in (3), taken from Ladefoged's (2005) *A Course in Phonetics*, d is the duration of interval k , m is the number of intervals in the utterance. The output is multiplied by 100 to avoid fractions.

(3) The nPVI formula (from Ladefoged 2005)

$$PVI = 100 \times \left[\sum_{k=1}^{m-1} \left| \frac{d_k - d_{k+1}}{(d_k + d_{k+1})/2} \right| / (m - 1) \right]$$

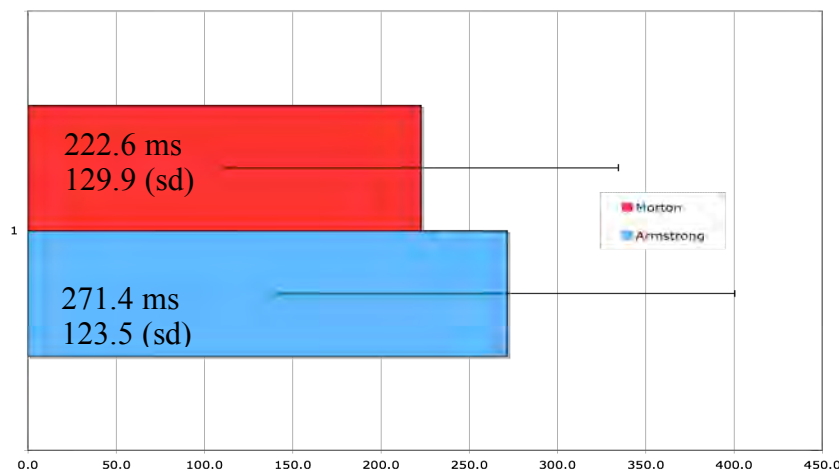
For this study we measured syllable durations from the onset of the syllable to the next onset, using the syllable as the interval for the PVI analysis, since English is the language spoken by both speakers. Also, these recordings were made in the 30's and in the 60's off a radio broadcast, we were able to reliably segment the speech only to the syllable level. An example of the segmentation is given in Figure 1.

3. Results

3.1 Duration

There is a difference in speech rate in the samples of the two men's speech. With respect to syllable duration, Morton is speaking faster than Armstrong, with an average syllable length of 222.6 ms (sd 129.9). Armstrong's average is longer (271.4 ms. SD 123.5), though their standard deviations are similar.

Figure 5 The average duration and standard deviation of the syllables in the Morton versus Armstrong speech



3.2 nPVI

For the Morton versus Armstrong speech samples, the nPVI scores are very different from each other. Morton is speaking at a fast rate and his nPVI is on the high side, at least compared to the nPVI of other languages (Grabe and Lowe 2002; Ladefoged 2006) and it is in line with that of standard English. A high PVI indicates that there are considerable duration differences in adjacent syllables, a characteristic of stress timed languages.

- (4) The nPVI scores of Morton and Armstrong in the speech of this study compared with the figures for other languages (taken from Grabe and Low 2002).

Morton	56.2	German	59.7
		English	57.2
		Polish	46.6
		French	43.5
Armstrong	40.6	Japanese	40.9
		Spanish	29.7

Armstrong's figure indicates that there is less variation among the syllables in duration and in fact the figure aligns with the figure for Japanese, more timed language. This speech profile

may be a contributing factor in his distinctive speaking style. syllable are much more evenly spaced than Morton's or than we usually find in English. Interestingly, although French is syllable timed, Morton, and not Armstrong, grew up in a French speaking community in New Orleans.

3.3 Musical notation

The tables present a comparison between the actual duration of the phrases in the study in ms. and the derived rhythmic measures of the annotation system in the 2nd column.

Table 1: Duration of Morton's phrases (P).

P	duration (actual)	1 m. = 960 ms 1/16 = 60 ms	duration of measures (ms)
1	3915 ms	4 mm. + 1/16	3900 (-15)
2	2839 ms	3 mm.	2880 (+41)
3	5940 ms	6 mm. + 3/16	5940 (0)
4	4610 ms	5 mm. - 3/16	4620 (+10)
5	4982 ms	5 mm. + 3/16	4980 (-2)
6	4617 ms	5 mm. - 3/16	4620 (+3)

The final column represents the duration of measures based on the annotation, for Morton (Table 1) and Armstrong (Table 2). The numbers in parenthesis in the last column indicate how much the annotation is off the actual measurement in ms..

Table 2: Duration of Armstrong's phrases (P).

P	duration (actual)	1 m. = 1600 ms 1/16 = 100 ms	duration of measures in ms
7	4734 ms	3 mm.	4800 (+66)
8	5842 ms	4 mm. - 6/16	5800 (-42)
9	3208 ms	2 mm.	3200 (-8)
10	2300 ms	1 m. + 7/16	2300 (0)

Armstrong speaks at a slower tempo than Morton, his phrases fall into 16/16 measures (1/16=100ms) (Table 2) with less ease, indicated by the residuals in the parathenses, though they still represent a rhythmic phrasing. Because his tempo was slower, the units notation were larger than Morton's, resulting in larger groups being left over. However we wished to use a measure reflective of each man's own speech, which we did by basing the unit on the smallest measure of a syllable, though this may not be the optimal way to proceed. The one exception is (10), which is exact. However, this phrase has no pause at the end, as Armstrong has finished his introduction and is interrupted by the applause at the beginning of the recording, so this is not a natural grouping delimited by a pause. Morton's phrases fall almost naturally into 16/16 measures where 1 beat (1/16) = 60ms (Table 1).

Of interest is the relationship between the rhythm of Morton's speech and his piano playing, which illustrates the production of multiple rhythmic levels. We were unable to find a consistent line up of metrical, rhythmic or linguistic units between the two domains. An example of the lack of alignment is found in Figure 1, the TextGrid from the Morton speech sample. As we see, the notes and measures of the music are very even and do not align regularly with the

speech. We point out that this is not easy to do and is a likely indication of Morton's familiarity and ease with rhythmic layering (Agawu 1993, Jones 1959). We note too that the use of rhythmic layering is also a property of Armstrong's performances.

4. Discussion and Conclusion

In this preliminary investigation, we used two methods to attempt to capture speech cadence: a standard PVI analysis and an algorithm to transform syllable durations into musical rhythmic notation to capture the cadence of speech. We used speech from recordings of two innovative musicians involved in the development of a new genre of music who were closely associated with a strong oral tradition. While the speech of both Morton and Armstrong in this study were performances, neither was overly stylistic or poetic. Both were natural, conversational in style, though reflective of their distinctive speech. We found that the speech of both fell naturally into regular rhythmical units within prosodic phrasal groupings, if we included the pauses in the speech. The rhythmic groups (16/16 measures) that we used were not isomorphic to any linguistic units, and, at times, the measures began in the middle of a syllable.

This study attempts to abstract across real speech events of iconic musicians associated with a strong oral tradition and musical innovation to capture generalizations about the rhythmic aspects of their spoken word by comparing PVI analysis to rhythmic musical notation. One observation is that the PVI analysis indicates that the two men have very different speaking styles, in fact Armstrong's style is quite different from the profile of English speakers, which have a higher PVI in general. We find this an interesting fact. Armstrong's speech sounds easy-going and colloquial, not foreign in any way. This indicates that speakers have a great deal of control over their speech patterns and can alter the underlying rhythms more freely than we assume, at least as far as these rhythms are expressed in syllable durations.

The music rhythm notations were interesting in that both speakers had a natural beat to their speech that fell somewhat easily into a 16/16 measures. However the notation system itself did not yield insights into the different cadences. This study was based on short stretches of speech, however we feel somewhat secure in our choice and we believe that the examples are very characteristic of the speakers.

Interestingly, with Morton, we found no alignment of phrasing or groups between the speech with the music Morton was playing. In effect, he was playing one rhythm and simultaneously speaking in another. With Morton, this interplay between speech and music reflects an innovation in the genre of jazz: ie. the introduction of a simplified African polyrhythmic layering into the music of this era, an innovation with which both he and Armstrong are associated (Jones 1959; Schuller 1968).

The PVI analysis is used to quantify an elusive percept of linguistic rhythm, the differences between languages that have strong stressed syllables alternating with shorter stressless or reduced syllables, like English, German, and languages in which the syllables sound more evenly spaced, such as French and Japanese. The original observation was noted by Pike (1945). Abercrombie (1967) proposed that the difference between these two language types was in what constituted an isochronous unit in speech. In stress-timed languages, the intervals between stresses were thought to be isochronous, in syllable timing, intersyllabic units. Evidence for this however has not been forthcoming (Dauer 1983). Isochrony is affected by many factors including syllable structure (consonant and vowel inventories) and distribution, word size and morphological type and, not surprisingly, has not proven to be a stable unit. The PVI analysis allows a measure along a continuum to be given to a language based on a running ratio of syllable durations; those with uneven syllables characteristic of strong stresses, will have higher

PVI's than languages that have syllables of even durations. One area of interest has been in using the PVI measure to quantify rhythms in the music produced by a community, in order to see if there is a correlation between the linguistic and musical rhythms. Up to this point however, most of these analyses have been done on national languages (English, French, German) and the classical repertoire (Patel and Danielle, 2003; Daniele and Patel, 2004; Patel and Iversen, et al., 2006). We (and others, see Kiparsky 2006 for discussion) suggest that a more revealing comparison between language and music might be found in communities whose members have a strong tradition of oral and musical performance. One such community is found in the origins of American jazz in New Orleans.

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