Syllable Weight in French and English
An experimental investigation through the lens of Hip-Hop

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1 Introduction

Hip-hop, (or rap) is a style of music characterized by its incorporation of rhyme and rhythm. In English, syllable stress can be used to complement the rhythm. As discussed below, we would expect heavier syllables to fall in predictable patterns in a rhythmic line, such as that of hip-hop, since weight correlates with stress, and stressed syllables are used in tandem with the rhythm of the beat.

During our in-class discussion on syllable weight, we noted that French, being a weight-insensitive language, should be theoretically unpredictable in terms of weight patterns, in any context. This raised questions about how French would behave in a rhythmic situation like hip-hop. The investigation into this question follows.

2 Theoretical Background

In many languages, the location of stress in a word is determined by syllable weight, that is, a syllable that is heavier is more likely to carry stress than a light one. These heavy syllables tend to be longer than light ones, generally containing either a long vowel and/or a coda. Historically, this heavy/light distinction has been binary, but has been attested to have more granularity in some languages. It has also been widely held that syllable weight is dependent only on the syllable rime.

In Ryan's 2016 article on the topic, he proposes a model of granularity that takes into account onset complexity as well as vowel length and coda. He proposes that rather than being a feature only of the syllable rime, syllable weight is dependent on the perceptual center, or p-center, of the syllable. This p-center begins approximately with the onset of the nucleus, and therefore contains all of the coda, however, Ryan proposes that it also takes into account a smaller fraction of the onset. As such, complex onsets would be predicted to play a role in determining syllable weight.

Ryan also notes that syllable weight plays a role in many types of poetic meter, pointing specifically to Vedic Sanskrit. In his 2014 paper, he presents a study of Epic Sanskrit showing that syllables in metrically heavy positions were drastically more likely to have (complex) onsets. It is off of this study that the present study is based. Instead of studying Sanskrit, however, we have turned our view to a more modern form of poetry: hip-hop. As a contemporary poetic form across many languages, hip-hop provides a lens into metrical syllable weight.

French, unlike English, has been widely attested to be weight-insensitive, that is, stress assignment occurs in the same position every time, regardless of syllable weight. Given these facts, English should show a metrical sensitivity to syllable weight in the same manner that Sanskrit does, while French should not. In the frame of hip-hop, this metrical sensitivity should correspond to heavier syllables falling on given positions in the lines, and lighter syllables in others.

3 Research Question and Hypothesis

The central research question is the following: in an environment where rhythm and stress differ from normal conversational conditions, will French demonstrate a sensitivity to syllable weight, including in the onset?

The null hypothesis here is that the proportion of heavy to light syllables in any given position in a line of a song would be the same as the overall proportion of heavy to light syllables in the data. My prediction is that this will not be the case, but rather that there will be patterns of systematically heavier and lighter positions in the line, in the same manner as is exhibited in Sanskrit. I would further predict that both English and French will demonstrate this systematic patterning of heavy and light, but that the differences will be much more stark in English.

French Artists	English Artists
Damso	Eminem
Nekfeu	Tupac Shakur (2Pac)
MHD	Kanye West
Booba	Jay-Z
Orelsan	Snoop Dogg
Lacrim'	50 Cent
Kaaris	The Notorious B.I.G.
MC Solaar	Nas
Kery James	Ice Cube
Maître Gims	Kendrick Lamar
Youssoupha	Dr. Dre
Akhenaton	
Lino	
Oxmo Puccino	
Médine	
Keny Arkana	
Niro	
Shurik'n	
Kool Shen	
Rohff	

Table 1: Artists whose lyrics were used.

4 Methods

This study uses an comparative analysis of French and English syllable structure as it appears in hip-hop music. The methods used in this study are detailed in the sections below.

4.1 Data Collection

All of the raw data were collected from GeniusLyrics, a website which allows users to upload, annotate, and comment on song lyrics. In order to determine which artists' lyrics to use, I looked up the 20 most popular French-language rappers and 20 most popular English-language rappers, on www.ranker.com. In order to procure this raw data, I used LyricsGenius, a module allowing Python to interact with the GeniusLyrics API. This allowed me to download lyrics for a total of 2,457 French songs and 3,731 English songs, though the English songs only came from the top 11 English-language artists, since several of these are highly prolific. The artists used in this study are summarized in table 1.

4.2 Data Processing

Once the raw lyrics were obtained, they were processed from raw, orthographic text into phonetically transcribed and syllabified forms using language specific tools:

4.2.1 French

In order to convert the raw data into a usable form for the purposes of this project, I used a Python-based tool called SPPAS, produced by the CNRS Laboratoire Parole et Langage in Aix-en-Provence. SPPAS conducts forced-phoneme alignment using Hidden Markov Models (HMM) via Julius, an open-source HMM speech recognition system. SPPAS uses these models to first tokenize the lyrics, produce all possible phonetic transcriptions, and then select the most likely candidate based on the context. Once the most likely phonetic transcription has been selected, SPPAS separates it into its most probable syllabic form. Due to the way the program works, and my own limited knowledge on the technical functionality of these tools, if any of these steps failed for a any word in a line in a song, the whole song was excluded from the analysis. Unfortunately this also significantly reduced the size of my data set from 2457 to 788 songs.

4.2.2 English

In order to process the English data, I first used a CMU Pronouncing Dictionary lookup tool to retrieve the ARPAbet pronunciations of each of the words, which was then passed to an English syllabification model. The pronunciation dictionary also returned which nucleus was stressed in the word. If any word in a line failed either the lookup or syllabification process, the line was excluded from the data set. Because this method conducted syllabifications by *line* and not by *song*, I was able to retain much more of the data than was the case with the French.

4.2.3 Filtering

Inevitably, the processes used for producing the syllabified song lines will have produced inaccuracies, but from satisfactory cursory checks and due to the limited scope of this project, a sweeping analysis of these errors was not conducted.

Once the phonetic and syllabified transcriptions were produced, the song-lines were filtered by length only to include lines of four or more syllables, and for which there were at minimum 40 exemplars of lines of that length in both the French and English data sets, such that they might produce a representative sample that was not too heavily biased by any one line. These criteria rendered data sets of lines containing between 4 and 21 syllables, inclusive, with the French data set containing 17,517 song-lines of lyrics, and the English data set containing 120,056 song-lines. Note that this English data set is several times larger than the French one, but I believe that both provided a representative sample of the data in that language.

Each syllable was then coded by the number of syllables of the line it was in, as well as by its relative position in that line. The analyses conducted below are based on this sample of 181,314 and 1,198,230 French and English syllables, respectively.

4.3 Analysis

The filtered data was subjected to several comparative analyses, both language-internal and between-language. All analyses were conducted in Python, using the SciPy.stats and NumPy modules.

Each syllable was weighed under the traditional (a syllable is heavy if it has a long vowel or a coda), and Ryanic (traditional weight + syllables with complex onsets) models. Mean weights were taken by language×model pair for later comparisons. Each line was then grouped into lines of equal length, and these lines were aggregated to produce a mean weight contour for a line of that length under each model. In English, a stress contour was also created for each line length, based on the stress returned by the pronunciation dictionary.

Once these contours had been made, the difference was taken between the Ryanic and traditional contours, rendering the proportion of otherwise-light syllables which are now considered heavy due to their complex onsets.

Pairwise comparisons were then made, taking Pearson's r for comparisons between the traditional and Ryanic contours for each language, as well as therebetween, between the traditional weight and the proportion of complex onsets. The English models were also compared to the stress contour.

4.3.1 A Closer Look

In order to give the reader a better idea for the data, I have included samples from two songs– one in English and the other in French:

French Figure 12 in the appendix provides a sample of French lyrics drawn from Kery James' *Vent D'État*. The first line of each chunk provides the original lyrics in their orthographic form, the second line provides a phonetic transcription, and the third provides an approximation of syllable structure where C is a consonant and V is a vowel. Note that any cluster is shortened to just CC, since this analysis did not take into account the length of the cluster, but only its presence and position. Figure 1 provides a graphical representation of the weight contours produced by the two different algorithms for a sample of lines from the same song. Note that the lines differ in length, raising questions about which syllables would be falling on the beats in each line.

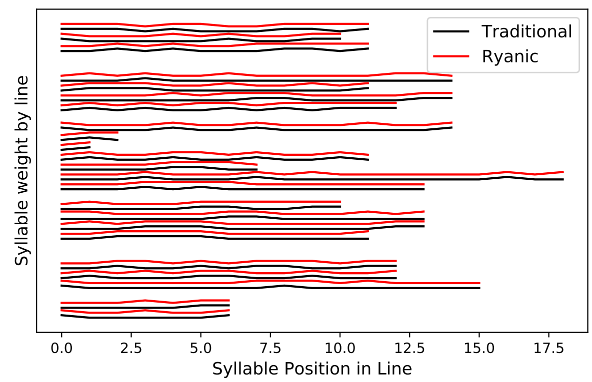

Figure 1: Weight contours for a sample of lines from Kery James' *Vent D'État*. Syllables are coded as either heavy (1) or light(0) under each model.

Note that in the lines in figure 1, despite being in the same lyrical grouping, not all of the lines have the same number of syllables. Because rappers will sometimes compress more syllables into a single beat, as lines get longer, it becomes more difficult to accurately line up the lines with their corresponding beats. For some line lengths, there is a proportional relationship between number of syllables and beats in that line, but for others, this is not the case, making it difficult to determine which syllables carried the stress and beats in that line.

English Figure 13 in the appendix provides a sample from Eminem's *Lose Yourself.* In each chunk, the first line is the lyrics, the second line is the syllabification in ARPAbet phonetic transcription format, and the third line is the syllable structure, where C is a consonant, V is an unstressed vowel, and VV is a stressed vowel.

The last line is included to provide an example of a line that failed lookup and syllabification due to the onomatopoeic token *blaow*.

The results from the analyses described here are presented in the next section.

5 Results

At the most basic, and unsurprising level, English showed a much higher proportion of heavy syllables than did French under both the traditional (57.14%

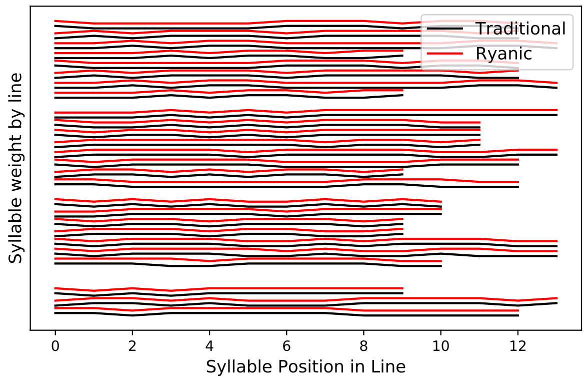

Figure 2: Weight contours for a sample of lines from Eminem's *Lose Yourself*.

vs. 31.51%) and Ryanic (59.76% vs. 43.72%) models. A close examination of each language and a comparison between them follows.

5.1 English Syllable Weight and Stress

As noted above, English demonstrated a high proportion of heavy syllables. This general heaviness was not flat across the board, however, with visible patterns in lines of almost every length examined. Figure 3 provides sample contours of the two models, as well as their difference, proportion of heavy onsets and stress, from lines of length 8 (n=11,627) and 14 (n=7,540). The two weight models in both line lengths exhibit visible pulses corresponding to fluctuations in syllable weight over the course of the line. Consistently, the last line in the syllable is heavy. The difference between the two models does not visually reveal anything interesting except that complex onsets do not contribute drastically to syllable weight in English.

Across line lengths, the two different weight models correlated extremely well (mean Pearson's r = 0.9901, p<0.001). This result is unsurprising, since one is only a slight adjustment from the other. More interestingly, the difference between these two models, or the contour of syllables with heavy onsets, consistently correlates negatively with traditional weight (mean Pearson's r = −0.5072, p = 0.17). While this trend was not significant for all line lengths, it was significant for some. The correlation coefficients for the comparisons between these across the range of line lengths are shown in figure 4.

Since stress would be predicted to correlate with syllable weight in English, I examined the correlations between the stress estimated by the pronouncing dictionary and the two weight models as well as

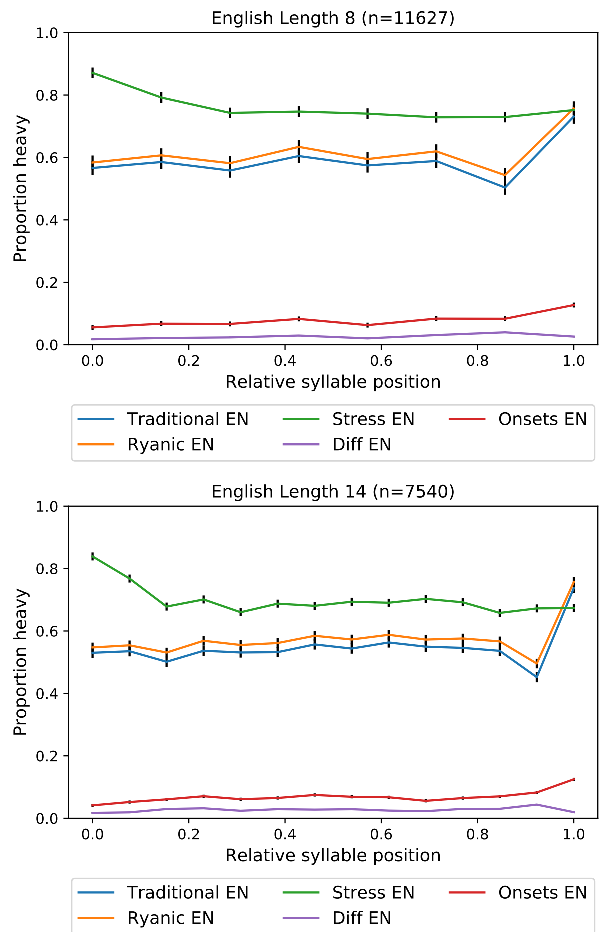

Figure 3: Sample contours of the two models, their difference, and estimated vocalic stress on lines of length 8 and 14 in English. Error bars indicate ±1 standard error from the mean. Note that in both of these samples (of 11,627 and 7,540 lines respectively), there are minute but visible pulses apparent over the course of the line. That is to say that syllable weight does not distribute evenly over the line. The last syllable in the line being heavy is consistent across all line lengths. We also note that there is not a major difference between the two models.

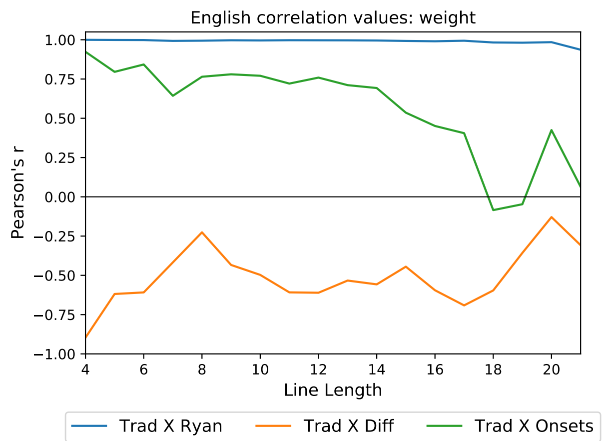

Figure 4: Pearson's r values by line length for the covariance between the two models as well as between the traditional model and the difference. While the two weight models correlated exceedingly well, this was not universally the case for Traditional weight and the presence of heavy onsets. This correlation was strong for some line lengths and not for others.

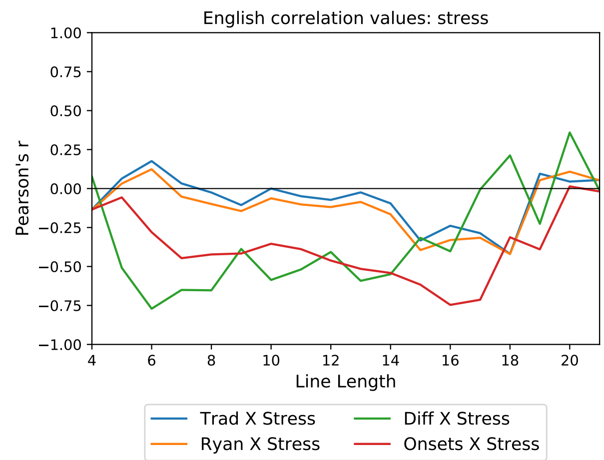

Figure 5: Pearson's r values by line length for the covariance between stress and the two models as well as their difference. None of these correlated especially well with stress, though the difference between the models had a strong negative correlation which weakened as line length increased.

their difference. As can be seen in figure 5, stress did not correlate well with either of the weight models, and showed a negative correlation with the models' difference for lower line lengths. I think this lack of correlation may be due to the shifting of stress in words and lines to better fit with the beats, but I have no concrete evidence of this.

5.2 French Syllable Weight

French has a relatively lower proportion of heavy syllables overall, but their patterning also exhibits visible patterns as can be seen in figure 6. There is a larger difference between the two models than was the case in English, but both models follow the same general trend. There is a visible trend of increasing and decreasing over the course of the line, however not quite so marked as in English. Note that these fluctuations in weight are also visible in the difference between the two models.

To investigate the extent to which the traditional model of stress correlates with the Ryanic model, as well as with the difference (or just those syllables with heavy onsets), pairwise comparisons were made between each of these and the results are shown in figure 7, for Pearson's r by line length. Note that these correlations start of strong and weaken as line lengthincreases. I have attributed this to the increase in noise as lines of greater numbers of syllables are more likely to fall out of synchronous proportion with the beats.

5.3 Comparing French and English

Finally, I compared the two languages to one another. Figures 8 and 9 provide side-by-side comparisons for the two languages for lines of length 8, which served to be a strong exemplar as it was one of the most common line lengths in both languages. In these figures, we see that despite English being an overall heavier language, the two languages closely resemble one another. This is backed up by their strong correlation cross-linguistically as shown in figure 10, where we see the Pearson's r correlation values between the traditional and Ryanic models cross-linguistically. Consistent with earlier observations, these correlations are much stronger for shorter lines, and this correlation decays as line length increases. The same initially strong correlation and decay pattern can also be seen in the cross-linguistic comparison between the model differences.

In order to compare the two languages one on top of the other, I subtracted the mean of each model from the model. In figure 11, two examples of these de-meaned systems have been provided for lines of length 8 and 12, both highly frequent line lengths. Despite their not lining up perfectly on top of one another, similar trends can be seen between the languages, often falling within 1 standard error from one another while still remaining significantly different from the mean at that point.

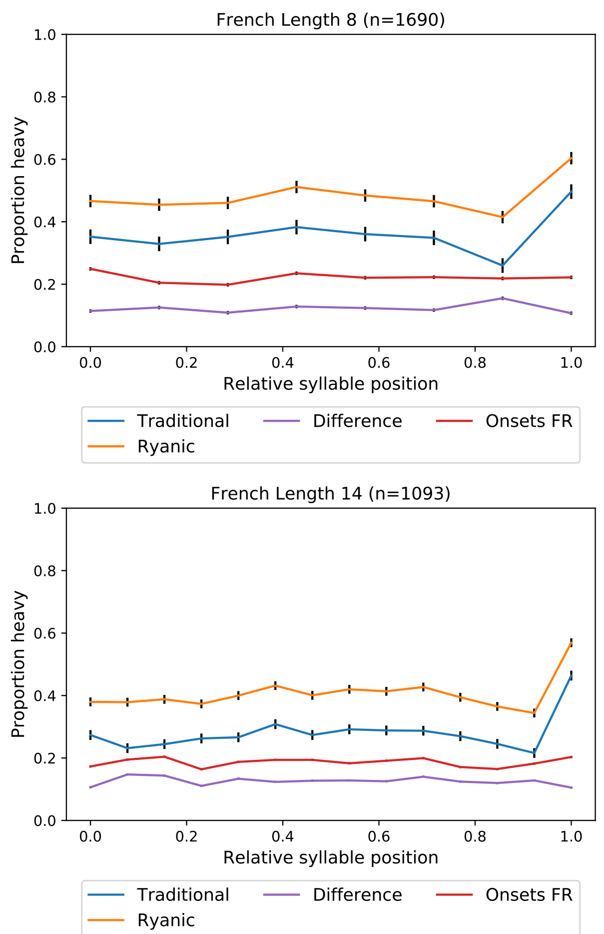

Figure 6: Sample contours of the two models and their difference on lines of length 8 and 14 in French. Error bars indicate ± 1 standard error from the mean. Note that in both of these samples (of 1,690 and 1,093 lines respectively), there are minute but visible pulses apparent over the course of the line. That is to say that syllable weight does not distribute evenly over the line. The last syllable in the line being heavy is consistent across all line lengths. We note that there is a fairly large difference between the two models, despite following the same general pattern.

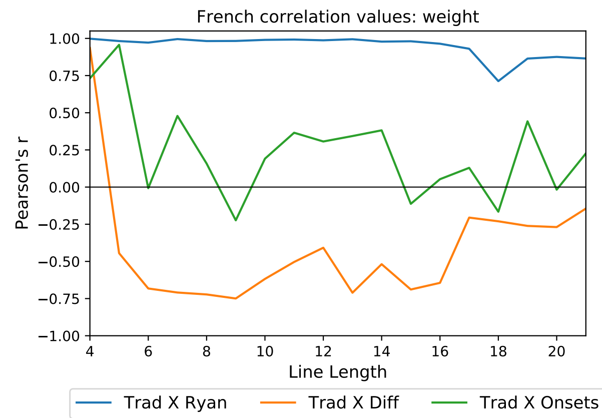

Figure 7: Pearson's r values by line length for the covariance between the two models as well as between the traditional model and the difference. Note that in both cases, the correlations start off strong and weaken as line length increases.

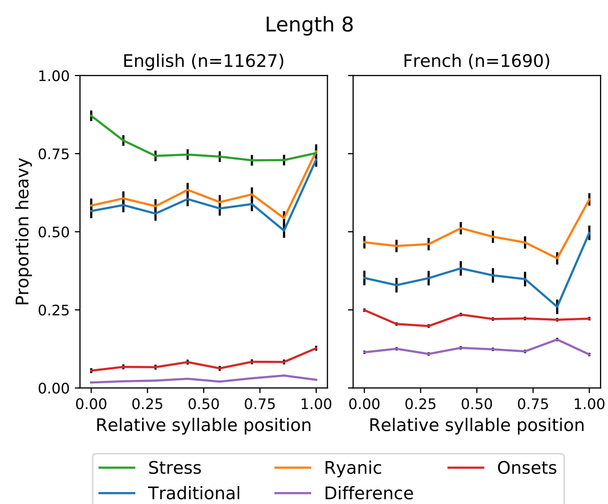

Figure 8: Side-by-side contours for lines of length 8 in English and French for all of the measures taken in each language (traditional weight, Ryanic weight, weight difference, and in the case of English, stress). Note that English is markedly heavier, and with less difference between the two weight models.

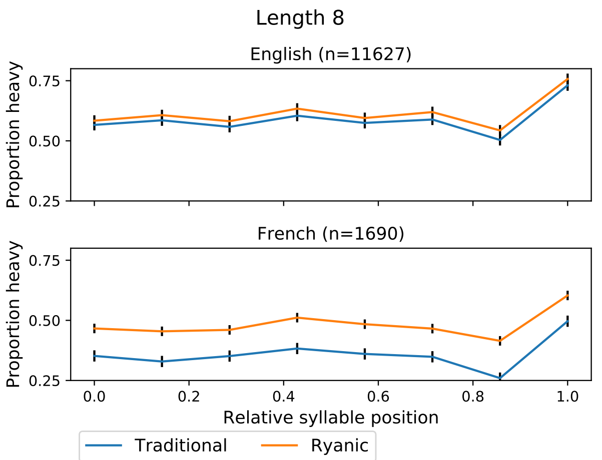

Figure 9: Side-by-side weight contours for lines of length 8. By zooming in on the y-axis, we get a better picture for the trends in these contours, which resemble one another cross-linguistically.

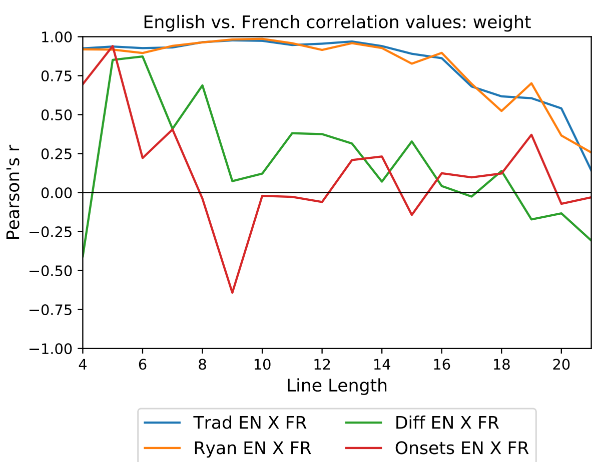

Figure 10: Pearson's r values by line length for comparisons between the same model in English and French. The models correlate much better for shorter lines, and less well for longer ones.

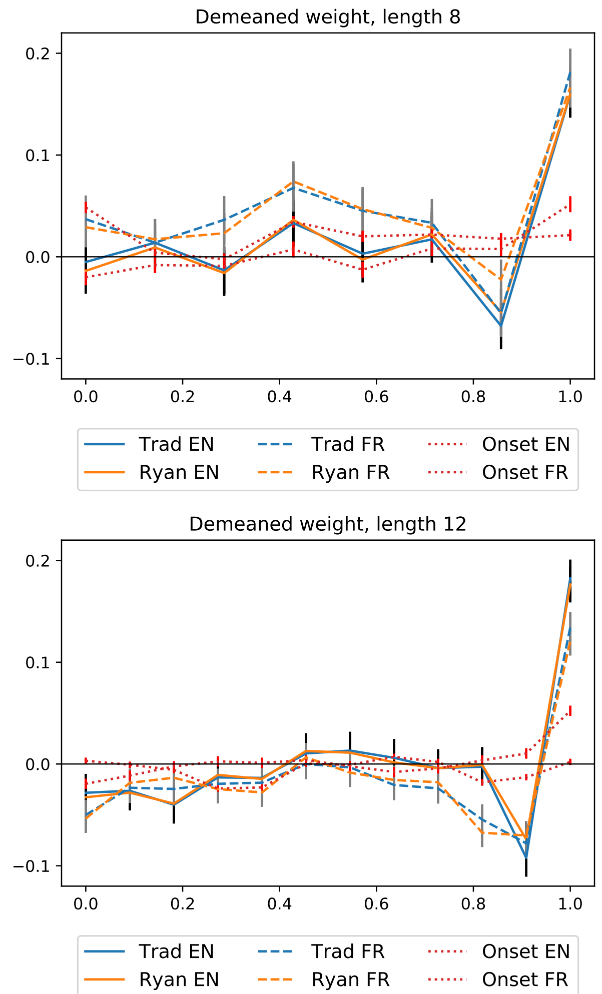

Figure 11: Sample contours with the mean subtracted from each model. While English and French do not perfectly overlap in all cases, markedly similar trends are still noticeable. Error bars indicate ±1 standard error from the mean.

On the whole, though, it is clear that both English and French show a sensitivity to syllable weight in a rhythmic environment. We note that their fluctuations in syllable weight in a rhythmic line show resemblance to one another, as well as to the complex-onset-only model.

6 Discussion

Overall, the data here, noisy thought they may be, do lend credence to Ryan's theory on the p-center, such that syllables with complex onsets tend to correspond to stressed positions and correlate with traditional models of syllable weight. Instead of random variation and placement of weight over the course of a line of hp-hop, we see distinctive and recognizable patterns of weight placement.

Interestingly, this appears to be true in both French and English, while theoretically it would only have been predicted in English. This may mean we need to reevaluate some of our assumptions about the French syllable, particularly as it pertains to weight and meter. It would appear that the p-center is used even in weight-insensitive languages in metrical or rhythmic environments.

7 Conclusions

Before any real and far-reaching conclusions can be drawn about the French syllable, more work is needed. Unarguably, cleaner data and actual human-verified transcriptions would be useful, as well as alignment with music to ensure that the appropriate syllable falls on the beat each time, which should theoretically reduce noise in the data.

In the future it may also be interesting to look at absolute position of weight in a line, regardless of line length. It would also be useful to look at other purportedly weight-insensitive languages to verify this cross-linguistically.

A Additional Materials

Si aux échecs je dois jouer, ce ne sera jamais pour être un pion
so,e,SEk,Zdwa,Zwes,nsRa,Za,me,pu,RE,tU˜,pjo˜
CV,V,CVC,CCCV,CCVC,CCCV,CV,CV,CV,CV,CV,CCV

J'écris des textes explosifs et je n'ai pas besoin de bombes
ZE,kRi,de,tEk,sEk,splo,zi,fE,Zeu,ne,pa,beu,zwU˜t,bo˜bz
CV,CCV,CV,CVC,CVC,CCCV,CV,CV,CV,CV,CV,CV,CCVC,CVCC

Si la France a un défi, il s'nomme "savoir et vivre ensemble"
sla,fRa˜,sa,U˜,dE,fi,is,nom,sa,Re,vi,vRa˜,sa˜,bleu
CCV,CCV,CV,V,CV,CV,VC,CVC,CV,CV,CV,CCV,CV,CCV

Les noirs et les arabes contres les Français de souche
leu,nwa,Re,le,a,Rab,ko˜t,Rle,fRa˜,sEt,suS
CV,CCV,CV,CV,V,CVC,CVC,CCV,CCV,CVC,CVC

Figure 12: Sample French lyrics showing orthographic text with phonetic and structural transcriptions below.

His palms are sweaty, knees weak, arms are heavy
1HHIHZ,1PAAMZ,1AAR,1SWEH,0TIY,1NIYZ,1WIYK,1AARMZ,1AAR,1HHEH,0VIY
CVVC,CVVCC,VVC,CCVV,CV,CVVC,CVVC,VVCC,VVC,CVV,CV

There's vomit on his sweater already, Mom's spaghetti
1DHEHRZ,1VAA,0MAHT,1AAN,1HHIHZ,1SWEH,0TER,0AOL,1REH,0DIY,1MAAMZ,0SPAH,1GEH,0TIY
CVVCC,CVV,CVC,VVC,CVVC,CCVV,CV,VC,CVV,CV,CVVCC,CCV,CVV,CV

He's nervous, but on the surface he looks calm and ready
1HHIYZ,1NER,0VAHS,1BAHT,1AAN,0DHAH,1SER,0FAHS,1HHIY,1LUHKS,1KAAM,0AHND,1REH,0DIY
CVVC,CVV,CVC,CVVC,VVC,CV,CVV,CVC,CVV,CVVCC,CVVC,VCC,CVV,CV

...

He's choking, how, Everybody's joking now
1HHIYZ,1CHOW,0KIHNG,1HHAW,1EHV,0RIY,2BAA,0DIYZ,1JHOW,0KIHNG,1NAW
CVVC,CVV,CVC,CVV,VVC,CV,CV,CVC,CVV,CVC,CVV

The clock's run out, time's up, over, blaow!

Figure 13: Sample English lyrics showing orthographic text with phonetic and structural transcriptions below.