

Stress-Meter Alignment in American Hip Hop

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Abstract

This paper presents stress-meter alignment patterns in the rapping of six American hip hop artists. The rate of shift in lexical stress in the rapping in order for stressed syllables to align with strong positions in the musical meter is explored. While differences exist between artists, results suggest that there is a strong correlation between strong metrical position and stressed syllables in American hip hop. Shifts in lexical stress also vary between artists, however it is shown that the majority of shifts allow stressed syllables to align with strong positions in the musical meter.

Index Terms: Prosody, meter, hip hop

1. Introduction

1.1. Hip hop – a background

The birth and early life of hip hop was a challenging one. Born out of the urban ghettos in New York City during the 1970s, it served as a means for youths to express their frustrations and experiences of underclass American society and life through rap, dance, and art, particularly in the African- and Latin-American communities [1]. At its core, hip hop is a platform for cultural, artistic, and political expression. Arguably, the lyrics used in the raps – the most salient aspect of the hip hop genre – are commonly misunderstood, where the language style, cultural meaning, and social implications are often times misinterpreted [2]. There are several studies that explore aspects of hip hop as a genre, with a large number focusing on its social and anthropological aspects [1]–[4].

Important to the current study of hip hop are the rhythmic aspects of the genre. Of particular importance is the relationship between linguistic prosody and musical rhythm. Hip hop, like other styles of Western music such as jazz and rock n’ roll, has its roots in African music. Rap performance brings together rhythmic elements of both Western and African music, where hip hop artists employ elements of Western meter while using African rhythmic sensibilities such as polyrhythm and, most prominently, syncopation – the emphasis of the weak or ‘off’ beats [5]. A small body of work exists that explores the relationship between language and music in hip hop; however this aspect of the genre is yet to be explored comprehensively. Investigations into the rhythmic aspects of hip hop, in particular American hip hop (henceforth AmHH), concluded that its roots in African traditions of music and spoken word have heavily influenced the way that lyrics are layered on top of the musical beat [6], [7]. Further, a study of rapping in Japanese hip hop reveals that stress patterns and the manipulation of pitch accent play a significant part in the style of Japanese hip hop [8].

1.2. Rhythmic relationships

As previously mentioned, the connection between linguistic prosody and musical rhythm is important in this examination hip hop. The patterns of lexical stress in the English dialects of the AmHH artists considered in this study and elements of

musical rhythm overlap and interact with one another. This relationship is known as stress-meter alignment. Studies of stress-meter alignment are concerned with the juxtaposition and interaction of linguistic prosody and musical rhythm; that is, the way that stress is layered on top of musical meter.

Rhythm is a key element that connects music and language, where periodicity is a feature that the two systems have in common; however the concept of a constant periodic pattern is strong in music but can be lacking in speech. The idea that linguistic rhythm involves regular intervals between stresses or syllables has come under some scrutiny, and prosodic representations of languages have largely been abandoned in prosodic theory [9], [10]. In music, there is a clearer alternation between strong and weak (shown in Figure 1) than in language. Nevertheless, there have been studies that focus on the rhythmic relationship between music and language. These have primarily been concerned with stress in languages such as English and French and their alignment with meter in songs in Western music genres such as classical, rock, and folk music. The results of these studies suggest that there is a strong relationship between meter and prosody in these genres, where stressed syllables tend to align with strong metrical position in the musical meter. Collectively, these studies suggest that alignment is influenced by several factors, including prosodic category of the language [11] and the composer’s innate awareness of prosodic rules in their language [12], [13].

Following the observations of previous studies of rhythm in hip hop, and those of stress-meter alignment studies of Western music, the purpose of the current study is to examine the pattern of stress-meter alignment in AmHH and determine the strength of the relationship between stressed syllables and strong beats in the musical meter. Patterns of stress-meter alignment across artists will also be compared. Further, the role of lexical stress shift, where a stressed syllable in a lexical item is shifted in order to align with strong beats in the musical meter, will be investigated.

Quarter-note Level	1		2		3		4									
Metrical Position	1	&	2	&	3	&	4	&								
Strength	s	w	s	w	s	w	s	w								
Eighth-note Level	1	&	2	&	3	&	4	&								
Metrical Position	1	3	2	3	1	3	2	3								
Strength	s	w	s	w	s	w	s	w								
Sixteenth-note Level	1	e	&	a	2	c	&	a	3	e	&	a	4	e	&	a
Metrical Position	1	4	3	4	2	4	3	4	1	4	3	4	2	4	3	4
Strength	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w

Figure 1: Alternation of strong and weak beats on each metrical level relevant to the analysis in the current study.

2. Method

Data presented here are from the rapping of six AmHH artists: Jay-Z, Eminem, Missy Elliott, Nicki Minaj, Macklemore, and Flo Rida [14]–[20]. To make up the corpus, three commercially successful songs from each artist were chosen to examine, making a total of 18 songs. Each song analysed was in a 4/4 meter. As only the rapping is of interest, only verses were analysed. Choruses tend to be more melodic sections

sung by the rapper or another artist, or sampled from a pre-existing song, and therefore are not relevant to this study. Any repetitions of verses were omitted from analysis.

In similar studies that have focused on classical music, the pieces that make up the corpora were examined and labelled from written scores. In contrast, this study relied solely on aural rhythmic transcription of the rapping from the recordings examined, as written scores do not exist for hip hop. Similarly, any instances of shift in lexical stress from the expected stress pattern of English were noted through aural perception.

The rhythmic transcriptions were carried out using Noteworthy Composer music notation software, followed by the prosodic and metrical labelling of each syllable. Using a modified version of Temperley and Temperley’s labelling schema [11], each syllable was placed into one of two prosodic groups: stressable syllables, considered to be strong, and unstressable syllables which were considered to be weak. Stressable syllables included three prosodic categories: primary stress syllables (*s*), secondary stress syllables (*b*), and monosyllabic content words (*c*), while weak syllables (*w*) and monosyllabic function words (*f*) made up the unstressable syllable group. Each syllable was also given a metrical label 1, 2, 3, or 4, depending on its position within the musical meter, where 1 indicates the strongest metrical position, and 4 indicates the weakest metrical position. Each measure was broken up into quarter note sections, where each quarter note was divided down into sixteenth notes (see Figure 1). The beats on the quarter note level were defined as either 1 or 2. Beats 1 and 3 (or the ‘down’ beats) in a measure of 4/4 are considered to be the strongest metrical position, and therefore all aligning syllables were labelled as 1. Syllables that fell on beats 2 and 4 (the ‘up’ beats) were labelled as 2. Within the quarter note sections, each syllable that fell on the eighth note level, or the ‘&’ of a beat, was labelled as 3. Any syllable that fell on the sixteenth note level and below was labelled as 4. *T*-tests were carried out to determine the statistical significance between alignments of stressable and unstressable prosodic categories.

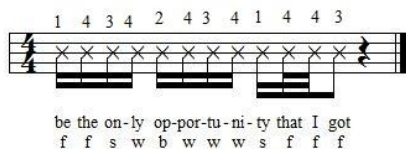


Figure 2: An example of metrical and prosodic labelling.

3. Results

3.1. Statistical analysis

Table 1 shows the distribution of the different prosodic categories across the four metrical positions in the rapping examined. It can be seen that the stressable syllables overall tend toward stronger metrical positions. While there is a preference for metrical position 2, with almost 29% of stressable syllables aligning in this position, the distribution of stressable syllables across metrical positions 1, 2, and 3 is quite even. Calculating the average metrical strength (AMS) for prosodic categories gives the average position of alignment of each prosodic category across the corpus. A lower AMS score indicates a greater preference for alignment in stronger metrical positions such as 1 or 2, while a higher AMS score indicates a preference toward weaker metrical positions. The AMS for stressable syllables overall was calculated to be 2.33. Examining each stressable prosodic category separately shows how each syllable type contributes to the overall pattern of

alignment. It can be seen that primary stress syllables (*s*) strongly tend to align in stronger metrical positions, particularly in position 2, where 34.63% of all *s* syllables align. These syllables have an AMS of 2.18. Secondary stress in polysyllabic words (*b*) has a tendency to fall in weaker metrical positions, with almost 74% of these syllables falling in position 3, and an AMS of 2.89. Depending on the position of the word within the meter, this patterning is to be expected if *s* syllables align with a strong metrical position due to the alternation of strong and weak beats in the meter. Monosyllabic content words (*c*) have a relatively even distribution across the four metrical positions, with the majority aligning in position 3, giving these syllables a slightly higher AMS of 2.45.

There is strong trend for unstressable syllables to fall in weaker metrical positions. It can be seen that over 55% of all unstressable syllables tend to fall in the weakest metrical position, resulting in an overall AMS of 3.36. It can be seen that the large majority of both unstressed syllables (*w*) and monosyllabic function words (*f*) align in metrical position 4, with very few syllables aligning in strong metrical positions. Unstressed syllables and monosyllabic function words have AMSs of 3.57 and 3.27 respectively. Figure 3 shows the relative AMS of each prosodic category across the rapping of all six AmHH artists.

To determine the statistical significance of the pattern of alignment of stressable and unstressable prosodic categories with meter, a paired-sample *t*-test was performed. The results showed a highly statistically significant difference in the metrical strength of stressable and unstressable syllables at the 0.05 significance level, where $t(6) = 13.13$, $p < 0.0001$. Subtracting the AMS of stressable syllables from that of unstressable syllables gives the degree of stress-meter alignment represented by a number. This is called the stress-meter alignment value (SMAV). The SMAV indicates the average strength difference between the alignments of stressable and unstressable syllables across the corpus. A higher SMAV score indicates that stressable syllables and unstressable syllables tend more toward strong and weak beats respectively in the musical meter. The SMAV for the rapping of the six AmHH artists considered here is 1.03.

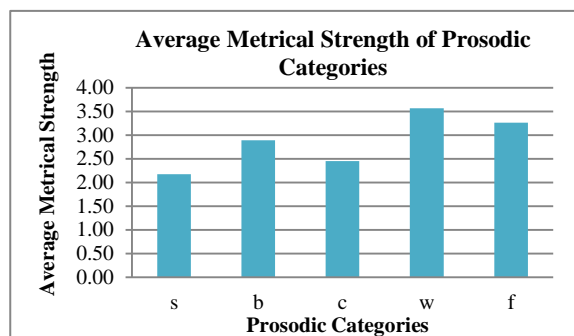


Figure 3: Average Metrical Strength of prosodic categories in the rapping of six AmHH artists. Labels are as follows: *s* = primary stress; *b* = secondary stress; *c* = monosyllabic function words; *w* = unstressed syllables; *f* = monosyllabic function words.

3.2. Artist comparison

Examining the rapping of each individual artist reveals how each artist contributes to the stress-meter alignment of AmHH as a whole. Table 2 shows the AMS of stressable and unstressable syllables for each artist. It can be seen that unstressable syllable AMS is relatively even across the six artists, where they all have a strong tendency to align weaker

Metrical Category	<i>s</i>	<i>b</i>	<i>c</i>	Stressable Total	<i>w</i>	<i>f</i>	Unstressable Total	Total
1	30.52 (430)	5.26 (3)	25.82 (418)	27.59 (851)	3.16 (54)	8.27 (291)	6.60 (345)	14.39 (1196)
2	34.63 (488)	10.53 (6)	24.46 (396)	28.85 (890)	4.44 (76)	7.02 (247)	6.18 (323)	14.59 (1213)
3	21.43 (302)	73.68 (42)	28.66 (464)	26.19 (808)	25.03 (428)	34.52 (1214)	31.41 (1642)	29.48 (2450)
4	13.41 (189)	10.53 (6)	21.06 (341)	17.37 (536)	67.37 (1152)	50.18 (1765)	55.81 (2917)	41.54 (3453)
Total	16.95 (1409)	0.69 (57)	19.48 (1619)	37.12 (3085)	20.57 (1710)	42.31 (3517)	62.88 (5227)	8312
AMS	2.18	2.89	2.45	2.33	3.57	3.27	3.36	2.98

Table 1: Percentages and syllable counts for each prosodic and metrical category across the corpus. Raw counts are in parentheses. *s* = primary stress; *b* = secondary stress; *c* = monosyllabic function words; *w* = unstressed syllables; *f* = monosyllabic function words.

syllables with weaker metrical positions. The comparison between stressable syllables is interesting, in that it shows each artist's individual pattern for stress-meter alignment. The table reveals that Missy Elliott has the highest AMS value for the unstressable syllables, and the lowest AMS value for stressable syllables, and therefore a high SMAV. This indicates that her rapping has the highest rate of stress-meter alignment, as the stressable and unstressable syllables used in her rapping are most likely to align in strong and weak metrical positions respectively. Eminem's comparatively high AMS value for stressable syllables, combined with a high AMS for unstressable syllables, resulting in a low SMAV, indicates that stress-meter alignment in his rapping may not be as rhythmically strict as what can be found in the rapping of Missy Elliott or Nicki Minaj.

Artist	Stressable AMS	Unstressable AMS	Stress-Meter Alignment Value (SMAV)
Missy Elliott	2.15	3.48	1.33
Flo Rida	2.10	3.29	1.19
Nicki Minaj	2.20	3.37	1.17
Macklemore	2.24	3.26	1.02
Jay-Z	2.51	3.42	0.91
Eminem	2.58	3.37	0.79

Table 2: A ranking of SMAVs across the six artists examined from highest to lowest. These numbers indicate the rate of stress-meter alignment.

3.3. Lexical stress shift

As well as examining the rate of stress-meter alignment, the rate of shift in lexical stress was also investigated. Lexical stress shifts occur when weak syllables which align with strong metrical position in the musical meter become stressed. Therefore, a shift in the expected stress pattern of lexical items is perceived. This phenomenon was explored to determine whether rappers shift the expected stress patterns of lexical items in order for stressable syllables to align with strong positions in the meter as much as possible. Figure 4 shows an example of lexical stress shift in Eminem's *Lose Yourself*.

Table 3 reveals the rates of lexical stress shift across the rapping of the AmHH artists in question in the current study. Of the 1393 bisyllabic and polysyllabic words in the 18 songs analysed, 148 words, or almost 11%, exhibited a shift in the expected stress pattern. Of these 148 shifted words, 58.73% were bisyllabic, and 41.27% were polysyllabic. It can be seen that there is a lot of variation between artists. Missy Elliott stands out as an artist who employs a significantly larger amount of lexical stress shift in her rapping in order for stressed syllables to align with strong metrical position. Over 22% of the bisyllabic and polysyllabic words used in her rapping exhibit evidence of a shift in stress – the highest rate of stress shift of the six artists in question. Of the 157 bisyllabic words used in her rapping, almost 16% exhibited stress shift, while over 53% of the polysyllabic words used shifted stress. This high rate of stress shift could attribute to

her high rate of stress-meter alignment, as discussed previously.

Figure 5 shows the trends for stress shift across the six AmHH artists examined in this study, indicating the metrical position of the shifted syllable post-shift. It can be seen that the large majority of shifted syllables are shifted to the strongest metrical positions 1 and 2, indicating that stressable syllables are preferred to align in strong positions in the musical meter. In particular, the majority of shifted syllables align in metrical position 2. While metrical position 2 is considered to be an 'off' beat in the musical meter and not quite as strong as metrical position 1, hip hop's African roots, where syncopation, or emphasis of the 'off' beat is an important rhythmic aspect of the music may have been an influencing factor in this tendency for alignment.



Figure 4: Opportunity in Eminem's *Lose Yourself*. Measure 1 shows the shift of the *s* syllable in order for it to align with strong metrical position. Measure 2 shows the alignment if shift had not occurred.

	Bi Total	Bi Shifted	Poly Total	Poly Shifted	Total words	Total Shifted
Nicki Minaj	137	5 (3.65)	33	5 (15.15)	170	10 (5.88)
Flo Rida	151	15 (9.93)	25	6 (24.00)	176	21 (11.93)
Macklemore	252	17 (6.85)	52	9 (17.31)	304	26 (8.55)
Jay-Z	193	7 (3.63)	48	10 (10.83)	241	17 (7.05)
Eminem	242	18 (7.44)	71	14 (19.72)	313	32 (10.29)
Missy Elliott	157	25 (15.92)	32	17 (53.13)	189	42 (22.22)
Total	1132	87 (7.69)	261	61 (23.37)	1393	148 (10.62)

Table 3: Rates of lexical stress shift across the rapping of all six AmHH artists examined in this study. Percentages are in parentheses.

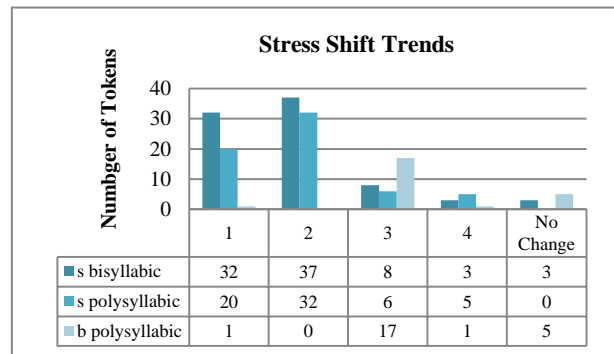


Figure 5: Position of shifted syllable post-shift in bisyllabic and polysyllabic words for the current study.

4. Discussion

The results presented here reinforce the notion that there is a strong correlation between strong metrical position and stressed syllables in AmHH. Syllables in the stressable syllable prosodic group have a high tendency to be aligned in strong metrical positions, while unstressable syllables tend to align in weaker metrical positions. Shifts in lexical stress take place in order for stressed syllables to align with strong metrical positions as much as possible.

Individual rates of stress-meter alignment vary and can skew the overall rate of alignment, as seen by the large range of SMAV scores across the six artists. This variation can also be perceived aurally. Missy Elliott, Flo Rida, and Nicki Minaj all possess rapping styles that are rhythmically quite simple and precise and have a tendency to use more rhythmic repetition in their raps in comparison to the more complex and free styles of Macklemore, Eminem, or Jay-Z. Further, a great deal of the syncopation that occurs in the artists with higher SMAV scores tends to occur as a result of the alignment of stressable syllables (in particular *s* and *c*) with the off beats of the quarter-note and eighth-note levels (i.e. metrical positions 2 and 3), whereas artists with lower SMAV scores tend to align stressable syllables with the off beats on the sixteenth note levels much more frequently (i.e. metrical position 4). These differences in the use of rhythm can be seen in the excerpts shown in Figure 6 and Figure 7.

Similarly, the rate of lexical stress shift varies greatly between artists. Each artist's creativity with prosody and meter, whether lyrics are written with stressable syllables naturally aligned to strong metrical position, or whether there is a shift in lexical stress for this to occur, dictates the overall rate of stress-meter alignment. It can be seen in the data presented that while these cross-artist variations exist, in general AmHH seems to prefer to align stressable syllables with metrical position 2. While this position is considered to be strong, it is also considered to be a metrical 'off' beat, in that it is weak or not generally emphasised. The emphasis of the 'off' beat, syncopation, is an important aspect of the rhythmic characteristics of African music, as mentioned previously. The overall tendency for AmHH artists to prefer this metrical position in stress-meter alignment suggests that AmHH is still strongly connected to its African roots.

The study of the alignment between linguistic prosody and musical meter can be valuable in the exploration of the connection between spoken language and music. Expanding the current corpus with additional artists would seek to further reinforce the conclusions of the current study. Additionally, exploring other branches of hip hop, such as Japanese or French could expand on and compare with previous findings on stress-meter alignment in music in these languages [8], [11].

Figure 6 shows two musical staves in 4/4 time. The first staff has lyrics: "like to get to know ya so I could show ya, put that puss-y on ya like I told ya." Above the staff are metrical positions 1, 4, 3, 4, 2, 3, 4, 1, 4, 3, 2, 1, 4, 3, 4, 2, 3, 1, 4, 3, 2. Below the staff are syllable stress markers: c f c f c f f f f c f c f s w f f c f c f. The second staff has lyrics: "Gim-me all your num-bers so I can phone ya, your girl ac-tin' stank so call me o-ver". Above the staff are metrical positions 1, 4, 3, 4, 2, 4, 3, 1, 4, 3, 2, 4, 1, 3, 4, 2, 3, 1, 4, 3, 2. Below the staff are syllable stress markers: s w f f s w f f f c f f c s w c f c f w s.

Figure 6: A four-measure excerpt from Missy Elliott's 'Work It', showing tendency for strict, repetitive rhythms and emphasis of stressable syllables with off beats on quarter-note and eighth-note levels.

Figure 7 shows two musical staves in 4/4 time. The first staff has lyrics: "to post mor-tem it on - ly grows har-der ho - mie grows hot-ter he blows it's all o-ver these hoes". Above the staff are metrical positions 4, 3, 2, 4, 3, 4, 4, 3, 2, 4, 4, 3, 2, 4, 3, 4, 4, 3, 2, 4, 3, 4. Below the staff are syllable stress markers: f c s w f s w c s w s w c s w f c f f s w f c. The second staff has lyrics: "is all on him coast to coast shows he's known as the globe tro-ter lone-ly roads God on-ly knows". Above the staff are metrical positions 4, 3, 2, 4, 4, 4, 3, 2, 3, 4, 4, 4, 3, 2, 4, 1, 4, 3, 2, 4, 3, 4. Below the staff are syllable stress markers: f f f f c f c c f c f f w s w s w c c s w f.

Figure 7: A four-measure excerpt from Eminem's 'Lose Yourself', showing greater fluidity of rhythm and tendency to align stressable syllables with off beats on the sixteenth-note level.

5. Acknowledgements

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