

## Effect of Note Intervals on Musical Emphasis Patterns

A “note interval” is a change in pitch between two notes. Note intervals are one of the most noticeable factor in figuring out if a lyric matches a musical emphasis. They also have the most direct analogy to lyrical emphases.

### Original Approach

I have been representing the pattern of musical emphases as constant binary rhythmic sequences. In a binary rhythmic sequence, the number "1" is used to represent an emphasized beat, and "0" represents an unemphasized beat.

Originally in my research, I was deriving the binary rhythmic sequence (BRS) solely using the time signature of a piece. For example, the sequence for a waltz would be "1 – 0 – 0, 1 – 0 – 0, 1 – 0 – 0", since the only emphasized beat in a piece with  $\frac{3}{4}$  time is the first beat<sup>1</sup>.

As it turned out, I was oversimplifying. You need to consider all sorts of musical accents<sup>2</sup> when determining how to make a lyric fit a melody. I had only been considering the case of simple meter, in which there is a strict succession of regularly spaced strong and weak beats.

I realized my omission when attempting to apply my algorithm to the chorus of The Bloodhound Gang’s, “The Bad Touch”. The first three clauses of the chorus are as follows:

“You and me” “baby ain’t” “nothing but mammals”

This breaks down like this:

WORD	You			and			me			ba-			by			ain’t		
NOTE_LEN	1			1			2			1			1			2		
EMPH										1			0					
SAMPSYL	ju			@nd			mi			be			bi			ent		
SYL_PART	on	nu	cd	on	nu	cd	on	nu	cd	on	nu	cd	on	nu	cd	on	nu	cd
		j	u		@	n	m	i		b	e		b	i			e	n
						d												t

<sup>1</sup> Though I use the waltz as an example here, I chose to test only songs with  $\frac{4}{4}$  time for simplicity's sake, since the binary rhythmic sequence per measure for that is "1 – 0 – 1 – 0", which is delightfully repetitive.

<sup>2</sup> The wikipedia page explains the concept of musical accents more than adequately, so I won't restate it here. [http://en.wikipedia.org/wiki/Accent\\_%28music%29](http://en.wikipedia.org/wiki/Accent_%28music%29)

WORD	no-			thing			but			mam-			mals		
NOTE_LEN	1			1			1			1			1		
EMPH	1			0						1			0		
SAMPSYL	nV			TIN			bVt			m{			ml=z		
SYL_PART	on	nu	cd	on	nu	cd	on	nu	cd	on	nu	cd	on	nu	cd
	n	V		T	I	N	b	V	t	m	{		m	l=	z

The main thing to notice here is the emphasis pattern:

you - and - me - ba - by - aint - no - thing - but - mam - mals

x - x - xx - 1 - 0 - xx - 1 - 0 - x - 1 - 0

( **x** is a wild-card syllable from a single-syllable word. **1** is an emphasized syllable in a multi-syllable word. **0** is an un-emphasized syllable in a multi-syllable word. )

Using my original assumptions, the beat of a 4/4 measure should always be 1 - 0 - 1 - 0. In this case, though, there's no way to fit that structure, because the two-syllable words “nothing” and “mammals” are only separated by a single syllable. This means that our emphasis pattern according to our current algorithm where we only look at syllable length and emphasis patterns, must be one of the following:

you - and - me - ba - by - aint - no - thing - but - mam - mals

1 - 0 - 10 - 1 - 0 - 10 - 1 - 0 - 1 - 1 - 0

OR

you - and - me - ba - by - aint - no - thing - but - mam - mals

1 - 0 - 10 - 1 - 0 - 10 - 1 - 0 - 0 - 1 - 0

Either way, in the third clause, “nothing but mammals”, we have two adjacent syllables of the same emphasis value. Under our original system of rules, this isn’t allowed. However, the song’s emphases still *sound* right, so there had to be another factor affecting emphasis (you see where this is going, right?).

As it turns out, the sheet music for this part sheds light on the situation:



You and me \_\_\_\_\_ ba- by, ain't \_\_\_\_\_ noth-ing but mam-mals

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The first two clauses, “You and me” and “baby, ain’t” have no note intervals (the pitch doesn’t change from note to note). However, in the third clause, there is a positive note interval between “but mam-”, and a negative note interval between “mam-mals”:



noth-ing but mam-mals

1 - 0 - 1 - 1 - 0

Obviously, my original approach fails if a lyrics clashes such that the textual emphases are not uniformly alternating. However, the failure can be countermanded (fixed/rectified/adjusted/revised) by adding the consideration of note intervals and other musical accents into the algorithm.

In my original examination of the situation, I completely failed to realize how a note's relation to the other notes around it could affect that pattern. Syncopation, accent marks in sheet music like the stacatto symbol, and single-note variations in previously-established chorus melodies are all aspects that are commonly used to heighten the dramatic tension of lyrics.

Though the aforementioned list of musical accents are useful, they require me to collect additional data on imported songs, and to add additional complex logic. Also, not all songs contain these elements. Because of that, I've decided to push the implementation of those off until a later date.

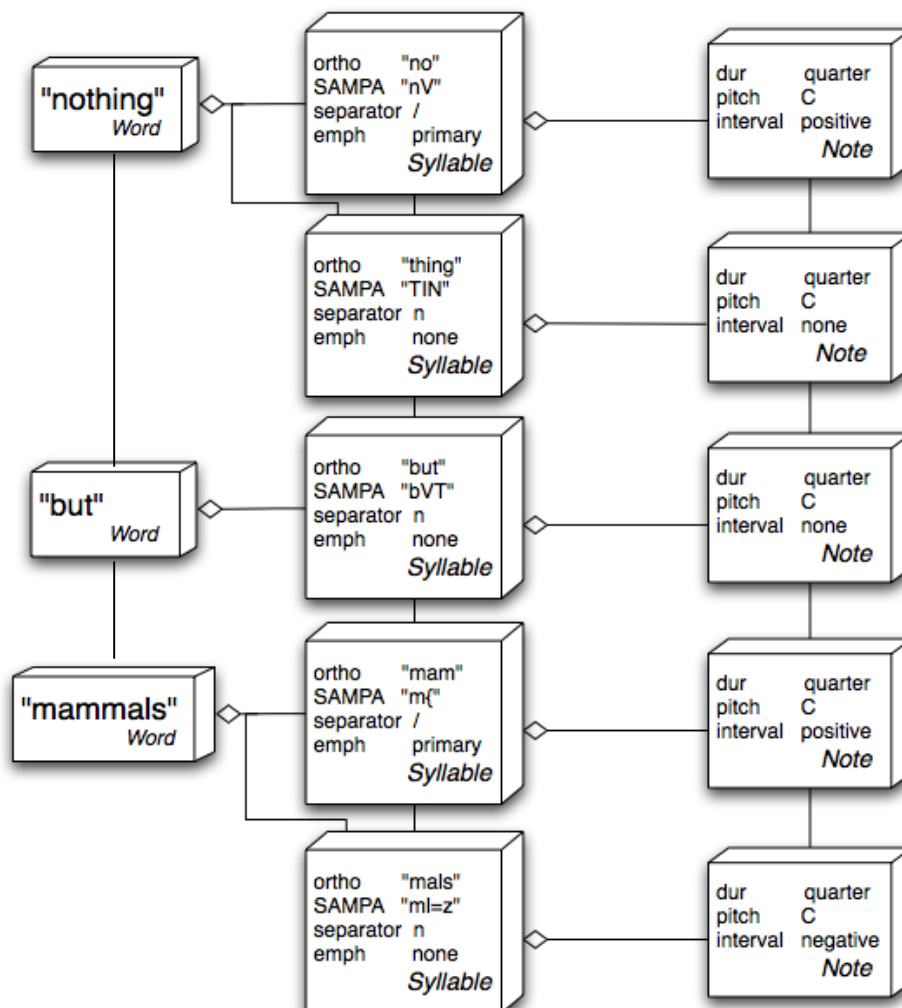
Note intervals are the most common (and, thankfully, easiest to incorporate using existing data) affecter of music emphases. Any time there is a change in pitch in a song, you've got a note interval. Without implementing note intervals, I would only be able to parse songs that never changed pitch in succession.

## Data Acquisition

Once a composition is fully parsed in from the Music XML format, there are just a few more steps to take. The program grabs correct phonetic information for each word for each word from the embedded CLIPS environment, and stores it in the Word and Syllable Objects

<u>Word</u>		<u>Syllable</u>		<u>Note</u>	
string	orthoSpelling	string	orthoSpelling	octave	o
string	SAMPASpelling	string	SAMPASpelling	duration	d
string	partOfSpeech	vector<Phone>	onset	pitch	p
int	uniqueId	vector<Phone>	nucleus	int	absPitchVal
string	uniqueIdNotes	vector<Phone>	coda	int	isNaturalFlatOrSharp
int	freq	emphasis	emph	int	hasChangeInInterval
string	etymBreakdown	char	separator		
		Note *	start		
		Note *	end		

At the end of the data acquisition phase, you'll have three interconnecting lists of Words, Syllables, and Notes, representing the song lyrics:



## Binary Rhythmic Sequence (BRS) Construction and Meaning

### Music BRS

Music BRS's are pretty simple: either a beat is emphasized, or it isn't. If a beat is emphasized, you represent it with a "1". If it's not, it's a "0". A simple, 4/4 time measure would have this music BRS:

1 – 0 – 1 – 0

In the above example, the first and third beats are emphasized, whereas the second and fourth are not.

### Lyric BRS

Lyric BRS's are slightly different than music BRS's, because of the possibility of secondary emphases in words. For example, the word "strawberry" has a primary emphasis on the first syllable, a secondary emphasis on the second, and no emphasis on the last. Go ahead, try to say "Strawberry" without your tone of voice going down with each syllable (Asking it as a question doesn't count, cheater!). It sounds wrong.

Because we have to deal with secondary emphases, we have to have more than just 0 and 1 for symbols in the BRS for lyrics. Here's the symbol breakdown:

<b>Symbol and Value:</b>	<b>0</b>	<	<b>2</b>	<	<b>1</b>
<b>Meaning:</b>	No Emphasis	<	Secondary Emphasis	<	Primary Emphasis
<b>Example:</b>	Straw-be-rry	→	1 – 2 – 0		

The fact that the emphasis scale for the symbols goes 0, 2, 1 is a little counter-intuitive, but it works better for most cases to pretend that 2 doesn't exist. Secondary emphases are pretty rare in English, so most of the time, we'll only need to use 1's and 0's in our Lyric BRS's.

## Evaluating Correctness of Note Intervals

To evaluate the fitness of note intervals, you need three things:

- (1) The meter of the piece and its implied **binary rhythmic sequence** (BRS)
- (2) The list of Syllables
- (3) The list of Notes.

In our example, "The Bad Touch", the meter is 4/4, so the music BRS is the basic "1 – 0 – 1 – 0 ", which (again) is delightfully repetitive. We already parsed in the lyrics, so we also have a list of Notes and Syllables. We're ready to start!

### Step One: Compute a Lyric BRS From The Syllable Emphases

Basically, you lookup each word in the lyrics in the phonetic dictionary. Single-syllable words are represented with the wildcard symbol 'x' because they can fall on both emphasized and unemphasized beats. For multi-syllable words, each syllable must be represented with either a 0 or a 1 (or a 2, in the case of secondary emphases). If the note that the syllable is associated with is longer than a single beat, then the emphasis value will be followed by however many x's are needed to have the correct number of beats.

In our example, the lyric is "nothing but mammals". That breaks down like this:

Lyric	<i>no-</i>	<i>thing</i>	<i>but</i>	<i>mam-</i>	<i>mals</i>
Note length <sup>3</sup>	1	1	1	1	1
Lyrics BRS	1 –	0 –	x –	1 –	0 –
Music BRS	1 –	0 –	1 –	0 –	1 –

### Step Two: Compare each syllable's lyric BRS to its music BRS

This step is pretty self explanatory. For each syllable, you look at the value that the Lyric BRS has, and compare it to the Music BRS value. If it's the same symbol or if the Lyric BRS symbol is x, it's a match. If the Lyric BRS is unemphasized, but the Music BRS is emphasized, then it still works, though it's not ideal. If there's a out-and-out mismatch, like there is on " *mam-* *mals* " in this example, you've got to move on to check if there are mitigating factors that might compensate for the **disjoint**.

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<sup>3</sup> Measured in the value of the shortest beat in the phrase.

### Step Three: In cases of BRS mismatch, check the intervals in the associated word or syllables

So, since we noticed the mismatch on "*mam-* *mals* ", we've got to go look into the details of its member syllables "*mam-*" and "*mals*".

Note intervals are the most important thing to notice here. They represent how the note is different in pitch than the one before it. The note interval on "*mam-*" has no relationship to "*mals*", because it's referring to the difference in pitch between it and the note associated with "*but*", the word that precedes it.

<i>Lyric</i>	<i>mam-</i>	<i>mals</i>
Note interval	-	-
Note length <sup>4</sup>	1	1
Lyrics BRS	1 –	0 –
Music BRS	0 –	1 –

We can actually use that knowledge to narrow down the scope of our problem. We only have to look at the note interval on "*mals*", since its note interval connects back to "*mam-*".

When we look at the note interval on "*mals*", we find that it's negative. This is perfect, since "*mals*" should be less emphasized than "*mam-*".

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<sup>4</sup> Measured in the value of the shortest beat in the phrase.

**Example: Van Halen, Running With the Devil**

<i>Lyric</i>	<i>run-</i>	<i>ning</i>	<i>with</i>	<i>the</i>	<i>de-</i>	<i>vil</i>
Note interval	0	0	-	-	+	-
Note length <sup>5</sup>	2	2	2	1	3	24(end)
Lyrics BRS	1 - x -	0 - x -	x - x -	x -	1 - x - x -	x - x....
Music BRS	1 - 0 -	1 - 0 -	1 - 0 -	1 -	0 - 1 - 0 -	1 - 0 -....

Notes on "*ning*": It's okay for unemphasized syllables to be on emphasized beats, so long as the new emphasis pattern doesn't match that of an existing word, and so long as the emphasized syllables in the same word are also on emphasized beats.

Notes on "*de-*": This syllable is emphasized, but the first beat that it falls on is not an emphasized beat. There are a few possible reasons why this might be true:

- (1) The note interval of "*de-*" is positive, so the emphasis is positive.

--More correctly, since note intervals refer to the change in pitch between a syllable's note and the preceding note, we'd want to look at "*vil*" to see if the word "*de- vil*" was emphasized correctly. When we do, we find that "*vil*" has a negative note interval, so it's less emphasized than "*de-*", so everything is hunky-dory!

- (2) The note that "*de-*" is associated with continues through an emphasized beat, so it's emphasized.
- (3) The slightly longer length of the note associated with "*de-*" makes it emphasized.

Since I'm focusing on the effects of note intervals right now, we're going to appoint that as the main cause.

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<sup>5</sup> Measured in the value of the shortest beat in the phrase.



**Example: The Beatles, Sgt. Pepper's Lonely Hearts Club Band**

<i>Lyric</i>	<i>We're</i>	<i>Ser-</i>	<i>geant</i>	<i>Pep-</i>	<i>per's</i>	<i>Lone-</i>	<i>ly</i>	<i>Hearts</i>	<i>Club</i>	<i>Band</i>
Note interval	0	+	0	0	0	+	0	-	-	-
Note length <sup>6</sup>	1	1	1	1	1	2	1	2	2	2
Lyrics BRS	x -	1 -	0 -	1 -	0 -	1 - x -	0 -	x - x -	x - x -	x - x -
Music BRS	0 -	1 -	0 -	1 -	0 -	1 - 0 -	1 -	0 - 1 -	0 - 1 -	0 - 1 -

Notes on "*We're*": If you notice, the music BRS value for this is 0, even though it's the first word in the lyric. This is because "*We're*" is on the downbeat, which is the beat that directly precedes the first beat of a measure. It's actually on the end of the previous measure.

Notes on "*ly*": It's okay for unemphasized syllables to be on emphasized beats, so long as the new emphasis pattern doesn't match that of an existing word, and so long as the emphasized syllables in the same word are also on emphasized beats.

Notes on "*Hearts Club Band*": Though this is outside the scope of what I'm investigating here, it's interesting to see how the obvious-to-the-ear syncopation of this phrase is mirrored in the way the music BRS lines up with the lyrics. I hypothesize that the syncopation is caused by the "backwards" matchup; instead of the music BRS of each word going "1 - 0 -", it goes, "0 - 1 -". Kind of cool.

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<sup>6</sup> Measured in the value of the shortest beat in the phrase.

**Example: The Beatles, While My Guitar Gently Weeps**

Lyric	<i>While</i>	<i>my</i>	<i>gui-</i>	<i>tar</i>	<i>gent-</i>	<i>ly</i>	<i>weeps</i>
Note interval	0	-	-	+	-	-	+
Note length <sup>7</sup>	2	2	1	4	2	2	2
Lyrics BRS	1 - x -	1 - x -	0 -	1 - x - x - x -	1 - x -	1 - x. ...	x - x -
Music BRS	1 - 0 -	1 - 0 -	1 -	0 - 1 - 0 - 1 -	0 - 1 -	0 - 1 -	0 - 1 -

Notes on " *gui- tar* ": The first syllable of the word "guitar" is emphasized, but the beat that that syllable is on is unemphasized. We overcome this by checking the emphasized syllable, " *tar* ". Since " *tar* " has a positive note interval, the word is still correctly emphasized. Hooray!

Notes on " *gent- ly* ": Again here, the word's emphasis pattern doesn't match the emphasis pattern in the music<sup>8</sup>. When we then check the intervals for both syllables, we find they both are negative. This isn't a problem, though. Since a note interval refers to the relationship of a note to the note preceding it, we only have to look at the second syllable of the word, " *ly* ". Since " *ly* " has a negative interval, it's less emphasized than " *gent* " in the song, which is exactly what we want.

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<sup>7</sup> Measured in the value of the shortest beat in the phrase.

<sup>8</sup> or maybe it does. I'm still not sure if having **any** emphasized beat in the Music BRS during a syllable counts as a "fit" for an emphasized syllable. That's why I'm going through these use cases. I'm pretty much convinced, though, that it has more to do with note intervals.

**Example: The Beatles, Strawberry Fields Forever**

Lyric	<i>Straw-</i>	<i>be-</i>	<i>rry</i>	<i>Fie-</i>	<i>lds</i>	<i>For-</i>	<i>e-</i>	<i>ver</i>
Note interval	0	-	-	+	-	-	+	-
Note length <sup>9</sup>	1	1	1	1	1	1	1	1
Lyrics BRS	1 –	2 –	0 –	1 –	0 –	0 –	1 –	0 –
Music BRS	1 –	0 –	0 –	1 –	0 –	0 –	1 –	0 –

Though most of "Strawberry Fields Forever" is in 4/4 time, the chorus, where this lyric is taken from, is a waltz, in  $\frac{3}{4}$  time. So, the Music BRS is "1 – 0 – 0 –, 1 – 0 – 0 –"

Notes on "*Straw- be- rry*": The secondary emphasis on "*be-*" slightly complicates this word. Though the primary emphasis on "*Straw-*" matches up with the emphasized beat in the music BRS, the secondary emphasis is on an un-emphasized beat. While it's alright for unemphasized syllables to be on emphasized notes normally, in this situation, since the next syllable "*rry*" is even *less* emphasized than "*be-*", we shouldn't have them on the same emphasis level if we want to avoid ambiguity. This is where note intervals come in! To compliment the fact both "*be-*" and "*rry*" are less emphasized than the syllables before them, they both have negative note intervals, so it sounds right!

Notes on "*For- e- ver*": If this wasn't in  $\frac{3}{4}$  time, the Lyric BRS and Music BRS wouldn't match up, but it still would be correct, since the note intervals mirror the syllable emphases.

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<sup>9</sup> Measured in the value of the shortest beat in the phrase.