

The Echo Nest Data Study

By Serge Daigno

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Introduction

There is, in the electromagnetic spectrum, a thin waveband perceptible to the human ear. In the West, these audible waves have been divided into twelve equal intervals (or semitones) to form the well-tempered scale ¹ :

C	C# / Db	D	D# / Eb	E	F	F# / Gb	G	G# / Ab	A	A# / Bb	B
---	---------	---	---------	---	---	---------	---	---------	---	---------	---

Or, by convention for this study :

C	Db	D	Eb	E	F	Gb	G	Ab	A	Bb	B
---	----	---	----	---	---	----	---	----	---	----	---

This system of division is used for the majority of the contemporary songs ². Usually the final chord of a song indicates its key. For example, a song played in the key of C major, will last with a final C major key. The choice of a key is often based on the nature of the performed musical instruments and the tonal range of the singer.

Usually a song is played in the major mode (M) or in the minor mode (m). It is commonly accepted that the major mode expresses joyful emotions, while the minor mode evokes sadness ³. But it seems much less obvious to establish such a consensus when addressing the issue of keys themselves. Over the centuries, musicians have sought to understand the nature of these keys without rely on verifiable data.

Nowadays, thanks to modern technologies, it is possible to address this field of exploration by using powerful and effective means. In recent years, **The Echo Nest** ⁴ company collected useful information on a multitude of songs and now offers the possibility to get the key for each of these songs. This huge database allows us to discover the nature of the keys with the help of data that was not available until now.

This study provides a synthesis of all these information collected in the year 2012. The study relies solely on information provided by **The Echo Nest** and was conducted by an independent researcher not being connected in any way to **The Echo Nest** or any other group, whatever it is.

¹ http://en.wikipedia.org/wiki/Equal_temperament

² http://en.wikipedia.org/wiki/Popular_music

³ https://en.wikipedia.org/wiki/Major_and_minor#Keys

⁴ https://en.wikipedia.org/wiki/The_Echo_Nest

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Data

1. Input File

The data source file comes from the Website **Million Song Dataset** ¹ and contains a selection of songs covering several musical genres. The selection criteria ² have been established by **Million Song Dataset**. This voluminous text file ³ is accessible to all.

Each line of this file is related to a song identified by a code **SO** (Song). The file may contain multiple versions of the same song. Each version of a song is identified by a code **TR** (Track). In addition, the name of the artist and the song title are added to the line :

```
<TRMMCZF128F9339016><SOIQGUI12A8C142E46><Leonard Cohen><Suzanne>
```

Some additional elements have been added to those already provided for each song. These elements, designated as "attributes", come directly from **The Echo Nest** database. These attributes Terms, Key (or tonality) ⁴, Mode, Energy and Tempo complete the full range of information that were used to carry out this study :

```
<TRMMCZF128F339016><SOIQGUI12A8C142E46><Leonard Cohen><Suzanne>...<pop,rock,folk> <D> <m> <0.264> <65>
```

The Echo Nest constantly improves the quality of his information and the attribute values may have evolved since this data was collected in year 2012.

2. Data Redundancy

A data cleanup allowed to remove 127,166 lines corresponding to different versions of the same songs. Through this process it was impossible to identify with certainty the original version of each song. Also, versions of a song performed on stage, sung by another artist, or being titled in foreign language could not be removed.

All in all, 806,782 songs performed by 69,900 artists were retained for this study.

¹ <http://labrosa.ee.columbia.edu/millionsong>

² <http://labrosa.ee.columbia.edu/millionsong/faq>

³ [Additional Files 1: List of all track Echo Nest ID](#)

⁴ <https://en.wikipedia.org/wiki/Tonality>

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Attributes

1. Energy

The Energy ¹ attribute was created by **The Echo Nest** to measure the perception of power that emerges from a song. The value assigned to each song is always set between 0 and 1. The calculation of this value is based on measurable data such as the loudness ², rhythm and tempo. The methods used to calculate this value are not available. However, **The Echo Nest** assures that these methods are applied consistently for all songs.

2. Key, Mode, Tempo

The Echo Nest gets the key ³, mode and tempo of a song by identifying ⁴ all the sounds that originate from the song. In this present study, it was impossible to assess with certainty whether the data provided by **The Echo Nest** are totally accurate. A second study could improve the quality of this information by using the attributes *Key Confidence* and *Mode Confidence* provided by **The Echo Nest**.

3. Terms

The Echo Nest uses various terms ⁵ that provide information such as the nationality of the artist, the kind of music he likes and any other feature that distinguishes this artist. The musical genre to which he belongs does not always appears on top of assigned terms and also more than one genre may be attributed to that same artist.

For the purposes of this study, the first three terms attributed to the artist have been retained to ensure that at least one musical genre will appear among these terms. Thus, each song could be associated with at least one musical genre, for example :

Song	Artist	Terms
I Love You	John Doe	Country, Nashville, Folk
You Love Me	Jane Doe	Signer, Blues, R&B
Je T'aime	Joe Bleau	French, Canada, Folk
: : :	: : :	: : :
: : :	: : :	: : :

It is important to take in account that terms are assigned to the artists instead of the songs. In addition, the terms given for each artist may have evolved after the data collection.

Arbitrarily determining a single and unique musical genre for each artist would have required significant work and could not be done impartially. Therefore, some songs may have been classified in more than one musical genre.

¹ <http://developer.echonest.com/acoustic-attributes.html>

² <http://en.wikipedia.org/wiki/Loudness>

³ http://developer.echonest.com/raw_tutorials/faqs/faq_04.html

⁴ http://web.media.mit.edu/~tristan/Papers/PhD_Tristan.pdf (Page 57 3.6)

⁵ <http://developer.echonest.com/docs/v4/artist.html#terms>

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Values

The Echo Nest Energy, key and mode attributes allowed to create a chart displaying a percentage usage and an average Energy value for each key.

- **Percentage**

Each song increments by one unit a counter corresponding to its key. Finally, the percentage usage calculated for each mode and each key is obtained by division :

Calculation of percentage usage for each mode :

- **Major mode** : $(538,939 \text{ songs} / 806,782 \text{ songs}) * 100 = 66.8\%$
- **minor mode** : $(267,843 \text{ songs} / 806,782 \text{ songs}) * 100 = 33.2\%$

Calculation of percentage usage for **CM** and **Am** :

- **C Major** : $(81,643 \text{ songs} / 538,939 \text{ songs}) * 100 = 15.1\%$
- **A minor** : $(36,209 \text{ songs} / 267,843 \text{ songs}) * 100 = 13.5\%$

(see Appendix 2)

- **Energy**

The Energy value of each song is added to a counter corresponding to its key. Finally, the average Energy value for each mode and each key is obtained by division :

Calculation of the average Energy value for each mode :

- **Major mode** : Sum of Energy values for major keys / 538,939 songs = .549
- **minor mode** : Sum of Energy values for minor keys / 267,843 songs = .571

Calculation of the average Energy value for **CM** and **Am**:

- **C Major** : Sum of Energy values for **CM** key / 81,643 songs = .532
- **A minor** : Sum of Energy values for **Am** key / 36,209 songs = .548

(see Appendix 2)

The Echo Nest Data Study

Analysis

1. Tempo

Charts **A** and **B** (Appendix 1) show, in varying proportions, the important contribution of the tempo in the calculation of the Energy value. The correlation between the tempo and energy is clear.

The physical structure of instruments ensures that songs are easier to play in certain keys. For example, a song is technically easier to execute in **CM** rather than **DbM**. The tempo, therefore the energy, could logically be mitigated if a song was played in **DbM** instead of **CM**.

The chart **A** (Appendix 1) shows however that the **DbM** Energy value is higher than the value of **CM**. If the difficulty of execution was an important factor then the Energy value of **DBM** should match the value displayed for **Ebm** which is equally difficult to master.

There is thus no correlation between the energy of a key and its difficulty of execution.

2. Percentage

Chart **C** (Appendix 1) shows the percentage usage for each major and relative minor key ¹ (e.g. **CM** and **Am**, **DM** and **Bm**, etc.). This chart confirms that the major keys **C**, **D** and **G** are those that prefer musicians, as well as are the relative minor keys **A**, **B** and **E** in the minor mode. This fact is already widely accepted by musicians.

This is quite logical since a major key can be transposed ² into a relative minor key using the same notes at a different starting point of the scale ³ :

	C Major								A minor								
Scale	C	D	E	F	G	A	B		Scale	A	B	C	D	E	F	G	

For example, a song in **CM**, built on the popular chord progression **CM-GM-Am-FM** ⁴, can be transposed and replayed with those same chords in **Am** into a different chord progression **Am-FM-CM-GM**. Therefore it makes sense that the percentage usage obtained for key **CM** can also be high for its relative minor **Am**.

¹ http://en.wikipedia.org/wiki/Relative_key

² [http://en.wikipedia.org/wiki/Transposition_\(music\)](http://en.wikipedia.org/wiki/Transposition_(music))

³ [http://en.wikipedia.org/wiki/Scale_\(music\)](http://en.wikipedia.org/wiki/Scale_(music))

⁴ http://en.wikipedia.org/wiki/I-V-vi-IV_progression

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3. Energy

Chart C (Appendix 1) shows the average energy calculated for each major and relative minor key (**CM** and **Am**, **DM** and **Bm**, etc...). The symmetry of the curves is obvious in this chart, unlike the chart D where the curves displayed for parallel keys ¹ (**CM** and **Cm**, **DM** and **Dm**, etc.) are asymmetric.

In terms of energy, major and relative minor keys show a relationship that does not exist into parallel keys. Major and relative minor keys share a same energy which is commonly lower in the major key. This aspect suggests that the sadness occurs with more intensity than joy.

4. Energy Networks

Each song is based on a chord progression, for example :

Major Progression I-IV-V ²

Tonic	I	C	Db	D	Eb	E	F	Gb	G	Ab	A	Bb	B
Subdominant	IV	F	Gb	G	Ab	A	Bb	B	C	Db	D	Eb	E
Dominant	V	G	Ab	A	Bb	B	C	Db	D	Eb	E	F	Gb
								✓				✓	

Minor Progression i-iv-v

Tonic	i	C	Db	D	Eb	E	F	Gb	G	Ab	A	Bb	B
Subdominant	iv	F	Gb	G	Ab	A	Bb	B	C	Db	D	Eb	E
Dominant	v	G	Ab	A	Bb	B	C	Db	D	Eb	E	F	Gb
								✓	✓				

These tables highlight the existence of two distinct energy networks :

- Chords which belong to major **Bb** and minor **G** progressions match the keys that display the lowest Energy values into chart C.
- Chords which belong to both major and minor **Gb** progressions match the keys that display the highest Energy values into chart D.

Any chord progression using one of these chords will have its energy attenuated or enhanced depending on the nature of that chord. For example, using the major chord **Bb** in a song will mitigate the energy of that song. The same logic applies for the major chord **Gb** that will raise the energy of a song regardless of the chord progression used.

To a lesser extent, **AM** and **Bm** chords will enhance energy of any chord progression that will make use of these chords.

¹ https://en.wikipedia.org/wiki/Parallel_key

² [https://en.wikipedia.org/wiki/Degree_\(music\)](https://en.wikipedia.org/wiki/Degree_(music))

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5. Musical genres

Guitar, piano and computers contributed to the emancipation of a multitude of musical genres. Each genre has a kind of energy signature of its own.

The collection of terms attributed to artists allowed to group the songs into various musical genres ¹ :

	Songs		Genre
001	260,721	[32%]	ROCK
002	144,079	[18%]	POP
003	073,273	[09%]	JAZZ
004	051,659	[06%]	HIP HOP
005	050,262	[06%]	ELECTRONIC
006	042,810	[05%]	BLUES
007	040,234	[05%]	PUNK
008	035,723	[04%]	RAP
009	035,415	[04%]	FOLK
010	033,754	[04%]	COUNTRY
011	032,093	[04%]	METAL
012	030,764	[04%]	R&B
013	029,044	[04%]	SOUL
014	025,730	[03%]	REGGAE
015	024,276	[03%]	INDIE ROCK
016	023,269	[03%]	DANCE
017	022,978	[03%]	LATIN
018	020,036	[03%]	ELECTRONICA
019	019,844	[03%]	HOUSE
020	019,678	[02%]	TECHNO
021	019,578	[02%]	ALTERNATIVE ROCK
022	018,495	[02%]	HARD ROCK
023	017,717	[02%]	HEAVY METAL
024	017,227	[02%]	INDIE
025	016,199	[02%]	SINGER-SONGWRITER

Some genres and subgenres have been merged in order to obtain a larger number of songs to be analyzed for a single group. In all, on 806,782 original songs, 538,558 songs performed by 55,463 artists have been grouped into 12 different genres.

Genres folk, country, jazz, blues, latin, indie rock, r&b (including the Soul subgenre), reggae, electronic (including electronica, techno, and house subgenres), hip hop (including the rap subgenre), heavy metal (including the metal subgenre), and punk have been selected for this study.

Several songs associated with a genre are also associated with pop and rock genres. Both genres have therefore been ignored in order to reduce a possible duplication of data.

Charts into Appendix 1 show the percentage of use and the average Energy value of each key. Charts are grouped by type of orchestration :

- Genres **1** to **5** where the guitar is leading.
- Genres **6** to **10** that include keyboards, guitar and brass ².
- Genres **11** and **12** where synthesized sounds and samples are strongly involved ³.

¹ http://en.wikipedia.org/wiki/List_of_popular_music_genres

² http://en.wikipedia.org/wiki/Horn_section

³ [http://en.wikipedia.org/wiki/Sampling_\(music\)](http://en.wikipedia.org/wiki/Sampling_(music))

The Echo Nest Data Study Conclusion

Each key has a special energy. This fact might be explained by a combination of factors such as the particular structure of instruments, musical conventions, trends and culture.

An Energy value does not reveal the nature of a key. However, it indicates how intense an emotion manifests itself. It reveals the place occupied by that key in the register of emotions. This whole set of values is already a very solid foundation for musicologists ¹, music therapists ² and musicians ^{3 4} who wish to deepen their knowledge in a field where the guidelines are difficult to establish.

The next step, which aims among other things to confirm the results of this study, could allow us to better understand the nature of each key. Each song expresses through his text an emotion that conjugates verbs **to have**, **to be** and **to love** in a past, present or future tense. The compilation of these conjugations on a wide range of songs should allow us to give a more precise meaning to the notion of Energy value.

Serge Daigno

¹ <https://en.wikipedia.org/wiki/Musicology>

² https://en.wikipedia.org/wiki/Music_therapy

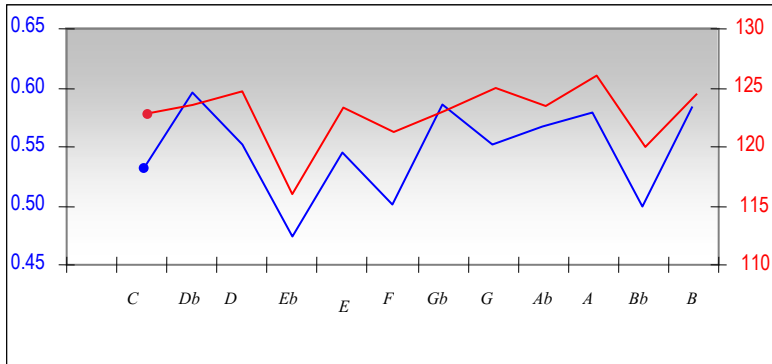
³ <http://www.hooktheory.com/trends>

⁴ <http://music.cbc.ca/#/blogs/2012/9/The-Signature-Series-on-CBC-Music>

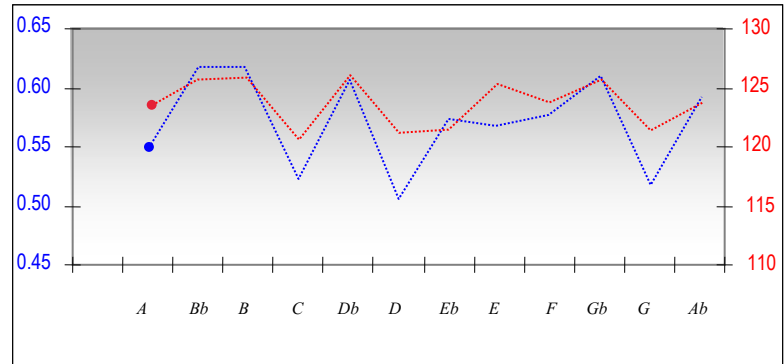
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Appendix 1

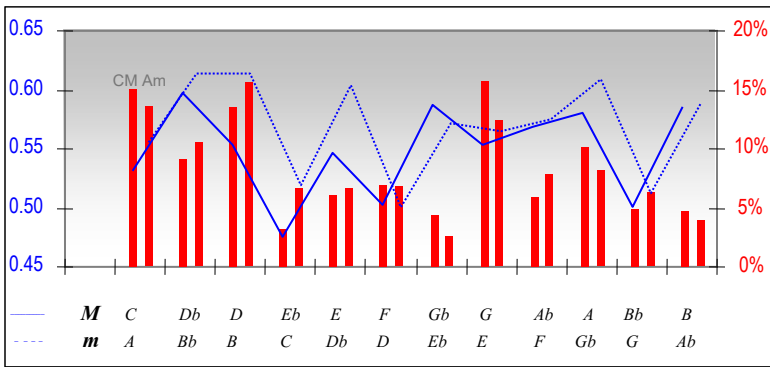
A. Tempo and Energy – Major keys



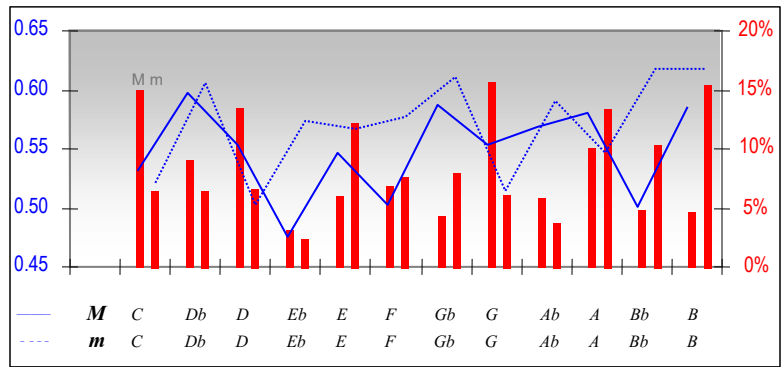
B. Tempo and Energy – Minor keys



C. Relative keys [806,782 songs – 69,900 artists]

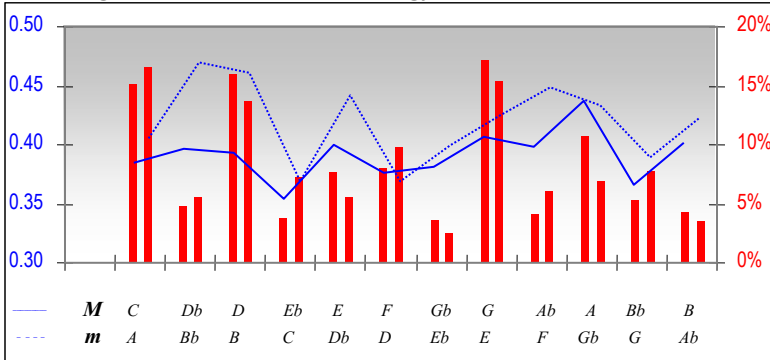


D. Parallel keys [806,782 songs – 69,900 artists]



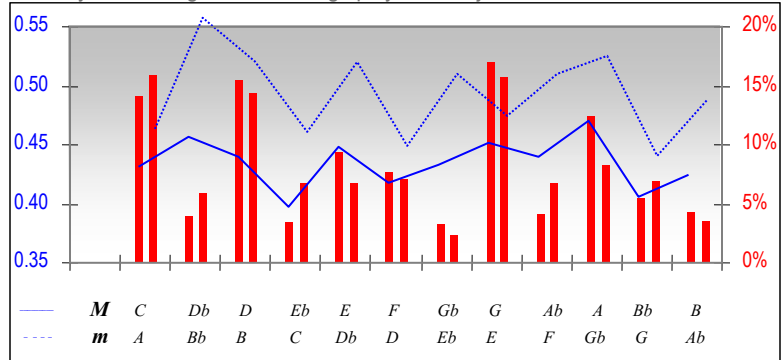
● **1. Folk [35,415 songs - 2,903 artists]**

Of all the genres, Folk has the lowest Energy value.



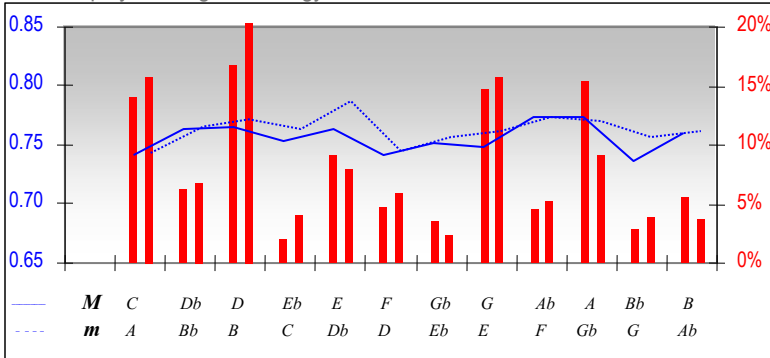
● **2. Country [33,754 songs - 2,402 artists]**

Country has the highest % of songs played in Major mode.



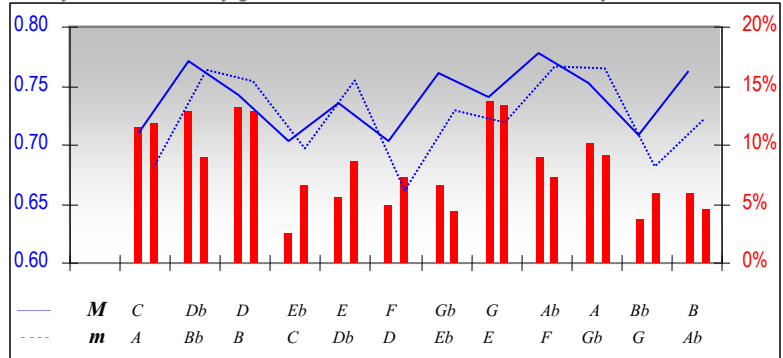
● **3. Punk [40,234 songs - 2,909 artists]**

Punk displays the highest Energy value overall.



● **4. Heavy Metal [44,250 songs - 2,935 artists]**

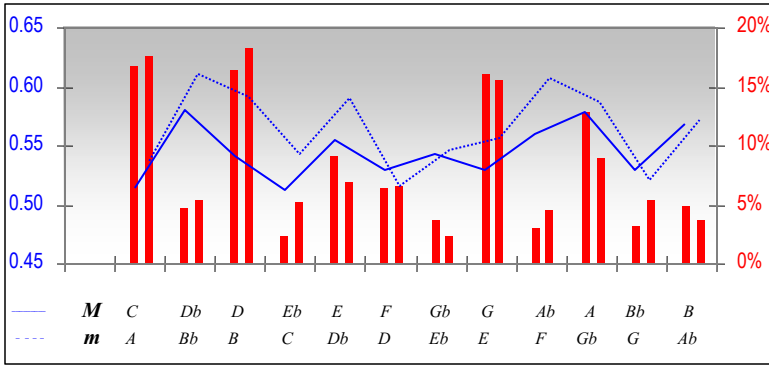
Heavy Metal is the only genre where E is the most used tonality in minor mode.



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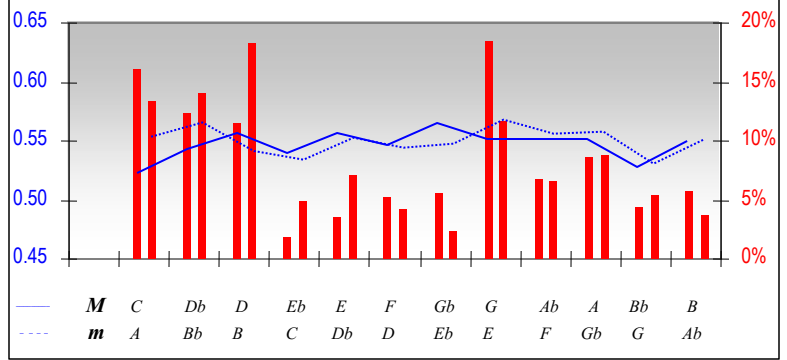
Appendix 1 (Continued)

● 5. Indie Rock [24,276 songs - 2,428 artists]

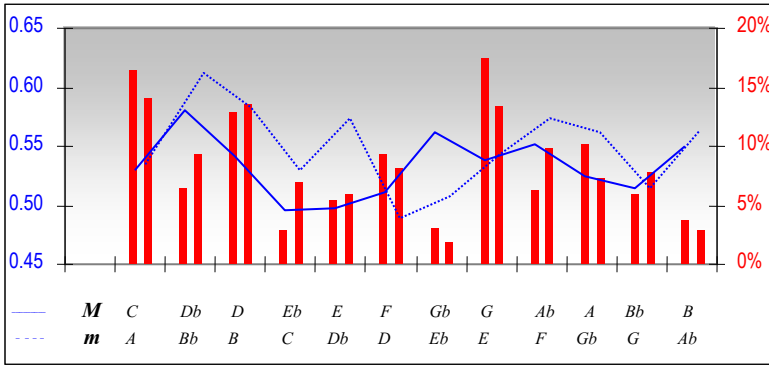


● 6. Reggae [25,730 songs - 2,571 artists]

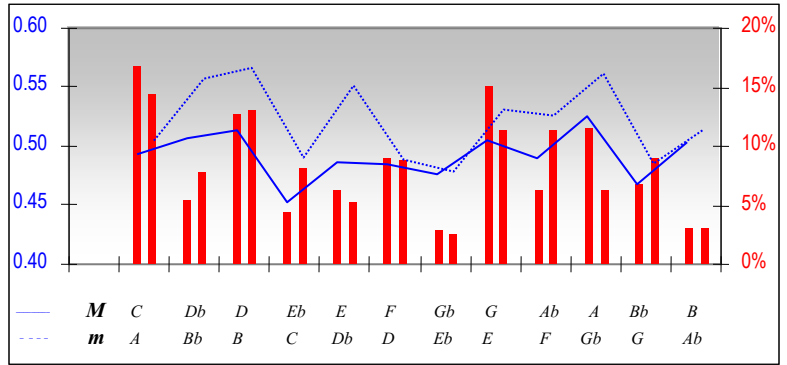
Reggae displays the most stable Energy value.



● 7. Latin [22,978 songs - 2,271 artists]

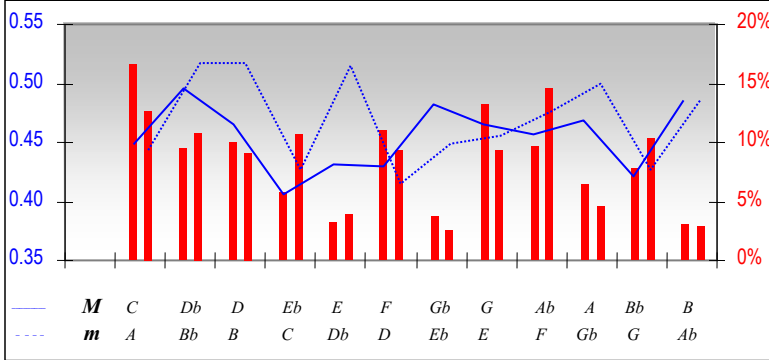


● 8. Blues [42,810 songs, 3,215 artists]

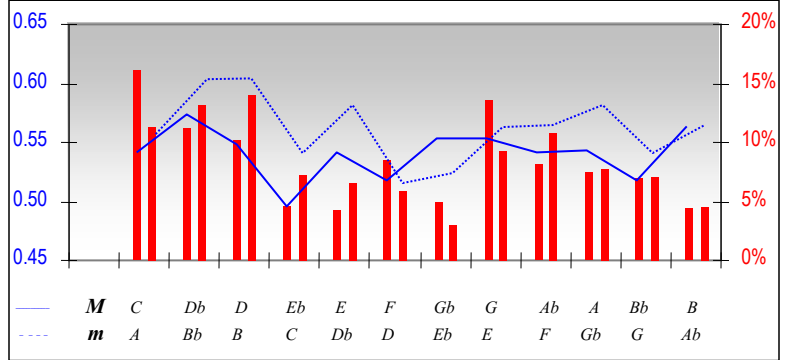


● 9. Jazz [73,273 songs - 6,791 artists]

Jazz is the only genre where F is the most used tonality in minor mode.

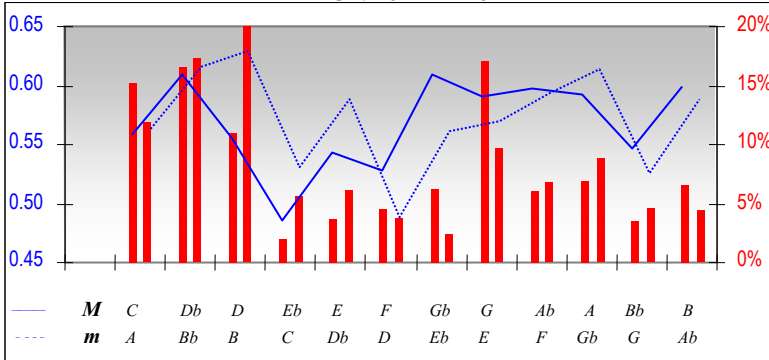


● 10. R&B [46,936 songs - 4,905 artists]



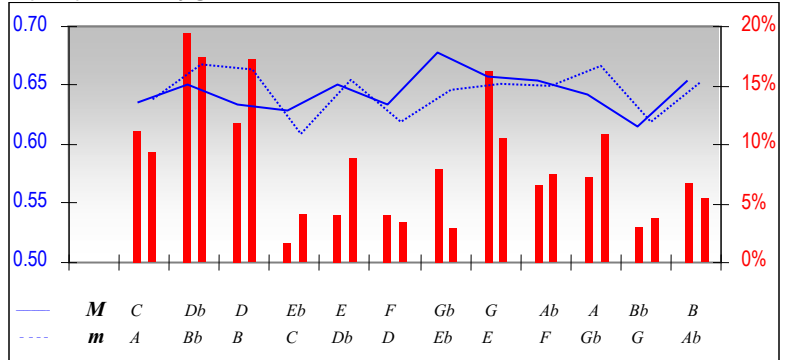
● 11. Electronic [86,522 songs - 12,072 artists]

Electronic has the lowest % of songs played in Major mode.



● 12. Hip Hop [62,380 songs - 10,061 artists]

Hip Hop is the only genre where DbM and Bbm tonalities are the most used.



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Appendix 2

1. Percentage usage for each Major and minor key per musical genre

	%	C	Db	D	Eb	E	F	Gb	G	Ab	A	Bb	B
806,782	M	66.8	15.1	9.1	13.5	3.2	6.1	7.1	4.4	15.7✓	5.9	10.2	4.8
	m	33.2	6.6	6.5	6.7	2.6	12.2	7.7	8.1	6.3	3.9	10.5	15.4✓
Folk		74.9	15.1	4.7	16.0	3.7	7.7	7.9	3.5	17.1✓	4.1	10.7	4.2
		25.1	7.2	5.6	9.7	2.5	15.3	6.0	6.9	7.7	3.5	16.5✓	13.6
Country		84.4	14.0	3.9	15.5	3.4	9.3	7.6	3.3	17.0✓	4.1	12.3	4.2
		15.6	6.7	6.8	7.0	2.3	15.7	6.8	8.3	6.9	3.6	15.8✓	14.3
Blues		73.3✓	16.8	5.4	12.7	4.4	6.2	9.0	2.8	15.1	6.2	11.6	3.1
		26.7	8.1	5.2	8.7	2.5	11.3	11.2	6.2	8.9	3.0	14.3✓	12.9
Indie Rock		70.6	16.7✓	4.8	16.4	2.4	9.1	6.5	3.7	16.1	3.1	12.9	5.0
		29.4	5.2	6.9	6.6	2.4	15.4	4.6	8.9	5.3	3.7	17.5	18.1✓
Punk		70.8	14.1	6.2	16.8✓	2.0	9.1	4.8	3.6	14.8	4.6	15.4	5.6
		29.2	4.1	7.9	5.9	2.4	15.6	5.2	9.0	3.8	3.7	15.6	20.1✓
Heavy Metal		61.9	11.5	12.8	13.2	2.6	5.6	5.0	6.6	13.8✓	8.9	10.1	6.0
		38.1	6.6	8.5	7.3	4.4	13.2✓	7.2	9.0	5.8	4.6	11.7	12.7
Latin		68.4	16.4	6.4	12.9	2.9	5.5	9.4	3.1	17.5✓	6.2	10.1	3.8
		31.6	6.9	5.8	8.0	1.8	13.2	9.7	7.2	7.7	2.9	13.9✓	13.5
Reggae		62.4	16.1	12.4	11.5	1.9	3.6	5.2	5.6	18.5✓	6.7	8.7	5.7
		37.6	4.9	7.0	4.2	2.4	11.6	6.6	8.8	5.4	3.7	13.2	18.1✓
Jazz		62.8✓	16.6	9.5	10.0	5.7	3.3	11.0	3.7	13.3	9.7	6.4	3.0
		37.2	10.6	3.8	9.2	2.6	9.2	14.5✓	4.6	10.3	2.8	12.6	9.1
R&B		65.6✓	16.1	11.2	10.1	4.5	4.2	8.4	5.0	13.5	8.2	7.4	4.4
		34.4	7.2	6.6	5.9	3.0	9.3	10.8	7.7	7.0	4.5	11.2	13.9✓
Electronic		58.0	15.3	16.6	11.0	2.1	3.8	4.6	6.2	17.1✓	6.1	7.0	6.6
		42.0	5.5	6.0	3.7	2.3	9.5	6.7	8.7	4.5	4.4	11.8	19.8✓
Hip Hop		59.7	11.2	19.5✓	11.8	1.7	4.0	4.1	7.9	16.2	6.6	7.3	6.7
		40.3	4.1	8.7	3.3	2.9	10.5	7.4	10.7	3.7	5.4	9.3	17.1✓

2. Average Energy value for each Major and minor key per musical genre

	Avg.	C	Db	D	Eb	E	F	Gb	G	Ab	A	Bb	B
806,782	M	.549	.532	.598✓	.553	.476	.546	.502	.588	.553	.569	.580	.585
	m	.571	.522	.606	.504	.574	.568	.577	.612	.515	.591	.548	.618✓
Folk		.392	.385	.397	.393	.354	.400	.377	.382	.407	.398	.438✓	.402
		.409	.358	.431	.358	.389	.414	.438	.422	.379	.412	.396	.458✓
Country		.435	.431	.456	.439	.398	.448	.418	.433	.451	.440	.470✓	.425
		.493	.461	.519	.449	.509	.475	.509	.524	.440	.488	.464	.558✓
Blues		.492	.493	.507	.514	.452	.487	.484	.476	.505	.489	.526✓	.503
		.521	.491	.551	.489	.479	.531	.526	.562	.486	.514	.504	.566✓
Indie Rock		.545	.514	.581✓	.541	.513	.555	.529	.543	.530	.560	.578	.569
		.566	.544	.591	.518	.547	.558	.608	.588	.523	.572	.537	.592
Punk		.756	.741	.763	.765	.753	.764	.742	.752	.748	.773	.774✓	.761
		.764	.764	.788✓	.745	.757	.763	.774	.771	.758	.763	.744	.772
Heavy Metal		.739	.711	.771	.743	.703	.736	.704	.761	.741	.778✓	.753	.762
		.725	.698	.754	.662	.730	.719	.766✓	.764	.683	.722	.681	.754
Latin		.533	.530	.580✓	.541	.496	.498	.511	.562	.538	.552	.524	.550
		.550	.531	.575	.490	.508	.544	.575	.562	.515	.564	.541	.582
Reggae		.547	.523	.543	.556	.539	.556	.547	.565✓	.551	.551	.552	.550
		.552	.536	.555	.545	.549	.569✓	.558	.559	.532	.552	.555	.544
Jazz		.455	.448	.495✓	.466	.406	.432	.429	.482	.465	.456	.469	.485
		.469	.428	.514	.416	.449	.456	.476	.500	.428	.486	.445	.517✓
R&B		.541	.542	.573✓	.549	.495	.541	.518	.554	.553	.542	.544	.563
		.563	.543	.583	.517	.526	.565	.566	.583	.543	.565	.559	.607✓
Electronic		.568	.558	.610✓	.555	.485	.543	.528	.609	.590	.598	.592	.600
		.573	.532	.589	.491	.562	.571	.594	.615	.528	.590	.565	.630✓
Hip Hop		.645	.635	.650	.634	.629	.650	.634	.678✓	.657	.654	.643	.655
		.645	.610	.654	.619	.646	.651	.649	.666✓	.620	.653	.638	.664