Multi-Dimensional Computer-Driven Quantitative Analysis of the Music and Lyrics of the Beatles

Cedric McDougal
Northeastern University

Data retrieved through computer-driven quantitative textual analysis of Beatles lyrics was combined with data retrieved from computer-driven quantitative auditory analysis of Beatles music in order to build an extensive dataset that can answer a wide variety of multi-dimensional questions. This dataset spans the Beatles' career and provides metrics such as danceability, energy, positive emotions, negative emotions, self-referential lyrics, big words, etc. It can be indexed by year, album, songwriter, chart position, and more. This study explores a number of general relationships and trends within the data in order to best demonstrate the types of questions that can be answered with this dataset.

Though the official Beatles career lasted less than a decade, they were extremely prolific during their time as a band. They wrote and performed over 200 songs, many of which were never recorded, never released, or released after the band broke up. Throughout this time, their songwriting style changed dramatically, and they consistently broke new ground in the pop music world. There has been much study of these changes using a number of different techniques. Riley[1] analyzes the music and lyrics within the context of the historical events of the Beatles' lives. Inglis[2] examines how the group's approach to love changed over time by categorizing their love songs. Whissell[3] and Petrie[4] use computer-driven linguistic analysis to reveal the emotional and stylistic progression of the band's lyrics over time. This study aims to expand on the last approach by combining computer-driven linguistic analysis with computer-driven auditory analysis.

The effectiveness of computer-driven analysis is important to consider before relying on it as a tool for study. Computers have a few distinct disadvantages over human beings in the task of parsing natural language. A computer program might not be flexible enough to correctly parse a sentence with multiple subjects, it often cannot handle words that are not in the English dictionary, and it is limited in its ability to extract high level patterns from an unstructured source of data.[5] On the other hand, a computer program can quickly analyze large amounts of text, eliminate human error, avoid human bias, elucidate a high number of interconnected patterns, and deterministically achieve results.[6] Furthermore, research has already suggested that computer-driven textual analysis can correctly deduce stylistic and emotional properties when given the lyrics to Beatles music.[7] This suggests that the use of computer-driven textual analysis is acceptable for the purpose of this study.

Currently, computers are better at analyzing audio than they are at parsing natural language. A program can verifiably extract (or fail to extract) tempo, key, mode, duration, time signature, and loudness from a given audio file. A computer program can also effectively extrapolate more generic concepts, such as how suitable a song is for dancing, the intensity of a song, and the presence of spoken words.[8] These

1 Riley, Tim. "For the Beatles: Notes on Their Achievement," *Popular Music*, Vol. 6, No. 3, Beatles Issue (Oct., 1987): 257-271.

2 Inglis, Ian. "Variations on a Theme: The Love Songs of the Beatles," *International Review of the Aesthetics and Sociology of Music*, Vol. 28, No. 1 (Jun., 1997): 37-62.

3 Whissell, Cynthia. "Traditional and Emotional Stylometric Analysis of the Songs of Beatles Paul McCartney and John Lennon," *Computers and the Humanities*, Vol. 30, No. 3 (1996): 257–265.

4 Petrie, Keith J., James W. Pennebaker and Borge Sivertsen. "Things We Said Today: A Linguistic Analysis of the Beatles," *Psychology of Aesthetics, Creativity, and the Arts*, Vol. 2, No. 4, (2008): 197–202.

5 Bright, Melissa A. and Dawn O'Connor. "Qualitative Data Analysis: Comparison Between Traditional and Computerized Text Analysis," *The Osprey Journal of Ideas and Inquiry*, All Volumes, Paper 21 (2007): 1.

6 Bright and O'Connor, "Qualitative Data Analysis," 2–3.

7 Whissell, " Emotional Stylometric Analysis," 257.

8 Schindler, Alexander and Andreas Rauber. "Capturing the Temporal Domain in Echonest Features for Improved Classification Effectiveness:" 4, accessed April 22, 2013. http://www.ifs.tuwien.ac.at/~schindler/pubs/AMR2012.pdf

metrics would be extremely difficult and bias-prone for a human to produce. This suggests that the use of a computer is also suitable for auditory analysis within this study.

Method

Selection of Songs

This study uses all the songs written by John Lennon, Paul McCartney, George Harrison, and/or Ringo Starr that were released on Beatles albums or as singles between 1962 and 1970. This included thirteen albums (including *Yellow* Submarine and *Magical Mystery Tour*) and 184 songs.

Information about each song, such as year, album, and songwriter, were taken from Wikipedia.[9] For the most part, this dataset uses the primary songwriter when a song was credited to Lennon-McCartney, but was written by one or the other. Some songs, such as "One After 909," have the songwriter listed as "Lennon, with McCartney." The Wikipedia dataset was the most convenient and comprehensive dataset available. However, it is possible that some of the information may be incorrect. If this is the case, the amount of incorrect data is likely minimal enough to have little affect on the results, as Wikipedia can usually be trusted for basic facts about well known subjects.

Lyrical Analysis

The lyrics were downloaded from two sources (beatlesnumber9.com/; sing365.com). No cleansing was done on the lyrics, and not every song was checked for accuracy. This means some analysis might be thrown off by a repeated chorus, vocal sounds, non-English words, or incorrect lyrics. These insufficiencies may affect the metrics related to lyrical analysis and should be taken into account when interpreting the results.

The lyrical analysis itself was done with a program called Linguistic Inquiry and Word Count (LIWC).[10] LIWC uses a special dictionary of almost 4,500 words, each of which defines one or more categories or subcategories, such as sadness, overall affect, verb, past tense, etc. This dictionary has been in development for over ten years and has undergone numerous updates and revisions. When LIWC analyzes a text, it uses this dictionary to give the text a score for each word-type category. The free version of LIWC, which was used for this study, gives access to seven language dimensions, which are explained on the LIWC website. "Self references" are words such as "I," "me," and "my." People who use a lot of self-referential words tend to be "more insecure, nervous, and possibly depressed." "Social words" reference other people. A high use of social words suggests that a person is outgoing. "Positive emotion words" suggest a person is optimistic. "Negative emotion words" suggest a person is anxious or neurotic. "Overall cognitive words" are words that "reflect how much people are actually thinking about their writing topic." "Articles" (a, an, the), in large amounts, suggest a person is more concrete. "Big words" (words with more than six letters) suggest a person is less emotional and more detached. These interpretations have been crafted through research, but do not apply to every situation. The metrics themselves must still be viewed within the context of their generation.

Along with the use of LIWC, a custom script was written to calculate simple lyrical metrics, including word count, unique word count, and longest word.

Auditory Analysis

The auditory analysis was done with a program called The Echo Nest (the.echonest.com). The Echo Nest offers an online API through which developers can upload music to be analyzed. The analysis provides simple metrics, such as tempo, key, duration, mode (major/minor), time signature, and loudness (dB). It also offers some derived metrics. "Danceability" is determined by tempo, rhythm stability, beat strength, and overall regularity. "Energy" is determined by dynamic range, perceived loudness, timbre, onset rate, and general entropy. The Echo Nest can also determine the amount of spoken words ("speechiness") and whether the recording is a live performance or not ("liveness"). The audio files that were uploaded for analysis were from Blackboard (blackboard.neu.edu).

One of the major downsides to The Echo Nest is that it cannot detect multiple keys. This is especially important with the music of the Beatles because their songs often change keys. Any analysis that uses the key must be tweaked to account for this limitation.

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9 Wikipedia. "List of songs recorded by the Beatles." Last modified April 21, 2013. http://en.wikipedia.org/wiki/List_of_songs_recorded_by_the_Beatles.

10 Pennebaker, James W., Roger J. Booth and Martha E. Francis. *Linguistic Inquiry and Word Count* (2007). Accessed April 22, 2013. http://www.liwc.net/index.php

Results

Danceability

It is generally accepted that the earlier Beatles songs were much better to dance to than the later Beatles songs, because many later songs, such as "Revolution 9" and "Tomorrow Never Knows" were a lot more experimental and non-traditional. This suggests that the danceability metric retrieved from The Echo Nest should decrease over time. In fact, this is not what the data shows (Fig. 1). 1963 has one of the lowest danceabilities, and 1969 has one of the highest. To explain this unexpected result, it is important to look at how the danceability is calculated. According to Jason Sundram, an Echo Nest developer, danceability is calculated using "beat strength, tempo stability, overall tempo, and more."[11] Using this description, the results start to make sense. Many of the songs written in 1969 are not high energy songs, but they have a steady beat. For example, "Two of Us" is a quiet, relaxed song, but it is supported by a regular punctuation from the kick drum. On the other hand, many of the songs the Beatles wrote in 1963 have a steady beat, but a melody that wanders all over, such as in "There's a Place" and "Not a Second Time." This wandering melody could contribute to the lower danceability score. Lastly, the middle years demonstrate the least danceability, which is to be expected because that is when the Beatles wrote some of their most non-standard music.

Fig. 1

	% Danceability	# of Songs
1962	59	4
1963	52	18
1964	63	24
1965	58	30
1966	49	16
1967	50	27
1968	51	36
1969	57	30
1970	39	1

Note. "% Danceability" is the average across songs.

Another test of the danceability metric is to examine the danceability of each songwriter. When viewed from this perspective, the metric behaves in a much more foreseeable manner (Fig. 2). Harrison has the lowest danceability, which is to be expected because of his songs that include free-form Indian rhythms. Lennon has the next lowest danceability. This is likely due to his tendency to write his music to fit the rhythm of his lyrics. McCartney's higher danceability is also expected due to his use of more standard rhythms. Finally, Ringo has the highest danceability, a side effect of his less creative songwriting skills.

Fig. 2

	% Danceability	# of Songs
Harrison	48	22
Lennon	52	74
Lennon/McCartney	55	13
McCartney	58	70
All	60	3
Starkey	61	2

Note. "% Danceability" is the average across songs.

Big Words

Just the presence of big words in a song is not enough to imply any meaningful insight. However, it is a compelling starting place for a more in depth conversation. The trend of big words in Beatles lyrics is an interesting one. (Note that "big words" are words with more than six letters.) The increase in big words within an album is almost directly proportional to the year that the album was released (Fig. 3). This suggests that the Beatles matured as lyricists over time. To truly quantify how they matured, however, more metrics must be considered. For example, the unique word count over time is a good indicator of more diverse lyrics, and thus more mature

Fig. 3

	Year	% Big Words
With the Beatles	1963	3.26
Beatles for Sale	1964	4.75
A Hard Day's Night	1964	4.88
Please Please Me	1963	5.61
Help!	1965	6.44
Rubber Soul	1965	6.47
Yellow Submarine	1968	8.07
Revolver	1966	8.09
The Beatles	1968	8.60
Magical Mystery Tour	1967	8.98
Let It Be	1970	10.31
Abbey Road	1969	10.42
Sgt. Pepper	1967	13.03

Note. "% Big Words" is the average across songs. "Big words" are words with more than six letters.

11 http://runningwithdata.com/post/1321504427/danceability-and-energy

Fig. 4

	Year	# of Unique Words
With the Beatles	1963	43
Abbey Road	1969	47
Please Please Me	1963	47
Let It Be	1970	56
Beatles for Sale	1964	56
Magical Mystery Tour	1967	56
The Beatles	1968	59
Help!	1965	61
A Hard Day's Night	1964	61
Yellow Submarine	1968	64
Revolver	1966	65
Rubber Soul	1965	66
Sgt. Pepper	1967	89

Note. "# of Unique Words" is the average across songs. Vocal noises such as "aaahhh" and "ooohhh" were excluded.

songwriting. However, the big words trend does not hold true for the average unique word count per album (Fig. 4). This is surprising because so many of the Beatles' earlier songs were extremely repetitive. This is the reason *With The Beatles* and *Please Please Me* have such a low unique word count – these albums feature songs such as "Love Me Do," which has only 19 different words in it. It is interesting that *Let It Be* and *Abbey Road*, the last two albums released by the Beatles, are ranked in the bottom four for unique words. This might be explained by the Beatles reuse of old songs for these albums, as well as their desire to get back to their roots. Also, the band was starting to fall apart by the late '60s, so it is possible that they simply didn't invest as much energy into their lyrics as they had during their peak. Many critics consider their peak to be *Revolver*, *Rubber Soul*, and *Sgt. Pepper*, so it is no surprise that these three top the unique word count chart.

Mode and Emotion

One of the benefits of the new dataset is the ability to examine correlations between the musical characteristics and the lyrics of Beatles songs. One interesting relationship to examine is between the mode (major/minor) of the music and the emotional characteristics of the lyrics. Typically, a song in a major mode will be mostly positive and a song in a minor mode will be mostly negative. This does not seem to hold true for Beatles songs (Fig. 5). Songs in both major and minor keys have a higher percentage of positive emotion words than negative emotion words. This suggests that the Beatles have predominantly positive lyrics and use mostly major

Fig. 5

	% Negative	% Positive	# of Songs
Major	1.63	3.76	113
Minor	1.16	2.65	31
Average	1.53	3.52	144

Note. All values are an average across songs.

keys. However, there are a number of problems with this analysis. Firstly, a lot of Beatles songs are in more than one key, and The Echo Nest cannot deduce multiple keys. To account for this, 40 songs with possible key changes[12] were excluded from the analysis. Secondly, the Beatles rely heavily on modified chords and they don't stick exclusively to notes within the key signature. These factors make it a lot more difficult to algorithmically extract the key from an audio file. Some websites list key signatures of various Beatles songs, but there does not seem to be a freely available, comprehensive list of key signatures for all Beatles songs. There also seems to be some disagreement as to the actual key of some songs. Ultimately, the lack of available data and the lack of means to automatically extrapolate the key signature means that it is not a suitable metric for analysis.

Popularity

One of the available data points is the position each song reached on the US and UK music charts. Combining this with the other available data could provide insights into the aspects of Beatles music that helped the band become so famous. It also becomes possible to compare the interests of the US and the UK.

The data suggests (Fig. 6) that danceability is somewhat important to a number one hit, but not excessively so. Hits in both the UK and the US had slightly higher danceability percentages. This could be because the Beatles had a huge presence outside of dancing venues. For example, their hits got a lot of radio air time and television broadcasts, though more so the former since the latter was mostly covers.

Energy was of significantly different importance in the UK and the US. In this context, "energy" is determined by dynamic range, perceived loudness, timbre, onset rate, and general entropy. It is not immediately obvious why energy was so important to hits in the UK and not important to hits in the US.

12 http://www.beatlesbible.com/forum/recording-and-musicology/key-changes-in-beatles-songs/

Fig. 6

	UK #1	US #1	Not #1
Danceability	57	56	54
Energy	66	46	54
Social words	17	12	14
Positive words	3	6	4
Negative words	0.9	0.8	2
Cognitive words	8	6	8
# of songs	11	6	151

Note. All values are percentages except "# of songs." "UK #1" is songs that reached number one in the UK and *not* the US. "US #1" is songs that reached number one in the US and *not* the UK. "Not #1" is songs that never reached number one.

Fig. 7

	Lennon	McCartney
Danceability	52	56
Energy	58	46
Self-reference words	9	10
Social words	15	12
Positive words	3.5	6
Negative words	2.0	0.8
Cognitive words	7.8	6
Big words	7.9	8.6
Avg. unique words	61	60
# of songs	74	70
# of Num. 1 hits	12	14

Note. All values are percentages except "Avg. unique words, ""# of songs" and "# of Num. 1 hits." "# of Num 1. 1 hits" includes both UK and US charts.

Perhaps listeners in the UK were looking for a stronger distraction from the political situations in Britain. Or perhaps listeners in the US simply valued other aspects of the music more than energy. Political rock, such as that of The Doors and Bob Dylan, was growing in popularity in the US during the '60s.

The rest of the data, however, suggests that this interpretation is backwards. Hits in the UK had a much higher percentage of social words, while hits in the US had a much higher percentage of positive words. Perhaps UK listeners were not looking for a distraction, but for an energetic nationalistic congregation. US listeners, on the other hand, might have been disillusioned by the Vietnam War and nation-wide riots, so instead of feeling a love for their fellow citizens, they sought to alleviate their pains through positive music.

Either way, negative songs did not find their way to number one in either country, suggesting that to reach the largest audience a group needs a large number of positive songs. This could have been one contributer to the Beatles wild success, because the majority of their songs were positive, with an average of 3.9% positive emotion words per song, and an average of 1.7% negative emotion words per song.

Lennon vs. McCartney

John Lennon and Paul McCartney were extremely prolific as song writers, but they both approached their songs in such different ways. Lennon has been described as introspective and moody, while McCartney is known for writing impersonal narrative songs. Lennon's music is constructed around his unique lyrical rhythms, while McCartney often wrote the music before the lyrics. Lennon is known for his "cosmic perspective"[13] while McCartney is considered to be less introspective but more stylistically eclectic.

The available data corroborates some of these considerations. For example, Lennon uses a lot more negative emotion words as well as words related to thinking and pondering. McCartney, on the other hand, uses more positive emotion words and uses slightly more large words. For the most part, however, both songwriters look very similar in the light of these metrics. They wrote almost the same number of songs and had almost the same number of hits. They also use almost the same average number of self-referential words. While their differences are so prominent on a case by case basis, when averaged out the they become a lot less contrasting. With more data and more accurate data, different trends might emerge.

Discussion

The widespread general analysis of the Beatles' music and lyrics revealed a number of interesting trends and surprises, from Ringo writing the most danceable songs to the lack of unique words in the last two albums to the odd differences in number one hits between the UK and the US. The dataset compiled for this study is verbose and flexible enough to quantitatively examine the Beatles' musical career from hundreds of different angles. This study demonstrates the variety of possible questions, but barely scratches the surface.

There is still a lot of room for improvement, however. To begin, the quality of parts of the data can be improved. For example, the data from Wikipedia should be cross-checked against a more reliable source. Also, The Echo Nest has limitations in key

13 Petrie, " Things We Said Today," 197.

signature discovery that could be overcome by finding transposed copies of the Beatles music, although it is important to make sure that the transposed music is actually in the proper key signature.[14] It could also be helpful to add more granular date information. Currently, the only reference to time is the year each song was written. It is possible to extend this to include the month and day they were written, as well as the month and day they were released. It could also be interesting to include a list of all albums on which a song appeared, as opposed to just the major UK album release. Finally, using a paid version of LIWC would allow access to dozens of more textual dimensions, which would greatly expand the number of questions that the dataset could answer. It might even help to also use another program, such as Diction.[15] In order to ensure accuracy of the textual analysis, it would also be necessary to manually review all of the lyrics. The current analysis operated on a set of lyrics that could have incorrect words, misspellings, and a number of other defects. Each of these improvements could also be extended to a larger array of Beatles music. This study excluded songs released after the group disbanded and songs performed but not written by the band. Including these other songs would allow for even more flexibility of analysis.

The program used to compile the dataset was built in a modular fashion to make it easy to extend with new information. There is a single script that merges together results from any number of modules. Each module can access data from anywhere, but must dump a CSV file with a "title" column that is used to join the rows from all the modules. For example, if a new data source becomes available that has a list of all key signatures in Beatles songs, incorporating this data would only require accessing that data source and creating a file that has the song title and key signature in each row.

Dataset Availability

I don't plan to make the dataset itself available right away, as I am still not sure what the licenses are for the free versions of The Echo Nest and LIWC. However, I do plan to put my code for compiling the dataset on my public GitHub account (https://github.com/mcdougal) at some point in the near future.

14 http://www.dmbeatles.com/forums/index.php?topic=11882.0

15 http://www.dictionsoftware.com/

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