The head of the raw data looks like this:

artist_name	album_name	track_name	genre_clean	key_clean	mode_clean	maste
Ed Sheeran	÷ (Deluxe)	Eraser	Pop	Ab	min	Ab r
Ed Sheeran	÷ (Deluxe)	Castle on the Hill	Pop	D	maj	D n
Ed Sheeran	÷ (Deluxe)	Dive	Pop	E	maj	E n
Ed Sheeran	÷ (Deluxe)	Shape of You	Pop	Db	min	Db r
Ed Sheeran	÷ (Deluxe)	Perfect	Pop	Ab	maj	Ab n
Ed Sheeran	÷ (Deluxe)	Galway Girl	Pop	A	maj	A n
Ed Sheeran	÷ (Deluxe)	Happier	Pop	C	maj	C n
Ed Sheeran	÷ (Deluxe)	New Man	Pop	G	maj	G n
Ed Sheeran	÷ (Deluxe)	Hearts Don’t Break Around Here	Pop	G	maj	G n
Ed Sheeran	÷ (Deluxe)	What Do I Know?	Pop	Db	min	Db r

For each album, we have the album name and genre, artist, as well as the names of each song. For each Spotify. I’ve concatenated the mode and the key to create a variable called *master_key*, which contains th songs in the cleaned dataset.

Number of Songs Per Genre

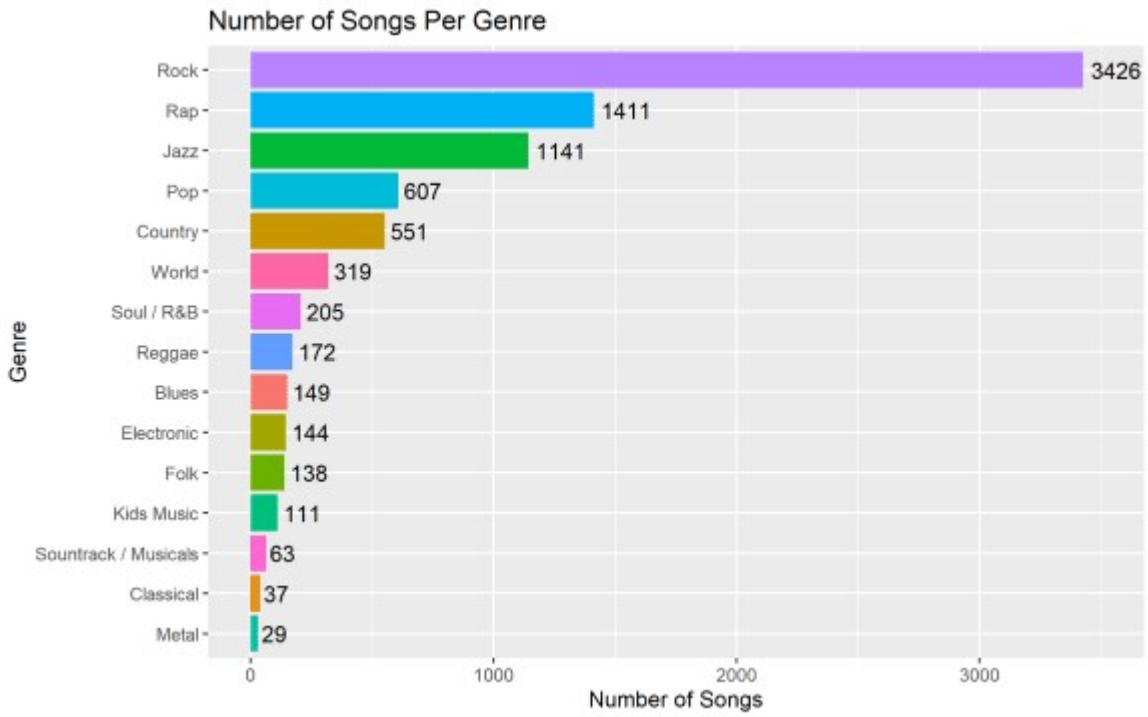
In this blog post, we are interested in the musical properties of the songs in my music collection. We will l our data, and we will also see how these musical qualities differ across genres.

As a first step in this process, let’s take a look at the frequency of the genres in our data set:

```
# load the libraries we'll need
library(plyr); library(dplyr)
library(ggplot2)
library(tidyverse)
library(gplots)
library(RColorBrewer)
library(kableExtra)

# barplot of song counts per genre
raw_data %>%
  group_by(genre_clean) %>%
  summarise(num_songs=n()) %>%
  ggplot(aes(x = reorder(genre_clean, num_songs),
             y = num_songs, fill = genre_clean)) +
  geom_bar(stat = 'identity') +
  geom_text(aes(label = num_songs),
            size = 4, hjust = -0.15) +
  coord_flip(ylim = c(0,3500)) +
  labs(x = "Genre", y = "Number of Songs",
       title = 'Number of Songs Per Genre' ) +
  theme(legend.position = "none")
```

Which yields the following plot:



The top three genres are rock (3,426 songs), rap (1,411 songs) and jazz (1,141 songs). This matches my
It must be noted that “rock” is somewhat of a catch-all genre, encompassing many different sub-categorie
they are primarily guitar-driven.

Mode Analysis Across All Songs

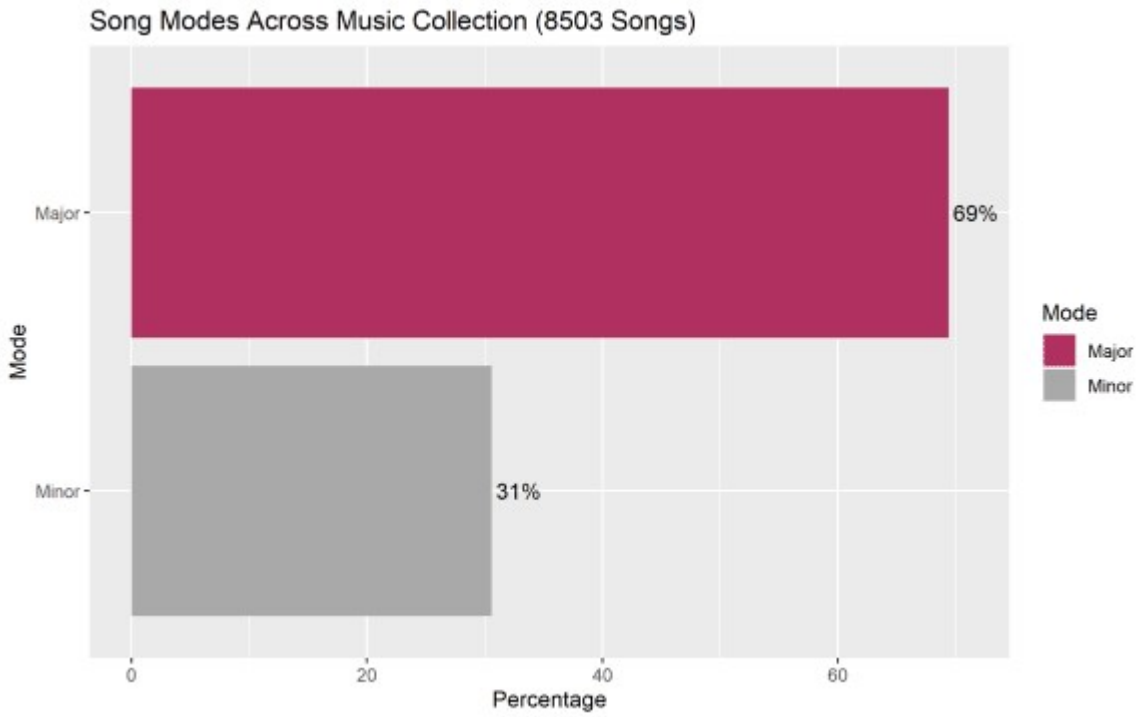
Let’s first take a look at the mode of the songs. The mode is a property that describes the tonal base of a
and if you’re interested in learning more this Wikipedia page is a good place to start. A simple heuristic w
sound happy and upbeat, whereas minor modes sound sad and dark.

In this analysis, we will include all of the 8,503 songs across all of the genres. We can make a barplot of t

```
# barplot of mode across songs
raw_data %>%
  select(genre_clean, mode_clean) %>%
  group_by(mode_clean) %>%
  # counts of songs per mode
  summarise(Percentage=n())  %>%
  # calculate the % of songs per mode
  mutate(Percentage=Percentage/sum(Percentage)*100,
         mode_clean = recode(mode_clean, 'maj' = 'Major',
                             'min' = 'Minor'))  %>%
  # pass to ggplot
  ggplot(aes(x = reorder(mode_clean, Percentage) , y = Percentage, fill =
  geom_bar(stat = 'identity') +
  # specify the colors
  scale_fill_manual(name = "Mode", values = c('maroon', 'darkgrey')) +
  # add the value labels above the bars
  geom_text(aes(label = paste(round(Percentage, 0), "%", sep = '')), hjus
  # flip the axes
  coord_flip(ylim = c(0,71)) +
  # add the titles
  labs(x = "Mode", y = "Percentage",
```

```
        title = 'Song Modes Across Music Collection (8503 Songs)' )
```

Which yields the following plot:



Across all of the songs in my music collection, nearly 70% of them are in major modes. I was expecting th
modes, but was somewhat surprised by the size of the difference.

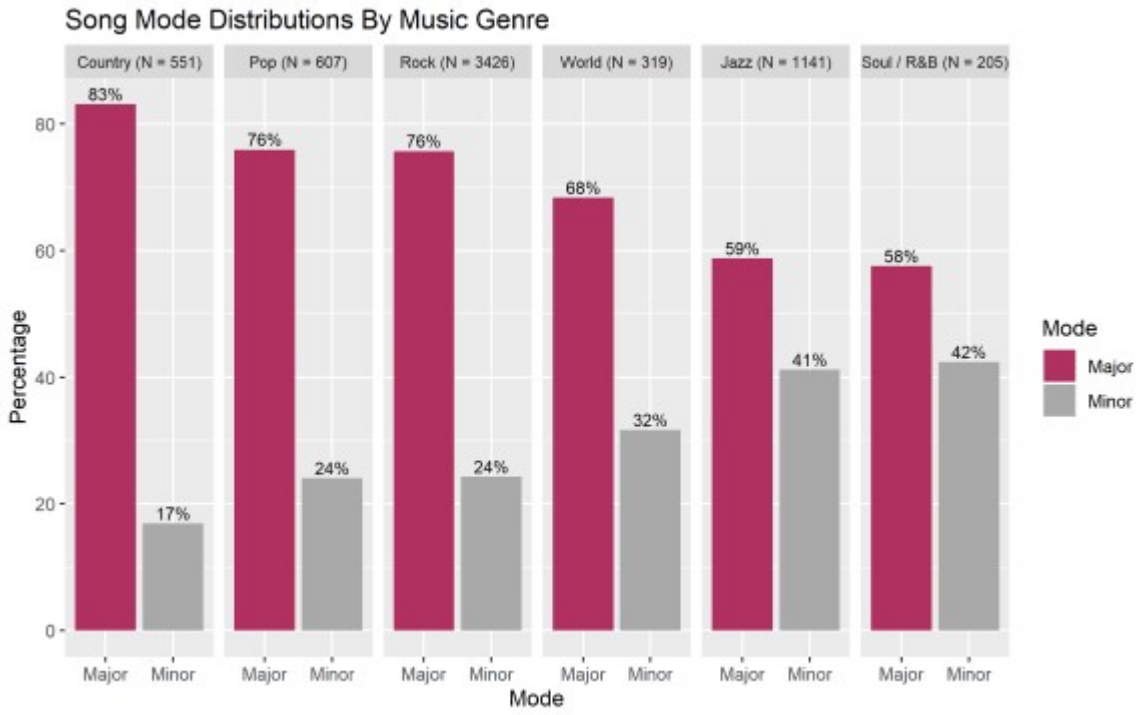
Mode Analysis By Genre

Now let's look at the distribution of modes across genres. In the analysis below, I only select genres with
that we're focused here on musicians playing instruments, whereas rap music is often built around sampl
there are definitely exceptions!).[1]

Let's look at the modes across the different genres:

```
# song mode by genre
raw_data %>%
  group_by(genre_clean) %>%
  # count the number of songs per genre
  # and include that in our genre text
  mutate(num_per_genre = n(),
         master_genre = paste(genre_clean, " (N = ", num_per_genre, ")",
  # select genres with 200+ songs and remove rap songs
  filter(num_per_genre > 200 & genre_clean != "Rap") %>%
  select(master_genre, mode_clean) %>%
  # group by genre and mode
  group_by(master_genre, mode_clean) %>%
  # calculate the number per mode per genre
  summarise(Percentage=n()) %>%
  # group by genre
  group_by(master_genre) %>%
  # and calculate the % per mode per genre
  # order the factor for the plot
```

```
# (ordered by % major mode)
mutate(Percentage=Percentage/sum(Percentage)*100,
       genre_clean_factor = factor(master_genre,
                                   levels = c("Country (N = 551)",
                                              "Pop (N = 607)",
                                              "Rock (N = 3426)",
                                              "World (N = 319)",
                                              "Jazz (N = 1141)",
                                              "Soul / R&B (N = 205)")),
       mode_clean = recode(mode_clean, 'maj' = 'Major',
                           'min' = 'Minor')) %>%
# pass to ggplot
ggplot(aes(x = mode_clean, y = Percentage, fill = mode_clean)) +
# we want a bar plot
geom_bar(stat = 'identity')  +
# add the value labels to the bars
geom_text(aes(label = paste(round(Percentage, 0), "%", sep = '')),
          hjust = .5, vjust =-.3, size = 3)  +
# add the labels
labs(x = "Mode", y = "Percentage",
     title = 'Song Mode Distributions By Music Genre' ) +
# facet per genre
facet_grid(. ~ genre_clean_factor) +
# specify the colors
scale_fill_manual(name = "Mode", values = c('maroon', 'darkgrey')) +
theme(strip.text.x = element_text(size = 8))
```



There are definitely differences across genres. The genres with the most songs in “major” modes are cou
each). World, jazz and soul/r&b all have less, with jazz and soul/r&b having just under 60% of the songs i
listening to music in these genres: country, pop and rock are definitely more consistently happy and upbe

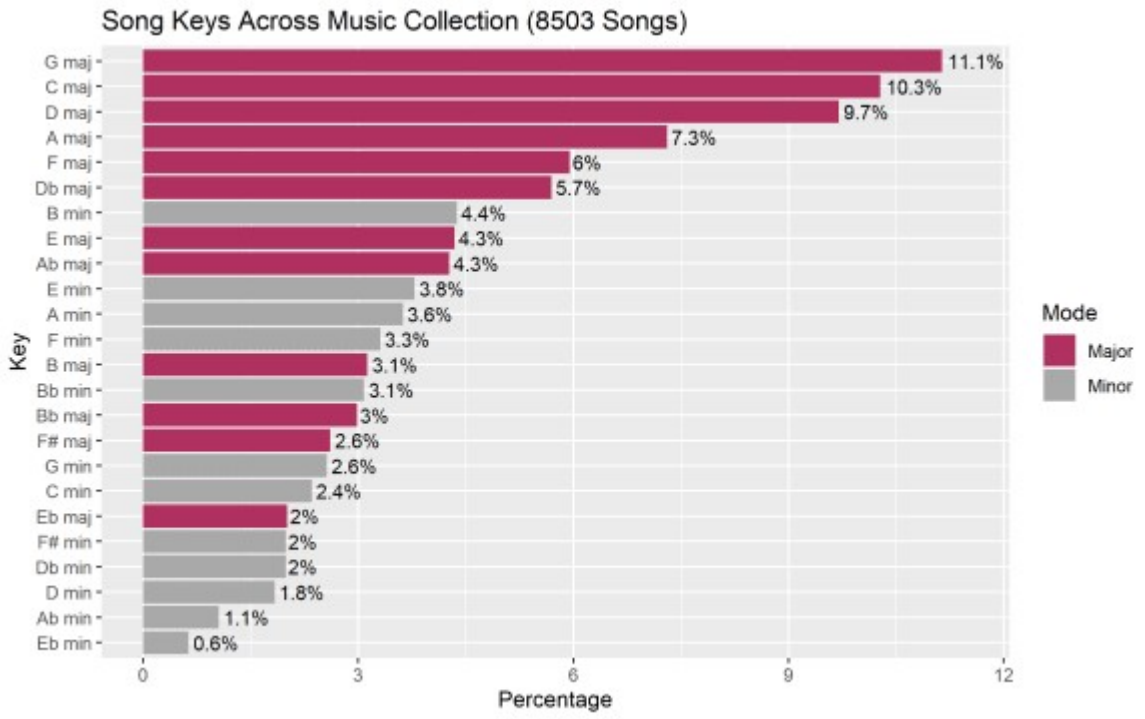
Key Analysis Across All Songs

Now let's take a look at the keys that the songs are played in. The key refers to the "group of pitches, or s
won't get into the details of musical keys here (see this Wikipedia page to learn more), but for the purpos
pitches (C, C#, D, Eb, etc.), each of which can be paired with a major or minor mode to produce a total of

We can plot the distribution of keys across all of the songs in my music collection with the following code:

```
# percentage of keys across all songs
raw_data %>%
  select(genre_clean, master_key, mode_clean) %>%
  group_by(master_key) %>%
  # calculate the number of songs for each key
  # hang on to the mode info - we'll use that
  # in our plot
  summarise(Percentage=n(),
            mode_clean = unique(mode_clean))  %>%
  # calculate the percentage of songs per key
  # recode the mode variable to make it clean
  # for the plot
  mutate(Percentage=Percentage/sum(Percentage)*100,
         mode_clean = recode(mode_clean, 'maj' = 'Major',
                             'min' = 'Minor'))  %>%
  # pass the data on to ggplot
  ggplot(aes(x = reorder(master_key, Percentage) , y = Percentage, fill =
  # we want a bar plot
  geom_bar(stat = 'identity') +
  # specify the colors
  scale_fill_manual(name = "Mode", values = c('maroon', 'darkgrey')) +
  # add the value labels
  geom_text(aes(label = paste(round(Percentage, 1), "%", sep = '')), hjus
+
  # flip the chart
  coord_flip(ylim = c(0, 11.5)) +
  # add the labels
  labs(x = "Key", y = "Percentage",
       title = 'Song Keys Across Music Collection (8503 Songs)' )
```

Which returns this plot:

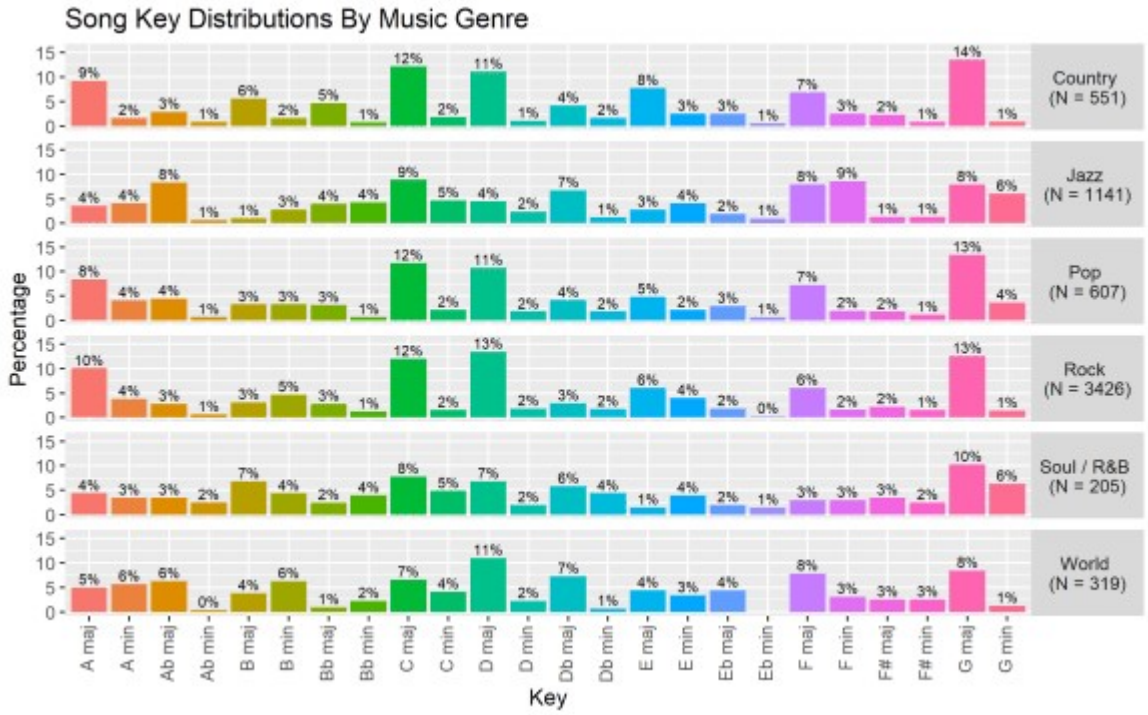


As we saw in our analysis above, the most popular keys are all in major modes. Furthermore, G, C and D is the most popular minor key.

Key Analysis By Genre

Now let's separate our analysis of key distribution by musical genre – do the patterns above differ across

```
# percentage of keys, separate per genre
raw_data %>%
  group_by(genre_clean) %>%
  mutate(num_per_genre = n(),
         master_genre = paste(genre_clean, " \n(N = ", num_per_genre, ")'
  filter(num_per_genre > 200 & genre_clean != "Rap") %>%
  select(master_genre, master_key) %>%
  group_by(master_genre, master_key) %>%
  summarise(Percentage=n()) %>%
  group_by(master_genre) %>%
  mutate(Percentage=Percentage/sum(Percentage)*100) %>%
  ggplot(aes(x = master_key, y = Percentage, fill = master_key)) +
  geom_bar(stat = 'identity') +
  # add the value labels above the bars
  geom_text(aes(label = paste(round(Percentage, 0), "%", sep = '')),
            hjust = .5, vjust =-.3, size = 2.5) +
  # rotate the x axis labels 90 degrees so they're horizontal
  # and hide the legend
  theme(axis.text.x = element_text(angle = 90, vjust = .3, hjust=1),
        legend.position = "none" , strip.text.x = element_text(size = 10(
  labs(x = "Key", y = "Percentage",
       title = 'Song Key Distributions By Music Genre' ) +
  coord_cartesian(ylim = c(0,16)) +
  facet_grid(master_genre ~ .) +
  theme(strip.text.y = element_text(size = 9, angle = 0))
```



The above graph is complete but somewhat overwhelming. We see the relative percentage within each g facet for each genre. Some keys appear to be universally popular (e.g. G major has a share of 8-14% acı frequent in some genres as compared to others (e.g. A major is relatively popular in country, rock, and pc

It is possible to eyeball every one of the 24 keys and compare differences across the genres, but we can and genres into groups. Below, we will make a simultaneous clustering of both the keys and the genres tc analysis and heatmap visualization that will make the underlying structure clearer.

Cluster Analysis + Heatmap

Preparing the Data

In order to make our heatmap, we need to extract the data we plotted above into a standalone dataset, w

```
# make the cluster data
# use tidyverse here - column to rownames
cluster_data <- raw_data %>%
  group_by(genre_clean) %>%
  mutate(num_per_genre = n()) %>%
  filter(num_per_genre > 200 & genre_clean != "Rap") %>%
  select(genre_clean, master_key) %>%
  group_by(genre_clean, master_key) %>%
  summarise(Percentage=n()) %>%
  group_by(genre_clean) %>%
  mutate(Percentage=Percentage/sum(Percentage)*100) %>%
  spread(master_key, Percentage) %>%
  replace(is.na(.), 0) %>%
  column_to_rownames(var = "genre_clean")
```

Our data set contains one row per genre, with the key row percentages contained in the columns:

```
head(cluster_data, 10) %>%
  mutate_if(is.numeric, round, 2)%>%
  kable("html", align= 'c')
```

	A maj	A min	Ab maj	Ab min	B maj	B min	Bb maj	Bb min	C maj	C min	D maj	D min	Db maj	Db min	E maj
Country	9.26	1.63	2.90	0.91	5.63	1.63	4.72	0.73	12.16	1.81	11.07	1.09	4.17	1.63	7.80
Jazz	3.59	4.12	8.33	0.61	1.05	2.81	3.94	4.29	8.85	4.65	4.47	2.37	6.75	1.23	2.80
Pop	8.40	4.12	4.45	0.66	3.29	3.29	3.13	0.66	11.70	2.14	10.71	1.81	4.12	1.81	4.78
Rock	10.04	3.82	2.77	0.64	3.06	4.70	2.77	1.23	11.97	1.55	13.46	1.78	2.89	1.69	6.01
Soul / R&B	4.39	3.42	3.42	2.44	6.83	4.39	2.44	3.90	7.80	4.88	6.83	1.95	5.85	4.39	1.46
World	5.02	5.64	6.27	0.31	3.76	6.27	0.94	2.19	6.58	4.08	10.97	2.19	7.21	0.63	4.39

The data above are expressed in percentages. For our cluster analysis, we need to scale the data so tha
deviation of one.

We scale our data and display the resulting data set with the following code:

```
# scale the data
cluster_data_scaled <- scale(cluster_data)

# what does it look like?
round(cluster_data_scaled,2) %>%
  kable("html", align= 'c')
```

	A maj	A min	Ab maj	Ab min	B maj	B min	Bb maj	Bb min	C maj	C min	D maj	D min	Db maj	Db min	E maj
Country	0.89	-1.66	-0.81	-0.03	0.83	-1.36	1.33	-0.90	0.96	-0.90	0.45	-1.75	-0.58	-0.20	1.45
Jazz	-1.15	0.25	1.65	-0.41	-1.42	-0.64	0.73	1.33	-0.41	0.97	-1.55	1.13	0.93	-0.52	-0.77
Pop	0.58	0.25	-0.11	-0.35	-0.32	-0.34	0.11	-0.94	0.77	-0.69	0.34	-0.12	-0.62	-0.07	0.10
Rock	1.18	0.02	-0.87	-0.38	-0.43	0.52	-0.17	-0.59	0.88	-1.08	1.18	-0.19	-1.34	-0.16	0.65
Soul / R&B	-0.86	-0.29	-0.58	1.98	1.42	0.33	-0.42	1.09	-0.85	1.12	-0.84	0.19	0.41	1.92	-1.37
World	-0.64	1.42	0.72	-0.81	-0.09	1.49	-1.58	0.02	-1.35	0.59	0.42	0.74	1.20	-0.98	-0.07

Making a Heatmap

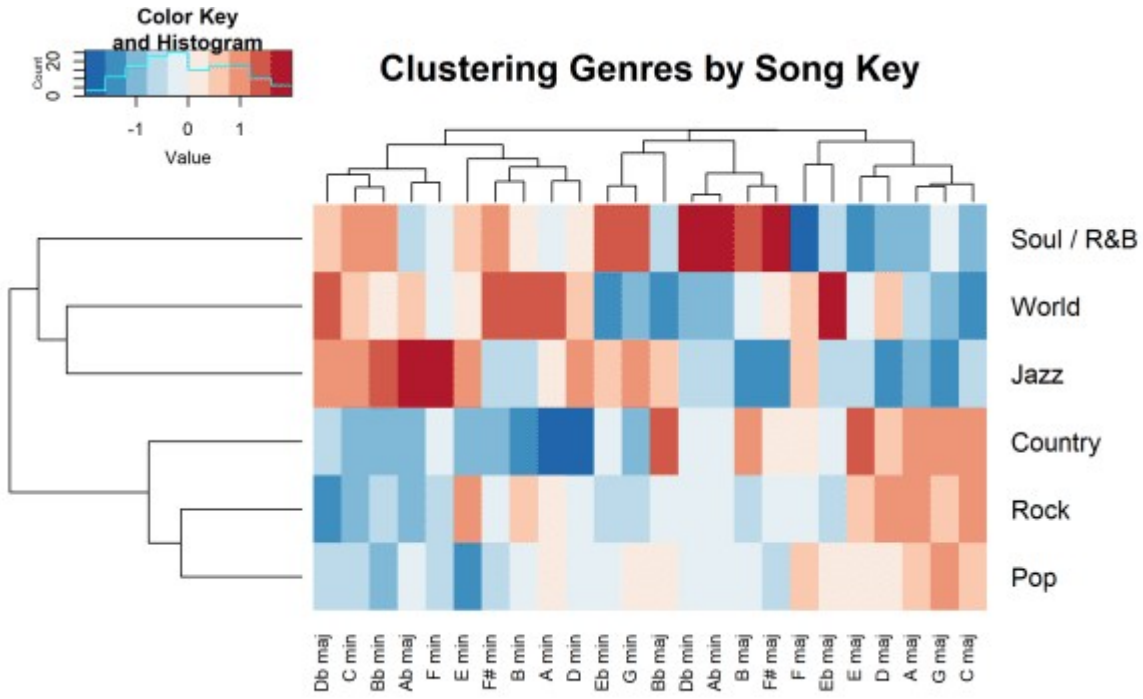
We are finally ready to make our heatmap. Heatmaps allow one to visualize clusters of samples and featu
clustering of the rows (musical genre in our case) and columns (keys in our case) of a matrix, ordering th
This makes it easy to see groupings present in both axes (clusterings of genres and clusterings of keys ir
songs in a given key for each genre, scaled per key) are represented with colors in the cluster solution.

Let's use the gplots package to produce our heatmap:

```
# red-blue color palette
# red is high, blue is low
hmcol = rev(colorRampPalette(brewer.pal(9, "RdBu"))(10))
heatmap.2(cluster_data_scaled,
          # we've already scaled the data above
          # so we turn of scaling here
          scale = c("none"),
          # show histogram on color key
          density.info=c("histogram"),
          # turn off tracing in the plot
```

```
    trace=c("none"),
    # specify our color palette
    # (defined above)
    col = hmcol,
    # set the font size for
    # row labels
    cexRow=1.3,
    # set the margins so we see
    # all axis labels
    margin=c(5, 7),
    # set the plot title
    main = 'Clustering Genres by Song Key')
```

Which returns the following plot:



The plot shows a simultaneous clustering of the genres (the rows of our input matrix) and of the keys (the standardized scores to the clustering algorithm, and the legend in the upper-left hand corner of the plot sh scores. Specifically, higher values are colored in red, while lower values are colored in blue. For each col

Clusters of Genres

We see two main genre clusters. The cluster on top groups together soul/r&b, world, and jazz music (with cluster). The second cluster of music genres groups country, rock and pop music together (within this clus

Clusters of Keys

The clustering of keys is a little more complicated, as there are 24 of them. The right-most cluster groups C. We see several sub-clusters here, including a grouping of E, D, A, G, and C, which which we'll discuss

The left-most cluster includes 10 keys, 8 of which are minor. The left-most sub-cluster includes Db, C mir

Genre / Key combinations

How are the genres separated by their use of different keys?

For the soul/r&b, world and jazz cluster, the keys colored in red at the upper-left hand side of the plot are genres are more likely to be in Db, C minor, Bb minor, and to some extent Ab and its relative minor F min two). Interestingly, these keys all have a lot of “flats.”

For the country, rock and pop cluster, the keys colored in red at the lower-right hand side of the plot are m in these genres are more likely to be in C, G, A, D, and E. Interestingly, with one exception (C), these key

Interpretation

What factors influence the key a song is played in?

In my experience, there are at least 3 things that can influence the key a song is played in:

1. **Vocal range of the singer** (not applicable for instrumental songs). Simply put, the requirements of highest and lowest notes in the vocal part) must match the natural range of the singer (e.g. which r without straining their voice). Selecting the key that best matches the singer’s vocal range allows fo
    - Although the vocal ranges of the singers in my music collection surely influence some of the different vocalists across the albums and the genres for us to see a systematic push towards
2. **“Easy” vs. “Hard” Keys.** When first learning to play music, particularly if learning how read scores those with fewer accidentals (sharps and flats). This makes it easier to read first pieces of music, b sharp or flat when reading them in the score. “Easier keys” therefore have fewer sharps and flats, s respectively), D and Bb (two sharps/flats, respectively), and A and Eb (three sharps/flats, respectiv
    - We do not see a systematic over-representation of the “easy keys” (e.g. those with fewer sha some over-representation of keys with relatively few sharps among country, rock and pop mu and E major are all more common in these musical genres. Interestingly, the corresponding rock, and pop music.
    - It appears that soul/r&b, world and jazz music are played in harder keys with more flats. Spe (5 flats), C minor (parallel minor to Eb; 3 flats), Bb minor (parallel minor to Db; 5 flats), and A and its parallel minor F minor (4 flats).
3. **The different instruments that are playing on a given song.** Different instruments have specific in. In particular, when playing music with different instruments, practical considerations tied to the i key. I see the potential impact of two such considerations in the data presented above:
    - Not all instruments play in the same keys. Piano, guitar, trombone, flute, among others, all p played on the instruments matches the pitch that corresponds to the note C. Other instrume saxophones, clarinets) instruments play in different pitches (e.g. Concert Bb or Eb), which m the pitch does not correspond to Concert C.
        - As we saw above, soul/r&b, world and jazz music (genres which are more likely to fea lot of flats. This is no doubt done in part to accomodate the wind instruments, most of section instruments (e.g. bass, guitar, and piano, which all play in Concert C). If we co (Ab and its parallel minor F minor; 4 flats), trumpets and tenor saxophones (Bb instrur instruments) play in F (1 flat). By choosing a somewhat more “complicated” concert ke see this balancing act play out in our data, with soul/r&b, world and jazz music played instruments a slightly easier key for a given song.
    - Open chords on the guitar. Open chords are chords that include one or more “open” strings down with one’s finger in order to play a note that fits in the chord). In essence, open chords among the first chords that one learns when starting to play the guitar. Examples of keys tha D, A and E.
        - These are precisely the chords that dominate in our country, rock and pop music clust driven, especially in comparison with soul/r&b, world and jazz music.

Implications for Musicians

What does this analysis teach us about playing music in different genres? I think there are 3 takeaways fo

1. Focus on the major modes. Across all of the songs, just about 70% were in in major modes, with e want to play world, soul/r&b or jazz, focus a bit more on the minor modes. Nevertheless, across ge modes.

2. If you want to play country, rock, and pop, you can pick a handful of relatively easy major keys (mo your time getting comfortable in them. For example, if you were very comfortable in C, G, D, A and current data for country, rock, and pop. If you add F to the mix, you're at around 60%. The compara are around 30% to 35%, respectively. Which leads to the final implication:

3. If you want to play jazz, soul/r&b, or world music, it's a good idea to be comfortable with a lot of ke are more spread out across the different keys. Given the relatively high frequency of songs with ma bad idea to get comfortable playing in keys with flats.

Caveats and Limitations

We should keep in mind that we are not examining a representative sample of songs; at the end of the da patterns examined here match my experience as a musician playing songs in different genres with differe

Summary and Conclusion

In this blog post, we examined the musical properties of songs in my digital music collection.

We first examined modes across all songs and saw that around 70% of the songs were in major modes, v upbeat and happy. However, the ratio of major to minor modes was not identical across the different musi percentage of major modes, whereas jazz and soul/r&b contained the smallest percentage of major mode

We then examined the distribution of musical keys. Looking across my entire music collection, G, C and D is the most popular minor key. We examined the distribution of keys across genres, and saw that some ke compared to others.

We made a heatmap to better understand the relationship between musical genres and keys. This analys containing soul/r&b, world and jazz music, and the other containing country, rock, and pop music. The so keys with a lot of flats, perhaps due to the fact that these genres typically include reed and brass instrume has flats. The country, rock and pop cluster had greater proportions of easy keys with sharps, and these l play on the guitar.

Finally, we looked at a couple of takeaway messages for the practicing musician. In sum: focus on the ma you can focus a handful of relatively easy keys with sharps. If you want to play jazz, world or sould/r&b, it keys, and in particular to be comfortable in keys with many flats!