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Measuring Anti-Vaxx Sentiment on Social Media

A thesis submitted in partial fulfillment of the requirement
for the degree of Bachelor of Arts in Government from
The College of William and Mary

by

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Accepted for Honors



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Intro

Vaccine hesitancy has been highlighted in the news, especially after measles outbreaks started across America early in 2019. WHO defines vaccine hesitancy as a “delay in acceptance or refusal of vaccines despite availability of vaccination services”. The delay or refusal to vaccinate is now internationally regarded as one of the top ten health threats to the world (Lancet, 2019). There has been a rise in the movement to not vaccinate children in the last two decades, fueled by celebrities, social media and online rhetoric (Hoffman, 2019). Vaccine hesitancy or the modern “anti-vaxx” movement has stemmed from an article which falsely asserts a correlation between childhood vaccinations and the development of autism (Wakefield, 1998). Diseases such as measles, which had been eradicated in the United States in 2000 have begun to make a reappearance and cause outbreaks across the country. While the publishing of Andrew Wakefield’s article was certainly a catalyst for the antivaccination movement, the use of the internet and the quick dissemination of information have really spurred the movement along. When the Wakefield article came out, the internet was still in Web 1.0 or mostly delivering information to people and social media was not starting yet. The years that followed the release of the article and the anti-vaxx movement picking up traction also coincided with the advent and rise of social media.

Research Question and Hypothesis

The goal of my research agenda is to explore how are anti-vaxxers so effective and persuasive on social media. My testable research question seeks to understand the difference in rhetoric among Facebook, Twitter and Reddit. I hypothesize that Facebook will be more emotive and contain fear-based language than Twitter and Reddit due to its narrative style of posts.

Paper Setup

This paper is outlined as follows: in the background section, information explaining why the anti-vaxx movement is a threat and how it is spread across social media site will be presented. This will be followed by a literature review that details the research already done surrounding social media and anti-vaxx groups and sentiment online. By reading about the research that has already taken place, it will become clear that there has not been a measure of emotions and sentiment across different social media platforms and this is what this research aims to complete. Next in the data and methods appears an explanation as to how the data was collected from three different social media sites. The reasoning for comparing the general rhetoric of the site to anti-vaxx specific rhetoric follows the data collection. Finally I present results with emotional frequency measures, p-values, and word lists from each of the sites and measures of different emotions and sentiment found in each of the different social media sites.

Background

Herd immunity is one of the most important concepts when it comes to vaccine effectiveness. To ensure that vaccines are effective for society, not just the individual who receives one, a certain percentage of the population needs to be vaccinated in order to prevent an outbreak. For the measles in school aged children, this threshold needs to be 90-95% of the population in order to maintain herd immunity (Funk, 2017). The WHO defines the threshold for herd immunity to be 95% of the population (Lancet, 2019). Online rhetoric and media in the past decade have significantly contributed to a collective action problem that leaves certain parts of society vulnerable, due to individuals' decisions not to vaccinate. While one parent may decide

that they do not want to vaccinate their child, they may also rationalize that it is just one child within their community not getting vaccinated. The issue arises when many members of a community decide to go with the same thinking, and then suddenly there is not just one unvaccinated child going into a classroom but rather ten. The disregard for the public as a whole and focusing on individual rights leads to selfish behavior that hurts others.

Immunocompromised persons are a main reason why herd immunity is so important. People who are severely immunocompromised are not recommended to have live vaccines administered to them due to the severe reaction that may occur from getting the vaccine (Arvas, 2014).

Many people remember measles as a childhood disease, one that simply resulted in a high fever and a rash, but that went away after a few days. The reality is that measles is a highly contagious disease, and especially harmful to children in the first year of life who cannot be fully vaccinated against the disease and have other risk factors due to their age (WHO, 2004). Vaccine hesitancy is evident in parents who are not giving the vaccine to their children because they are unaware of the full effect of the disease.

Parents who do not want to vaccinate may choose this because they have anecdotes from their parents that put them under the impression that the measles is not a very deadly disease. In opposition, many people who propagate their anti-vaxx beliefs online do so by employing horror stories and anecdotes that describe the “vaccine injury” or concerning medical condition contracted shortly after having a vaccine administered. They range from high fevers to seizures and general mood changes within their child after being vaccinated.

The anti-vaxx movement is not a uniquely American phenomenon. There has been an increase of measles cases worldwide by 30% in the past few years and has prompted WHO to declare it one of the most important medical threats.

The internet and social media are full of stories, information, and even medical advice from normal people who are not necessarily medically trained. While overall access to more information online has helped people manage their own care better overall (Health Applications of the Internet, 2000), it has also allowed for the outliers and extremists in society to participate in this group experiment. People who believe in other types of conspiracy theories can latch on and impart their own “wisdom” about vaccines. Conspiracists are not the same as medical professionals and as such the information that they are putting on the internet is not necessarily scientifically proven or reliable. While many have argued that those who hold conspiracist beliefs are irrational, there is an argument that defines conspiracy as “A radical and generalized manifestation of distrust that is deeply embedded in the cultural logic of modernity and is, ultimately, produced by ongoing processes of modernization in contemporary society” (Aupers, 2012). This lens shows motivated reasoning for some to ignore science that stems from a lack of trust.

The problem is that when someone goes to the internet to consult on treatment for a loved one or child, 70% of them take what they have read into consideration when deciding treatment (Kata, 2009). There has been a shift from the white lab coat clad authority figure of a doctor, to the ethos and rhetoric of persons online who may have experienced a similar scenario to the one someone Googles. Motivated reasoning may cause new parents to research and google conditions that they want to affirm as true (Dasitgar, 2019)

Some of the key findings that explain what causes vaccine hesitancy include misinformation, fear rhetoric, personal anecdotes that rely heavily on appealing to a person's ethos, and the concept of individual liberty and freedom. Several studies have been done to assess what makes online rhetoric so persuasive. They have looked at a multitude of different sites including YouTube, Facebook, Pinterest, Twitter, and Instagram (Beneck & Young, Ma& Stahl, Buck). While they all agree that ethos and fear-based rhetoric is what drives the conversation on anti-vaccination, these studies have not attempted to measure the amount of fear or ethos rhetoric across multiple platforms. Questions such as do certain platforms produce more fear-based rhetoric than others cannot be answered with the current research that has been done. The following studies can only give an in-depth dive into the specific platform they are researching.

Social media echo chambers exist for those who want to discuss same minded vaccine beliefs and much like with politics, people enjoy surrounding themselves with like-minded opinions and news feeds which tailored to their beliefs, both of which help create confirmation bias. Entire groups of parents sharing horror stories like one another other created confirmation bias, backing up each "vaccine injury" with another story of how their child had the same symptoms and physical changes post vaccination. The repetition leads to increased belief in the validation of the information, regardless of its lack of scientific evidence (Stafford BBC, 2016).

Psychological Attitudes

Anti-vaxxers or those who may be thinking about not vaccinating their children tend to do research in order to decide what they should do that would be best for their children. They do this by looking for information to better help them understand the topic. Psychologically speaking there has not been specific research to get at the motivations for people when it comes to making decisions about vaccination in the past few decades. *Vaxxed* details the religious

motivations for the anti-vaxx movement in the early 1900s and up through the 1980s but does not contain any more current research. Looking into the realm of political science and psychology however may help illuminate research that can be used to explain modern day motivations. The use of social media to learn and hear about the anti-vaxx movement is centered around parents' anxiety and needing to make a choice. Parents often feel overwhelmed and that there is information overload. Albertson and Gadarian discuss how those looking for political information engage in information seeking to attempt to ease anxieties and regulate their emotions about the topic. "In the throes of political anxiety, citizens seek information that is relevant to the source of their anxiety..." (Pg.11). Applying this to anti-vaxx communities it suggests that people look for information that they do not already have. Therefore, people will seek out social media presence and sites that talk to them about vaccines, and if they are looking directly for why they should not vaccinate their children, will likely stumble into anti-vaxx groups.

Ethos Pathos and Logos

As Aristotle defines it, Ethos is a person's ability to convince their audience of their character and ethics. Pathos is the ability to cater emotions, and finally logos refers to logic, ordering and specific words. According to Aristotle, these three elements make up the basis of a successful argument. From my initial analysis of anti-vaxx corpora, it seems as though anti-vaxx supporters may only employ ethos and pathos, often in tandem to convince their audiences that they are right or should at least highly consider the anti-vaxx point of view. One noticeable difference between the anti-vaxx and pro-vaxx community is the difference in the presentation of information. Those who are pro-vaxx typically rely simply on scientific facts and data. They do not stray into the world of emotions and you do not ever hear the story of the child who got his

measles shot and so nothing medically bad ever happened to him. Rather, with the anti-vaxx community there are posts paragraphs long with cautionary anecdotal tales of a child receiving a vaccine and then ending up in the hospital in unimaginable shape, with their life now forever and completely altered, due to that vaccine they received 72 hours ago.

Ethos, pathos, and logos could be measured within the scope of the anti-vaxx community and these findings would likely help to get at how they spread messaging so effectively. First, pathos, or the use of emotions is able to be measured. In this research the use of emotion frequency can be a measure of what types of emotions are employed by anti-vaxxers. The ethos of those in the anti-vaxx community would be slightly more challenging to measure. This measurement would likely use lexical analysis to pull instances of first person writing as these users are authority figures for spreading their anecdotes. Due to the nature of the three social media sites a uniform approach to collecting this type of data is beyond the scope of this study. While there are groups in both Facebook and Reddit that make it clear that people contributing may be authority figures to the group, Twitter has tweets which are just directed into the void of news feeds on the platform. Finally, measuring logos would likely require the presence of keywords used by not just the anti-vaxx community but the conspiracy theory community as a whole. By pulling key words from social media detailing incidents such as JFK's assassination, 9/11, and even Princess Diana's death, a pattern of logical words that describe the incidents may become apparent.

Literature Review

Smith and Graham (2019) look at Facebook using information from anti vaccination pages. They conclude that the discourse is centered on anger against the government and include references to conspiracy theory beliefs. Another one of their findings was that most of the users

within these social media groups that were commenting and posting content were women. These findings can help pinpoint what pieces of rhetoric may be helpful in crafting specific tools to determine who is most effective in spreading antivaccination rhetoric by. And while the “who” is interesting information however does not entirely get at the “how” for the information being effectively spread. This does however help inform that it is likely parents and more specifically woman, spreading this information. Understanding the psyche of the person who is using social media to collect “facts” about vaccines may help to scientifically and emotionally appeal to parents by using facts.

The book “Why Vaccines Threaten Us All” provides for a historical context surrounding the issue that predates the Andrew Wakefield published articles. It highlights the religious and conservative views that vaccines are “impure” and provides a different explanation as to why some do not believe in vaccinating. It gives a religious and moral backing for the anti-vaccination movement in the early 1900s. The book also forcibly restates the idea that fear is one of the driving motivators for antivaccination rhetoric by connecting the first waves of the movement to modern day and identifying fear as a unifying factor decades later.

The most recent context for the antivaccination movement stems from the now discredited article published by Andrew Wakefield, who claimed that there was a correlation between autism and the Measles Mumps and Rubella (MMR) vaccine (Wakefield, 1998). Religious groups in the later 1800s and early 1900s labeled vaccines to be of the devil. Modern day opposition groups have also tried to deter people from getting vaccinations based on the unsubstantiated and outrageous claim that a vaccine was made from the cell line of an aborted baby (Offit, 2015). All these instances are similar in their use of ethos and fear.

Benecke and DeYoung (2019) very clearly explain what safeguards have been put in place by social media sites in effort to combat the spread of misinformation about vaccinations. They clearly identify the “overnight narrative” of families that go to be vaccinated with the MMR vaccine and then witness a degeneration of their child the day after. Benecke and DeYoung (2019) highlight the policies that Pinterest, Facebook, and YouTube have implemented to combat the spread of anti-vaxx misinformation. As of 2018, Pinterest the search term vaccine is simply not allowed anymore and does not return any results (Washington Post, 2019). Facebook does not recommend anti-vaccination groups to individuals and YouTube does not allow users to get money from ads or other users if their channels are anti-vaccine (Shu, 2019).

Benecke and DeYoung (2019) also claim that many of the users of anti-vaxx social media are strong proponents of liberty and individual choice, especially when it comes to the government. Like many other studies Benecke and DeYoung (2019) also note that anti-vaccine communities are geographically clustered, and this can make it harder for herd immunity thresholds to be reached within a community.

Ma and Stahl (2017) perform a multimodal analysis of an antivaccine Facebook page and creates new methods of analyzing posts and comments within a group. Ma and Stahl (2017) include the use of other types of media, specifically graphic images displaying emotions to make their point, even if the image has nothing to do with vaccines. This structure follows for the comments as well.

This study finds that people look to groups such as anti-vaxx communities this for confirmation of information they find to be true. Users who post in or visit groups that discuss anti-vaxx sentiment may be seeking emotional support from other people with similar views. It

also suggests that there is a circular flow of information with people feeding in anecdotes about hospital stays and doctors' visits and spurned the same kind of content from others in the group.

According to Ma and Stahl (2017) another tactic employed by the antivaccination movement is the use of misinformation. Even though what is being written within a social media group may be factually incorrect, the reader has submitted to the authority of the writer, taking their words as true.

In January of 2019 Washington state declared a state of emergency when a case of the measles became a widespread outbreak with 72 people in one county becoming infected. This is just one example of the types of news stories that have been popping up in the last decade, and according to researchers, other vaccine preventable communicable diseases will continue if those who do not believe in vaccinating continue down this path and convince others not to as well (CDC).

While Twitter tweets have been proven to be stylistically more stream of consciousness (Buck, 2012), and Facebook strategically focused in its dialogue (CNN, 2019), no study has truly compared the two or any others. I hope that with my research the results will uncover the differences between dialogue and rhetoric on both sites by looking at the same topic of vaccination. By building a fear specific sentiment dictionary, I will be able to compare qualitative results across multiple types of media on various platforms, not just generate quantitative and descriptive analysis of a singular social media site.

Collecting Data

Anti-vaxx sentiment can be found across the internet on many different platforms. I have read anti-vaxx material on Facebook, Twitter, YouTube, Reddit, comments on newspaper

stories, and even Instagram. I choose to focus on a smaller subset of social media that was mostly text based. While the New York Times and the Washington Post also have compelling discourse that attracts anti-vaxxers and sentimentally charged comments, I wanted to use media that is free to the public. Having a Facebook, Twitter or Reddit account is free, whereas only those who pay can comment on articles online for newspapers. I also eliminated YouTube and Instagram because the two platforms use photos and videos as their main content and that was not in line with the text analysis I wanted to perform.

Facebook is based on individual accounts where people can share content to their followers, the public and in groups online. This allows for many people to see content from this site and is highly structured. Twitter is comprised of people writing short messages called tweets which are sent from their personal accounts and appears in the feeds of whomever follows them, and if they have a public account, anyone who looks at their profile. I would consider Reddit to be the most compartmentalized site, People can comment and post as themselves, however they can only do so inside of what are called subreddits. These are groups that are generally categorized by the content that is posted inside of them.

In this research I sought to collect a corpus of anti-vaxx content for each of the social media sites as well as a baseline corpus which should be closer to the general content that would normally be found on each of these sites. This helps to determine how the anti-vaxx content is different from normal content posted online when I measure the emotions of the content.

For Facebook posts I identified groups that contain people that are antivaxx or discuss their experiences that caused them to become anti-vax. I had to collect the data by hand as scraping it through any sort of Application Programming Interface (API) is illegal for Facebook data. I only used public groups that are available for everyone to see and names of group users

were not used in my analysis. The three groups I pulled from on Facebook for my analysis were called “Vaccine injury is not rare”, “Stop killer vaccines for children that cause cancer and disease” and “MAVRIC- Mission Against Vaccine Related Injuries in Children”. In total these groups totaled 97 individual posts from the members and were dated from January 1st of 2019 through December 1st of 2019. I used this as my cutoff because I did not want the events of the COVID-19 outbreak to be included in the data I was pulling.

Additionally, I pulled a data set from Kaggle that has collected anti-vaccination posts from Facebook. There is no published information on the collection strategy, however it is publicly available now. The person who posted the data set is named Alex Hayler and was created on April 4th of 2019. The URL I used to obtain the dataset is <https://www.kaggle.com/alechelyar/facebook-antivaccination-dataset/tasks>. This data set’s timestamp goes from December 30th of 2013 all the way through April 1st of 2019. No additional information about the dataset was available on Kaggle. This should provide a good sample; however, I did not curate the data myself so that is why it is supplemental as opposed to the main dataset I am relying on. The data set from Kaggle contained 89,918 posts and I pooled these with my collected Facebook data which brought the total to 90,016 posts.

The tweets that I collected I did so using twint, which generates and accesses the URLs of tweets that I want based on a key word and date range as parameters. After trial and error with human examining of the tweets that resulted from this method, the best keyword I determined was “Vaccine-injured”. Those who have become vaccine injured in almost all cases also seem to state that they are anti-vaxx. In addition, these are the people who I wanted to study who seem to be anti-vaxx rather than the rest of the general public who may use key words such as “anti-vaxx” but in a disparaging or sarcastic way towards that specific group. This was the best filter

as only the group I want to study seems to mainly use this terminology. This does mean that it likely did not pull from the entire anti-vaxx community on Twitter, rather a smaller subset of it, however I believe that it provides good insight to the type of rhetoric I am looking at, without pulling from the general population of Twitter too.

The baseline dataset that I used for Twitter was taken from the public access stream of Twitter which means it accounts for approximately 1% of the data on Twitter. It was pulled for the tweets on May 1st of 2019. This should allow for a good comparison between the emotions used on my anti-vaxx data set and a sample of the rest of Twitter.

For Reddit I used code that scrapes utilizing the API within Reddit and allows for data collection by subreddit. For my anti-vaxx data set I pulled from “Antivax”, “Vaccine Truths” and “Vax Talk” subreddits and combined them to create the dataset. While the information that got pulled using the API did not collect the dates of the posts and comments, the subreddits themselves were created on Feb 18th, 2015, January 5th of 2019, and September 6th of 2012. These date ranges match up with the same timeframe being used in the Twitter and Facebook data roughly.

For the baseline dataset for Reddit I looked for subreddits that had debates but theoretically would not necessarily cross over into any vaccine related talk. I choose subreddits that discussed Harry Potter, Hamilton the Musical, Farming and Coffee. I gave all these subreddits a preliminary read through to ensure that the posts and comments were still substantial and could provide an adequate baseline of rhetoric for the platform. I also wanted to make sure conversations about COVID-19 had not overtaken the subreddits, which was the case in many other discussion style subreddits.

One of the downfalls of reddit is that even though the subject of the subreddit or the name may indicate that certain types of people and conversations are happening, such as it may indicate that it is a forum for people who do not believe in vaccination, in reality most of the time there is “trolling” of people who don’t believe in vaccinating, and for data collection purposes this makes this medium a poor place to gain actual insight into the minds of those who don’t or are trying to choose whether or not to vaccinate their children. Additionally, there is a lot of general sarcasm around these kinds of subreddits. In place of actual text many people also use memes to display their sentiments and the way I was collecting data was pulling straight from posts. The technology I have does not have the ability to pull the text from these memes as a means of content analysis. If someone wanted to measure sarcasm in this realm of conversation, it would be reasonable to consider that pulling text from memes, especially on Reddit, would be very effective in capturing this language.

In terms of the users of each individual site the demographics of the users vary. 73% of Twitter users are under the age of 50 (Wojcik and Hughes 2019). Facebook users when broken down by age tend to be highest concentrated in the 18-24 year-old range and 24-34 year-old range (Clement, 2020). Finally, 65% of Reddit users are between the ages of 18-24 years old (Sattelberg, 2020). These demographics seem help explain some of the differences in the rhetoric on the various social media sites. I would expect parents to fall in the age range most associated with Facebook rather than Reddit. This could lead to more discussions and posts about the anti-vaxx movement simply because it would pertain far more to the Facebook user group rather than the group on Reddit.

Facebook groups that discuss issues such as vaccination or are clearly for anti-vaccination purposes have a banner at the top of the group redirecting you to the CDC for the most up to date and scientific facts about vaccines. Reddit does the same thing as you enter a subreddit that discusses anti-vaccine issues, it warns you that the community is quarantined and has a quick link back to the main page of Reddit or straight to the CDC's guidelines on vaccines. On Twitter since there are no groups to flag, unless you explicitly search for a term that Twitter has flagged you will not be redirected to the CDC for information. Twitter has stopped promoting anti-vaxx content in its algorithm instead.

Text Examples

Below are some examples of the posts and tweets from the various social media sites.

Anti-vaxx

Twitter: "You may also want to watch the movie, "Vaccine Syndrome" where soldier's speak about how their life has changed after vaccine injury."

Facebook: "Some people might be wondering why I take a particular interest in vaccines. Well my daughter died 10 days after being vaccinated with the MMR. She had blood on her lips; evidence of seizure which was ignored by the post-mortem result"

Reddit: "When you push vaccines for commercial reasons, it undermines public confidence and creates the type of suspicion that fuels the antivax movement."

Methods for Analysis

To measure the types of emotion in the tweets, Facebook posts, and Reddit comments I employed a method of a lexical analysis that included a custom sentiment dictionary. I included

words in my preliminary data analysis that kept appearing. I used Twitter as my base for these words because since it was the largest data set it would provide the broadest scope of words.

Many of the phrases and concepts discussed in the data I collected are conspiracy theory based or references other events that are conspiracy theory based. I obtained them by first running an LDA topic model on my anti-vaxx twitter corpus to be used as a process of obtaining relevant words. While I had an idea of the topics that come up in anti-vaxx rhetoric, I cannot predict which ones are most salient for a corpus that contains 27,000 tweets.

Word embeddings are used to help a network learn from text data. By representing words as vectors, this maps a set of words, in my case the corpus I am feeding it, and turned it into vectors of numerical values. It then knows which words are numerically similar to each other in this vector space and is able to group them together (Agrawal, 2019). I then created a category within the lexicon called conspiracy which is derived of words from the corpora I created. I fed a Non-negative Matrix Factorization (NMF) topic model my corpora and the topic model outputted the top used words. This process gave me my words that were used to create the conspiracy lexica. Using a mixture of corpuses that reference different conspiracy theories other than simply anti-vaxx movements could help to create a more robust lexicon that more accurately represents conspiracism beliefs more broadly but would have required collecting additional corpora which was beyond the scope of this project.

In addition to a lexicon of conspiracy-related words that I created, I used an existing lexicon developed by the STAIR lab at William & Mary containing word lists for each of 8 basic emotions: joy, trust, fear, surprise, sadness, anticipation, anger, and disgust. Moreover, these lists can be combined to get an aggregate list containing “emotional” words. I fed the corpuses into

the dictionaries and created embeddings from matching the words in the lexica to the words in the corpora.

The following table shows for each category used in my analysis the total length of the associated word list and some of the key words that were used as a basis for collecting all closely related words for the category. The lists are shorter than the seed dictionaries used because most of the words are variations of the ones given here, just as a different part of speech.

Seed Dictionary Examples

Anger-Length 382 [annoyance, angry, infuriatingly, enrage]

Anticipation- Length 184 [interest, forecast, prediction, expectant]

Conspiracy- Length 481 [claim, epidemic, truth, profit, cover-up]

Disgust-Length 386 [boredom, disgust, loathe]

Fear-Length 197 [apprehension, terror, scare, intimidate]

Joy- Length 214 [serenity, happiness, elate, joyfully]

Sadness- Length 229 [pensiveness, grief, sad]

Surprise- Length 290 [distraction, amazement, surprisingly, startle]

Trust-Length 453 [acceptance, trust, admire, honesty]

Emotion-Length 96 [emotion, feelings]

I wanted to specifically look at the overall level of emotion used within the anti-vaxx corpora, along with anger, trust, fear, and conspiracy. Fear, anger, and conspiracy are three

concepts that the literature heavily supports as being a consistently used emotion and tactic to get people to believe and agree with their views.

The notebook that I set up for analysis is designed to compare two corpora against each other, with one being a “baseline” of material so that the subset looking at anti-vaccination rhetoric can be properly assessed as to whether or not it is different from what people normally write online on the specific social media platform.

For Facebook I compared a corpus of Anti-vaxx posts obtained from Facebook, against a corpus of posts from a neighborhood group that discussed issues in their community as my baseline. Ideally having a less specific corpora would be helpful, however as stated earlier scraping Facebook through any sort of API is not allowed by Facebook and putting together a dataset by hand is tedious and so this was a good piece of data to find.

For Twitter I ran a corpus I set against a sample corpus of general tweets from May 2019 from Twitter as my baseline. This will provide a comparison of anti-vaxx rhetoric directly against the general whole of Twitter and lead me to qualitatively and quantitatively discuss the difference in emotion of the two.

For Reddit I draw comparisons between my dataset that I compiled from subreddits that discuss anti-vaccination and several non-vaccine related subreddits. Since Reddit is broken down into subreddits I had to choose subreddits that I felt would simply elicit discord, and preferably about things not extremely related to anti-vaccination as my baseline.

While each of the baseline data sets chosen did elicit statistically significant results, they could have been better. The optimal baseline corpus would be comprised of people who are pro-vaccination and be able to measure how they talk about vaccines. Unfortunately, this is a

difficult task, as it is much harder to find groups of people that talk about vaccines on the internet the same way anti-vaxxers do. Therefore, the baseline corpora picked will only help get at what anti-vaxxers are saying and how emotional these sentiments are in comparison to a sample of the social media site as a whole.

To test whether the frequencies of words (or sets of words) are different, I use the t-test for independent samples, as implemented in the function `ttest_ind` in the python library `scipy`. The t-test is recommended (and widely used) for this purpose in corpus linguistics. The test assumes individual texts (tweets, posts, etc.) are statistically independent, and that mean word frequencies follow a normal distribution. Individual texts may not be fully independent on social media, since they may form part of an ongoing discussion; however, given the myriad different ways of expressing the same idea in a text, they are likely close enough to independent in a statistical sense. As for word frequencies (bounded between 0 and 1), the Central Limit Theorem tells us that, for all but very small corpora, we can safely assume a normal distribution. The t-test is preferable to bag-of-words tests such as chi-squared, since the latter assumes words are statistically independent, which they never are. See for additional discussion Lijffijt et al. 2016

Results

Facebook

Category	Anti-vaxx	Baseline	P-Value
Anger	0.02%	0.01%	0.000*
Anticipation	0.15%	0.17%	0.078
Conspiracy	2.87%	1.26%	0.000*
Disgust	0.04%	0.02%	0.001*

Emotion	0.08%	0.03%	0.000*
Emotions All	3.71%	1.89%	0.000*
Fear	0.05%	0.02%	0.000*
Joy	0.13%	0.12%	0.442
Sadness	0.02%	0.01%	0.024*
Surprise	0.03%	0.02%	0.000*

Twitter

Category	Anti-vaxx	Baseline	P-Value
Anger	0.02%	0.02%	0.567
Anticipation	0.19%	0.04%	0.000*
Conspiracy	7.99%	0.45%	0.000*
Disgust	0.05%	0.04%	0.014*
Emotions	0.02%	0.02%	0.082
Emotions All	8.62%	0.82%	0.000*
Fear	0.05%	0.02%	0.000*
Joy	0.02%	0.07%	0.000*
Sadness	0.03%	0.02%	0.000*
Surprise	0.03%	0.01%	0.000*

Reddit

Category	Anti-vaxx	Baseline	P-Value
Anger	0.00%	0.01%	0.023*
Anticipation	0.02%	0.02%	0.403
Conspiracy	0.48%	0.25%	0.000*
Disgust	0.01%	0.02%	0.397
Emotions	0.01%	0.01%	0.052
Emotions All	0.60%	0.38%	0.000*
Fear	0.01%	0.01%	0.081*
Joy	0.02%	0.03%	0.733
Sadness	0.00%	0.00%	0.703
Surprise	0.01%	0.01%	0.723

The tables show the frequency of words within each of the various word lists, both in the anti-vaxx corpora and in the baseline comparisons. The third column lists the p-values for the t-test for the difference in these frequencies, with values below 0.05 marked with an asterisk to indicate statistical significance. From these results it is apparent Twitter was the most emotionally charged of all the three social media platforms. It has the highest percentage of emotion and conspiracy words in the corpus for anti-vaxx. This is interesting because there is a character cap on tweets, whereas there is not for Facebook and Reddit. This can possibly be explained by saying those who tweet are more deliberate and precise in their use of language on Twitter. Additionally, this is the only social media where there are not groups for people to post

in, meaning that maybe content about anti-vaxx is just less monitored on this platform. If you search for vaccines or anti-vaxx within the site, it does direct your attention to the first result which is a redirect to the vaccines.gov page. However, there are not entire communities within Twitter, simply individual users.

Facebook was the second most emotionally charged in terms of the words that were used within the corpus. This was also a large corpus and still significantly emotionally charged with almost every emotion category except two being statistically significant. Due to the very direct nature of posts in groups on Facebook and no character limit, the fact that so much emotion was present in most categories is unsurprising.

Reddit was the least emotional of the three. Only anger, conspiracy, emotions all and fear were statistically significant. This was unsurprising because much of the content on Reddit was sarcastic or making fun of people who were anti-vaxx and did not provide very much content from those who were vaccine hesitant or anti-vaxx.

Discussion

The following tables show the top 15 words used on anti-vaxx corpus by frequency.

Top 15 Frequency Words by Social Media Platform

Twitter Words	Number of Hits	Facebook Word	Number of Hits	Reddit Word	Number of Hits
Vaccine	18805	Vaccination	3005	Vaccines	66
Vaccines	2784	Measles	1343	Vaccine	48
Pharma	1006	Adverse	1075	Medical	33
Liability	824	Pharmaceutical	1055	Benefits	30
Risk	745	Pharma	703	Disease	28
Adverse	714	Polio	490	Anxiety	27
Medical	678	Infection	457	Vaccination	26
Claims	674	Outbreak	413	Evidence	25
Autism	672	Outbreaks	292	Safe	25
Pharmaceutical	506	Diabetes	170	Autism	24
Industry	490	Painful	122	Drug	23
Vaccination	466	Lethal	116	Scientific	23
Measles	403	Obesity	104	Diseases	21
Facts	397	Smallpox	104	Risk	21
Companies	390	Justify	92	Symptoms	18

Looking at these frequency lists the most apparent thing to jump out is that “vaccine” “vaccination” and “vaccines” are all the first word in the list. The highlighting on the tables also shows cross-referenced words that appear in two or more of the corpora. What is interesting is that there is overlap of 5 words from Twitter and Reddit and 5 words overlapping between Twitter and Facebook, but the only word overlapping between Reddit and Facebook is the word “vaccination”. This seems to suggest that the way vaccines are being discussed varies widely between Facebook and Reddit, but that Twitter may be where it is discussed the most in a variety of different ways.

The presence of the words polio, measles, smallpox and outbreaks leads to the conclusion that the history of vaccines and outbreaks is being heavily discussed on Facebook and perhaps this historical context is what many anti-vaxxers are drawing on for persuasion.

Reddit’s top key words including benefits, safe, evidence, and scientific may indicate conversation around why vaccines are helpful rather than why people should not get them. This fits with the sample texts that were read as the subreddits were being chosen. This may indicate that Reddit is not a place for anti-vaxx discussion and that it is often shutdown or overpowered by pro-vaccination rhetoric.

Finally, the Twitter key words include words such as risk, adverse, liability, pharma, claims, and companies. Given that many of the tweets collected using the key search term “vaccine-injured” pulled tweets that also reference the National Vaccine Injury Compensation Program, which is an American run government program, it is safe to much of this corpus is American rhetoric. These terms seem to indicate a level of blame and an attitude of holding the pharmaceutical industry accountable.

The three social media sites that I chose to analyze appear to host anti-vaccination sentiment in different ways. Though tweets can be search for and grouped together by hashtags and key words, or could be analyzed by having the same username, many tweets that are written about anti vaccination are simply a shout into the void. They are sent into the larger community of Twitter to those who may follow a specific person, or their friend may interact with the tweet and cause it to show up in someone's feed, however there are not groups and networks on this platform to facilitate specific conversations. The way in which this information is disseminated across Twitter users is very different from the other two social media platforms.

Both Reddit and Facebook appear to be more community based in the dissemination of information on the platforms.

Conclusion

Understanding how the spread of anti-vaccination rhetoric happens and its effectiveness is ultimately the first step in beginning to address it. Vaccine hesitation has been named one of the issues of our generation to watch vigilantly and understand more about it, because of the devastating effects it can have on the world community. This research has allowed for what I would consider to be a preliminary window of insight into this issue, but due to the short and dynamic nature of social media, more research is necessary. While it is evident that anti-vaxx social media employed more conspiracy words, and higher levels of fear and overall emotion, pinpointing the exact how and why is hard with such small pieces to use as input.

On ideas for future research, by studying people of authority or the ethos component, I believe that one could better understand how to position themselves as a point of authority in the pro-vaccination movement that may actually speak to persons who are vaccine hesitant.

As it relates to the broader context of the world, this is important research as we move through a global pandemic of COVID-19. Even though there is not yet a vaccine for the virus there is a lot of research underway trying to create a vaccine. This has already sparked debates with people in the anti-vaxx community about the issues of government regulation and whose choice it will be to vaccinate once it is found (Mooney, 2020). With information about where anti-vaxx sentiment is most prevalent on the internet, along with additional research into who is using specific social media sites there can be more of a coordinated effort to direct resources to individuals that may be on the edge regarding vaccine hesitancy. They may not have decided to go against vaccinations altogether yet, and if the information regarding vaccines could be delivered in an appropriate manner, it may be able to prevent or at least mitigate another wave of the virus. By having information about how each of the individual social media sites operates, target approaches or campaigns could be put in place. Additionally, expanding this kind of research to other social media sites, such as YouTube, Instagram and TikTok, which utilize pictures and videos more so than written text components, could lead to new insights about how information and sentiment is relayed to whole new group of users.

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