

Data Science Capstone\_DATS-6501

# Tracking Vaccine Misinformation on Facebook

Adwoa Brako<sup>1</sup>, Rashmi Menon<sup>2</sup>

Columbian College of Arts & Sciences, The George Washington University, Washington, D.C.

<sup>1</sup>[abrako64@gwu.edu](mailto:abrako64@gwu.edu) <sup>2</sup>[rashmimenon62@gwu.edu](mailto:rashmimenon62@gwu.edu)



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# **Introduction**

## *Problem Statement*

One of the most contested topics about health policies over the years has been the efficacy and viability of vaccinations. The advent of social media platforms has led to a torrent of vaccine misinformation.

According to a recent Annenberg Public Policy Center study based on surveys of nearly 2,500 US adults, up to 20% of respondents, were somewhat misinformed about vaccines [1]. This social media vaccine misinformation is life or death, especially with the development of COVID-19 vaccine.

Utilizing data science technologies, this capstone project will create mechanisms to help public health researchers better understand the nature of this misinformation in order to develop strategies to counter and get ahead of this curve.

## *Problem Elaboration*

The objective of mining this information is to identify the main topics reflected in both negative and positive content on Facebook. The safety and long-term side effects of vaccines have been questioned over the years, but with Health Organizations around the world speeding up vaccination trials on COVID-19, these concerns have been heightened.

A sentiment analysis would analyze both the positive and negative comments associated with vaccines on Facebook.

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## Literature Review

The core publications used for this project form the basis of our research study. The main publications utilized include;

- *Title & Date:* How the Anti-Vaccine Community Is Responding to Covid-19 [April 2020]
  - *Description:* How conspiratorial thinking and government mistrust affect stance on vaccination.
- *Title & Date:* Mandatory Vaccination: Why We Still Got To Get Folks To Take Their Shots [April 2016]
  - *Description:* How communicable diseases can be effectively eliminated by administering vaccines to sufficient levels of persons in the community.
- *Title & Date:* A Natural Language Processing Framework To Analyse The Opinions On HPV Vaccination Reflected On Twitter Over 10 Years (2008 - 2017). [June 2019]
  - *Description:* An NLP framework was developed to investigate opinions on HPV vaccination as discussed on Twitter
- *Title & Date:* Studying Public Perception about Vaccination: A Sentiment Analysis of Tweets [May 2020]
  - *Description:* Using text analysis to research attitudes towards vaccination

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## Methodology

### *Data Collection Pipeline*

For our data-collection, a crowd-tangle API was used to shortlist 1256 vaccine pages. By creating a custom pipeline, posts were downloaded based on a specific set of keywords. In addition to that, we chose a collection of over-performing posts from crowdtangle to give us the best results. The overperforming posts accounted for 581 off the 1256 pages. The data was downloaded in the form of a csv file and labelled manually as pro-vaccination, anti-vaccination and neutral based on the content. The data was then exported to a PostgreSQL database for easy accessibility.

### *Data Description*

We have a total of 91,026 posts ranging from February 2019 to October 2020. The columns that were used for this project were the Page name(which we based the categories on), Facebook Id, Likes(fans), Source, Target and the description. Columns like shares, urls, emojis, image text, links, link text and over-performing scores were done away with.

## Data Cleaning and Preprocessing

To perform any analysis, it was important to normalize the text that would be used. This step was done to ensure only the relevant text would be used for modeling and any further analysis. To do this, *Spacy and NLTK libraries* were imported to clean and preprocess the text.

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To begin with, columns that were irrelevant to our analysis were dropped to reduce the features and variables in the dataset. Next, punctuation marks and emojis were deleted from the data. After this, the words were then separated via unique space characters, by means of lowercase word tokenization.

The standard set of stopwords, as well as a custom set of irrelevant words in the text were then excluded, to decrease feature dimensionality, which allowed us to analyze only content-bearing words.

## **Exploratory Data Analysis [EDA]**

The EDA process is critical in identifying patterns or anomalies in the dataset. The two methods used to visualize the text include;

### *Word Cloud*

This graphic was used to visualize words that are present in the data. The Word Cloud gives prominence to words that occur more frequently in the source text. Thus, the larger the word, the more common the word in the document.

### *Stemming*

For this step, the inflectional endings of the tokens were removed, so as to return the base or root form, known as stems. *NLTK's PorterStemmer* library was used to achieve this and the result of this showed how different variations of the same word were combined into one base form.

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## *Network Data Structure and Analysis*

A Nodes and Edges table was created from the original dataset to get a basic understanding of how interconnected and popular the facebook pages are. An additional column was added with the label names associated with the pages i.e pro-vaccination, anti-vaccination and neutral.

Using the Gephi software, a network graph was plotted. The reds represent the anti-vaccination group, the Blues represent the pro vaccination groups and the greens the neutral group. The nodes represent the page name, the edges or the links represent one page liked by another.

The node size is based on its betweenness centrality or how influential a node is in the network.

## **Overview of Models**

The Modeling and validation methods used for this analysis include;

TF-IDF, which is a numerical statistic that is intended to reflect how important a word is to a document. The vectorization model was implemented to determine the frequency of words in the text. *Sk-learn's TF-IDFVectorizer* was used to achieve this. An NMF model, which is a topic modeling technique that decomposes high-dimensional vectors into a lower-dimensional representation was also used. This was done to identify any relevant topics that were present in the data. Next, a K-means model was used to produce clusters associated with each vaccine group (anti & pro) and the K-means results were evaluated based on silhouette score. Additionally, each word belonging to a cluster was processed by VADER sentiment analyzer.

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## Results and Analysis

### *NMF model*

For our project, we used the top 3000 words for TFIDFVectorization and also added a custom list of stopwords to remove additional irrelevant words. To use a NMF model, we used the number of topics (10 topics in this case) as input and fit the model on TD-IDF normalized term-document matrix. We then returned a DataFrame of the 10 topics with the top associated words that map to these topics. The model was run separately on vaccination data for 2019 & 2020 to determine major vaccine topics for these years.

**2019 Results:** The model produced topics such as *measles, outbreak, health, vaccine, children, mandatory, death, childrenshealthdefence* (vaccine group), among other relevant topics.

**2020 Results:** Topics such as *flu, covid, death, reaction, mandatory, health, vaccine groups, the vaccinereact, michiganvaccinechoice, medicalfreedom*, among others were returned by the model for this year. This proved that the model performed well in identifying topics of relevance in both years.

### *K-Means*

In order to improve on the NMF model, a K-Means clustering algorithm was used. The reason behind our choosing K-means clustering is because of its low time complexity, which indicates faster performance and also works well with large datasets.

A specific number of clusters were created based on a silhouette score as seen in figure 13. The closer the silhouette score is to 1 the more similar it is to vectors it is in its cluster and dissimilar

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to vectors in neighbouring clusters. We ran a test for 2-15 clusters and the silhouette score for 13 clusters was the highest which signified the optimal number of clusters. The same was done for the pro-vaccination network. The optimal number of clusters for the pro-vaccination network was 8. The results for these can be seen in the Appendix, figure 12.

### *VADER Sentiment Analysis- Anti-Vaccination*

A Vader Sentiment Analysis was run on the clusters for the anti-vaccination and pro-vaccination groups. The reason behind our choosing the API is because it is specifically trained on sentiments from social media and returns the sentiment associated with each word and automatically labels it with negative, neutral, positive and a compound score attached to each category. A compound score is computed by normalizing 3 categories. If the compound score is greater than 0.05, it's considered a positive result. If it's less than 0.05 it's considered a negative result and if it's equal to 0.05 the result is considered neutral. The results for these can be seen in the Appendix, in figure 14.

The anti-vaccination network produces 8 negative clusters and 5 positive clusters as seen in figure 15. Based on the frequent keywords, the topics for the 13 clusters in the anti-vaccination network revolved around families harassed by paediatricians to vaccinate their children, vaccine safety claims made by Health officials, a call to question the efficacy of vaccinations. People who fall into this cluster are skeptical of vaccines and consider them unnecessary. They start questioning the truth behind the sciences. Another cluster discusses vaccinations as a risk for cancer. There is a prevalent claim in this cluster that vaccines could cause cancer and result in

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death. People in this cluster advise others to learn more about vaccinations. Cluster 6 discusses the freedom and expression of a right to choose. Vaccinations have become a requirement for different social and economic activities in many countries. It is vague to interpret the reason why parents might not vaccinate their child. It is apparent in this cluster however, that parents are reinforcing the value of choice and the ability to decide for themselves to opt to vaccination or not. Cluster 7 discusses a growing opposition and protests against Government mandates and vaccines. This cluster is part of a group of people who want all businesses to open in the US and claim that the virus is a hoax . Cluster 8 discusses the adverse effects of vaccinations associated with Hepatitis, Covid-19, Meningitis, Polio. There is a prevalent claim in this cluster that vaccines could result in death based on claims made by anti-vaxxers about the Gates Foundation trying to hush up deaths in the Philippines about the Gardasil vaccine that was administered to young women out there as part of a trial. Cluster 9 discusses the false notions surrounding vaccine and development

This cluster allows us to understand that people in this cluster are not motivated by fear but are people who believe in findings in “research”, although there has been no research so far that suggests with confidence about the significant harms of the ingredients present in vaccines.

Cluster 10 discusses the scandals surrounding vaccine companies with a focus on AstraZeneca and its fraudulent practices resulting in people suffering from life-long health conditions. Cluster 11 discusses the side-effects of the MMR vaccine. Cluster 12 talks about the lack of faith in vaccines One way to interpret this result is to say that people in this cluster encourage others to learn about the toxicity in vaccines. The results for these can be seen in the Appendix, figures

26-37.

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### *VADER Sentiment Analysis- Pro-Vaccination*

The pro-vaccination network produces 6 positive clusters and 2 negative clusters as is seen in figures 16 and 17.

Cluster 1 discusses the improvement in numbers associated with Meningitis, HPC, Polio while cluster 2 discusses the benefits of Global Immunizations with an emphasis on polio being eradicated in the African continent. Cluster 3 discusses making vaccinations mandatory through campaigns that would raise awareness against vaccine injuries. Cluster 4 discusses a need to get Influenza vaccine to prevent a “twindemic”(convi-19 and the flu). Cluster 6 discusses the importance of vaccinating children against chickenpox, polio and whooping cough. Cluster 6, being a negative cluster, discusses the deception and misinformation provided by anti-vaccination groups which are fuelling new outbreaks Group 7 discusses the Importance of HPV vaccines to help protect women against cervical cancer. Group 8, a negative cluster, further discusses misinformation by anti-vaccination groups as propaganda. The results for these can be seen in the Appendix, figures 18-25.

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## **Conclusion**

The NMF models produced some topics that were relevant to vaccination discussions, as expected. Topics such as vaccine, injury, mandatory, measles, coronavirus, outbreak, death and health, among other topics were returned by the models. The results from the anti-vaccination community detail the side-effects of vaccines such as: autism, links to cancer, death and how the freedom of choice must be reinforced. These claims are allegedly spearheaded and backed by scientific studies and narratives. The results from the pro-vaccination community detail the importance of vaccines such as preventing outbreaks of polio, measles etc. The average Silhouette scores for anti-vaccinations is 0.008 and the average Silhouette scores for pro-vaccinations is 0.007 indicating the right fit of the data to its cluster. The sentiments of the anti-vaccination community were more negative in comparison to its pro-vaccination counterpart.

## **Limitations and Future Work**

Due to computational cost, our data is limited to a single social media platform, Facebook. Exploring other platforms where communities and groups are formed around similar ideologies would be interesting.

Our analysis focuses on textual data and not on memes and images. Moving forward, we would like to extend our analysis to encompass all data.

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Our analysis is also limited to only pro-vaccination and anti-vaccination groups. Expanding our research to include neutral groups would be an interesting analysis to formulate a better understanding around the vaccine study.

For future research, we would like to explore other topic modeling techniques that will improve on the existing topics generated.

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## References

Annenberg Public Policy Center of the University of Pennsylvania. (2020, February 17). Vaccine misinformation and social media: People exposed to vaccine content on social media more likely misinformed than those exposed to it on traditional media. ScienceDaily. Retrieved September 21, 2020 from [www.sciencedaily.com/releases/2020/02/200217163004.htm](https://www.sciencedaily.com/releases/2020/02/200217163004.htm)

Gammon 04.16.2020, K., Schulson 08.14.2020, M., & Peeples 04.14.2020, L. (2020, April 17). How the Anti-Vaccine Community Is Responding to Covid-19. Retrieved September 18, 2020, from <https://undark.org/2020/04/16/anti-vaccine-covid-19/>

Garay, J., Yap, R., & Sabellano, M. J. (2019). An analysis on the insights of the anti-vaccine movement from social media posts using k-means clustering algorithm and VADER sentiment analyzer. *IOP Conference Series: Materials Science and Engineering*, 482, 012043. doi:10.1088/1757-899x/482/1/012043

Raghupathi, V., Ren, J., & Raghupathi, W. (2020). Studying Public Perception about Vaccination: A Sentiment Analysis of Tweets. *International Journal of Environmental Research and Public Health*, 17(10), 3464. doi:10.3390/ijerph17103464

Luo, X., Zimet, G., & Shah, S. (2019). A natural language processing framework to analyse the opinions on HPV vaccination reflected in twitter over 10 years (2008 - 2017). *Human Vaccines & Immunotherapeutics*, 15(7-8), 1496-1504. doi:10.1080/21645515.2019.1627821

Balding, B. (2006). Mandatory Vaccination: Why We Still Got To Get Folks To Take Their Shots. Retrieved September 20, 2020, from <https://dash.harvard.edu/handle/1/8852146>

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## Appendix

```
Index(['Page Name', 'User Name', 'Facebook Id', 'Likes at Posting', 'Created',
       'Type', 'Likes', 'Comments', 'Shares', 'Love', 'Wow', 'Haha', 'Sad',
       'Angry', 'Care', 'Video Share Status', 'Post Views', 'Total Views',
       'Total Views For All Crossposts', 'Video Length', 'URL', 'Message',
       'Link', 'Final Link', 'Image Text', 'Link Text', 'Description',
       'Sponsor Id', 'Sponsor Name', 'Overperforming Score'],
      dtype='object')

Index(['Page Name', 'User Name', 'Facebook Id', 'Likes at Posting', 'Created',
       'Likes', 'Comments', 'Shares', 'Post Views', 'Total Views',
       'Total Views For All Crossposts', 'Message', 'Description',
       'Overperforming Score', 'new_message'],
      dtype='object')
```

Figure 1. Dropped irrelevant columns

```
So the Major of Newcastle thinks she can ban a...
Well today LNP showed their cards the party de...
nan
Proof of causality for COVID19 has not been pr...
nan
...
nan
Shattered dreams in the wake of Gardasil Anoth...
nan

So the Major of Newcastle thinks she can ban a...
Well, today LNP showed their cards the party d...
NaN
Proof of causality for COVID19 has not been pr...
NaN
...
NaN
Shattered dreams in the wake of Gardasil. Anot...
NaN
```

Figure 2. Removal of punctuations

'The simple, poignant question: How could the ...  
I couldn't help but notice something from this...  
NaN  
Vaccine mandates are created by the pharmaceut...  
The Volunteers of Mississippi Parents for...

The simple poignant question How could the ino...  
I couldnt help but notice something from this ...  
nan  
Vaccine mandates are created by the pharmaceut...  
The Volunteers of Mississippi Parents for Vac...

Figure 3. Removal of emojis

So the Major of Newcastle thinks she can ban a...  
Well today LNP showed their cards the party de...  
nan  
Proof of causality for COVID19 has not been pr...  
nan  
...  
nan  
Shattered dreams in the wake of Gardasil Anoth...

[so, the, major, of, newcastle, thinks, she, c...  
[well, today, lnp, showed, their, cards, the, ...  
[nan]  
[proof, of, causality, for, covid19, has, not,...  
[nan]  
[get, your, tickets, today, the, online, confe...  
[nan]

Figure 4. Lowercase tokenization

[proof, of, causality, for, covid19, has, not,...  
[get, your tickets, today, the online, confe...  
[fb, is, admittedly, censoring, our, reach, to...  
[watch, httpbitlyttavoct2020, httpsgothetrutha...  
[media, release, newcastle, council, bans, vac...  
[media, release, newcastle, council, bans, vac...  
are, you, over, the, age, of, 65, and feelin...  
[this, looks, like, it, will, be, quite, power...

[proof, causality, covid19, provided, crime, h...  
[nan]  
[get, tickets, today, online, conference, star...  
[nan]  
[fb, admittedly, censoring, reach, fraction, p...  
[watch, httpbitlyttavoct2020, httpsgothetrutha...  
[media, release, newcastle, council, bans, vac...  
[media, release, newcastle, council, bans, vac...  
[age, 65, feeling, pressure, get, flu, shot, r...

*Figure 5. Removal of stopwords*



*Figure 6. Word cloud*

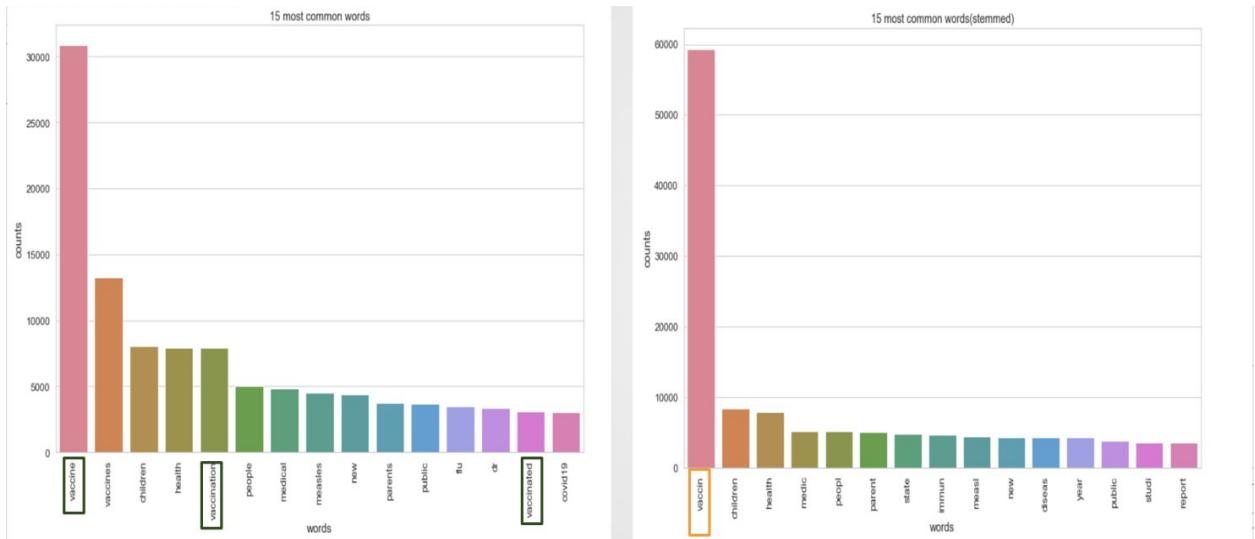


Figure 7. Before & after images of stemming

Source bigint	Target bigint	Date date
10288724013	1410720899202390	2019-02-18
10288724013	205183899497146	2019-02-18
10288724013	289446947817747	2019-02-18
10288724013	103551633078066	2019-10-05

fb_uid [PK] bigint	label character varying	page name character varying	fans bigint
184599864915751	Pro Vaccination	Women's Rights News	1675758
206630642689393	Neutral	LGBT News	1463161
69667273997	Anti Vaxxination	Vaccination Information Ne...	158557
231827776896578	Neutral	Brain Injury Awareness	22641

Figure 8. Node & Edge tables of network data structure

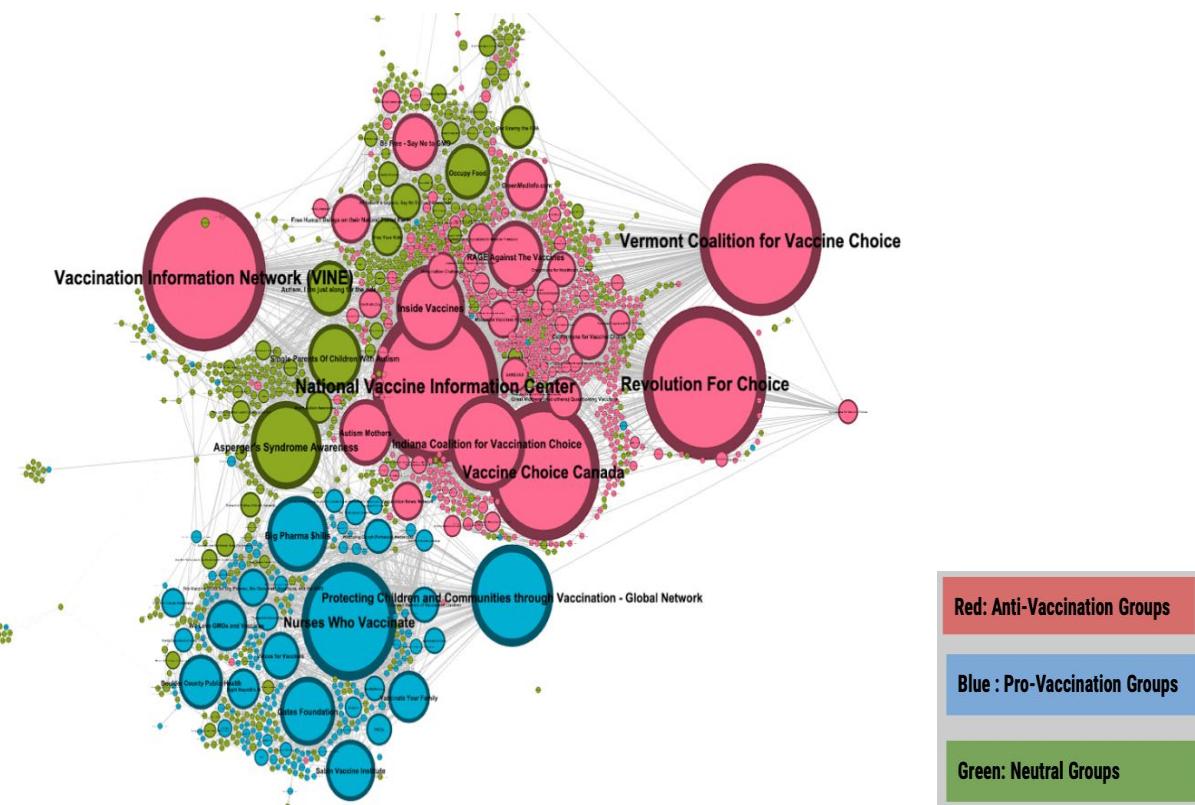


Figure 9. Network graph of vaccination groups

	Topic # 01	Topic # 02	Topic # 03	Topic # 04	Topic # 05	Topic # 06	Topic # 07	Topic # 08	Topic # 09	Topic # 10
0	michiganvaccinechoic	vaccin	facebook	watch	fan	thank	good	know	vax	measl
1	org	hpv	post	featur	sub	dr	news	fact	cdcwistleblow	outbreak
2	michiganforvaccinechoic	injuri	video	share	submiss	share	read	truth	childrenshealthdefens	case
3	thevaccinereact	children	stor	desktop	found	jim	share	doctor	anti	samo
4	video	mandat	fbid	app	anti	speak	question	need	truth	diseas
5	type	parent	php	video	sure	pleas	great	want	meme	immun
6	theater	flu	revolutionforchoic	fbclid	think	inform	pleas	read	refut	viru
7	live	get	photo	iwar	sad	doctor	articl	one	vaxxer	health
8	photo	health	group	pleas	happen	via	fight	better	pro	news
9	facebook	news	event	must	get	truth	greater	right	peopl	org
10	iwar	death	type	live	say	paul	keep	pleas	video	fbclid

Figure 10. Topics produced by NMF model for 2019

	Topic # 01	Topic # 02	Topic # 03	Topic # 04	Topic # 05	Topic # 06	Topic # 07	Topic # 08	Topic # 09	Topic # 10
0	vaxxeddownund	michiganvaccinechoic	vaccin	watch	facebook	thank	flu	injuri	interest	import
1	unvaccin	michiganforvaccinechoic	covid	featur	post	pic	know	gardasil	conflict	agre
2	healthi	org	need	egg	video	absolut	coronaviru	awar	studi	inform
3	injuri	childrenshealthdefens	mandat	sorri	highwirletalk	del	get	peoplestruth	thought	ever
4	dtap	thevaccinereact	mandatori	googl	photo	ted	say	vxd	theori	flu
5	investig	live	thevaccinereact	index	fbid	nvic	good	vaccin	live	show
6	stori	medicalfreedom	refus	continu	php	check	pleas	month	understand	appeal
7	pro	vaccineinjuri	thehighwir	must	comment	believ	covid	stori	call	miss
8	ex	learn	take	video	stori	number	mandatori	flu	time	placebo
9	flu	reaction	reaction	share	vax	interview	news	octob	alway	stay
10	vax	event	death	link	login	share	petit	compens	ago	awar

Figure 11. Topics produced by NMF model for 2020

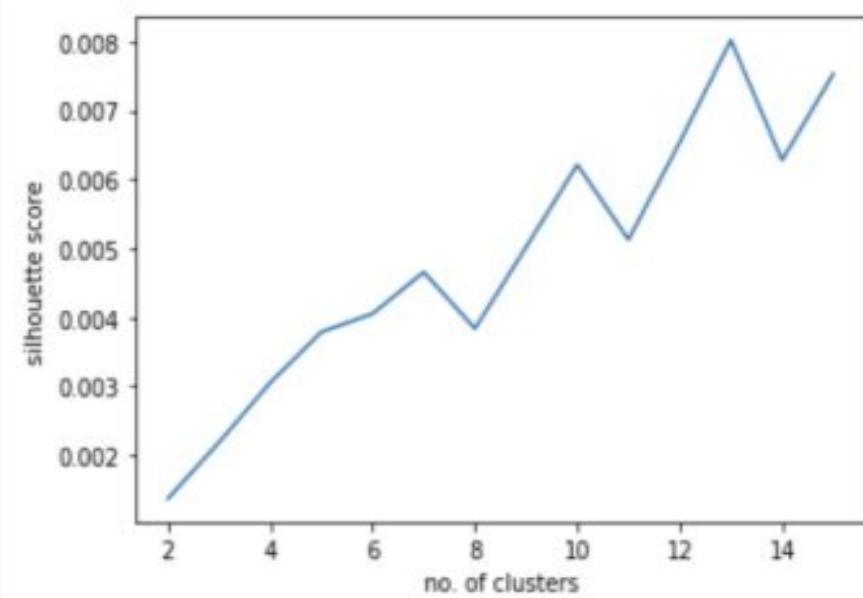


Figure 12. K-Means of Anti-vaccination groups

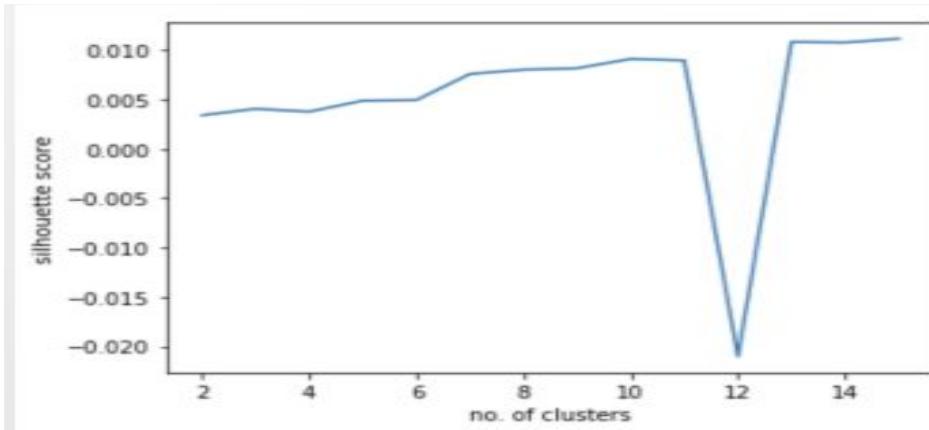


Figure 13. K-Means of Pro-vaccination groups

```
{
  'neg': 0.173, 'neu': 0.654, 'pos': 0.173, 'compound': -0.4549}

  {'neg': 0.106, 'neu': 0.699, 'pos': 0.194, 'compound': 0.936}

  {'neg': 0.108, 'neu': 0.745, 'pos': 0.147, 'compound': 0.7449}

  {'neg': 0.161, 'neu': 0.68, 'pos': 0.159, 'compound': -0.5277}

  {'neg': 0.171, 'neu': 0.714, 'pos': 0.115, 'compound': -0.9492}

  {'neg': 0.065, 'neu': 0.739, 'pos': 0.195, 'compound': 0.9769}

  {'neg': 0.051, 'neu': 0.824, 'pos': 0.124, 'compound': 0.881}

  {'neg': 0.172, 'neu': 0.691, 'pos': 0.137, 'compound': -0.891}

  {'neg': 0.105, 'neu': 0.747, 'pos': 0.148, 'compound': 0.802}

  {'neg': 0.211, 'neu': 0.64, 'pos': 0.149, 'compound': -0.9515}

  {'neg': 0.191, 'neu': 0.695, 'pos': 0.113, 'compound': -0.9726}

  {'neg': 0.204, 'neu': 0.639, 'pos': 0.156, 'compound': -0.9064}

  {'neg': 0.062, 'neu': 0.923, 'pos': 0.014, 'compound': -0.8442}
```

Figure 14. VADER sentiment analysis of Anti-vaccination groups

Topic	Frequent Keywords	Sentiment
Families harassed by doctors to vaccinate their children	harassment, bully, agonizing, struggle, catastrophe, bloody, lose, disagree	Negative
Vaccine safety claims made by Health officials	defence, safety, authority, consent, challenge, trustworthiness, support, responsible	Positive
A call to question the efficacy of vaccinations	share, truth, safety, well, safe, positive, protect, effective	Positive
Vaccinations as a risk for cancer	risk, harm, damage, death, dangerous, cancer	Negative
Failure of vaccines leading to "death"	died, death, die, sick, lost, cry, injured, cancer, severe	Negative
Expression of right to choose	free, consent, freedom, allow, support, friend, save, care, healthy	Positive
Growing opposition/Protests against Government mandates and vaccines	mandatory, exempt, bill, allow, support, care, legislative	Positive
Adverse effects of vaccinations associated with Hepatitis, Covid-19, Meningitis, Polio	flu, death, injury, disorder, failing, adverse, strain	Negative
False notions surrounding vaccine and development	ready, novel, effective, safe, immune, promising, hope, approval	Positive
Scandals surrounding Vaccine companies	fraudulent, lawsuit, exposed, risk, tragedy, suffering, fraud, harmed	Negative
Side-effects of the MMR vaccine	death, strain, emergency, fear, infected, rash, died, illness, worst, adverse	Negative
Lack of faith in vaccines	failure, shocking, lying, lack, doubt, forced, problem	Negative

Figure 15. VADER sentiment analysis topics of Anti-vaccination groups

```
{'neg': 0.074, 'neu': 0.767, 'pos': 0.159, 'compound': 0.8991}

{'neg': 0.101, 'neu': 0.703, 'pos': 0.196, 'compound': 0.9274}

{'neg': 0.073, 'neu': 0.821, 'pos': 0.106, 'compound': 0.4019}

{'neg': 0.151, 'neu': 0.656, 'pos': 0.194, 'compound': 0.802}

{'neg': 0.153, 'neu': 0.658, 'pos': 0.189, 'compound': 0.5713}

{'neg': 0.196, 'neu': 0.737, 'pos': 0.068, 'compound': -0.975}

{'neg': 0.059, 'neu': 0.741, 'pos': 0.2, 'compound': 0.9633}

{'neg': 0.225, 'neu': 0.681, 'pos': 0.094, 'compound': -0.976}
```

Figure 16. VADER sentiment analysis of Pro-vaccination groups

	Topic	Frequent Keywords	Sentiment
0	Improvement in numbers associated with Meningitis, HPC, Polio	safety, help, important, protect, well, support, safe, share	Positive
1	Benefits of Global Immunizations	interest, free, help, effective, passion, protect, approved, join, united	Positive
2	Making vaccinations mandatory	support, improve, allow, mandatory, care, bill, requirement, legislation, modernizing	Positive
3	Need for an Influenza vaccine to prevent a "twindemic"	important, protect, best, health, care, healthy, immune, community, hospitalization, seasonal	Positive
4	Importance of vaccinating children against chickenpox, polio and whooping cough	protect, prevent, recommended, help, save, study, control, immunization, preventable	Positive
5	Vaccine deception fuelling new outbreaks	contagious, hesitancy, misinformation, fear, blame, infected, death, emergency	Negative
6	Importance of HPV vaccines for women	benefit, recommended, safe, approved, effective, protect, prevents, effectiveness	Positive
7	Vaccine Pseudoscience	propaganda, fake, misinformation, harassment, ridiculous, crisis, attack	Negative

Figure 17. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.101, 'neu': 0.703, 'pos': 0.196, 'compound': 0.9274}
Positive: ['interest', 'free', 'like', 'prevent', 'reached', 'help', 'effective', 'safety', 'safe', 'passion', 'protect', 'approved', 'join', 'united']
Neutral: ['covid19', 'vaccine', 'coronavirus', 'trial', 'pandemic', 'development', 'research', 'health', 'world', 'collection', 'find', 'clinical', 'new', 'develop', 'people', 'expert', 'article', 'take', 'first', 'available', 'pediatrics', 'one', 'human', 'get', 'news', 'public', 'dr', 'race', 'latest', 'global', 'researcher', 'potential', 'even', 'disease', 'may', 'say', 'updated', 'effort', 'scientist', 'already', 'american', 'early', 'pediatric', 'official', 'candidate', 'vaccination', 'view', 'related', 'virus', 'university', 'make', 'discus', 'trump', 'state', 'look', 'around', 'question', 'cause', 'use', 'year', 'drug', '2020', 'regularly', 'month', 'registered', 'president', 'child', 'time', 'need', 'said', 'result', 'resource', 'testing', 'dont', 'ongoing', 'outbreak', 'leader', 'speed', 'group', 'recognizes', 'currently', 'also', 'country', 'aap', 'volunteer', 'published', 'government', 'long', 'gate', 'influenza', 'fasttracking', 'track', 'maryland', 'politics', 'working', 'could', 'participant', 'work', 'future', 'response', 'developed', 'know', 'effect', 'fda', 'process', 'treatment', 'claim', 'sarscov2', 'today', 'antivaccine', 'would', 'read', 'publishing', 'quickly', 'social', 'massive', 'there', 'here', 'phase', '2019', 'college', 'access', 'science', 'company', 'uk', 'administration', 'keeping', 'list', 'report', 'grad']
Negative: ['fight', 'racism', 'conspiracy', 'misinformation', 'risk', 'crisis']

```

Figure 18. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.073, 'neu': 0.821, 'pos': 0.106, 'compound': 0.4019}
Positive: ['support', 'improve', 'ability', 'allow', 'increase', 'mandatory', 'challenge', 'care']
Neutral: ['exemption', 'school', 'state', 'vaccination', 'bill', 'law', 'medical', 'california', 'religious', 'vaccine', 'new', 'rate', 'child', 'immunization', 'nonmedical', 'requirement', 'parent', 'york', 'would', 'public', 'health', 'personal', 'student', 'colorado', 'mandate', 'newsom', 'kid', 'governor', 'gavin', 'opt', 'belief', 'doctor', 'signed', 'senate', 's b', 'maine', 'official', '276', 'lawmaker', 'legislature', 'family', 'reason', 'measles', 'district', 'sb276', 'outbreak', 'board', 'philosophical', 'passed', 'get', 'say', 'seattle', 'make', 'legislator', 'attend', 'year', 'community', 'gov', 'legislation', 'required', 'vote', 'eliminate', 'bogus ', '2019', 'activist', 'vaccinated', 'eliminating', 'writing', 'vaccinating', 'washington', 'tightening', 'several', 'committee', 'arizona', 'hb', 'june', 'monday', 'provaccine', 'amid', 'skip', '13', 'voter', 'tuesday', 'dr', 'effect', 'right', 'diego', 'people', 'robert', 'san', 'shot', 'entry ', 'end', 'jr', 'remove', 'kennedy', 'record', 'modernizing', 'vaccinate', 'house', 'capitol', '191312', 'need', 'proposed', 'pacific', 'oregon', 'joined', 'lax', 'pan', 'oversight', 'northwest', 'require', 'considering', 'revised', 'trend', 'across', 'childhood', 'exempting', 'catholic', 'last', 'three', 'show', 'veto', 'bar', 'loophole', 'making', 'jersey', 'one', 'ended', 'office', 'unvaccinated', 'harder', 'fifth', 'zandvliet', 'week', 'hearing', 'go', 'oppose']
Negative: ['rejected', 'accused', 'critical', 'catastrophe']

```

Figure 19. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.074, 'neu': 0.767, 'pos': 0.159, 'compound': 0.8991}
Positive: ['like', 'safety', 'help', 'important', 'effective', 'safe', 'share', 'protect', 'well', 'support']
Neutral: ['vaccine', 'health', 'vaccination', 'new', 'people', 'coronavirus', 'one', 'year', 'antivaccination', 'say', 'get', 'world', 'public', 'immunization', 'science', 'dr', 'facebook', 'time', 'antivaxxers', 'study', 'could', 'group', 'day', 'make', 'expert', 'trial', 'would', 'global', 'research', 'disease', 'scientist', 'virus', 'parent', 'take', 'hiv', 'information', 'read', 'month', 'work', 'medium', 'video', 'social', 'may', 'influenza', 'community', 'medical', 'national', 'even', 'need', 'mother', 'two ', 'state', 'antivax', 'show', 'story', 'post', 'said', 'spread', 'meningitis', 'movement', 'vaccinated', 'autism', 'comment', 'country', 'family', 'doctor', 'question', 'first', '2019', 'american', 'case', 'also', 'claim', 'many', 'human', 'effort', 'researcher', 'life', 'outbreak', 'antivaxxer', 'news', 'development', 'company', 'way', 'cdc', 'know', 'dont', 'rate', 'use', 'million', 'university', 'article', 'see', 'platform', 'cause', 'come', 'go', 'nurse', 'made', 'baby', 'found', 'online', 'getting', 'kid', 'program', 'medicine', 'still', 'advocate', 'report', 'school', 'organization', 'pandemic', 'antivaccine', 'hepatitis', 'patient', 'polio', 'page', 'last', 'recent', 'think', 'issue', 'talk', 'government', 'today', 'campaign', 'child', 'back', 'develop', 'three', 'much', 'end', 'ebola', 'center', 'find', 'used']
Negative: ['misinformation', 'death', 'dangerous', 'conspiracy', 'threat']

```

Figure 20. VADER sentiment analysis topics of Pro-vaccination groups

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Scores: {'neg': 0.153, 'neu': 0.658, 'pos': 0.189, 'compound': 0.5713}
Positive: ['protect', 'help', 'important', 'like', 'sure', 'prevent', 'well', 'save', 'healthy', 'best', 'effective', 'want', 'protected', 'recommended']
Neutral: ['child', 'disease', 'vaccine', 'parent', 'vaccination', 'vaccine preventable', 'learn', 'need', 'people', 'year', 'one', 'vaccinate', 'million', 'preventable', 'life', 'many', 'baby', 'vaccinated', 'immunization', 'health', 'age', 'two', 'make', 'kid', 'deadly', 'get', 'family', 'infectious', 'outbreak', 'immunity', 'rotavirus', 'country', 'measles', 'cough', 'study', 'polio', 'community', 'whooping', 'spread', 'time', 'new', 'first', 'know', 'still', 'adult', 'see', 'even', 'world', 'shingle', 'chickenpox', 'effect', 'person', 'today', 'public', 'way', 'state', 'put', 'mother', 'doctor', 'vaccinating', 'work', 'fact', 'diabetes', 'every', 'alzheimers', 'infection', 'cause', 'protecting', 'would', 'schedule', 'seen', 'autism', 'young', 'influenza', 'lead', 'eventually', 'dont', 'show', 'living', 'rate', 'virus', 'herd', '58', 'childhood', 'case', 'month', 'also', 'sixth largest', 'available', 'memory', 'week', 'take', 'getting', 'personality', 'control', 'among', 'story', 'thousand', 'keep', 'potentially', 'putting', 'currently', 'say', 'talk', 'three', 'evidence', 'unvaccinated', '14', 'woman', 'count', 'within', 'day', 'school', 'access', 'according', 'recent', 'visit', 'despite', 'side', 'hepatitis', 'protection', 'could', 'lifetaker', 'research']
Negative: ['risk', 'serious', 'dangerous', 'stop', 'vulnerable', 'losing', 'death', 'robs', 'horrible', 'battle', 'illness', 'hard']

```

Figure 21. VADER sentiment analysis topics of Pro-vaccination groups

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```

Scores: {'neg': 0.151, 'neu': 0.656, 'pos': 0.194, 'compound': 0.802}
Positive: ['protect', 'best', 'help', 'care', 'effective', 'important', 'good', 'prevent', 'healthy', 'immune', 'like', 'well', 'importance', 'free']
Neutral: ['season', 'shot', 'get', 'vaccine', 'year', 'influenza', 'health', 'getting', 'vaccination', 'family', 'people', 'virus', 'child', 'annual', 'cdc', 'time', 'seasonal', 'one', 'new', 'say', 'vaccinated', 'covid19', 'fall', 'official', 'pandemic', 'could', 'story', 'read', 'everyone', 'complication', 'still', 'know', 'disease', 'way', 'two', 'even', 'month', 'last', 'around', 'center', 'adult', 'week', 'many', 'according', 'may', 'universal', 'also', 'system', 'state', 'late', 'information', 'appeared', 'first', 'end', 'found', 'protection', 'report', 'said', 'full', 'cause', 'patient', 'hospital', 'community', 'every', 'make', 'need', 'million', 'expert', 'pregnant', 'researcher', 'likely', 'find', 'case', 'take', 'prevention', 'flu', 'related', 'latest', 'ever', 'american', 'symptom', 'winter', 'including', 'doctor', 'three', 'dont', 'older', 'hospitalization', 'clinic', 'working', 'kid', 'early', 'least', 'control', 'far', 'mean', 'life', 't', 'hats', 'got', 'parent', 'rate', 'give', 'october', 'day', 'learn', 'department', 'dr', 'pregnancy', 'circulating', 'national', 'urging', 'fact', 'article', 'study', 'target', 'second', 'start', 'pharmacy', '20192020', 'would', 'effectiveness', 'young', 'see', 'part', 'infection', 'le']
Negative: ['flu', 'strain', 'illness', 'death', 'died', 'sick', 'serious', 'severe', 'risk', 'lost', 'attack']

```

Figure 22. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.196, 'neu': 0.737, 'pos': 0.068, 'compound': -0.975}
Positive: ['united', 'number', 'increase', 'immune', 'prevent', 'played']
Neutral: ['measles', 'outbreak', 'case', 'health', 'year', 'state', 'disease', 'vaccine', 'vaccination', 'child', 'official', 'confirmed', 'reported', 'new', 'country', 'county', 'people', '2019', 'mumps', 'since', 'mmr', 'one', 'world', 'public', 'unvaccinated', 'epidemic', 'across', 'virus', '20', 'cdc', 'many', 'spread', 'rubella', 'samoan', 'according', 'say', 'control', 'vaccinated', 'center', 'york', 'last', 'city', '30', 'decade', 'rate', 'washington', 'said', 'amid', 'declared', 'individual', 'may', 'week', 'parent', 'prevention', 'infection', 'eliminated', 'time', '10', 'clark', '2018', 'first', 'organization', 'month', 'area', 'europe', 'around', '2000', 'big', 'antivaccine', 'two', 'polio', 'vaccinepreventable', 'article', 'highly', 'doctor', 'viral', 'need', 'rise', 'get', 'least', 'read', 'nearly', 'part', 'recent', 'department', 'complication', 'percent', 'movement', 'current', 'cause', 'eradicated', 'central', 'amnesia', 'system', 'expert', 'deadly', 'global', 'highest', 'recently', 'study', 'contributing', 'spreading', 'school', 'bernard', 'selz', 'making', 'ongoing', 'due', 'contracted', 'could', 'factor', 'texas', 'government', 'person', 'america', 'five', 'dos', 'another', 'news', 'lisa', 'california', 'region', 'even', 'medium', 'hospital', 'result', 'donor', 'wednesday', 'know', 'student', 'wash', 'show']
Negative: ['worst', 'contagious', 'hesitancy', 'misinformation', 'death', 'emergency', 'risk', 'threat', 'fear', 'infected', 'died', 'blame']

```

Figure 23. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.059, 'neu': 0.741, 'pos': 0.2, 'compound': 0.9633}
Positive: ['prevent', 'prevents', 'important', 'recommended', 'safe', 'safety', 'certain', 'approved', 'united', 'protect', 'effective', 'help', 'share', 'protects', 'benefit']
Neutral: ['hpv', 'vaccine', 'cervical', 'study', 'woman', 'human', 'papillomavirus', 'year', 'evidence', 'gardasil', 'new', 'vaccination', 'virus', 'age', 'girl', 'nearly', 'could', '45', 'infection', 'effectiveness', 'breast', 'question', 'type', 'caused', 'published', 'men', 'one', 'get', 'young', 'laura', 'researcher', 'say', 'several', 'prevention', 'decade', 'parent', 'article', 'cause', 'two', 'hpvrelated', 'provides', 'adult', 'disease', 'written', 'wiped', 'according', 'screening', 'myth', 'optional', 'within', 'american', 'fda', 'dose', 'video', 'teen', 'genital', 'people', 'vaccinated', 'adolescent', 'answer', 'world', 'know', 'uptake', 'show', 'related', 'boy', 'need', 'life', 'case', 'despite', 'rate', 'state', 'recent', 'health', 'cdc', 'million', 'series', 'many', 'old', 'immunisation', 'preventing', 'link', 'papilloma', 'campaign', 'ireland', 'linked', '27', 'dos', '2006', 'fall', 'awareness', 'use', 'anal', 'way', 'efficacy', 'prevalence', 'sudden', 'oral', 'large', 'learn', 'reducing', 'experience', 'claim', 'country', 'may', 'introduction', 'make', 'still', 'lead', 'child', 'story', 'antivaccine', 'doctor', 'thats', 'newly', 'common', 'diagnosed', 'significantly', 'autonomic', 'nine', 'fact', '2015', 'throat', 'find', 'imp', 'three', 'involved', 'recommendation', 'every', 'receive', 'society', 'also']
Negative: ['cancer', 'risk', 'dysfunction']

```

Figure 24. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.225, 'neu': 0.681, 'pos': 0.094, 'compound': -0.976}
Positive: ['convince', 'growing', 'like', 'important', 'prominent', 'legal',
', 'increase']
Neutral: ['antivaccine', 'dorit', 'reiss', 'rubinstein', 'professor', 'art
icle', 'meme', 'law', 'written', 'refutation', 'vaccine', 'california', 'a
ctivist', 'university', 'facebook', 'religion', 'movement', 'hastings', 't
rope', 'group', 'published', 'claim', 'advocate', 'another', 'one', 'socia
l', 'used', 'doctor', 'medium', 'parent', 'science', '2019', 'provaccine',
'health', 'recently', 'ican', 'college', 'foia', 'baby', 'autism', 'lie',
'called', 'blog', 'page', 'robert', 'public', 'unexpectedly', 'website',
'commenters', 'frequent', 'contributor', 'post', 'folk', 'recent', 'acip',
'bill', 'study', 'try', 'question', 'made', 'go', 'measles', 'whose', 'tea
med', 'myth', '2020', 'kennedy', 'time', 'get', 'world', 'scientist', 'yeh
uda', 'protester', 'online', 'pseudoscientific', 'course', 'paper', 'pharm
a', 'story', 'many', 'child', 'right', 'old', 'pushed', 'wakefield', 'acti
on', 'practice', 'andrew', 'organization', 'immunization', 'conference',
'film', 'meeting', 'find', 'mmr', 'lydia', 'woman', 'telling', 'belief',
'say', 'staple', 'posted', 'dont', 'two', 'modern', 'behind', 'cause', 'make
', 'economic', 'james', 'believe', 'flood', 'kid', 'former', 'wrote',
'february', 'link', 'look', 'retracted', 'jr', 'connected', 'reality',
'physician', '1986', 'hear', 'spread', 'coordinated']
Negative: ['fake', 'propaganda', 'attack', 'lawsuit', 'misinformation',
'b
lame', 'harassment', 'risk', 'died', 'flu', 'ridiculous', 'crisis', 'press
ure', 'whore', 'pseudoscience', 'killer']

```

Figure 25. VADER sentiment analysis topics of Pro-vaccination groups

```

Scores: {'neg': 0.173, 'neu': 0.654, 'pos': 0.173, 'compound': -0.4549}
Positive: ['share', 'truth', 'free', 'safety', 'please', 'help', 'mandator
y', 'want', 'amazon', 'friend', 'trusted', 'encourages', 'gain', 'safe',
'credit', 'effective', 'brave']
Neutral: ['vaxxed', 'parent', 'watch', 'film', 'vaccine', 'ii', 'story',
'polly', 'child', 'bus', 'must', 'every', 'video', 'documentary', 'docuseri
es', 'tommey', 'dayayear', '365', 'vaccinate', 'question', 'emotionally',
'247', 'endure', 'mentally', 'efficacy', 'physically', 'people', 'financia
lly', 'interview', 'sara', 'often', 'team', 'mention', 'doctor', 'pediatrician',
'mother', 'interviewed', 'tour', 'producer', 'vaccination', 'episod
e', 'policymakers', 'call', 'coverup', 'firmly', 'day', 'released', 'del',
'click', 'world', 'bigtree', 'yaccineinjured', 'nurse', 'know', 'industry',
'start', '9part', 'ama', 'around', 'family', 'mile', 'revealed', '180',
'level', 'cover', 'th', 'crew', 'son', 'vac', 'wound', 'happened', 'parent
rights', 'costello', 'interviewing', 'beinformed', 'coronavirus', 'decide
', 'online', 'really', 'daughter', 'movie', 'dr', 'project', 'screening',
'government', 'get', 'highwire', 'ticket', 'visit', 'weve', 'event', 'oppo
se', 'explains', 'mirrored', 'travel', 'blow', 'see', 'recently', 'think',
'autistic', 'camera', 'health', 'mmr', 'usa', 'asked', 'series', 'epidemic
', 'mind', 'across', 'viewer', 'vaccinated', 'april', 'tell', '22', 'told',
'new', 'caused', 'dvd', 'show', 'nothing', 'medicalindustrial', 'link',
'50000', 'dillon', 'everything', 'overstep', 'medium', 'viewing', 'year',
'dont', 'cdcwhistleblower', 'california', 'continues', 'need', 'australia',
'brisbane', 'tearful', 'theater', 'grandfather', 'far', 'cousin', 'strea
ming', 'grandmother', 'araajo', 'egregious', 'jorge', 'woman', 'many',
'de
serves', 'member', 'made', 'speak', 'message', 'filmmaker', 'wide', 'editi
ng', 'brother', 'supervisor', 'old', 'outweigh', 'nov', 'action', 'page',
'discus', 'brill', 'vaxxed2', 'always', 'go']
Negative: ['harassment', 'bully', 'agonizing', 'injury', 'struggle', 'refu
se', 'catastrophe', 'rejected', 'hide', 'bloody', 'misinformation', 'injur
ed', 'lose', 'death', 'disagree']

```

Figure 26. VADER sentiment analysis topics of Anti-vaccination groups

```

Scores: {'neg': 0.106, 'neu': 0.699, 'pos': 0.194, 'compound': 0.936}
Positive: ['defense', 'freedom', 'care', 'safety', 'free', 'authority', 'consent', 'top', 'legal', 'challenge', 'interest', 'mandatory', 'united', 'truth', 'trustworthiness', 'support', 'protect', 'important', 'want', 'responsible', 'number']
Neutral: ['health', 'public', 'vaccine', 'world', 'official', 'childrens', 'organization', 'department', 'vaccination', 'child', 'parent', 'say', 'state', 'global', 'new', 'many', 'agency', 'right', 'people', 'school', 'government', 'human', '2019', 'measles', 'said', 'policy', 'medical', 'outbreak', 'service', 'one', 'national', 'immunization', 'informed', 'choice', 'would', 'county', 'mandate', 'program', 'committee', 'york', 'robert', 'jr', 'country', 'respond', '300', 'cdc', 'city', 'kennedy', '100', 'year', 'level', 'secretary', 'dr', 'news', 'doctor', 'study', 'medium', 'article', 'case', 'may', 'bill', 'hearing', 'unvaccinated', 'hhs', 'individual', 'old', 'give', 'family', 'published', 'information', 'law', 'make', 'expert', 'control', 'vaccinated', 'team', 'report', 'take', 'minister', 'group', 'part', 'philippine', 'effort', 'organisation', 'research', 'declared', 'disease', 'get', 'could', 'gate', 'professional', 'list', 'governmental', 'million', 'time', 'pandemic', 'director', 'action', 'recently', 'federal', 'education', 'science', 'according', 'concern', 'board', 'exposure', 'dengue', 'order', 'event', 'scientist', 'international', 'chd', 'childhood', 'today', 'advocate', 'response', 'rise', 'institute', 'polio', 'fda', '10', 'issue', 'need', 'plan', 'student', 'statement', 'tuesday', 'given', 'decade', 'condition', 'first', 'social', 'ten', 'senate', '2018', 'infection', 'week', 'rate', 'current', 'patient', 'malaria', 'environmental', 'must', 'community', 'court', 'april', 'covid19', 'medicine', 'including', 'requires', 'leading', 'product', 'virus', 'thousand', 'mmr', 'legislator', 'house', 'facility', 'coronavirus', 'across', 'parental', 'two', 'rockland', 'citizen', 'put', 'video', 'kid', 'force', 'washington']
Negative: ['threat', 'risk', 'emergency', 'conflict', 'hesitancy', 'problem', 'crisis', 'serious', 'shocking', 'fight']

```

Figure 27. VADER sentiment analysis topics of Anti-vaccination groups

```

Scores: {'neg': 0.108, 'neu': 0.745, 'pos': 0.147, 'compound': 0.7449}
Positive: ['immune', 'truth', 'like', 'effective', 'protect', 'united', 'energy', 'strongly', 'safe', 'healthy', 'free', 'help', 'justice', 'natural']
Neutral: ['disease', 'vaccine', 'infectious', 'outbreak', 'center', 'vaccination', 'child', 'prevention', 'control', 'cdc', 'childhood', 'health', 'dr', 'vaccinated', 'federal', 'meeting', 'measles', 'pox', 'immunity', 'people', '2019', 'department', 'committee', 'population', 'government', 'study', 'one', 'accv', 'new', 'prevent', 'case', 'autoimmune', 'cause', 'advisory', 'concluded', 'human', 'chronic', 'rate', 'commission', 'whooping', 'year', 'american', 'cough', 'service', 'fever', 'state', 'many', 'system', 'virus', 'fully', 'infection', 'may', 'medical', 'preventable', 'time', 'diphtheria', 'first', 'research', 'vaccinepreventable', 'say', 'pension', 'chicken', 'scientist', 'herd', 'instigator', 'epidemic', 'labor', 'introduced', 'said', 'caused', 'immunized', 'mumps', 'immunization', 'occurred', 'march', 'country', 'body', 'highly', 'small', 'senate', 'polio', '2004', 'become', 'report', 'spread', 'include', 'suggests', 'even', 'get', 'mostly', 'history', 'william', 'allergy', 'education', 'thompson', 'antibody', 'could', 'know', 'opposes', 'make', 'agency', 'public', 'according', 'settled', 'life', 'doctor', 'would', 'mandate', 'data', 'aaps', '1950s', 'official', 'tuberculosis', 'world', 'common', 'quarterly', 'house', 'need', 'last', 'commerce', 'adult', 'also', 'parent', 'food', 'within', 'physician', 'syndrome', 'subcommittee', 'scarlet', 'unvaccinated', 'drug', 'surgeon', 'reported', 'feb', 'effect', 'shingle', 'made', 'mild', 'national', 'autism', 'far', 'doj', 'since', 'oversight', 'mortality', '26', 'expert', 'contracted', '8th', 'decade', 'medi', 'dying', 'deadly', 'investigation', 'two', 'kid', 'rarely', 'due', 'student', '6th', 'chickenpox', 'shot', 'senior', 'including', 'coronavirus', 'fauci', 'received', 'every', 'association', 'never', 'fact', 'science', 'researcher', 'today', 'claim', 'used', 'interference', 'school']
Negative: ['death', 'illness', 'serious', 'cancer', 'fear', 'risk', 'discomfort', 'contagious']

```

Figure 28. VADER sentiment analysis topics of Anti-vaccination groups

```

Scores: {'neg': 0.161, 'neu': 0.68, 'pos': 0.159, 'compound': -0.5277}
Positive: ['safety', 'safe', 'like', 'want', 'free', 'truth', 'consent', 'well', 'immune', 'effective', 'important', 'freedom', 'help', 'approved', 'protect', 'good', 'number']
Neutral: ['vaccine', 'child', 'cdc', 'study', 'aluminum', 'one', 'people', 'new', 'know', 'information', 'autism', 'dont', 'science', 'dr', 'cause', 'research', 'cell', 'medical', 'doctor', 'parent', 'vaccination', 'fda', 'time', 'many', 'government', 'get', 'question', 'human', 'mmr', 'ingredient', 'used', 'reaction', 'public', 'make', 'mandate', 'would', 'right', 'year', 'schedule', 'say', 'pharmaceutical', 'industry', 'virus', 'need', 'effect', 'fetal', 'scientist', 'dna', 'issue', 'first', 'health', 'insert', 'use', 'american', 'company', 'tested', 'medium', 'even', 'aborted', 'choice', 'informed', 'vaccinated', 'may', 'side', 'every', 'take', 'never', 'article', 'read', 'also', 'immunity', 'drug', 'product', 'see', 'world', 'adjuvant', 'line', 'fact', 'scientific', 'system', 'manufacturer', 'life', 'could', 'book', 'today', 'state', 'work', 'expert', 'given', 'follow', 'data', 'childhood', 'come', 'woman', 'show', 'think', 'made', 'evidence', 'link', 'pregnant', 'concern', 'ever', 'researcher', 'country', 'body', 'rock', 'jr', 'infant', 'policy', 'brain', 'kid', 'story', 'hepatitis', 'including', 'response', 'report', 'two', 'mother', 'found', 'way', 'global', 'family', 'disease', 'debate', 'go', 'believe', 'vaccinate', 'going', 'muc', 'yet', 'let', 'event', 'trial', 'law', 'said', '2019', 'injected', 'marker', 'twitter', 'full', 'another', 'pharma', 'baby', 'informedconsent', 'pertussis', 'letter', 'mom', 'list', 'adult', 'case', 'find', 'million', 'video', 'influenza', 'billion', 'big', 'dos', 'day', 'give', 'market', 'group', 'developed', 'told', 'patient', 'result', 'development', 'tell', 'live', 'administration', 'efficacy']
Negative: ['risk', 'injured', 'adverse', 'harm', 'misinformation', 'damage', 'lawsuit', 'death', 'problem', 'disorder', 'injury', 'dangerous', 'cancer']

```

Figure 29. VADER sentiment analysis topics of Anti-vaccination groups

```

Scores: {'neg': 0.171, 'neu': 0.714, 'pos': 0.115, 'compound': -0.9492}
Positive: ['healthy', 'like', 'number', 'well', 'want', 'help', 'please', 'care', 'friend', 'good', 'share']
Neutral: ['vaccine', 'polio', 'baby', 'child', 'month', 'infant', 'year', 'case', 'one', 'vaccination', 'doctor', 'never', 'old', 'two', 'life', 'would', 'virus', 'know', 'time', 'even', 'shot', 'receiving', 'first', 'hour', 'parent', 'get', 'within', 'oral', 'dy', 'received', 'sids', 'took', 'hospital', 'people', 'said', 'told', 'getting', 'still', 'boy', 'reaction', 'many', 'wild', 'caused', 'country', 'didnt', 'daughter', 'india', 'seizure', 'given', 'started', 'dont', 'health', 'brain', 'every', 'back', 'week', 'later', 'ive', 'say', 'got', 'son', 'medical', 'mother', 'im', 'story', 'dtap', 'could', 'cause', 'report', 'vaccinated', 'new', 'hepatitis', 'following', 'girl', 'family', 'kid', 'go', 'though', 'mmr', 'pentavale', 'nt', 'see', 'six', 'went', 'pediatrician', 'dos', 'vaccinederived', 'eye', 'little', 'think', 'hep', 'make', 'away', 'take', 'last', 'give', 'disease', 'world', 'came', 'going', 'study', 'way', 'thing', 'reported', 'also', 'nurse', 'fever', 'system', 'ever', 'three', 'another', 'right', 'tell', 'found', 'known', 'called', 'autopsy', 'cdc', 'age', '12', 'much', 'live', 'something', 'since', 'show', 'due', 'born', 'developed', 'today', '10', 'million', 'paralyzed', 'nothing', 'home', 'done', 'african', 'sleep', 'need', 'made', 'meningitis', 'body', 'research', 'around', 'nicholas', 'far', 'visit', 'infection', 'result', 'believe', 'government', 'cant', 'may', 'birth', 'matter', 'come', 'almost', 'autism', 'long', 'dpt', 'normal', 'look', 'night', 'always', 'paralysis', 'four', 'high', 'wasnt', 'side', 'happened', 'syria', 'causing', 'knew', 'schedule', '20', 'really']
Negative: ['died', 'death', 'die', 'damage', 'sick', 'risk', 'injury', 'lost', 'cry', 'cancer', 'injured', 'pain', 'delayed', 'severe']

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Figure 30. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.065, 'neu': 0.739, 'pos': 0.195, 'compound': 0.9769}
Positive: ['mandatory', 'freedom', 'please', 'support', 'like', 'want', 'help', 'free', 'share', 'good', 'well', 'truth', 'consent', 'healthy', 'friend', 'thank', 'join', 'protect', 'number']
Neutral: ['vaccination', 'vaccine', 'child', 'dr', 'new', 'one', 'parent', 'people', 'medical', 'right', '2019', 'government', 'year', 'vaccinated', 'say', 'vaxxeddownunder', 'state', 'get', 'school', 'medium', 'said', 'time', 'doctor', 'facebook', 'article', 'video', 'autism', 'family', 'case', 'news', 'research', 'day', 'today', 'group', 'law', 'may', 'see', 'bill', 'antivaccine', 'study', 'know', 'post', 'event', 'make', 'two', 'need', 'would', 'report', '2020', 'information', 'many', 'could', 'take', 'big', 'antivaccination', 'public', 'read', 'first', 'social', 'unvaccinated', 'story', 'way', 'back', 'company', 'world', 'dont', 'pharma', 'go', 'science', 'kid', 'life', 'choice', 'question', 'virus', 'show', 'cdc', 'last', 'link', 'movement', 'country', 'page', 'vaccinate', 'drug', 'kennedy', 'week', 'di', 'month', 'court', 'comment', 'jr', 'rate', 'also', 'following', 'attorney', 'merck', 'robert', 'immunization', 'come', 'california', 'order', 'adult', 'community', 'member', 'fact', 'medicine', 'american', 'find', 'every', 'gate', 'book', 'mother', 'interview', 'informed', 'york', 'patient', 'going', 'immunity', 'pharmaceutical', 'made', 'mmr', 'del', 'censorship', 'live', 'action', 'national', 'think', 'letter', 'call', 'million', 'debate', 'official', 'mandate', 'student', 'issue', 'county', 'president', 'recent', 'response', 'content', 'human', 'outbreak', 'even', 'son', 'work', 'found', 'test', 'much', 'baby', 'program', 'without', 'email', 'health', 'former', 'published', 'home', 'told', 'expert', 'industry', 'cause', 'recently', 'march', 'end', 'let', 'give', 'full', 'still', 'measles', 'scientific', 'part', 'claim', 'next', 'believe', 'city', 'website', 'since']
Negative: ['risk', 'stop', 'death', 'misinformation', 'forced', 'protest']

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Figure 31. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.051, 'neu': 0.824, 'pos': 0.124, 'compound': 0.881}
Positive: ['freedom', 'support', 'consent', 'mandatory', 'please', 'allow', 'want', 'protect', 'care', 'exempt', 'thank', 'like', 'number']
Neutral: ['exemption', 'bill', 'state', 'religious', 'vaccine', 'child', 'school', 'medical', 'would', 'new', 'vaccination', 'law', 'california', 'right', 'parent', 'senate', 'york', 'house', 'senator', 'maine', 'remove', 'public', 'health', 'philosophical', 'doctor', 'family', 'committee', 'passed', 'hearing', 'legislation', 'requirement', 'vote', 'sb', 'lawmaker', '276', 'colorado', 'legislature', 'student', 'get', 'legislator', 'repeal', 'parental', 'mandate', '2019', 'capitol', 'attend', 'introduced', 'make', 'personal', 'ny', 'governor', 'one', 'end', 'assembly', 'immunization', 'nonmedical', 'albany', 'sb276', 'decision', 'proposed', 'belief', 'ld', 'education', 'year', 'require', 'say', 'arizona', 'action', 'eliminate', 'need', 'measles', 'time', 'legislative', 'government', 'call', 'voted', 'info', 'med', 'oregon', 'people', 'take', 'opposition', 'hb', 'day', '798', 'may', 'choice', 'also', 'physician', 'thursday', 'kid', 'pan', 'jersey', 'reason', 'go', 'vaccinated', 'required', 'many', 'department', 'robert', 'information', 'board', 'wednesday', 'today', 'last', 'oppose', 'federal', 'representative', 'know', 'email', 'newsom', 'private', 'believe', 'without', 'ohio', 'sen', 'daycare', 'washington', 'signed', 'june', 'must', 'first', 'monday', 'outbreak', 'group', 'effort', 'week', 'back', 'even', 'republican', 'connecticut', 'made', 'district', 'removing', 'nvic', 'said', 'dakota', 'minor', 'session', 'policy', 'dont', 'kennedy', 'filed', 'democrat', 'away', 'childhood', 'gov', 'office', 'way', 'come', 'written', 'attorney', 'member', 'hpv', 'vaccinate', 'every', 'force', 'gavin', 'official', 'give', 'amendment', 'florida', 'across', 'could', 'opt', 'hundred', 'let', 'dr', 'receive', 'case', 'south', 'rally', 'issue', 'service', 'pas', 'sacr', 'amento', 'show', 'opponent', 'sign', 'human', 'news', 'citizen', 'act', 'mandated']
Negative: ['protest', 'restrict', 'fight', 'ban']

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Figure 32. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.172, 'neu': 0.691, 'pos': 0.137, 'compound': -0.891}
Positive: ['free', 'effective', 'friend', 'like', 'top', 'immune', 'number',
    'want', 'well', 'increase', 'protect', 'safety', 'care', 'share']
Neutral: ['shot', 'vaccine', 'season', 'influenza', 'get', 'swine', 'year',
    'people', 'vaccination', 'got', 'study', 'woman', 'received', 'cdc',
    'say', 'child', 'virus', 'health', 'receiving', 'getting', 'pregnant',
    'sterling', 'might', 'pandemic', 'annual', 'elderly', 'new', 'vaccinated',
    'mount', 'doctor', 'infection', 'one', 'million', 'spanish', 'nurse',
    'time', 'last', 'even', 'fact', 'thats', 'work', 'senior', 'according',
    'found', 'may', 'cause', 'effectiveness', 'hospitalization', 'narcolepsy',
    'dr', 'department', 'jab', 'would', 'also', 'cough', '1976', 'reaction',
    'claim', 'whooing', 'day', 'coronavirus', 'percent', 'student', 'early',
    'evan', 'half', 'family', 'every', 'hospital', 'news', 'state', 'seasonal',
    'made', 'actually', 'h1n1', 'wh', 'bug', 'showed', 'case', 'show', 'medical',
    'researcher', '2009', 'syndrome', 'developed', 'report', 'dont', 'result',
    'data', 'disease', 'story', 'mandate', 'system', 'mercury', 'recent',
    'compensated', 'article', 'think', 'know', 'miscarriage', 'receive',
    'kentucky', 'wkrc', 'citizen', 'grew', 'friday', 'way', 'court', 'many',
    'three', 'givin', '50100', 'two', 'guillainbarré', 'ky', 'popped', 'bc',
    'healthier', 'including', 'week', 'mankato', '100', 'said', 'son', 'told',
    'still', 'program', 'read', '191819', 'everyone', 'night', 'make', 'need',
    'preventing', 'research', 'body', 'school', 'estimated', 'respiratory',
    'government', 'shedding', 'caused', 'covid19', 'location', 'expert',
    'started', 'meet', 'vaxxeddownunder', 'instead', 'record', 'rate',
    'official', 'science', 'high', '10', 'jama', 'among', 'uc',
    'hepatitis', '2019', 'cbs', 'month', 'isnt',
    'question', 'university', 'insert', 'young', 'documentary', 'could',
    'first', 'worked', 'another']
Negative: ['flu', 'death', 'strain', 'risk', 'injury', 'killed', 'died',
    'disorder', 'failing', 'infected', 'miserably', 'adverse', 'alarm', 'bad']

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Figure 33. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.105, 'neu': 0.747, 'pos': 0.148, 'compound': 0.802}
Positive: ['ready', 'novel', 'effective', 'safety', 'mandatory', 'want',
    'safe', 'united', 'like', 'immune', 'promising', 'challenge', 'hope',
    'appoval']
Neutral: ['covid19', 'coronavirus', 'vaccine', 'trial', 'clinical', 'people',
    'gate', 'pandemic', 'said', 'could', 'company', 'may', 'virus', 'say',
    'new', 'moderna', 'testing', 'astrazeneca', 'experimental', 'scientist',
    'government', 'available', 'human', 'get', 'first', 'test', 'oxford',
    'volunteer', 'fauci', 'study', 'american', 'world', 'one', 'development',
    'potential', 'would', 'university', 'developed', 'develop', 'dr',
    'take', 'johnson', 'million', 'drug', 'phase', 'expert', 'bill',
    'health', 'year', 'researcher', 'participant', '2020', 'candidate',
    'billion', 'race', 'trump', 'result', 'part', 'africa',
    'vaccination', 'infection', 'state', 'animal', 'news',
    'developing', 'response', 'public', 'immunity', 'china', 'poll',
    'modernas', 'month', 'antibody', 'two', 'anthony', 'make',
    'country', 'global', 'medical', 'treatment', 'become',
    'announced', 'shot', 'effect', 'even', 'covid',
    'speed', 'according', 'tested', 'around', 'federal', 'concern',
    'president', 'uk', 'begin', 'likely', 'vaccinated', 'biotech',
    'need', 'australian', 'week', 'time', 'institute', 'early',
    'told', 'already', 'spread', 'fda', 'pharmaceutical',
    'wednesday', 'end', 'outbreak', 'many', 'patient',
    'dos', 'next', 'rushing', 'disease', 'plan', 'influenza',
    'work', 'claim', 'event', 'soon', 'population', 'foundation',
    'jab', 'use', 'sarscov2', 'report', 'whether', 'case',
    'becomes', 'research', 'fasttracked', 'prevent',
    'getting', 'reaction', 'child', 'possible', 'executive',
    'given', 'full',
    'effort', 'medium', 'history', '18', 'melinda', 'group',
    'therapeutic', 'working', 'life', 'key', 'without',
    'go', 'reuters', 'data', 'sars', 'canada',
    'compulsory', 'also', 'rush', 'return', 'much', 'question',
    'action', 'morrison', 'administration', 'pfizer',
    'received', 'show', 'used', 'find', 'national',
    'future', 'technology']
Negative: ['risk', 'adverse', 'serious', 'warning', 'illness', 'death',
    'severe', 'problem', 'liability', 'emergency']

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Figure 34. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.211, 'neu': 0.64, 'pos': 0.149, 'compound': -0.9515}
Positive: ['approved', 'safety', 'approval', 'healthy', 'popular', 'protect', 'giving', 'consent', 'truth', 'safe', 'recommended', 'help', 'active', 'share', 'hope']
Neutral: ['hpv', 'gardasil', 'vaccine', 'cervical', 'papillomavirus', 'girl', 'human', 'merck', 'vaccination', 'young', 'woman', 'reaction', 'health', 'trial', 'reported', 'year', 'mercks', 'case', 'receiving', 'study', 'new', 'age', 'effect', 'rate', 'sexually', 'child', 'cause', 'school', 'dr', 'event', 'side', 'boy', 'following', 'around', 'given', 'doctor', '2006', 'found', 'one', 'according', '2018', 'fda', 'court', 'world', 'efficacy', 'daughter', 'never', 'mother', 'published', 'research', 'family', 'without', 'prevent', 'life', 'since', 'report', 'science', 'many', 'first', 'transmitted', 'thousand', 'introduced', 'group', 'received', 'virus', 'papiloma', 'article', 'public', 'state', 'cervarix', 'may', 'get', 'also', 'researcher', 'presentation', 'two', 'link', 'fact', 'clinical', '2019', 'day', 'globe', 'know', 'evidence', 'data', 'said', 'teen', 'medical', 'say', 'analysis', 'mandate', 'receive', 'parent', 'tarsell', 'end', 'jennifer', 'country', 'infection', 'australia', 'video', 'jab', 'teenager', '25', 'ovarian', 'robi', 'cdc', 'government', 'caused', 'japan', 'shortly', 'shot', 'people', 'several', 'would', '2008', 'information', 'syndrome', 'kaiser', 'autoimmune', 'scientist', 'use', 'administration', 'january', 'second', 'disease', 'twitter', 'read', 'angeles', 'injection', 'los', 'time', 'whether', 'ministry', 'developed', 'could', 'schoolgirl', 'result', 'hold', 'database', 'jr', 'getting', 'make', 'manufacturer', 'permanente', 'million', 'three', 'discovering', 'news', 'already', '9th', 'son', 'august', 'symptom', 'june', 'includes', 'conceive', '13', 'diagnosed', 'maryland', 'screening', 'gardasilrelated', '100000', 'virgin', 'sacrificial', 'manufactured', 'genevieve', 'sterilized']
Negative: ['cancer', 'adverse', 'death', 'serious', 'injury', 'suffering', 'lawsuit', 'risk', 'fraud', 'dangerous', 'died', 'severe', 'scandal', 'pain', 'harmed', 'problem', 'suffered', 'damage']

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Figure 35. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.191, 'neu': 0.695, 'pos': 0.113, 'compound': -0.9726}
Positive: ['united', 'number', 'like', 'natural', 'vitamin', 'effective', 'want', 'well', 'mandatory', 'important', 'immune', 'help']
Neutral: ['measles', 'vaccine', 'outbreak', 'mmr', 'child', 'case', 'vaccinated', 'vaccination', 'mumps', 'autism', 'year', 'immunity', 'rubella', 'state', 'rate', 'virus', 'health', 'people', 'parent', 'unvaccinated', 'new', 'study', 'medium', 'disease', 'one', 'two', 'cdc', 'fact', 'reported', 'seizure', 'infection', 'samoa', 'cause', 'public', 'dr', 'article', 'may', 'know', 'adult', 'get', 'school', 'county', 'medical', 'reaction', 'york', 'doctor', 'report', 'time', 'say', 'response', 'many', 'population', 'news', 'link', 'dos', 'even', 'caused', 'dont', 'found', 'evidence', 'also', 'recent', 'age', 'since', 'informedconsent', 'country', 'city', 'would', 'yet', 'mortality', 'day', '2019', 'fully', 'today', 'high', 'last', 'washington', 'herd', 'following', 'merck', 'confirmed', 'picphysicians', 'highly', 'baby', 'become', 'law', 'government', 'million', 'physicians4informatics', 'official', 'need', 'according', 'research', 'kid', 'month', '1963', 'make', 'physician', 'among', 'result', 'individual', 'symptom', 'student', 'developed', 'received', 'question', 'spread', 'due', 'brain', 'community', 'antibody', 'live', 'exemption', 'brooklyn', 'receiving', 'order', 'likely', 'decade', 'right', 'effect', 'percent', 'said', 'infant', 'vaccinate', 'around', 'occurred', 'every', 'first', 'still', 'higher', '2015', 'claimed', 'see', 'encephalitis', 'several', 'least', 'claim', 'world', 'mainstream', 'pic', 'scientific', 'debate', 'american', 'rockland', 'jewish', 'california', 'given', 'week', 'epidemic', 'fever', 'dose', 'mandate', 'despite', 'show', '2018', 'blasio', 'compared', 'current', 'campaign', 'three', 'read', 'science', 'investigation', 'others', 'could', 'declared', 'informed', 'childhood', 'without', 'reporting', 'distinguish']
Negative: ['death', 'risk', 'failure', 'strain', 'emergency', 'fear', 'infected', 'blamed', 'rash', 'died', 'cancer', 'disorder', 'illness', 'avoid', 'worst', 'low', 'adverse']

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Figure 36. VADER sentiment analysis topics of Anti-vaccination groups

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Scores: {'neg': 0.204, 'neu': 0.639, 'pos': 0.156, 'compound': -0.9064}
Positive: ['shared', 'safety', 'consent', 'save', 'legal', 'safe', 'special', 'care', 'win', 'dedicated', 'please', 'charitable', 'significant', 'number', 'freedom', 'join', 'share', 'united', 'mandatory']
Neutral: ['vaccine', 'national', 'compensation', 'act', 'program', 'childhood', '1986', 'paid', 'vaxeddownunder', 'child', 'awareness', 'story', 'federal', 'billion', 'compilation', '14th', 'court', 'parent', 'event', 'brain', 'time', 'investigate', '2016', 'february', 'report', 'potus', 'facebook', 'vaccination', 'many', 'one', 'people', 'ncvia', 'post', 'today', 'medical', 'group', 'little', 'information', 'year', 'vaers', 'drug', 'manufacturer', 'congress', 'vie', 'informed', 'day', 'life', 'nonprofit', 'reaction', 'biggest', 'petition', 'controversy', 'government', 'including', 'much', 'public', 'health', 'regression', 'injure', 'reported', '180', 'rarely', '2019', 'establish', 'there', 'th', 'washington', 'vaccinate', 'make', 'dc', 'since', 'even', 'cause', 'never', 'law', 'case', 'lccds', 'administration', '2the', 'family', 'nvic', 'reason', 'monitor', 'mmr', 'commission', 'system', 'reporting', 'claim', 'implementation', 'center', 'va', 'autism', 'president', 'hold', 'vicp', 'month', 'concluding', 'right', 'maker', 'request', 'new', 'know', 'get', 'schedule', 'ba', 'pharmaceutical', 'doctor', 'rare', 'product', 'dr', 'epidemic', 'prnewswire', 'given', 'austin', 'unable', 'following', 'revealed', 'may', 'thousand', 'disclosure', 'unit', 'live', 'company', 'licensed', 'intensive', 'fda', 'research', 'lay', 'million', 'attorney', 'action', 'state', 'preventing', 'ican', 'first', 'reagan', 'diagnosis', 'cdc', 'paying', 'fact', 'network', 'texas', 'carry', 'call', 'caused', 'medicine', 'question', 'attention', 'education', 'vacinerelated', 'sand', 'industry', 'measles', 'dont', 'food', 'defending', 'permanent', 'nvicp', 'date', '30', 'wake', 'here', 'dollar', 'bring', 'immunity']
Negative: ['injury', 'death', 'damage', 'injured', 'liability', 'adverse', 'dispute', 'risk', 'failure', 'kill', 'severe', 'limited', 'victim', 'suffering', 'lawsuit', 'harm']
```

Figure 37. VADER sentiment analysis topics of Anti-vaccination groups