Winds of Change: Impact of COVID-19 on Vaccine-related Opinions of Twitter users

Saptarshi Ghosh
Indian Institute of Technology Kharagpur
cse.iitkgp.ac.in/~saptarshi

Joint work with

Soham Poddar   Mainack Mondal   Niloy Ganguly   Janardan Misra

COVID-19 pandemic and the need for vaccines

- Administering COVID-19 vaccines at a societal scale is deemed as the most appropriate way to defend against the pandemic

- Only mass adoption of vaccines in a society can lead to herd immunity

Societal vaccination drives are going on …

Bloomberg

More Than 6.13 Billion Shots Given: Covid-19 Tracker

In the U.S., 390 million doses have been administered

Pew Research Center

Growing Share of Americans Say They Plan To Get a COVID-19 Vaccine – or Already Have

BBC NEWS

Covid vaccine: India gives 20 million jabs to mark PM Modi's birthday

However, there is a long-drawn debate on vaccines

Pro-vaxxers
support and promote the benefits of vaccines

Anti-vaxxers
believe that vaccines do more harm than good

Anti-vaxxer movement also gaining momentum ...

REUTERS

It's not for me: speed of COVID-19 vaccine race raises safety concerns

REUTERS

Social media disinformation campaigns tied to vaccine hesitancy

Los Angeles Times

Why is the 'anti-vaxxer' movement growing during a pandemic?

nature

Anti-vaccine movement could undermine efforts to end coronavirus pandemic, researchers warn

Important questions

1. What are the opinions of ==Anti-Vaxxers== and ==Pro-Vaxxers== towards COVID vaccines?
   - ➢ *Are the anti-vax opinions about COVID-19 vaccines similar to the traditional anti-vax arguments that were prevalent in pre-COVID times?*

2. Has the vaccine-related stance of some users changed over time due to the pandemic?
   - ➢ If so, *what factors could have caused this change in stance?*

Our research

1. Attempts to answer these questions using automated analyses over social media (Twitter) data

2. Conducts a long-term (over 3 years) analysis of people's attitudes towards vaccines, both individually and collectively

3. Shows for the first time, that some people have changed their vaccine-stance (e.g., from Pro to Anti or vice-versa) during the pandemic

4. Analyses potential reasons behind such changes in vaccine-stance

➢ **Data collection**

➢ **Identifying vaccine-stance**

➢ **How the vaccine discourse has changed**

➢ **How users' vaccine-stance has changed**

➢ **Implications**

➢ **Data collection**

➢ Identifying vaccine-stance

➢ How the vaccine discourse has changed

➢ How users' vaccine-stance has changed

➢ Implications

Data Collection

- Rely on social media (Twitter)

- Decided to collect Twitter data since 2018, to study long-term dynamics of vaccine stances both before and during COVID-19

- Official Twitter API only allows data from past 7-10 days.

- Thus, used the **Twint** Library* to collect vaccine-related English tweets from different time periods

*https://github.com/twintproject/twint

Data Collection - time periods

1. "**Pre-COVID**" period:
   ➢ *Jan 2018 - Dec 2019*

2. "**COVID**" period:
   ➢ *January-December 2020*

3. "**COVID-vax**" period:
   ➢ *January-March 2021*

Data Collection - queries used

1. **"Pre-COVID"** period:
   - Jan 2018 - Dec 2019

2. **"COVID"** period:
   - January-December 2020

3. **"COVID-vax"** period:
   - January-March 2021

- ❖ Pro-Vax Hashtags*
  - ➤ #VaccinesSaveLives, #GetVaccinated

- ❖ Anti-Vax Hashtags*
  - ➤ #VaccinesKill, #SayNoToVaccines

- ❖ Generic Keywords
  - ➤ "covid vaccine", "Vaxxer"

- ❖ Vaccine Names
  - ➤ "Pfizer", "Moderna"

*Provided by Gunaratne, Keith et.al. "Temporal trends in anti-vaccine discourse on Twitter"

Data Collection - number of tweets collected

1. "**Pre-COVID**" period:
    ➢ *Jan 2018 - Dec 2019*

    ➢ *2.9M Tweets*

2. "**COVID**" period:
    ➢ *January-December 2020.*

    ➢ *6.6M Tweets*

3. "**COVID-vax**" period:
    ➢ *January-March 2021.*

    ➢ *6.3M Tweets*

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    - ➢ *January-March 2021.*

    ➢ *6.3M Tweets*

Huge surge in vaccine-related tweets in 2021 (more on this later)

Identifying vaccine-stance

- Developed 3-class classifiers

- First developed a classifier for **individual tweets** (Pro-vax, Neutral, Anti-vax)

- Next, used the tweet-classifier to identify vaccine-stance of Twitter **users** (Pro-vaxxer, Neutral, Anti-vaxxer) in different time periods

Developing a tweet-classifier: available datasets

Dataset	Time Period	#tweets	Anti-Vax	Pro-Vax	Neutral
Muller[1]	Before 2019	18.5k	10.5%	40.3%	49.3%
Cotfas[2]	Nov-Dec 2020	2,792	25.3%	35.5%	36.2%

[1]Müller, M. M., & Salathé, M. (2019). Crowdbreaks: tracking health trends using public social media data and crowdsourcing. Frontiers in public health.

[2]Cotfas, L. A. et.al. (2021). The Longest Month: Analyzing COVID-19 Vaccination Opinions Dynamics from Tweets in the Month following the First Vaccine Announcement. IEEE Access.

Data Annotation

- Wanted to construct a labeled dataset of tweets posted throughout the pandemic times

- A random sample of 1,700 tweets posted during Jan 2020 - Mar 2021

- Tweets labeled by 3 annotators on Prolific crowdsourcing platform

- Each tweet labelled into the 3 classes (Pro-vax, Neutral, Anti-vax)

  ➢ 1,606 tweets with majority agreement

  ➢ **785** tweets with unanimous agreement

All Datasets

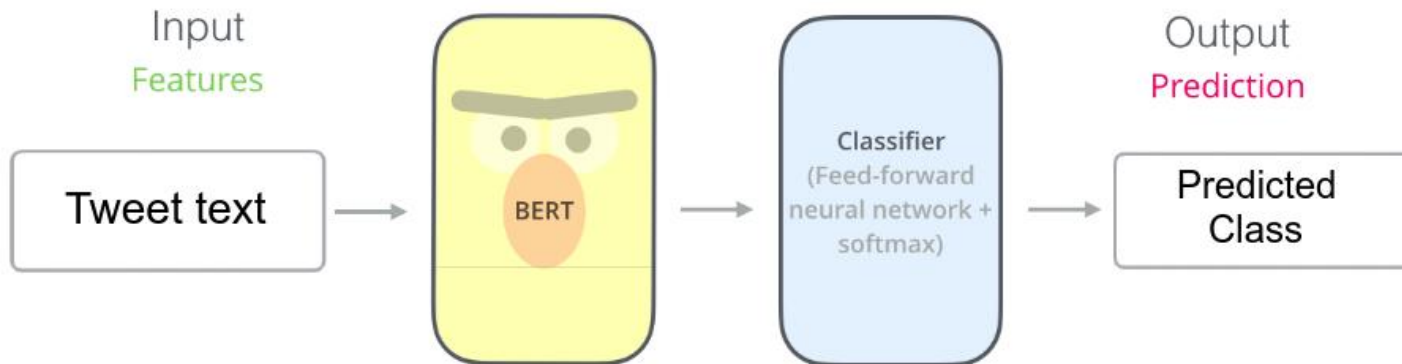| Dataset	Time Period	#tweets	Anti-Vax	Pro-Vax	Neutral
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Cotfas	Nov-Dec 2020	2,792	25.3%	35.5%	36.2%
Cotfas + our data	Jan 2020 - Mar 2021	3,577	26.0%	38.7%	35.3%

Tweet Classifiers

- SVM with TF-IDF features

- Random Forest with TF-IDF features

- Supervised FastText

- BERT-Base

- BERT-Large

- BERTweet

- CT-BERT-v2*
  (*COVID-Twitter BERT*)

Müller, M. et.al. (2020). "Covid-twitter-bert: A natural language processing model to analyse covid-19 content on Twitter". arXiv preprint arXiv:2005.07503.

Tweet Classifiers

- **CT-BERT++**
  - CT-BERT-v2 was first fine-tuned on the largest Muller dataset
  - This model further cross-validated on the datasets containing COVID-related tweets

Evaluation of Tweet Classifiers

- Stratified 5-fold cross validation on each dataset
- Average macro-F1 scores reported

	Muller	*Cotfas*	*Cotfas + our data*
SVM	0.628	0.751	0.695
FastText	0.650	0.735	0.683
Bert-Large	0.661	0.763	0.720
CT-BERT	**0.687**	0.768	0.797
CT-BERT++	-	**0.858**	**0.825**

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Used to classify pre-COVID tweets (2018-19)

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Used to classify pre-COVID tweets (2018-19)

Used to classify tweets in COVID times (2020-21)

User Classification method

- Identified the stance of a user separately during each time period

- A user is called **Anti-Vaxxer** during a particular time period if

  ➢ The user posted at least **3 tweets** during this time period

  ➢ **70%** of these tweets were **Anti-Vax** *(threshold selected based on a prior work*)*

- Similarly **Pro-Vaxxers** were also identified.

*Mitra, T., Counts, S., & Pennebaker, J. W. "Understanding anti-vaccination attitudes in social media". ICWSM 2016.

Evaluation of the User Classification method

Annotators manually checked tweets and profiles of 300 users (100 from each time period) who were identified as Anti-vaxxers or Pro-vaxxers

Time Period	Anti-Vaxxers (correct / checked)	Pro-Vaxxers (correct / checked)
Pre-COVID (2018-19)	50 / 50	50 / 50
COVID (2020)	50 / 50	48 / 50
COVID-Vax (Jan-Mar 2021)	44 / 50	49 / 50
Overall	291 / 300	

Evaluation of the User Classification method

Annotators manually checked tweets and profiles of 300 users (100 from each time period) who were identified as Anti-vaxxers or Pro-vaxxers

Our methods classify the vaccine-stance of users with **97%** precision over all three time-periods

COVID (2020)	50 / 50	48 / 50
COVID-Vax (Jan-Mar 2021)	44 / 50	49 / 50
Overall	291 / 300	

Classification results over all tweets
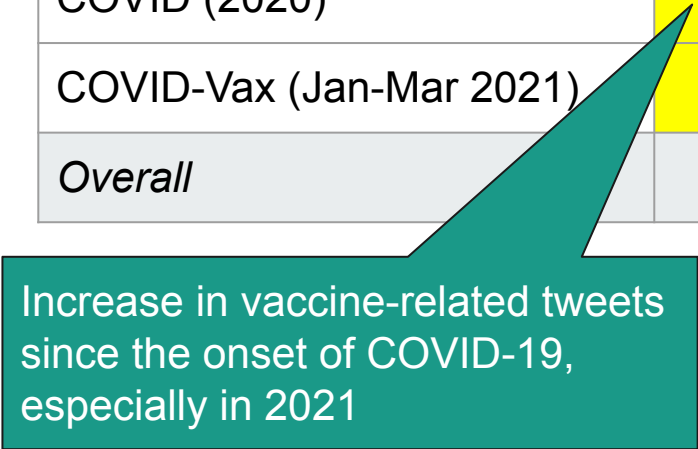
Time Period	Total	Anti-Vax	Pro-Vax
Pre-COVID (2018-19)	2.9M	577k	1.4M
COVID (2020)	6.6M	1.3M	1.8M
COVID-Vax (Jan-Mar 2021)	6.3M	1.1M	2.6M
Overall	*15.7M*	*3.0M*	*5.8M*

Classification results over all tweets

Time Period	Total	Anti-Vax	Pro-Vax
Pre-COVID (2018-19)	**2.9M**	577k	1.4M
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Increase in vaccine-related tweets since the onset of COVID-19, especially in 2021

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Increase in Pro-Vax tweets after vaccine distribution started.

Predicted user stances
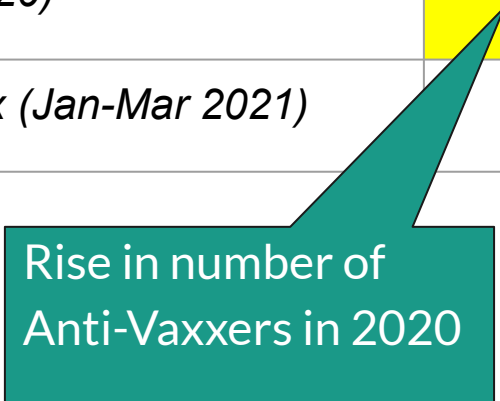
Time Period	Anti-Vaxxers	Pro-Vaxxers
Pre-COVID (2018-19)	14k	58k
COVID (2020)	47k	55k
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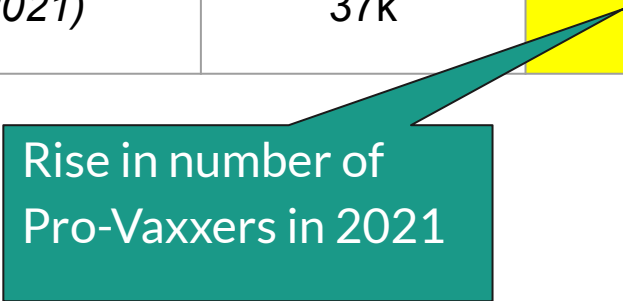
Rise in number of Anti-Vaxxers in 2020

Predicted user stances

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Rise in number of Pro-Vaxxers in 2021

Topic modeling over Anti-vax and Pro-vax tweets

- Used a combination of vanilla LDA, Labeled LDA and manual merging / splitting of topics

- 8 Anti-Vax themes from tweets posted by Anti-vaxxers

- 4 Pro-Vax themes from tweets posted by Pro-Vaxxers
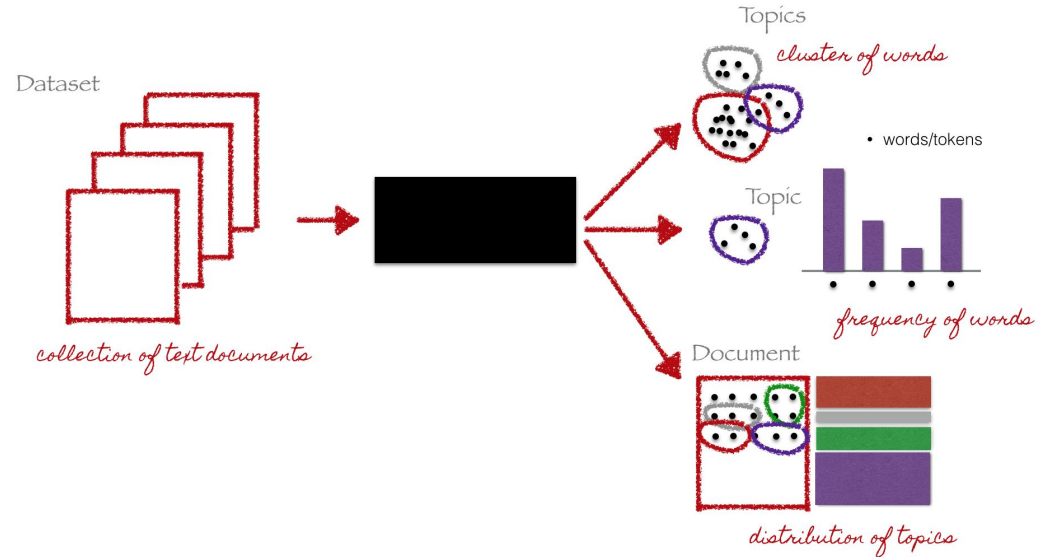
Dataset

collection of text documents

Topics
cluster of words

Topic

• words/tokens

frequency of words

Document

distribution of topics

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. Big Pharma

4. Political

5. Ineffective

6. Rushed

7. Shedding

8. Deeper Conspiracy

Anti-Vax Themes

1. **Health Concerns**
2. Against Mandatory
3. Big Pharma
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Health Concerns

Concerns about the ingredients and side effects of vaccines, including deaths.

Sample tweet:

I won't take one derived from any aborted fetal tissues. AstraZeneca does come from a cell line from aborted fetal tissues. No way I'm taking that.

Anti-Vax Themes

1. Health Concerns

2. **Against Mandatory**

3. Big Pharma

4. Political

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Against Mandatory

Against mandatory vaccination – prefers freedom and choice.

Sample tweet:

Biden is going to do his best to get a mandatory Covid vaccine . I feel very bad for what's going to happen in America

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. **Big Pharma**

4. Political

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Big Pharma

Dissatisfied with the role of pharmaceutical companies – they are tricking people, trying to make money.

Sample tweet:

Big Pharma lines their pockets, doctors get bonuses for having 63% of their patients vaccinated

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

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4. Political

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Political

The vaccine is political in nature – Governments are promoting their own agenda.

Sample tweet:

the CDC is spewing govt scripted propaganda and lies daily

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. Big Pharma

4. Political

5. **Ineffective**

6. Rushed

7. Shedding

8. Deeper Conspiracy

Ineffective

Skeptical about the effectiveness of vaccines

Sample tweet:

I just read an article explaining that the first Covid-19 dose is only 52% effective.

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. Big Pharma

4. Political

5. Ineffective

6. **Rushed**

7. Shedding

8. Deeper Conspiracy

Rushed

Vaccine development is being rushed – Not enough testing has been done

Sample tweet:

What's the rush? Better to be safe than sorry with the politically timed vaccine

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. Big Pharma

4. Political

5. Ineffective

6. Rushed

7. **Shedding**

8. Deeper Conspiracy

Shedding

Virus Shedding – People who take vaccines will transmit the disease to others

Sample tweet:

we shouldn't be surprised if these new 'variant' strains are the vaccinated shedding the virus, or the virus mutating because of the vaccine.

Anti-Vax Themes

1. Health Concerns

2. Against Mandatory

3. Big Pharma

4. Political

5. Ineffective

6. Rushed

7. Shedding

8. **Deeper Conspiracy**

Deeper Conspiracy

Disease is a Hoax, Tracking Chips and talks of other conspiracies (other than just money making)

Sample tweet:

get to the end game implant us with tracking chips and drug us to become the brainwashed robots

Pro-Vax Themes

1. Want Vaccines

2. Promote Vaccines

3. Against Anti-Vaxxer

4. Supports Authorities

Pro-Vax Themes

1. **Want Vaccines**

2. Promote Vaccines

3. Against Anti-Vaxxer

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Want Vaccines:

User wants to get vaccinated or has got the vaccine.

Sample tweet:

Yes, I will get the COVID-19 vaccine. (No, you cannot change my mind.)

Pro-Vax Themes

1. Want Vaccines

2. **Promote Vaccines**

3. Against Anti-Vaxxer

4. Supports Authorities

<u>**Promote Vaccines:**</u>

User is sharing positive emotions about vaccines.

Sample tweet:

Very good news on the Pfizer / BioNTech SE mRNA vaccine: early data shows 90% effectiveness!!

Pro-Vax Themes

1. Want Vaccines

2. Promote Vaccines

3. **Against Anti-Vaxxer**

4. Supports Authorities

Against Anti-Vaxxer:

Showing disagreement with Anti-Vaxxers

Sample tweet:

Anti-vaxx conspiracy bollocks preys on marginalized people living in news deserts. I heard a person wants to take ivermectin - not COVID vaccine.

Pro-Vax Themes

1. Want Vaccines

2. Promote Vaccines

3. Against Anti-Vaxxer

4. **Supports Authorities**

Supports Authorities:

Thanking or supporting medical staff or frontline workers for vaccines.

Sample tweet:

Thanks to funding and support from UNICEF, cold chain equipment, used to store vaccines

Variations in themes over time

	Pre-COVID (2018-19)	COVID (2020)	COVID-vax (2021)
1. Big Pharma	17.4%	13.3%	9.9%
2. Health Concerns	19.0%	15.1%	18.3%
3. Political	9.8%	12.2%	10.8%
4. Against Mandatory	17.6%	12.1%	13.0%
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Health Concerns is the most common topic across all periods

Variations in themes

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Most increased topics since the pandemic -- Rushed, Ineffective, and Deeper conspiracies

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Even more concerns about the ineffectiveness, especially in COVID-vax period

Variations in themes

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Most reduced topics since the pandemic - Against Mandatory, Big Pharma

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Political reasons more prevalent in 2020 (triggered by the US elections)

Recap: predicted user stances

Time Period	Anti-Vaxxers	Pro-Vaxxers
Pre-COVID (2018-19)	14k	58k
COVID (2020)	47k	55k
COVID-Vax (Jan-Mar 2021)	37k	124k

Did the stance of individual users evolve with time?

	Pre-COVID stance (2018-19)		
COVID Stance (2020)		*Anti-Vax*	*Pro-Vax*
	Anti-Vax	2791	218
	Pro-Vax	21	6853

	COVID stance (2020)		
COVID-vax Stance (2021)		*Anti-Vax*	*Pro-Vax*
	Anti-Vax	7855	121
	Pro-Vax	329	9898

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COVID Stance (2020)	Pre-COVID stance (2018-19)		
		Anti-Vax	Pro-Vax
	Anti-Vax	**2791**	218
	Pro-Vax	21	**6853**

COVID-vax Stance (2021)	COVID stance (2020)		
		Anti-Vax	Pro-Vax
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Most users continue to follow the same stance towards vaccines

Stance-changed users

	Pre-COVID stance (2018-19)		
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	COVID stance (2020)		
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We find 675 users who have changed their stance towards vaccines

Stance-changed users

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	COVID stance (2020)		
COVID-vax Stance (2021)		*Anti-Vax*	*Pro-Vax*
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14 users who changed their stance multiple times (Pro → Anti → Pro)

# Example tweets from stance-changed Users

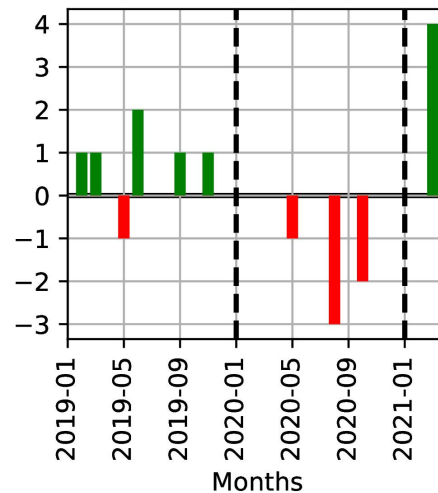|	Pro-Vaxxer in pre-COVID period (2018-19), Anti-Vaxxer in COVID period (2020)	
U1	*Every child should be vaccinated. I don't understand why parents wouldn't. Sad ... endangering others*	*Honestly this administration caused so much sickness and death, I will not trust a vaccine. #LyingTrump*
	Anti-Vaxxer in COVID period (2020), Pro-Vaxxer in COVID-vax period (2021)	
U2	*I'm not paying Big Pharma for a vaccine against something that they invented in order to sell vaccines.*	*I've had the first shot of the Pfizer vaccine. I'm a school bus driver. I'm in contact with kids daily and several times*

Visualising the stance change of some users
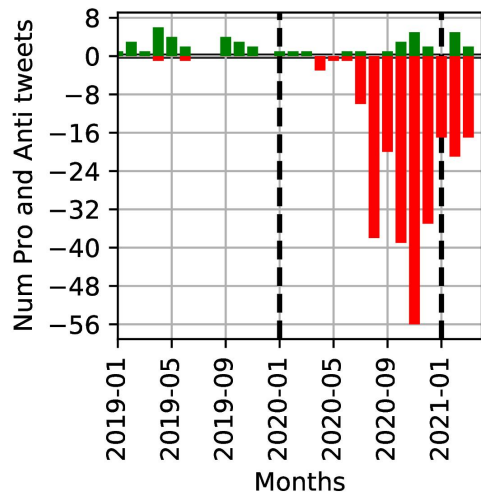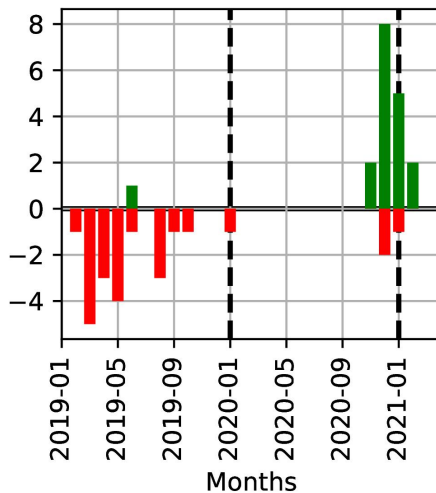

Pro to Anti   Anti to Pro   Pro to Anti to Pro

A few checks on the stance-changed users

- ==Are they automated bots?==
  - Checked using Botometer v2, followed by manual observation
  - Only 1 both account found; removed from further analyses

- Is the observed stance-change an artefact of a user supporting vaccine X at one point of time and opposing vaccine Y at some other time?
  - Found only 13 such users (2% of 674)
  - All these users expressed support in general for vaccines at some point, and opposed vaccines in general at some other point

Are stance-changed users representative of the general active Twitter population?
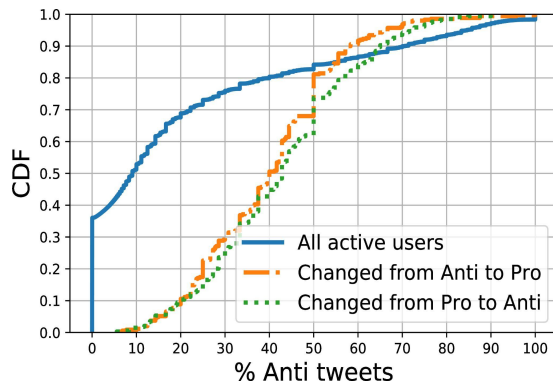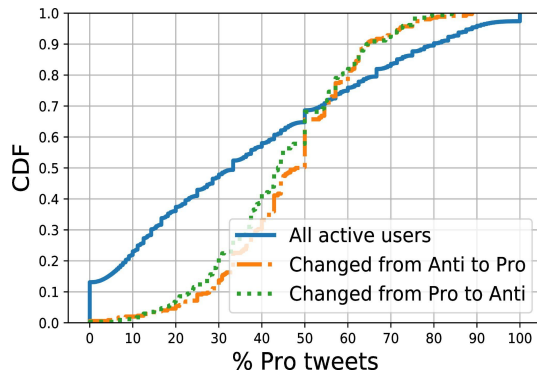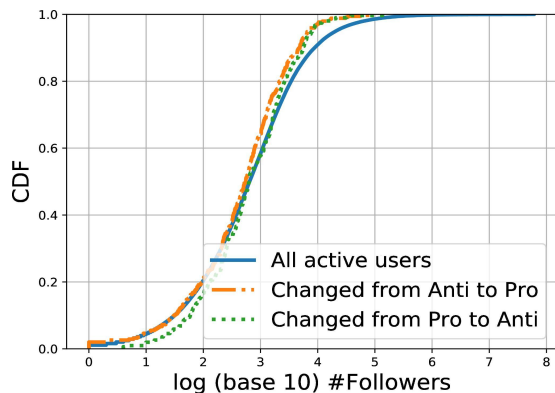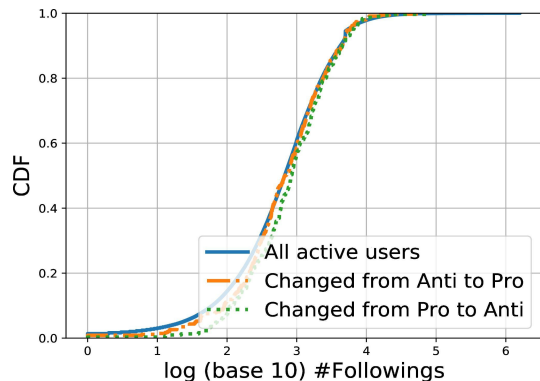
Compared stance-changed users with the general active Twitter population talking about vaccines

Both groups are very similar in terms of network properties (#followings & #followers).

Stance-changed users post more Anti-Vax and Pro-Vax opinions than others.

Why the stance change?

Investigated potential reasons for stance change of users

- ➢ Life-changing events

- ➢ ==Effect of social connections==

Users who had life changing events

U1	Thank you, @USER. You know your son. Seizures followed vaccination. Vaccine safety has not been proven. Cases like yours demand further investigation.	My husband died after becoming ill with corona virus. I am glad a vaccine has been developed in record time. I intend to be vaccinated as soon as possible
U2	Having an autistic child destroyed my family. I took my healthy baby to the doctor that gave the vaccine that caused it.	My husband and I both are frontline healthcare workers and we both are getting vaccinated Thursday. Yeah, we are nervous, but the daily stress of walking into a room with a covid patient is worse.

Effect of social connections

- Is the stance change of a user influenced by the stance of his/her social connections (followings) at various points of time?

Computing change in stance of followings

- Not possible to get the followings of a user at different points of time in history

- Hence for a user *u*:
  1. What fraction of *u*'s current followings were Pro-Vaxxers and Anti-Vaxxers (by our classifier) during each time period (2018-19, 2020 and 2021)
  2. Calculate the change in the Pro-Vaxxer and Anti-Vaxxer followings of *u* during two consecutive time periods (from 2018-19 to 2020, and from 2020 to 2021)

- Average the changes in followings across all users *u* in a subgroup of stance-changed users (e.g., who changed from Anti in 2020 to Pro in 2021)

Change in stance of followings

5 subgroups of stance-changed users	2018-19 to 2020		2020 to 2021	
	Pro	Anti	Pro	Anti
Anti (2018-19) to Pro (2020)	1.06x	1.94x	1.45x	0.70x
Pro (2018-19) to Anti (2020)	1.04x	4.43x	1.67x	0.85x
Anti (2020) to Pro (2021)	1.34x	4.38x	2.25x	0.70x
Pro (2020) to Anti (2021)	1.38x	5.89x	1.49x	1.25x
Pro (2018-19) to Anti (2020) to Pro (2021)	0.72x	1.94x	2.17x	0.35x

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	0.72x	1.94x		

For this group of users, the #Pro-Vax followings increased from 2018-19 to 2020 by 1.06 times (on average, across all users in this group)

For this group of users, the #Anti-Vax followings increased from 2018-19 to 2020 by 1.94 times (on average, across all users in this group)

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Even though overall #Anti-Vaxxers increased in 2020, the change was much more in the neighbourhood of those who turned Anti-Vaxxers in 2020

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For the users who changed stance twice, the #Anti-Vax followings increased more than #Pro-Vax followings in 2020, and vice versa in 2021.

Users seem to have different reasons for changing vaccine-stance, including life-changing events and influence of their social contacts.

➢ Data collection

➢ Identifying vaccine-stance

➢ How the vaccine discourse has changed

➢ How users' vaccine-stance has changed

➢ **Implications**

Summary

➢ A method to infer the vaccine-stance of Twitter users with 97% precision

➢ How a global event (the COVID-19 pandemic) has changed
  ○ The vaccine-related discourse on Twitter
  ○ The vaccine-stances/opinions of people

➢ Stance-change of a user influenced by factors such as major events in his/her life (e.g., death of a close relative) or changes in his/her social neighborhood

Implications for policy-makers

➢ Devising targeted approaches to address people's vaccine-related concerns

➢ Identifying people who have changed their stances - can serve as ambassadors for convincing others

➢ Utilizing social media for nudging people towards vaccination

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Thank you
Questions / Suggestions ?