

Understanding the COVID Vaccination Stances in Brazil: a Temporal Analysis using Twitter Data

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Abstract. Collective immunization is the only current solution available for combating COVID, but resistance towards vaccination have been observed in many countries. Brazil is a world-class reference on large-scale National Immunization Programs (NPI). However, the Federal Government was criticized for the delay and difficulties in developing a COVID NPI compatible with its large population. By May 2021, only 35 million Brazilians were vaccinated with at least one dose. This article developed a temporal analysis of pro/against stances towards COVID vaccination in Brazil. Considering tweets from February 2020 to May 2021, we summarized the main topics expressed by pro/anti-vaxxers using BERTopic, a dynamic topic modeling technique, and related them to events in the national scenario. The anti-vaxxers were more active throughout 2020, but the pro-vaxxers' movement significantly increased by late 2020 with the begging of immunization, becoming prevalent in 2021. We conclude that anti-vaxxers reacted to isolated events (e.g., mandatory vaccination, political disputes) and do not constitute an effective campaign against vaccination. The pro-vaxxer's stance denotes a continuous pro-vaccination advocacy effort, confirming that Brazil is among the most receptive countries regarding COVID vaccination.

Categories and Subject Descriptors: H.4 [Social and Behavioral Sciences]: General; I.7 [Document and Text Processing]: General

Keywords: vaccination stances, COVID-19, temporal analysis, group behavior, Twitter, topic modeling, BERTopic

1. INTRODUCTION

The COVID-19 pandemic presents itself as the most significant health challenge of this century, resulting in millions of deaths worldwide [WHO 2021]. Science has advanced in great strides regarding the knowledge of the virus, its treatments, its contagion, and preventive measures. Vaccines against COVID were developed, tested, and approved in a fast time, without abandoning legal requirements of quality and safety and pharmaceutical efficacy dispensed with other medicines. However, a high level of hesitation is observed worldwide, which has hampered the coverage of collective immunization [Debus and Tosun 2021; Omer et al. 2021].

Anti-vaccination movements have grown in the world [Hornsey et al. 2018], resulting in lower vaccine acceptance rates and an increase in vaccine-preventable disease outbreaks. Studies indicate that anti-vaccination attitudes used to be more related to conspiratorial thinking rather than political bias or religious beliefs [Hornsey et al. 2018; Bryden et al. 2019; Cossard et al. 2020]. Regarding COVID, studies have shown hesitation in European countries [Debus and Tosun 2021], and high acceptance in some Asian or middle-economy countries, including Brazil [Lazarus et al. 2020; Solís Arce et al. 2021]. These studies conclude the importance of governments in defining public policies and forming alliances between parties to increase public trust and support to achieve minimum levels of collective immunization.

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Works such as [Makridis and Rothwell 2020; de Bruin et al. 2020] reveal that partisan affiliation is often the strongest single predictor of behavior towards COVID-19 in the USA. Studies [Omer et al. 2021; Hotez 2021] alert that the anti-vaccine movement is undermining USA public health and that many anti-vaccine groups were already organized and ready to campaign against measures considered essential to pandemic control (e.g., masks, social distance). This is also the case in Brazil, where political differences also influenced basic COVID prevention measures, such as social distancing, the use of medicines without scientific evidence and even vaccination [Pereira et al. 2020; Ebeling et al. 2020; Ebeling et al. 2021; Ebeling et al. 2022].

Despite Brazil having a successful history of immunization programs and being a world-class reference on the large-scale eradication of many diseases [Domingues et al. 2020], political polarization has also influenced the implementation of a National Immunization Program (PNI) for COVID. The central government is criticized by many for not having made concrete efforts throughout 2020 to secure contracts with international pharmaceutical companies for the purchase of vaccines and for not supporting national research centers capable of producing vaccines. Much of this discussion about PNI COVID took place in a climate of political dispute between the future candidates for the 2022 presidential elections, Governor João Dória and President Jair Bolsonaro.

The analysis of the perception of COVID19 on social media is a very active area of research, particularly Twitter. Most works focus on identifying the topics discussed and emotional reactions about COVID [Garcia and Berton 2021; Xue et al. 2020; Amara et al. 2021; Tao et al. 2020], typically using the LDA topic modeling technique. Reddit data is explored in [Melton et al. 2021] using LDA to understand the public's concerns about COVID vaccines. LDA is used in combination with BERTopic in [Ebeling et al. 2022] to identify the underlying arguments supporting pro/against COVID vaccination in Brazil, as an extension of their original work in social isolation [Ebeling et al. 2020; Ebeling et al. 2021]. All these works examine a corpus representing a specific period extracted as a static snapshot. Dynamic topic modeling to understand topic evolution is addressed in [Zamani et al. 2020], where LDA is adapted to track societal shifts in COVID-specific discourse, and in [Sha et al. 2020], to relate the topics to governmental and administrative actions. In our research, we leverage the features of BERTopic as a finer-grained topic analysis method and for dynamic topic modeling to analyze vaccination stances in Brazil.

In this article, we develop a temporal study in order to understand the arguments used by Brazilians on Twitter to defend stances pro and against COVID vaccination. We developed this analysis using 159,215 tweets collected between February 2020 and May 2021, a period encompassing the beginning of the pandemic to the vaccination of 35 million Brazilians with at least one dose. We used the dynamic modeling technique BERTopic and related the stances found and the underlying arguments according to events that occurred in this period, which caused significant changes in the volume and content of tweets associated with each specific moment [Dou et al. 2012]. Our analysis aims to answer the following research questions:

RQ1: What are the main topics underlying pro/anti COVID vaccination stances in Brazil?

RQ2: Did the representativeness of the stances change over time?

RQ3: Did the topics underlying each stance change over time?

Our results showed the prevalence of the pro-vaccination stance, in line with the country's legacy of large-scale vaccination and the urgency of the pandemic. The anti-vaccination stance was prevalent in 2020, mainly as a political response to specific events on the national landscape, but almost disappeared with the beginning of vaccination in Brazil in 2021. The pro-stance is mainly characterized by praises to science, gratitude and expectations about vaccination, and criticisms against the president and the government. The anti-vaccination stance expresses distrust regarding the safety of the vaccine, defense of vaccination as an individual choice, restrictions against the so-called "Chinese vaccine" and political disputes.

This article is an extension of our previously presented work [de Sousa and Becker 2021]. We have provided more details on the topic modeling analysis and its evolution over time, and expanded the theoretical background and related work.

The remaining of this work is structured as follows. Section 2 presents the theoretical foundation and related work. Section 3 describes the data and the proposed method of analysis. Section 4 presents the results of the analyzes aimed at answering the research questions. Section 5 presents conclusions and future work.

2. THEORETICAL BACKGROUND

Topic Modeling deals with computational techniques that create clusters of similar documents according to a criterion. Basically, these models estimate that each document is a collection of articles, and each topic is a collection of words.

LDA [Blei et al. 2003] is one of the most popular topic modeling techniques. It treats each document in the corpus as a mixture of topics, where each topic is likely to be related to the document. In turn, each topic is composed of a list of words (terms) that are likely to be related to the topic. LDA results in topics where terms are more likely to occur together in documents. A difficulty in using LDA is that it requires the number of topics as input. There are metrics to evaluate the resulting topics of LDA, Coherence Value (CV) [Röder et al. 2015] among them. The CV metric was used in different works as a reference to find the appropriate number of topics in LDA (e.g., [Ebeling et al. 2020; Vargas-Calderón et al. 2019; Walter and Becker 2018]). LDA also requires many pre-processing actions to improve the results, normalization, removal of stopwords and special characters/terms, lemmatization [Denny and Spirling 2018].

Distributed representations of words and documents such as embeddings have gained popularity due to their ability to capture semantics. An embedding is a relatively low-dimensional space into which high-dimensional vectors, such as words or documents, can be translated. Embeddings capture different syntactical and relationships between words and documents, where BERT models [Devlin et al. 2019] represent the state-of-the-art.

Derived from Top2Vec [Angelov 2020], BERTopic [Grootendorst 2020] is a framework that encompasses algorithms to automatically search for dense topics in a collection of documents, assuming that semantically similar documents form topics. It requires as input a *corpus* and a pre-trained language representation model (BERT). After dimensionality reduction, it finds similar documents using a clustering algorithm. For the interpretation of topics, BERTopic associates all terms with the measure c-TF-IDF, a metric that calculates the TF-IDF of the terms per class. It also provides features for visualization similar to *LDAvis*, with hierarchical topic reduction and support for dynamic topic modeling (DMT), which allows one to observe how topics evolve over time. Finally, it also provides resources for identifying the most representative documents in each cluster based on their similarity.

In this work, we deploy the DTM BERTopic to understand the underlying arguments that support COVID vaccination stances in Brazil and to observe how they evolve over time.

3. RELATED WORK

Several works have deployed topic modeling techniques to extract from social media data the perception of the population about COVID. The trends on people's perception on COVID were examined in [Amara et al. 2021] using Facebook data and distinct languages. The extraction of trend topics in people's perception about COVID worldwide using Twitter data was addressed in [Tao et al. 2020; Xue et al. 2020]. Twitter data was analyzed in [Garcia and Berton 2021] to understand the differences in the emotional perceptions to COVID in the USA and Brazil, while [Oliveira et al. 2022] examined the emotional response to COVID news. Political polarization was addressed in [Jiang et al.

2020], which analyzed the alignment of topics in Twitter data and administrative actions from the government regarding COVID in the USA, and in [Ebeling et al. 2020], which proposed an analysis framework to understand the influence of political polarization in social distance stances in Brazil.

A common characteristic of the works mentioned above is the use of LDA and its variations, where data reflecting an observed period was analyzed in a single snapshot. [Zamani et al. 2020] proposed a dynamic content-specific LDA topic modeling technique to identify different domains of COVID-specific discourse that can be used to track societal shifts in concerns or views for regular reports (e.g., monthly). [Sha et al. 2020] also addressed dynamic topic modeling in the context of COVID, proposing the use of network Hawkes binomial topic model to track evolving sub-topics around risk, testing, and treatment.

Works that extract from social media the population’s perception on COVID vaccination also addresses static topic modeling. Reddit data is analyzed in [Melton et al. 2021] to understand issues around resistance and acceptance of COVID vaccination. The method originally proposed in [Ebeling et al. 2020] is extended in [Ebeling et al. 2022] to address vaccination stances in Brazil. This work combines LDA and BERTopic to understand the underlying arguments for pro/anti-vaccination stances.

In this work, we contribute with a temporal analysis of the topics expressed by pro/anti-vaccination positions in the Brazilian context of COVID using BERTopic as a basis for dynamic modeling.

4. MATERIALS AND METHODS

This work presents a temporal study to understand the behavior of Brazilians in Twitter when defending positions pro and against COVID vaccination. We used tweets related to vaccination between February/2020 and May/2021. This period covers the pandemic since its beginning in 2020, all phases of vaccine development and approval, to the vaccination of 35 million Brazilians with at least one dose in 2021. To answer the research questions listed in Section 1, we used the dynamic modeling technique BERTopic (RQ1 and RQ3) and the analysis of the volume distribution of tweets in time (RQ2). The rest of this section details the data and dynamic modeling of the topics.

The code was developed in python in the Jupyter Notebook environment with the help of libraries such as NLTK and Pandas. The notebooks are available in a public repository¹.

4.1 Tweet collect and pre-processing

Through the Twitter API, we collected approximately 6 million tweets, using the search terms “vaccine”, “vaccination” or both, in the period from February 29th 2020 to May 3rd 2021. We chose this deadline to avoid validity threats in our findings since a commission of inquiry (Comissão Parlamentar de Inquerito - CPI) was settled by May 2021 to debate negligence and corruption regarding COVID management Brazil. This event completely changed the focus of tweets involving vaccination, making it hard to distinguish between pro/against stances and CPI-related issues (e.g., the government’s refusal to secure vaccines in 2020).

To select the tweets representing the stances in our analysis, we manually inspected all the hashtags denoting pro and against vaccination stances in the collection of crawled tweets. We selected the five prevalent ones for each stance and filtered only the tweets containing at least one of these hashtags. The hashtags, the number of tweets and unique users resulting from this filtering are summarized in Table I (Raw).

We removed tweets with less than three terms, retweets, and duplicated tweets. In addition, to improve the quality of topic modeling, we also performed some pre-processing over the contents of

¹<https://github.com/mediate/twAnalytics>

the tweets, removing punctuation, special characters, hashtags, and URLs. The resulting number of tweets and unique users for each stance is also depicted in Table I (Pre-processed). The final dataset used in our analysis amounts to 159.215 tweets and 65.939 unique users.

Table I. Summary of tweets the representing stances

Stance	Hashtags	Raw		Preprocessed	
		Tweets	Users	Tweets	Users
pro-vaxxers	todospelasvacinas, vacinaja, vemvacina, vacinaparatos vacinasim	216.377	76.316	139.131	55.695
eunaanti-vaxxers	eunaovoutomarvacina, vacinaorbrigatoriano, vacinanao naovoutomarvacina, vacinaorbrigatorianunca	39.073	16.675	20.084	10.244
Total		255.450	92.991	159.215	65.939

4.2 BERTopic Topic Modeling

We applied BERTopic to the pre-processed tweets representing each stance. We chosed HDBScan as the clustering algorithm, which is a density-based clustering method. All the parameters used are described in the code available in our public repository. Initially, we performed a preliminary analysis, in which the most influential parameters were $min_topic_size = 50$ and $nr_topic = auto$. We used the same values for modeling the topics in both stances. We found 245 topics for the pro-vaxxers and 31 topics for the anti-vaxxers.

Due to the difficulty of interpreting this large number of topics, we used the following resources offered by the BERTopic framework: a) union of the most similar documents after training the model; b) plots of clusters in a two-dimensional plane according to similarity; c) analysis of topics using terms with high c-TF-IDF score (unigrams and bigrams); c) analysis of the most central documents for each topic. After some iterations, we limited the number of topics, setting the parameter $nr_topic = 11$ (10 topics) for both stances. Figure 1 compares the resulting clusters with the preliminary and the final analyses according to each parameterization.

Given the resulting modeling, to answer the research question RQ1, we used the resources provided by BERTopic to identify the significant terms for each topic (c-TF-IDF), eventually with the analysis of a sample of tweets to provide context to interpret them. For the research question RQ3, we distributed the volume of documents on each topic over time, and extracted the significant terms at specific time intervals.

5. RESULTS

5.1 RQ1: What are the main topics underlying pro/anti COVID vaccination positions in Brazil?

Tables II and III summarize the topics extracted according the method described in Section 4.2, sorted by number of tweets. Each topic is characterized by the respective amount of tweets, the five most representative terms (unigram or bigram) in terms of c-TF-IDF score, and three representative arguments. Note that not all tweets were grouped in the identified topics since BERTopic is a in density-based clustering method, and hence tweets belonging to non-dense areas were considered noise.

The pro-vaxxers are engaged in promoting the vaccination campaign and criticizing the policies adopted by the Federal Government for managing the pandemic. In Topic 0, it is clear that Brazilians are very anxious to get vaccinated, and blame the Federal Government for the lack of vaccines. Topic 1 and 4 reveal support for the vaccination, joy with the approval of vaccines by the National Health Agency (Anvisa), and happiness with the vaccination of Brazilians. Praises to science and to the

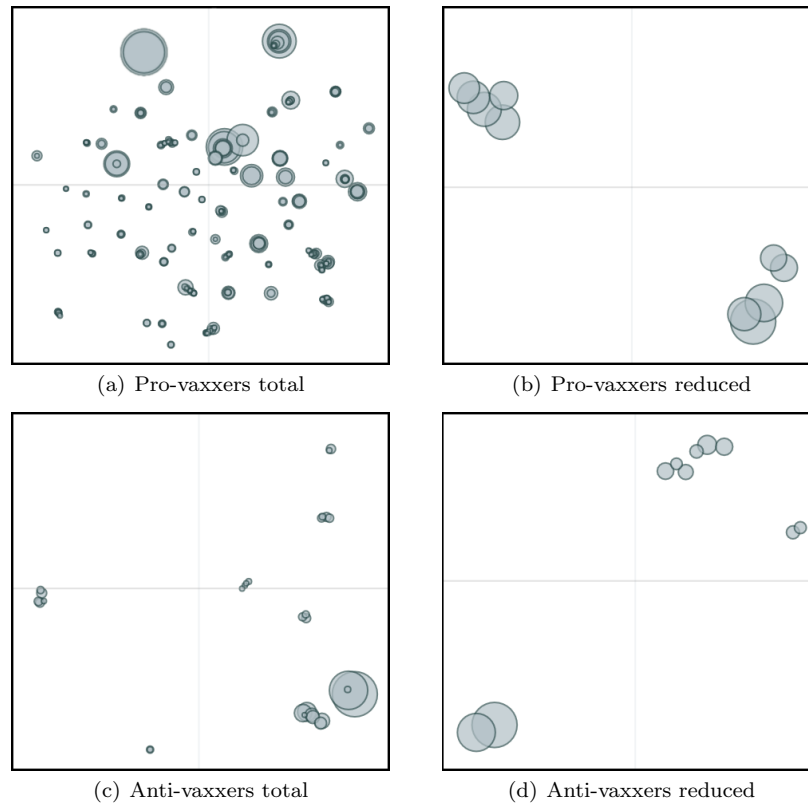


Fig. 1. Topic reduction

National Health System (SUS), joy and gratitude for getting vaccinated or having their loved ones protected, are the central arguments in Topics 5 and 6.

To understand Topics 7 and 8, we closely examined a large sample of tweets, and realized they represent two different arguments regarding education. Topic 7 expresses that teachers should be prioritized for vaccination, such that in-person education activities can be resumed. On the other hand, Topic 8 expresses opposition against Bill 5595/20², which aims to recognize basic education and higher education as essential activities, so as to enable the return to in-person classes even if teachers are not vaccinated.

The central argument of Topic 9 is criticisms and offenses to the President, Minister of Health, Federal government and President's supporters. This argument is found in other topics too.

A significant number of tweets involve artificial lifting of hashtags to keep the pro-vaccination movement in evidence and engage the population. In Topic 2, the term "life goes" correspond to requests for the song "Life Goes On" by artist Oliver Tree in an attempt to lift hashtags. In the same direction, in Topic 3, there are terms associated with the South Korean singer and songwriter Kim Tae-Hyung, better known in his musical career by his stage name V.

Table III summarizes the topics identified for the anti-vaxxers movement. They are against mandatory vaccination, questions vaccine's safety, and focus on political disputes. Concerns against mandatory vaccination are mainly represented in Topics 2, 6, and 8. Mandatory vaccination was advocated by many governors, including Governor João Dória, as a means to combat the nefarious pandemic scenario. In general, there are many criticisms to the Supreme Federal Court for ruling mandatory

²<https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2267745>

Table II. Global topic representation for the Pro-vaxxers
The terms and arguments were translated from Portuguese

Topic	Tweets	Pro-vaxxers Terms	Representative Argument
0	9185	brazil, brazilian brazilians, deaths, no	“Brazil deserves it ! Poor abandoned Brazilians, need to be saved from these brainwashed” “Only vaccines save. How many lives would have been saved if vaccines were bought earlier?” “Shame on you, thousand deaths by the end of the week”
1	7486	brazil, vaccine, brazilians vaccination, no	“So emotional with the speech of nurse Monica.” “I’m so proud of our nurses, bless SUS” “First Brazilian vaccinated !”
2	6338	on, life goes, goes on goes, defend vaccines	“I love to hear Life Goes On on the radio ! Play it again ! Thank you, defend vaccination” “kim taehyung defend vaccines, keep us informed” “Jezz, this vaccine is so good that silenced Bolsonaro ”
3	4829	defend vaccines, defend vaccines vaccine, keep informed	“defend vaccination, spread information” “defend vaccination kim taehyung” “stop preventing us from getting vaccination”
4	4554	coronavac, coronavirus emergency, vaccine, dose	“What a day for Brazil with Anvisa’s aproval of Coronavac. Approve Oxford too. Way to go Brazil” “Completely vaccinated with second dose, Gratitude” “covid retreats in the world, but not in Brazil. Get us more vaccines incompetent and criminal government”
5	3901	viva, science, viva science sus, viva sus	“long live sus, long live science” “What a day ! Long live sus, long live science, f**** Bolsonaro” “Officially an alien: vaccinated ! Bless sus, long live science”
6	3288	dose, first dose, vaccine dose second, first	“my dearest Mom was vaccinated” “Mom, I got my first dose today” “My dad got the first dose today, and Mom will get it on Monday”
7	2410	teachers, classes, education schools, no	“Everybody so excited ! Soon our children too will be happy and back to school” “back to in-person classes, our children deserve it” “all my support to the teachers! I commend Sao Paulo for prioritizing he vaccination of these guardian angles”
8	2361	pandemic, uncontrolled, socially responsible responsible criticism uncontrolled pandemic	“how to reopen the schools with this controlled pandemic?” “Share, all against this bill, social responsibility” “we need to control the pandemic before we can safely return no schools”
9	1961	president, no, vaccine, presidency, already	“Pazuello, we need hope. Sh*** President” “Idolizing the president and yearn the vaccine: incompatible” “we need a President, not a pathetic youtuber”

vaccination as constitutional due to sanitary reasons in the pandemic context. People also express strong resistance, charging a position from elected representatives, and calling on Brazilians to take to the streets to protest against politicians and authorities who support the mandatory vaccine.

Topic 3 is devoted to raising awareness about the unconstitutionality of the mandatory vaccine, where article 15 of the Civil Code³ (“No one can be compelled to submit life-threatening medical treatment or surgical intervention”) is used to promote this idea.

Topics 4 and 9 are characterized by a solid resistance for Coronavac, resulting from the partnership between the Chinese Sinovac laboratory and Brazilian Butantan Institute. People express prejudice and distrust due to its supposed “Chinese origins”, and criticisms to João Doria, who some people claim explored the production of this vaccine for political purposes.

³<http://www.planalto.gov.br/ccivil03/leis/l3071imprensa.htm>

Table III. Global topic representation for the Anti-vaxxers
The terms and arguments were translated from Portuguese

Topic	Tweets	Anti-vaxxers Terms	Representative Argument
0	5361	vaccine, take vaccine take, no, go	“so good you won’t get vaccinated: one more dose for those who deserve it” “I’m glad you will not take your dose, I’ll get mine earlier” “don’t get vaccinated, shove chloroquine up your @ss”
1	3251	yuri, is, is coming coming, gomes	“gandalf sweet melody yuri against all Santos sos is coming luiz fernando diego souza atletico copa brasil igor gomes rabello everson thaciano yuri” “I don’t want, I won’t go” “great, bolsonaristas won’t take it: there will be more vaccines for us”
2	869	brazil, brazilian people, no, brazilians	“congratulations fearless population buzios dictators can’t be obeyed mocked until they disappear spread brazil initiative” “Brazilian Communist Dictators Prison” “stf sends Brazil a message they wanted to give”
3	654	doctor, treatment medical treatment surgical intervention embarrassed submit	“copy and share this art of the constitution - no one can be forced to any medical treatment or surgical intervention” “it is the law - no one can be forced to any medical treatment or surgical intervention, my body my rules” “Anvisa approval is the result of corruption”
4	534	china, vaccine, chinese chinese vaccine, no	“Trust WHO? Trust the Chinese vaccine? No thanks” “Pazuello will buy us real vaccines” “Dictator Doria will for us to get vaccinate, Absurd. Sao Paulo citizens do not want the Chinese vaccine”
5	409	cattle, no, cattle vaccine, take	“sad to hear the cattle won’t get vaccinated” “the cattle will not get vaccine: the queue will be shorter for us” “see the bright side: there will be no more cattle herd”
6	384	senators, councilors, deputies, senators deputies councilors senators	“governors mayors councilmen senators deputies. Where are the politicians that represent us? lying in a splendid cradle. Riot” “STF ministers, that’s not your role” “senators deputies councilmen, do something”
7	346	tag, twitter, watching just, logging in	“These insane people keep lifting tags.” “Lifting hashtags. Bolsonaro’s cattle herd is tweeting madly” “The cattle is represented in this insane hashtag”
8	326	brazil, vaccine, no brazilian, brazilians	“The volunteer who tested the vaccine committed suicide. Do you think Brazilians are stupid? ” “let’s rebel against the vaccine, Brazil will make a decent one” “no one should be forced to take a vaccine. Brazilians are not ignorants. Evolve, you stupid people”
9	321	china, chinese, no, chinese, vachina	“any nationality, specially Chinese” “he wants to sell sp to China” “doormat of China”

In Topic 1, we identified the artificial use of popular hashtags to generate engagement and strengthen the interest of the anti-vaccine movement. Tweets have no relation to vaccination, and they refer to actors, soccer players and teams, singers, television programs or important events.

An interesting phenomenon is the confrontational position of pro-vaxxers to anti-vaxxers’ tweets. Even after careful inspection of hashtags as explained in Section 4.1, this occurs due to the massive presence of replies, in which pro-vaxxers refute tweet or hashtags used by anti-vaxxers to promote the anti-vaccination stance. In Topics 0 and 5, pro-vaxxers make sarcastic comments about the

availability of more vaccines due to the anti-vaxxers’ refusal to get immunized. In Topic 7, they criticize their attempt of lifting an antivaxx hashtag. Derogatory comments are used to relate anti-vaxxers to President supporters. It should be noted that tweeters expressing they are not willing to get vaccination do exists within these topics, but the prevalent arguments are confrontational. In the pro-vaxxers this behavior also exists, but it is diluted mainly due to the large amount of tweets, and thus it does not stand out.

In conclusion, pro-vaxxers are aligned with the tradition of Brazil of NIP to maintain the health of the population, with people expressing joy or expectations about vaccination and criticizing all people who are not willing to get vaccinated. The anti-vaxxers are concerned with vaccine’s safety and mandatory vaccination. Both sides express their stances interwoven with political comments that criticize the government for the lack of a NIP, or endorse the actions of the President and Federal government. Also, both sides attempt to engage the population on their stances with artificial hashtags.

5.2 RQ2: Did the representativeness of the stances change over time?

Figure 2 distributes in a timeline the tweets representing each stance. The figure also quantifies the number of replies identified in each dataset. The number of replies are a representation of the confrontations, but should be considered with care, since there are replies that both confront and support an argument. Nevertheless, it provides a overview of this activity in both groups.

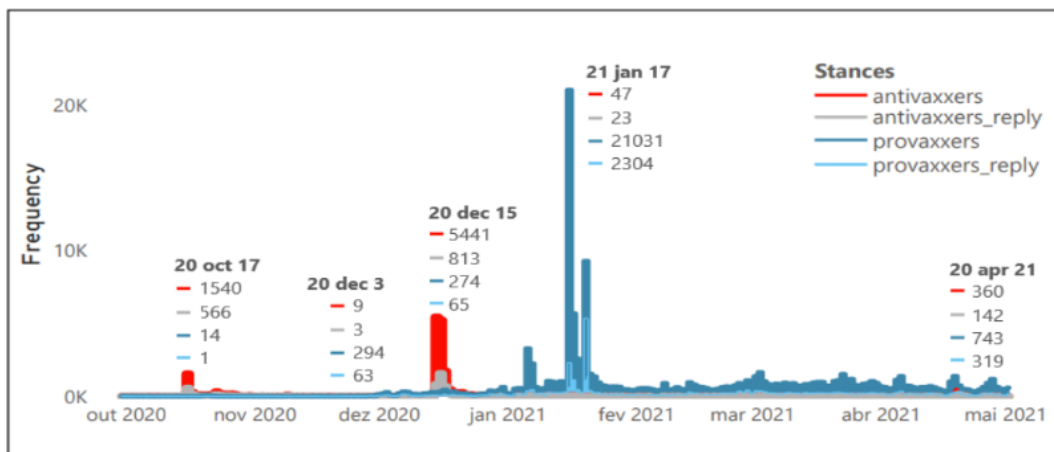


Fig. 2. Stances over time

The anti-vaxxers were the first group to massively express a stance on vaccination on October 17th 2020, when Brazil celebrates National Vaccination Day. A possible explanation for this uprising is a reaction to declarations made by Dória about mandatory vaccination in São Paulo. Except for the confrontational position to respond to the anti-vax movement, pro-vaxxers did not engage on promoting the pro-vaccination stance until early December. The volume of provaxers’ tweets slightly increased by December 3rd 2020, when vaccination started in some countries around the world.

On December 15th 2020, we observe a significant increase in the activities of anti-vaxxers, with a peak of 5.441 tweets. Possible explanations are an eventual reaction to the beginning of vaccination at a global level and a counterpoint to the beginning of the more intense movement of the pro-vaxxers. From that point on, the manifestation of the pro-vaxxers has grown and continued as the prevalent stance. A timid attempt of an anti-vaxxers’ orchestrated activity is observed on April 2021 (with a

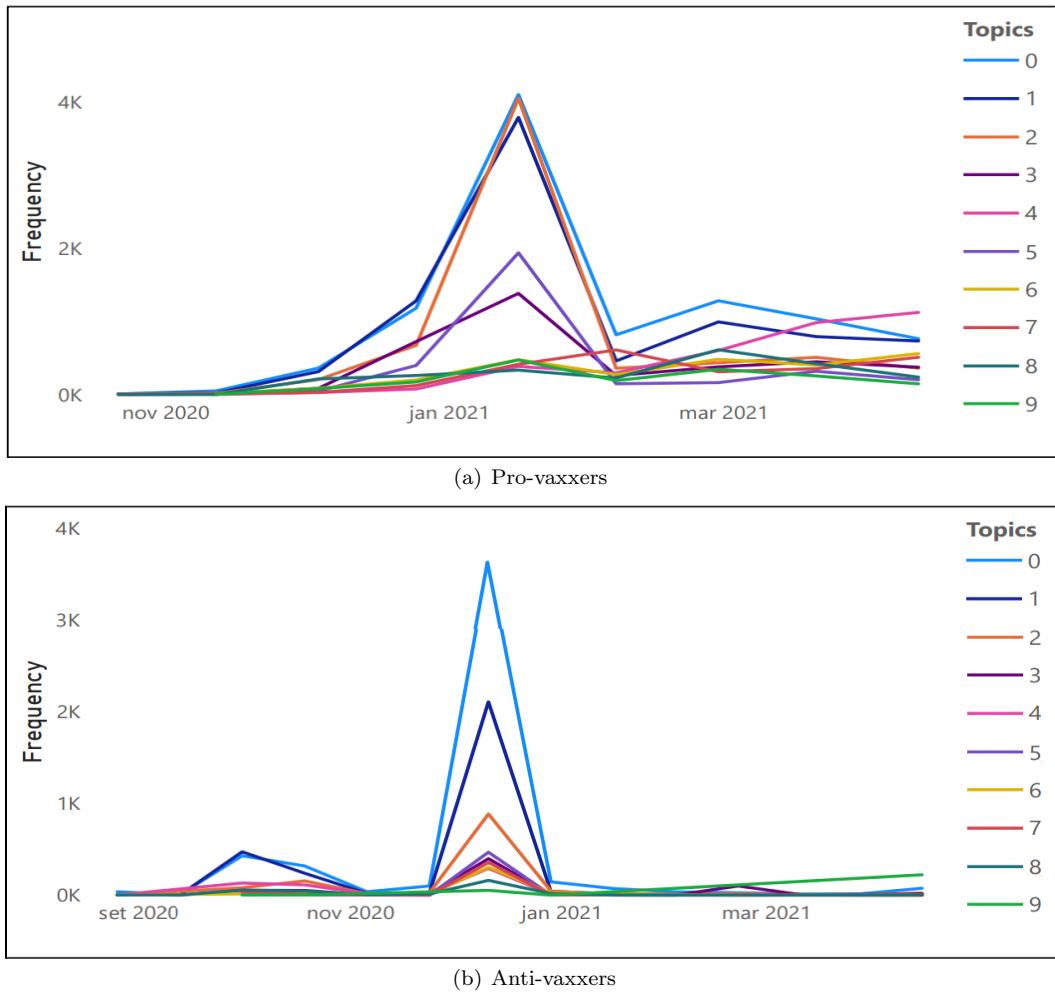


Fig. 3. Topics over time

peak on day 20th), possibly in reaction to measures by the government of São Paulo that required vaccination as a constraint for certain activities of the society (e.g. to go to bars and cinemas).

The highest level of activity from pro-vaxxers occurred between January and February 2021, with a peak of 21.031 tweets on February 17th. This period was characterized by several events in Brazil: political discussions between Bolsonaro and Dória; the calamity situation declaration in Manaus, due to a variant of the coronavirus and subsequent lack of oxygen in hospitals; the approval of the emergency use of Coronavac and other vaccines; and vaccination of the first person in Brazil (nurse Mônica Calazans).

5.3 RQ3: Did the topics underlying each stance change over time?

By adding a temporal dimension to the global representation of the main topics extracted, BERTopic allows us to create a distribution of topics and visualize how they are represented at different points in time. With this temporal dimension, the representation of the topic at the moment t may differ from the global representation of the topic, highlighting details. Figure 3 shows the distribution of the topics described in Table 1 over time for pro-vaxxers (a) and anti-vaxxers (b). To assess the evolution of topics over time, we divided each global topic into 4 time slices and described them using the most

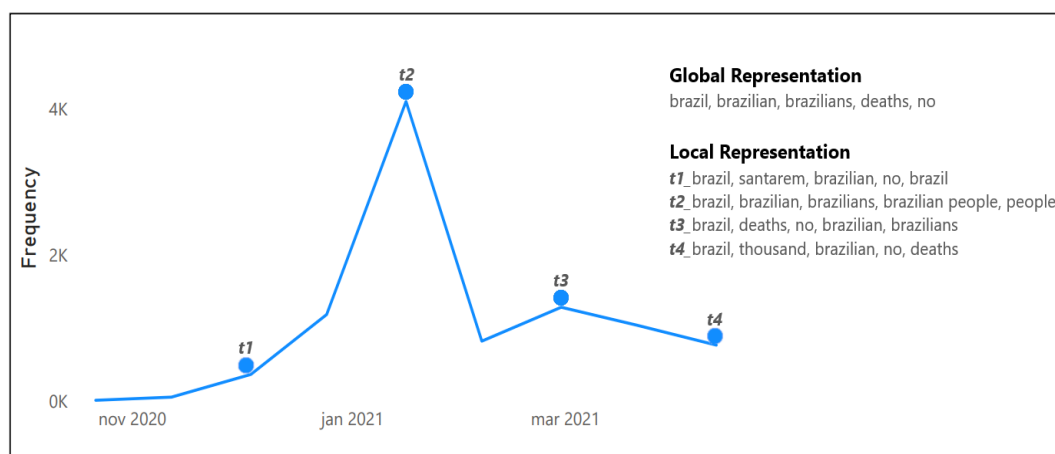


Fig. 4. Evolution of Pro-vaccination arguments in Topic 1
The arguments were translated from Portuguese

representative terms. The chosen slices correspond to the peaks identified in the respective timeline in Figures 3.

a) Pro-Vaccination Arguments Overtime

Figure 4 shows illustrates the changes considering the Topic 0 for each timestamp considered, with the respective representative terms describing the topic at each t_i . Despite the slight difference in the terminology used, represent a common concern. At all times the words “deaths”, “thousand” and “Brazil” represent that Brazilians are afraid due to the increasing number of victims of the pandemic. As mentioned, Brazilians are very anxious to get vaccinated, and blame the Federal Government for the lack of vaccine.

Table IV display for the remaining topics for the pro-vaxxers movement the changes for each time slice. We can observe that while some topics remain basically unchanged overtime (e.g. 0, 5, 6 and 9), others significantly change (e.g., 1, 2 and 7).

Topic 1, in the moment t_1 , people started to speak out in favor of vaccination; in t_2 , the terms “nurse”, “first” and “vaccinated”, indicate reactions to the first vaccination in Brazil (nurse Mônica); in t_3 and t_4 the terms “vaccine” and “Brazilians” indicate the continuity of support for the vaccination campaign.

In the global interpretation (Section 5.1), we described Topics 2 and 3 as related to the behavior of artificial lifting of hashtags. However, the evolution of topics shows that it is basically anchored in events that generate more engagement by the time of posting. For example in Topic 2, while in t_1 the terms correspond to new year celebrations, by time t_2 there is an attempt to leverage engagement using requests for the song “Life Goes On” in an attempt to lift hashtags (“programming”, “life goes”). t_3 and t_4 involve reactions to events promoted by Bolsonaro. The terms “wearing”, “use” and “mask” are incentives for the population to get vaccinated so that people can stop wearing a mask. The terms “Bolsonaro” and “invade hospitals” at t_3 are criticisms of President Jair Bolsonaro for asking supporters to enter public or campaign hospitals that treat COVID patients and film the interior of the premises, to provide evidences of the real dimension of the epidemic. Bolsonaro raised suspicions that data regarding the disease in the country were being manipulated to reach his government⁴.

⁴<https://oglobo.globo.com/saude/coronavirus/bolsonaro-pede-apoiadores-que-entrem-em-hospitais-para-filmar-leitos-24475348>

Table IV. Pro-vaxxers arguments over time
The arguments were translated from Portuguese

Topic	Moment	Terms - Pro-vaxxers
0	t1	brazil, santarem, brazilian, No, brazil
	t2	brazil, brazilian, brazilians, brazilian people, people
	t3	brazil, deaths, no, brazilian, brazilians
	t4	brazil, a thousand, brazilian, no, deaths
1	t1	brazil, vaccines, brazilians, vaccine, no
	t2	brazil, vaccine, nurse, first, vaccinated
	t3	brazil, vaccine, vaccination, brazilians, vaccines
	t4	brazil, vaccine, brazilians, vaccination, vaccines
2	t1	year, no, charge, for, ok
	t2	on, life goes, goes on, goes, defend vaccines
	t3	no, we want homeland, homeland, wear, mask carries
	t4	bolsonaro, mask carries, carries children, invades hospitals, carries
3	t1	vaccine, defend vaccines, defend, vaccines, not
	t2	defend vaccines, defend, vaccines, keep informed, vaccines keep
	t3	vaccine, vaccines, defend vaccines, defend, not
	t4	vaccine, vaccines, defend vaccines, defend, not
4	t1	start vaccinating, want to delay, usa germany, united russia, ideological usa
	t2	coronavac, emergency, emergency use, use, anvisa
	t3	coronavac, dose coronavac, dose, coronavirus, first dose
	t4	coronavac, dose, coronavac, coronavirus, second dose
5	t1	intervene, contamination, mass, death, immunization
	t2	live science, live science, sus, live sus
	t3	science, live, live science, sus, live sus
	t4	live science, live science, sus, live sus
6	t1	dose, vaccine dose, doses, first dose, first
	t2	dose, doses, first dose, first, vaccine dose
	t3	dose, first dose, first, dose, second
	t4	dose, second dose, second, vaccine dose, first dose
7	t1	education, teachers, classes, school, schools
	t2	teachers, classes, education, schools, no
	t3	teachers, education, schools, classes, professionals
	t4	teachers, classes, education, schools, face-to-face
8	t1	pandemic, in, pandemic, no, we need, social responsible
	t2	pandemic, so much celebration, little late, so much, celebration
	t3	pandemic, no, deaths, this
	t4	pandemic, social responsible, responsible criticism, share we count, we count vision
9	t1	president, madness perversity, applied upa, offer to take, idiots bless
	t2	president, no, vaccine, doria, presidency
	t3	president, no, vaccine, already, for
	t4	president, no, vaccine, already, president no

Topic 5 is quite stable in the arguments expressed overtime, where terms “praise science”, “praise sus” and “sus” present at all times indicate support to SUS and gratitude for all the scientists involved in the process.

For Topic 4, the terms “start to vaccinate”, “USA”, “Germany” and “Russia” indicate the start of vaccination around the world. The terms “coronavac” and “emergency” in t_2 indicate manifestations regarding the approval of the emergency use of coronavac in Brazil. In t_3 and t_4 , the terms “first dose” and “second dose” correspond to reactions of gratitude and relief when people receive the first or second dose of vaccines. In Topic 6, all timestamps refer to the counting of the vaccination progress.

The discussions on Topics 7 and 8 are about returning to in-person classes. In Topic 7, the terms “teachers”, “schools”, “classes” and “in-person” at all times, represent expressions of support for the priority for vaccination of teachers. While the return is regarded unsafe in Topic 8, evolution of arguments claim that the vaccination of teachers enable the return to in-person classes to minimize

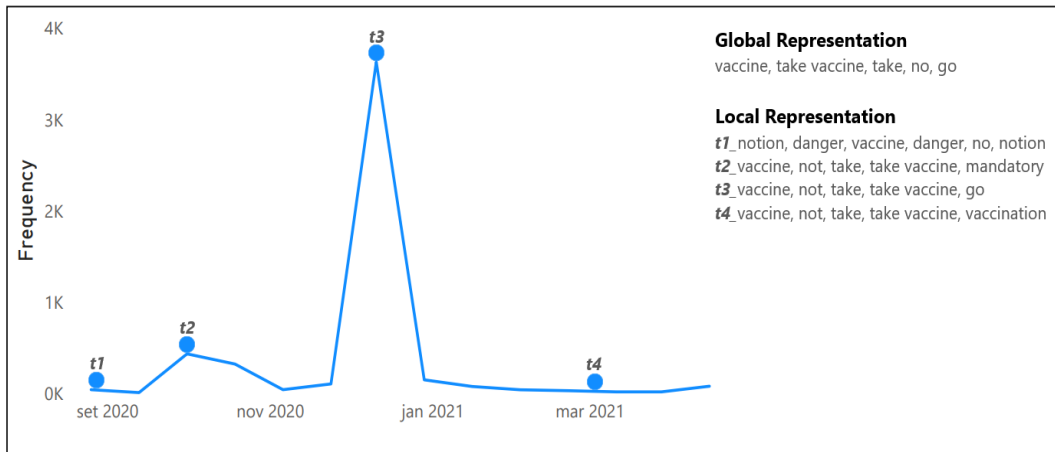


Fig. 5. Evolution of Anti-vaccination arguments in Topic 0

the significant damage caused by isolation to the education of millions of Brazilian children and young people. For Topic 8, a deep analysis of a sample of tweets enabled us to understand that most posts are an attempt to artificially survey hashtags mentioning law 5595/20⁵, which provides for the recognition of basic education and higher education, in in-person format, as essential services and activities. At all times in Topic 9, the terms “president”, “madness” and “vaccine” are critical of President Bolsonaro’s stance regarding his declarations and the coping measures adopted by the Federal Government in the face of the calamity scenario caused by the pandemic.

In conclusion, basically pro-vaxxers topics evolve in the sense that initially there is an expectation of vaccination, concern with measures to ensure population health and later gratitude for science and scientists. The criticisms to the President and Federal government are related to specific events overtime.

b) Anti-Vaccination Arguments Overtime

Figure 5 details the evolution for Topic 0: in t_1 , concerns about the safety of the vaccine, mainly because it was developed in record time; in t_2 , the reactions are against mandatory vaccination; in t_3 and t_4 the arguments are similar and against vaccination in general. Notice that although the global interpretation of this topic (Section 5.1) highlighted the confrontational behavior of pro-vaxxers, when considered in specific timestamps, the topic modeling captures the original expression of anti-vaxxers’ ideas.

Table V display the changes for the remaining topics for the anti-vaxxers movement, which also present stable (e.g. 1, 3, 6, 9) and dynamic (e.g. 0, 2, 8) topics. In Topic 1, as explained earlier (Section 5.1) we identified the artificial use of hashtags. The tweets are not related to vaccination and this behavior does not change over time. Criticisms against mandatory vaccination is the main argument in Topics 2, 6 and 8. In Topic 2, the terms “greatest president”, “dear president” in t_1 denote support for the President. In t_2 and t_3 people urge the Brazilian people to go to the streets to protest against authorities and politicians who support compulsory vaccination. In t_4 the terms “reads”, “icu closed”, are positioned in response to the dating of icu that had been raised in response to the first wave of the pandemic. Arguments in Topic 6 also are critical against authorities and politicians, but they are stable overtime. Topic 8 involves stable arguments in t_1 , t_2 and t_3 , while the terms “test” and “vaccine” t_4 show criticism against the first tests carried out in humans in 2020.

⁵<https://www.camara.leg.br/proposicoesWeb/fibradetransmission?idProposicao=2267745>

Table V. Anti-vaxxers over time
The arguments were translated from Portuguese

Topic	Moment	Terms - Anti-vaxxers
0	t1	notion danger, vaccine, danger, no, notion
	t2	vaccine, not, take, take vaccine, mandatory
	t3	vaccine, don't, take, take vaccine, go
	t4	vaccine, not, take, take vaccine, vaccination
1	t1	crazy street, crazy fuck, fuck jair, thing locks, bolsonaro knife
	t2	mirella, mirella deserves, deserves respect, deserves, respect
	t3	yuri, no, is, coming, is coming
	t4	it was bolsonaro, fair, no, not you, bolsonaro no
2	t1	greatest president, Brazil history, laboratory wake up, dear greatest, dear president
	t2	brazil, brazilian, people, no, brazilians
	t3	brazil, brazilian, people, no, brazilians
	t4	beds, icu, closed, icu closed, icu beds
3	t1	doctor, may be, surgical, doctor, intervention, constrained submit
	t2	treatment, intervention, no one can, risk, doctor
	t3	doctor, treatment, submit, medical treatment, surgical intervention
	t4	surgical intervention, life treatment, constrained to submit, medical intervention, surgical
4	t1	chinese, take thing, no chinese, want, chinese vaccine
	t2	vaccine, chinese, china, chinese vaccine, no
	t3	china, vaccine, chinese, chinese vaccine, no
	t4	chinese virus, vaccine made, chinese, virus, in china
5	t1	bolsopetistas against, cowboy, begging cowboy, treats them, fight bolsopetistas
	t2	cattle, vaccine, tag, for, no
	t3	cattle, no, no cattle, vaccine, take
	t4	cattle, all guinea pigs, anxious cattle, snare bino, believe these
6	t1	governor, deputies, governors, senators, councilors
	t2	senators, senators deputies, councilors, deputies, councilors deputies
	t3	senators deputies, councilors, senators, state councilors, deputies
	t4	senators, senators, deputies, councilors, deputies, councilors senators
7	t1	tag, twitter, seeing, only, people
	t2	tag, twitter, watching, entering, only
	t3	tag, twitter, watching, entering, only
	t4	twitter, shut up, want to ban, parler, parler telegram
8	t1	brazil, vaccine, no, brazilian, all
	t2	brazil, vaccine, no, brazilian, brazilians
	t3	brasil, vacina, nao, brasileiro, brasileiros
	t4	brazil, vaccine, public, tests, wanting to try
9	t1	china, chinese, no, chinese, chinese
	t2	china, chinese, vachina, no communist
	t3	china, chinese, chinese, no, communist
	t4	learning lesson, home right, home lesson, chinese puppy, is learning

The terms “medical” and “surgical” are present at all times in Topic 3, since the arguments revolve around the unconstitutionality of the mandatory vaccine based on article 15 of the Civil Code, as explained in subsection 5.1. In Topics 4 and 9, the prevailing argument at all times expresses strong resistance to the vaccine due to its supposed Chinese origins.

Topics 5 and 7 are the confrontational position of pro-vaxxers to anti-vaxxers’ tweets due to the massive presence of replies as mentioned in subsection 5.1. Unlike Topic 0, the confrontation is also captured over time.

In conclusion, the anti-vaxxers topics argue that the state is authoritarian when discussing mandatory vaccination, focus on spreading that the vaccine is dangerous and seek to reinforce this argument through mentions of facts without scientific evidence, especially in relation to vaccines of Chinese origin. However, positioning does not evolve in a chronological sequence, characterizing isolated events, typically triggered by an orchestrated (possibly political) movement.

6. THREATS TO VALIDITY

This section discusses the threats to the validity of our study. One of the main threats is the way the groups were defined. The use of hashtags for automatic collection⁶ of groups on social networks is a widely used form for this purpose. However, it can lead to different types of bias. The hashtags may not represent the target population, and we mitigated this risk by carefully examining frequent hashtags.

Another risk is that tweets might be falsely inserted in the context of a hashtag because they refute an idea represented by the hashtag (false positives). BERTopic enabled us to identify fine-grained representative arguments, and we realized there are a significant number of tweets representing confrontational responses from people with an opposite stance. This phenomenon was observed more clearly in the set of the tweets representing the anti-vaxxers. We tried different strategies to sanitize the dataset, such as removing all users that tweeted with hashtags representing both sides or removing tweets involving mentions. However, when inspecting the result, we realized that none of these attempts led to reliable results, with a loss of significant tweets identified in our previous analysis. The results reported in this article may contain bias due to this issue, but we were able to clearly indicate the topics that involve confrontation of stances. In addition, the existence of this confrontation of ideas is of interest in our analysis.

Another issue is the challenges involved in the parameterization, evaluation, and interpretation of the topics. The terms that represent the topics can sometimes be confusing, generating the need to inspect text samples manually, making the interpretation a little subjective. We mitigated this problem by leveraging BERTopic resources to identify each cluster's most representative arguments based on their similarity with other elements in the same cluster.

Finally, it is common knowledge that the Twitter audience may not represent characteristics of the general population, especially in analyzes such as ours, which represents a frame of the public of this social network.

7. CONCLUSIONS AND FUTURE WORK

In this work, we analyzed two movements expressing stances on COVID vaccination in Brazil, namely pro-vaxxers and anti-vaxxers. Unlike related works, which employ LDA over a static data sample, we used the BERTopic modeling technique to understand the main arguments at a finer-grained and develop a temporal analysis on how the stances represented over the observed period and the respective evolution.

The value of dynamic topic modeling is revealed when comparing the differences in the results of global topic modeling and topic modeling in specific timestamps. It provides a fine-grained and accurate understanding of the captured behavior. For instance, although hashtag lifting was identified in pro-vaxxers topics, it is representative of a specific event. It stands out since it constitutes the most similar argument considering all tweets in that cluster. Another example is the confrontation between anti-vaxxers and pro-vaxxers. Globally, Topic 0 of Anti-vaxxers highlight replies of pro-vaxxers criticizing the arguments used by the anti-vaxxers, but this is the most similar argument used throughout the whole period. When considered in the specific events that generated peaks of anti-vaxxers tweets, the defense of their stance against safety of vaccines of mandatory vaccination become apparent.

The anti-vaxxers made massive manifestations throughout 2020, focused on the mandatory vaccine, insecurity, distrust of the "Chinese" vaccine and political disputes. We observed an artificial effort to lift representative hashtags of this line of thought. The manifestation of pro-vaxxers is five times

⁶<https://help.twitter.com/en/using-twitter/how-to-use-hashtags>

greater and intensified only when vaccination began worldwide. In 2021 it became prevalent, with its peak associated with the tragedy of Manaus and the beginning of vaccination in Brazil. However, we observed pro-vaxxers manifestation as a response to anti-vaxxers tweets expressing they would not take the vaccine.

The pro-vaxxers speak out in favor of science, gratitude and expectations about vaccination, while showing strong resistance to the president and government actions that delay vaccination in Brazil. Much of the tweets in both positions involve political discussions, especially between President Jair Bolsonaro and Governor João Dória.

We conclude that anti-vaxxers react to isolated events and do not constitute an effective campaign against vaccination. The pro-vaxxer position is considerably higher and denotes a continuous pro-vaccination advocacy effort, confirming that Brazil is part of the countries receptive to vaccination [Lazarus et al. 2020].

As future work, we expect to evolve with the expansion of this analysis to other topics related to vaccination (eg vaccine *someliars*), to develop a semi-automatic method that facilitates the evaluation of BERTopic topics on a large scale and over time, develop a method to better compose the datasets expressing each vaccination stance without loss of relevant information, identification of conspiracy theories and comparison with similar movements in other countries.

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