

Public sentiment on Covid-19 vaccination rollout through Twitter content analysis

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ABSTRACT

This study looks at what people are saying about Covid-19 vaccines on Twitter. Text mining techniques and sentiment analysis were used to analyze the tweets and see what patterns and trends emerged. The study found that most tweets were positive, showing hope and confidence in vaccines. People believe vaccines can help reduce deaths, severe illness, and the spread of the virus. However, the result also noticed that people express different emotions like sadness, fear, joy, and surprise in their tweets. These emotions can change based on how people feel and what's happening around them. Understanding how people think about Covid-19 vaccines can help policymakers, doctors, and community leaders. It can guide them in addressing concerns, sharing accurate information, and building vaccine trust. This can ultimately help in the fight against the pandemic.

1. Introduction

The invention of vaccines has made an enormous contribution to global health (Greenwood, 2014), protecting millions worldwide. Vaccines have prevented more than 20 life-threatening infectious diseases that can spread by working with the body's natural defenses to build protection. The coronavirus SARS-CoV-2, or Covid-19, has profoundly affected human health, economic, and social activities, threatening millions' long-term livelihoods and well-being bringing the world to a standstill (Mahmood et al., 2020).

While Covid-19 continues to rage worldwide, the need for effective vaccines is highly anticipated (Lin et al., 2020). However, increasing Covid-19 vaccine hesitancy among the general population is now a leading global health threat that lessens the probability of herd immunity (Lin et al., 2020; World Health Organization, 2021). Access to social media, such as Twitter, has become a global structure to express views and opinions on Covid-19 vaccines (Puri et al., 2020). With over 187 million active users, Twitter is vital in spreading misinformation and misinformation about vaccines (Piedrahita-Valdés et al., 2021). So, monitoring Covid-19 vaccination conversations on Twitter could involve text mining techniques to extract, analyze, and classify data to understand the public perception of Covid-19 vaccination better (Saleh et al., 2021). Likewise, sentiment analysis allows opinion classification according to positive, negative, or neutral polarity (Miranda et al., 2017), emotion (Cambria, 2016), or the intensity of agreement, which could help identify factors contributing to vaccine confidence (Colón-Ruiz et al., 201; Saleh et al., 2021).

By definition, text mining is a process to discover hidden patterns (Kaushik & Naithani, 2016) that derives high-quality information (Gupta et al., 2020) from vast amounts of semi-structured (Talib et al., 2016) and unstructured text language material (Kaushik & Naithani,

2016) (Prema & Muthukumar, 2019). Text mining is also a method of inquiry that enables both novice and more experienced innovation researchers (Antons et al., 2020) to extract exciting and non-trivial information (Ananiadou et al., 2006) and interpret text mining techniques in a way that generates valid and reliable knowledge (Antons et al., 2020). In addition, text mining techniques can help produce a more structured analysis of textual knowledge than simple word searches and discover more unseen patterns and trends on Twitter (Ananiadou et al., 2006; Nie & Sun, 2017).

Therefore, this study aims to determine the patterns and trends of the public perception of Covid-19 vaccines and vaccinations to uncover themes of concern posted by Twitter users worldwide using text mining techniques. Additionally, text mining is employed in this study to automate the analysis of Covid-19 Vaccination Roll-out texts gathered from Twitter. The qualitative sentiments generate graphs and diverse data visualizations, unveiling patterns of emotions and opinions. This process provides valuable insights for promptly identifying emerging concerns and enabling proactive responses to prevent escalation.

The result of this sentiment analysis is significant for governments, health practitioners, and communities. Using text mining techniques to understand public perception of Covid-19 vaccines, stakeholders can develop targeted interventions, improve communication strategies, and ultimately enhance vaccine acceptance and uptake, leading to better control of the pandemic and improved public health outcomes.

The outline of this paper is subdivided into several chapters. Section 1 highlights the introduction; Section 2 presents related work and systems architecture. Section 3 discusses the methods and proposed solutions. Section 4 features results and discussions. Finally, section 5 concludes the paper.

2. Theoretical basis/Literature review

Social networking applications are excellent communication and information-sharing platforms, fostering interaction among active information seekers and facilitating mutual learning and knowledge exchange (Salloum et al., 2017). Furthermore, the significant growth of technology (Singh et al., 2017) has led to a proliferation of big text data across various forms of social media, providing a rich source of material for academic research (Research Guides, 2021). Text mining tools are utilized to interpret these unstructured forms of data (Irfan et al., 2015) and extract valuable knowledge (Salloum et al., 2017), offering insights into information patterns in or near real-time (Tsapatsoulis & Djouvas, 2019).

Text mining involves extracting valid (Feldman & Sanger, 2007) and previously unknown information (Hon & Park, 2019) from extensive unstructured data repositories (Gong, 2018) to identify valuable patterns and trends. This multidisciplinary field integrates information retrieval, machine learning, and computational semantics (Babu & Srinivasu, 2019), enabling text data input, pattern derivation within structured data, and output interpretation (Preethi & Radha, 2017). Text mining finds applications in word counts, author linkages, content evaluation, opinion mining, feature extraction, sentiment analysis, predictive analysis, trend analysis (Qi, 2013), bioinformatics (He, 2013), and the advancement of information technology (Mohan, 2002).

On the other hand, sentiment analysis or emotional polarity computation (Aslam et al., 2020) represents one of the fastest-growing research areas within the text mining community. It yields valuable insights when analyzing free-form text such as social media posts, customer reviews, feedback comments, and survey responses. Sentiment analysis employs natural

language techniques and machine learning algorithms to discern the sentiment and emotions of individuals towards something or someone, whether positive, negative, neutral, or beyond (Li & Wu, 2010). It extracts critical phrases from text sources to identify trends, popular topics, and themes (Li & Wu, 2010).

Moreover, sentiment analysis facilitates quantitative analysis of text data, often combined with visually engaging dashboards to unlock the value of textual data. For instance, Keith-Norambuena et al. (2019) extracted and classified sentiments and emotions from 141,208 global English news source headlines related to the Covid-19 pandemic, revealing high emotional scores with a negative polarity. Chehal et al. (2020) studied the attitudes of Indian people during the 2019-nCoV lockdown through their tweets on Twitter, aiding health specialists in understanding public sentiment and devising measures to combat the virus. Similarly, Boon-Itt and Skunkan (2020) analyzed tweets on Covid-19 pandemic trends using time series, sentiment analysis, and topic modeling, concluding that sentiment analysis and topic modeling offered valuable insights into the direction of the pandemic and alternative perspectives for investigation. Komasaawa et al. (2020) conducted text mining analysis to elucidate perceptions among 124 final-year medical students towards the Covid-19 pandemic, identifying keywords such as medical, infection, patient, and human, indicating a strong impact of the pandemic on them.

De Caro (2020) utilized text mining analysis to identify the driving factors behind public conversation and the impact of Covid-19 tweets, confirming their use for information dissemination, opinions, emotions, and real-time content analysis. Samuel et al. (2020) identified public sentiment associated with the pandemic using Coronavirus-specific tweets and R statistical software, providing insights into fear sentiment progression and related methods, implications, limitations, and opportunities through descriptive textual analytics supported by necessary textual data visualizations (Borst et al., 2022). Finally, Addawood et al. (2020) examined a collection of Arabic tweets from Saudi Arabia, revealing a positive reaction that supported each other during the pandemic.

The literature review analysis indicates that research trends in emotion and sentiment analysis during pandemics and natural disasters are still evolving. Hence, there is a critical need for practice-ready studies to enable policymakers and researchers to make data-driven decisions and understand the emotional impact of a pandemic through real-time social media insights. This study contributes to this growing body of research by analyzing a comprehensive set of Twitter data during the Covid-19 pandemic.

3. Methodology

3.1. Twitter developer's approval

The researcher first applied for a developer account through the Twitter Developer Portal to access Twitter's APIs. This portal is a hub for managing access to Twitter's APIs and related tools. The researcher creates and manages projects and apps utilizing Twitter's APIs for various purposes within the portal. The researcher provided detailed information about the intended use of Twitter's APIs during the application process. This includes specifying the use cases and functionalities planned to be implemented using the APIs. Providing specific and comprehensive details about how the APIs will be used helps Twitter evaluate the application and ensure that it aligns with its terms of service and policies.

Additionally, the researcher confirmed the required email address as part of the application process. This email address serves as a means of communication between Twitter

and the researcher regarding the application's status and any updates or notifications related to their developer account.

Once the application was approved, the researcher accessed Twitter's APIs and began integrating them into their projects and apps. This access enables the researcher to interact with Twitter's platform, retrieve data, and build innovative applications that influence Twitter's vast array of content and functionality.

Regarding ethical considerations, researchers have very little guidance on conducting ethical research on social media (Cilliers, 2022). However, the increasing prevalence of utilizing social media platforms like Twitter for extracting and analyzing data is due to their openness and accessibility, especially compared to other platforms. Researchers often justify the ethical use of Twitter data by pointing to its public nature and compliance with Twitter's Terms of Service (Blazhevski, 2022).

Hence, the researcher agreed to Twitter's Terms of Service set by Twitter Company on using datasets scraped from their platform.

3.2. Text mining

Text mining and sentiment analysis are powerful tools for extracting valuable insights from large volumes of text data, such as tweets, and understanding public perception. To begin the analysis, tweets related to Covid-19 vaccination were collected using the Twitter API, targeting specific keywords associated with vaccination efforts. Over 60,000 tweets were gathered from Twitter users worldwide from April to June 2021. These tweets were identified through top trending hashtags during the pandemic, including #Covid-19Vaccinations, #Covid-19VaccineHesistancy, and #Covid-19Vaccines. These trending hashtags are gathered from Twitter's built-in search functionality that navigates to the "trending" section to view a list of current topics and hashtags trending in the region.

Next, the collected text data underwent preprocessing to enhance accuracy before sentiment analysis. Several techniques are commonly employed for preprocessing text data before analysis to ensure the data are clean and ready for further processing. Tokenization, the process of breaking down text into individual words or tokens, can be achieved using Tokenizers tools. Stopword removal, which involves eliminating common words like "and," "the," and "is," can be accomplished using sci-kit-learn libraries, which provide a built-in list of English stopwords. Stemming and lemmatization reduce words to their base or root form. Stemming, available through TextBlob libraries, chops off suffixes to achieve the root form of words.

In contrast, lemmatization, also available in TextBlob, considers the word's context and reduces it to a meaningful base form. The combined techniques significantly enhance the quality of text data for analysis. They can effectively preprocess large volumes of text data, such as tweets about Covid-19 vaccination, enabling more accurate and insightful public perception and sentiment analyses.

Furthermore, sentiment analysis techniques were then applied to categorize the tweets into positive, negative, or neutral sentiments, providing insights into the overall sentiment expressed in each tweet. A rule-based sentiment analysis tool (Valence Aware Dictionary and sEntiment Reasoner)-specifically designed for social media text, was utilized to assign sentiment scores to individual words and then combine them to measure the intensity of sentiment expressed, enabling a deeper understanding of the emotional tone conveyed in the tweets.

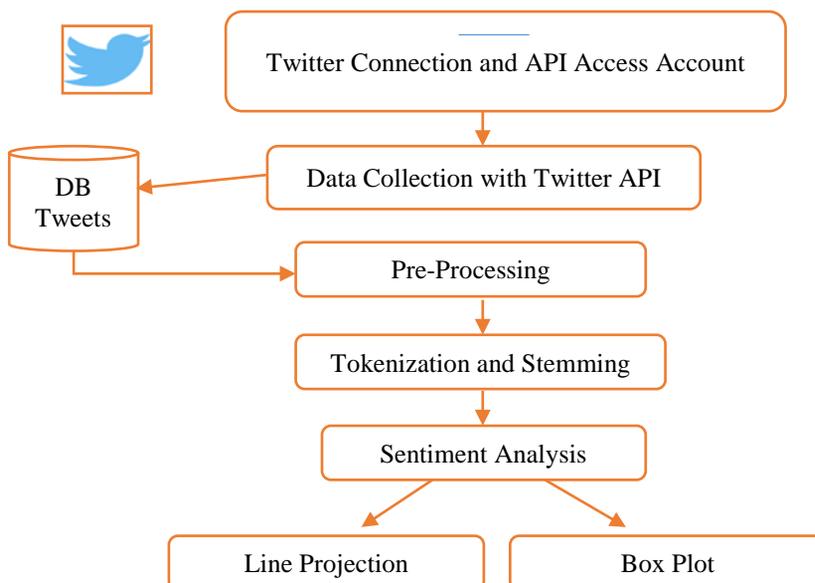
Subsequently, patterns and trends in public perception of Covid-19 vaccination were identified by analyzing sentiment scores and examining common themes or topics mentioned in the tweets. Analyzing the changes in sentiment scores over time can reveal trends and fluctuations in public opinion on the Covid-19 Vaccination Roll-out. The average sentiment scores are calculated for specific time intervals (e.g., daily, weekly, or monthly), and these trends are visualized using line charts or heat maps. Additionally, the distribution of sentiment scores across the dataset provides the overall sentiment balance. The mean, median, and standard deviation of sentiment scores were calculated. This allowed for the detection of patterns related to vaccine efficacy, side effects, access to vaccines, and misinformation, among other factors. To make the findings more accessible, visualizations were created to represent the analysis results visually using the Orange data mining software (Magtangob & Palaoag, 2023). Box plots and line graphs were utilized to display sentiment trends over time. These visualizations effectively communicated insights to stakeholders and facilitated comprehension of the complex data.

Finally, the analysis results were interpreted to draw meaningful insights into public perception of Covid-19 vaccination. These insights could inform various initiatives, including public health strategies, communication efforts, and policy decisions. By identifying areas of concern or positive sentiment, interventions could be tailored to address misinformation, enhance vaccine acceptance, and promote public health awareness effectively.

Figure 1 below illustrates the flowchart of the methodology.

Figure 1

Text Mining with Sentiment Analysis Flowchart



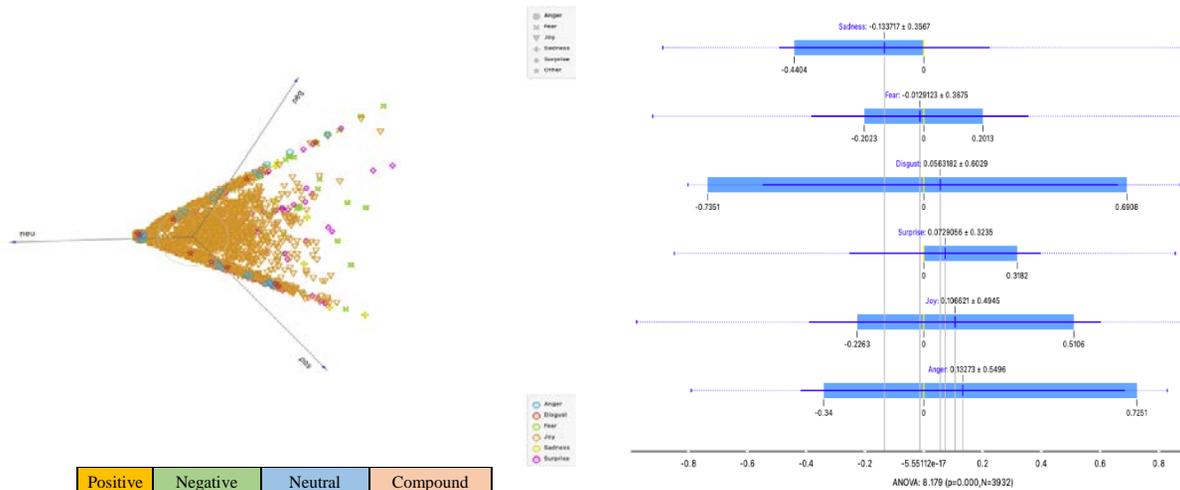
Note. The data are from “Twitter sentiment analysis using textual information and diffusion patterns” by M. P. Pawar and P. Agarkar, 2020, *International Journal of Advance Scientific Research and Engineering Trends*, 5(7), pp. 59-62

4. Result and discussions

Text mining techniques with sentiment analysis on the collected tweets from Twitter users across the globe enable the researcher to determine the patterns and trends of their perception of Covid-19 vaccines and vaccinations. In addition, the sentiment results of collected tweets are graphically represented to understand better the tweeter user’s sentiment related to Covid-19 vaccines and vaccinations.

Figure 2

Graphical Representation of Sentiments to Covid-19 Vaccinations (March 26, 2021, to April 3, 2021)



Note. Data analysis result of the research

In Figure 2, the emotion of the tweets is used to generate the results for both Box Plot and Linear Projection Visualization. From March 26, 2021, to April 3, 2021, the emotions of “disgust” and “anger” have the most comprehensive ranges. The feeling might be due to the dysfunctional’ approach to Covid-19 vaccine distribution.

Below are some of the tweets showing both “disgust” and “anger” emotions on the rollout of the Covid-19 vaccinations program as posted by Twitter users worldwide:

“Why U.S. Approval of the #AstraZeneca #Covid-19 #Vaccine Is Taking So Long | Smart News | Smithsonian Magazine”.

“A bunch of people who have had two shots are saying we should delay the second shot. #SkinInTheGame #SITG #Covid #vaccine”.

“I wanna get shown off like how people show their vaccination cards”.

“I find it strange that when I type , vaccination-related deaths, in my search bar, nothing AT ALL ever populates”.

Furthermore, emotions of “disgust” and “anger” may stem from various news headlines worldwide. For instance, the BioNTech vaccines were suspended in Hong Kong and Macau due to a packaging defect. At the same time, Europe and India announced discontinuing the AstraZeneca vaccine due to its association with blood clots. Concurrently, Brazil faced devastation from a new coronavirus variant, with hospitals teetering on the brink of collapse amidst rising Covid-19 cases. In Myanmar, military forces killed at least 114 people and ravaged 44 cities, marking one of the deadliest days since a seven-year-old girl was killed in her father’s arms. Additionally, reports emerged of rescuers working to dislodge the Evergreen container ship lodged in the Suez Canal, needing to lift 706,000 cubic feet of sand, a task expected to take weeks.

Despite these challenging circumstances, overall sentiments expressed on Twitter leaned towards positive polarity. This suggests that, despite feelings of “anger” and “disgust,” Twitter users remain hopeful and confident in the ability of vaccines to combat the Covid-19 pandemic. For many, receiving the vaccine provides increased physical security and instills hope for a return to normalcy, including the ability to touch, hug, and socialize again.

Some of the tweets posted:

“Herd immunity, see you in July”.

“I haven’t been this excited to do a shot since the 90’s#vaccine #firstdose #Covid-19AB”.

“#beatCovid #vaccinated #VaccinateNY #vaccine. Thank you”.

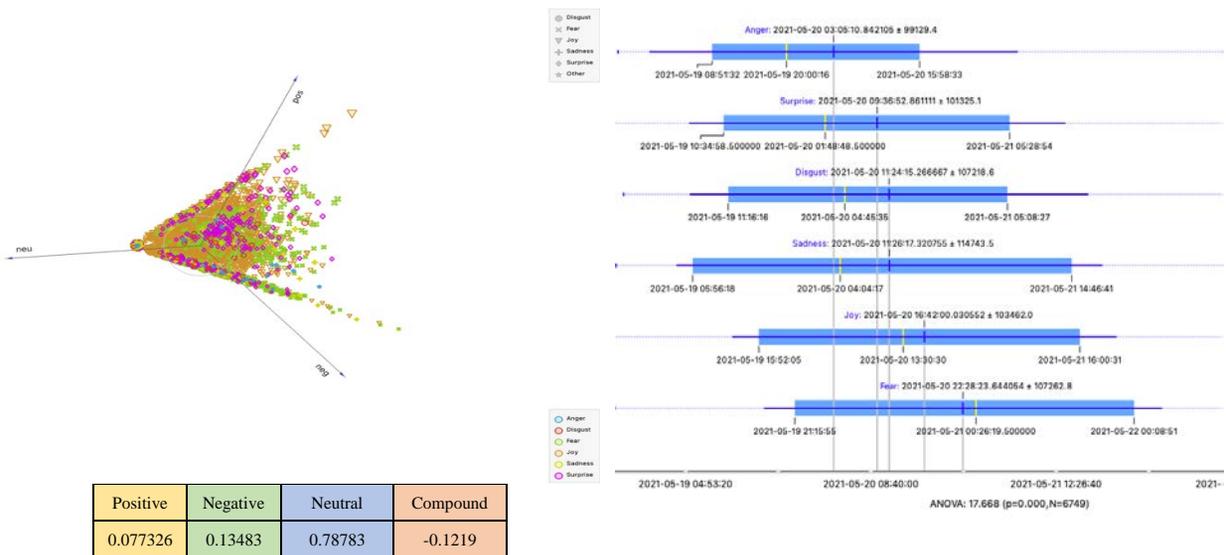
“Nearly 7.8 million Texans have received at least one dose, and more than 4.3 million are now fully vaccinated. #Covid-19 #Coronavirus #Vaccine”.

“Think Global Health has identified 14 countries donating vaccines to 97 nations. See the tracker of this timely project that explains the politics of the #vaccine diplomacy”.

Below are the sentiments and emotional results from the tweets posted from May 19 to May 22, 2021.

Figure 3

Graphical Representation of Sentiments to Covid-19 Vaccinations (May 19, 2021, to May 22, 2021)



Note. Data analysis result of the research

From May 19, 2021, to May 22, 2021, the most dominant emotion was “Sadness” and “Fear.” As the virus continues to spread every day, a rise in mental health crises is eminent due to various stressors, including economic issues, uncertainty about the future, isolation due to lockdown, fear of contracting the virus, and the threat of death. These emotions were evident in their tweets:

“Disappointed in @Potus. As a refugee, the only way I could get edu was through student loans. Since I only worked in public service jobs. My partner - a black woman, 1st gen to graduate from college - is a research nurse, worked on Covid-19 vaccines & andn’t get relief”.

“Ghana using Zipline drones to deliver #Covid-19 vaccines to rural communities”.

“Covid-19 Vaccines Don,t Work as Well for Immunocompromised People”.

“The vaccine of Covid-19 is also gender bias causing changes in menstruation”.

“Vaccine hesitancy for Astra Zeneca could be because people are comparing it to Pfizer or Moderna - which Greg Hunt did mention could be coming later this year”.

There was also worldwide sadness and grief when seven children died in a school shooting, and 17 students were injured during the attack at a Kazan school in Russia. Additionally, 35 people were killed in another airstrike against Gaza as Israeli-Palestinian

conflicts continued, and 14 people died after a cable car accident occurred in northern Italy. India imposed a nationwide lockdown as cases reached more than 20 million. Furthermore, South America saw a surge in Covid-19 cases as mask mandates and social distancing continued to be disregarded in some areas. In South and Southeast Asia, regions like Nepal, Sri Lanka, Thailand, Cambodia, and Indonesia saw spikes in Covid-19 cases. These tragic events could trigger negative emotions in tweets.

On the other hand, there was a tweet of “joy” and “surprise” when the WHO approved the Chinese vaccine Sinopharm, the first non-Western-made vaccine backed by the WHO. Canada announced plans to reopen despite the number of hospital patients, reporting a vaccine dose for everyone. However, in general, sentiments tended towards negative polarity due to false information fueling skepticism and distrust, discrediting the Covid-19 vaccination program, as evident in the sample tweets below:

“Vaccine HESITANCY is even more challenging. It is fed by the misinformation rampant on the internet and by word of mouth. It is worsened considerably by the very inconsistent and overall poor messaging”.

“Covid-19 vaccines designed to elicit neutralizing antibodies may sensitize vaccine recipients to more severe disease than if they were not vaccinated”.

“Vaccine hesitancy plays a major role, but so does a lack of incentives. A lot of states re-opened while vaccination rates were still low. Therefore, there’s less of an urgency for many people”.

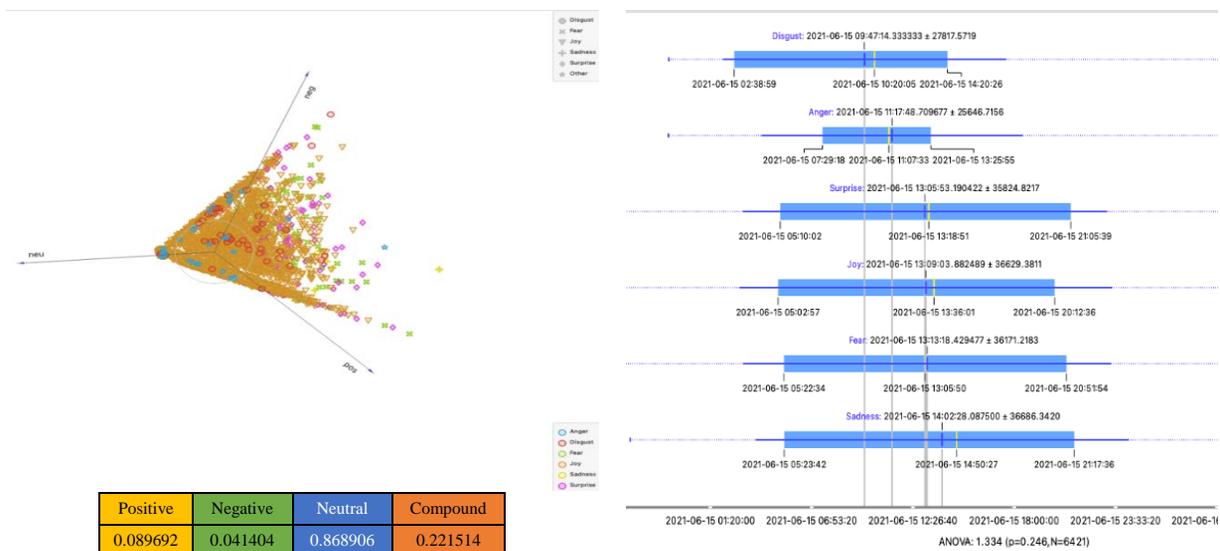
“The data is not telling us that at all. The people filling the hospitals with unplanned admissions are those reacting to the vaccines. They always needed a patsy for those dying or ill because of the jab and this so-called India”.

“Residents of rural communities are at increased risk for severe Covid-associated morbidity and mortality etc. Vaccine hesitancy in rural areas is a major barrier that public health practitioners and healthcare providers”.

Figure 4 presents the Covid-19 vaccination tweets from June 14, 2021, to June 16, 2021.

Figure 4

Graphical Representation of Sentiments to Covid-19 Vaccinations (June 14, 2021, to June 16, 2021)



Note. Data analysis result of the research

The most notable emotions during this period are “surprise,” “joy,” “fear,” and “sadness.” More people are using social media to express “joy” after completing two doses of Covid-19 vaccinations. Many are also “surprised” and filled with “joy” when the UK lifted coronavirus lockdown restrictions, and the infection rate fell to its lowest. It is entirely understandable that access to vaccines is bringing a sense of joy and relief. Therefore, it is reassuring to see tweets proudly displaying their Covid-19 vaccination cards and sharing their stories. Below are some examples of these tweets:

“We’re continuing to make good progress, with 85 percent of eligible adults #vaccinated with a first dose”.

“In northern Thailand, 65-year-old Inkham Thongkham got his Covid-19 vaccination and won a one-year-old female cow worth 10,000 baht in a raffle, part of the city’s incentives to vaccinate people. He said he was very pleased and will raise it”.

“To help with the Covid-19 vaccination process, the Columbus City Council unanimously voted to approve a new initiative that will put cash into residents’ pockets”.

“Covid-19 vaccination drive in Spain: 45% of the population has had at least one dose”.

“Taking the Covid-19 vaccine ensures that you stay protected against the virus! Having fears and doubts”.

“We need mass testing in each state. Mobilize community centers, clinics, and schools. Come on, Malaysia, we can do better than this. Unless we take mass testing seriously, opening more Covid-19 Vaccination centers will not be effective. It takes 02 parts to tango”.

“Got my first shot of Covid-19 Vaccination”.

Meanwhile, “fear” and “sadness” loom in their tweets due to Covid’s deadly second wave, which has sparked fear. The uncertainty surrounding its rapid transmission method has evoked additional fear and anxiety among everyone (Zhong et al., 2020). The number of Covid-19 cases and death tolls are rising each day, and it remains unknown how many people will be infected by Covid-19. Unemployment, economic losses, lockdowns, social isolation, and working from home are additional stressors that add to individuals’ emotional burdens (Tucker & Czaplá, 2020). People are now scared and even panic-stricken about their health and well-being, fearing potential loss of life and wealth. Moreover, the ongoing exposure to the Covid-19 pandemic can induce acute stress responses and psychological stress reactions.

Likewise, one possible worldwide event that might trigger their “sadness” is the celebration in the United States marking the 100th anniversary of the Tulsa Race Massacre, one of the deadliest episodes of racial violence in U.S. history.

Finally, the general sentiment, which tends towards positive polarity, implies that Twitter users remain hopeful and confident about Covid-19 vaccinations despite the challenges posed by the pandemic.

5. Conclusions & recommendations

This study successfully explores sentiment and emotions to reveal critical patterns and trends in public perception regarding the worldwide rollout of Covid-19 vaccination. Overall, tweets exhibited a positive sentiment, expressing hope and confidence in the ability of vaccination to reduce deaths, severe illness from Covid-19, and virus transmission. However, the emotions of sadness, fear, joy, and surprise were the most prevalent.

The emotions of sadness and fear are not solely related to the vaccination rollout but also encompass the mental and physical trauma brought about by the Covid-19 pandemic. In this context, health experts, government leaders, and the community must prioritize the psychological and physical well-being of individuals greatly affected by the pandemic. Conversely, there is a surprise when access to Covid-19 vaccines brings joy and relief.

Nevertheless, individual emotions expressed on social media vary over time and are influenced by physical, mental, and environmental factors that may affect their posts. Therefore, future work will leverage these natural language processing tools to engage in targeted messaging based on user interests, demographics, and location.

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