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Sentiment Computation of UK-originated COVID-19 Vaccine Tweets: A Chronological Analysis and News Effect

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Abstract: This study aimed to analyse public sentiments of UK-originated tweets about COVID-19 vaccines using six chronological data periods between January and December 2021. The dates are based on six BBC news reports about the most significant developments in the three main vaccines administered in the UK - Pfizer-BioNTech, Moderna, and Oxford-AstraZeneca. Each data period spans seven days, starting from the news report. The study employed the Bidirectional Encoder Representations from Transformers (BERT) model to analyse the sentiments in the 4,172 extracted tweets. The BERT model adopts the transformer architecture and uses the 'Masked Language Model' and 'Next Sentence Prediction'. The results show that the overall sentiments for all three vaccines were negative across all six periods, with Moderna having the least negative tweets and the highest percentage of positive tweets overall, while AstraZeneca attracted the most negative tweets. However, for all the considered periods, period 3 (23 -29 May 2021) received the least negative and the most positive tweets, following the BBC report – *COVID - Pfizer and AstraZeneca jabs work against Indian variant*, despite reports of blood clot cases associated with AstraZeneca in the same period. Periods 5 to 6, where there was no breaking news relating to COVID Vaccines, had no significant changes. We, therefore, conclude that the BBC News reports on COVID Vaccines significantly impacted public sentiments regarding the COVID-19 Vaccines.

Keywords: COVID-19; sentiment Analysis; Tweets; Breaking News; Vaccines

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1. Introduction

The novel coronavirus, SARS-CoV-2, behind the coronavirus disease, COVID-19, was first detected in Wuhan, Hubei Province, People's Republic of China, in December 2019 and was declared a pandemic by the World Health Organisation (WHO) on 11 March 2020. By 27 October 2021, there has been more than 4.9 million COVID-19-related deaths and 245.5 million confirmed COVID-19 cases reported globally [1]. As of 27 October 2021, more than 6.94 billion doses of COVID-19 vaccines have been administered worldwide, which enabled at least 48.9% of the total global population to be at least partly vaccinated, and 37.9% fully vaccinated against COVID-19 (Our World in Data 2021:a). While 272 vaccines were in development against COVID-19, 104 vaccines were in clinical testing, and 22 were in use on 29 October 2021 (Milken Institute 2021), it is the Pfizer-BioNTech, Moderna, and Oxford-AstraZeneca COVID-19 vaccines that are of interest to this study owing to their crucial role in the UK's mass immunisation programme [2]. The pandemic disrupted a lot of activities all over the world; schools and education systems were halted and later proceeded to online studies [3,4]. Another worrying devlopment of the pandemic was information overload, some of which were fake news [5], leading to contrasting opinions from the general public [6,7].

1.1. The COVID-19 Pandemic and Vaccination in the UK

The first officially confirmed COVID-19 case and death in the United Kingdom (UK) were discovered in January and March, respectively. The UK was the first western country to authorise a COVID-19 vaccine for emergency use with the approval by the Medicines and Healthcare products Regulatory Agency (MHRA) on 2 December 2020 and subsequently became the first country to start mass immunisation with the Pfizer-BioNTech COVID-19 vaccine on 8 December 2020. The Oxford-AstraZeneca vaccine was approved in the UK by the MHRA on 30 December 2020 and was administered outside of clinical trials on 4 January 2021, whereas the Moderna COVID-19 vaccine was first administered on 7 April 2021. Promoting COVID-19 vaccination uptake was necessary for reducing the strain on the National Health Service (NHS), especially since the number of patients in UK hospitals with a confirmed COVID-19 infection had been mainly on the rise. The number of patients in mechanical ventilation (MV) beds in UK hospitals also increased significantly. Furthermore, the number of daily deaths within 28 days of testing positive for COVID-19 has increased approximately 20-fold in five months: from 10 deaths on 27 May 2021 to 207 deaths on 27 October 2021 in the UK. By 27 October 2021, there has been more than 140,000 confirmed deaths within 28 days of testing positive for COVID-19 and 8.8 million confirmed COVID-19 cases reported in the UK. However, as at 27 October 2021, there has also been more than 102.1 million doses of COVID-19 vaccines administered in the UK, with more than 49.7 million recipients of the first COVID-19 vaccine dose [8]. Moreover, the COVID-19 booster vaccination programme was already underway by 27 October 2021 for people most at risk from COVID-19 without the third dose of vaccine, thus promoting vaccine uptake continues to be indispensable for keeping people protected against severe illness [9].

1.2. COVID-19 vaccine sentiment on Twitter

Government-imposed public health interventions, such as stay-at-home orders or quarantines, introduced additional challenges for the traditional methods used for gathering data on people's opinions [10]. For instance, utilising surveys for data collection had drawbacks even before the COVID-19 pandemic, manifesting in their small and unrepresentative samples or relatively expensive and time-consuming implementation [11,12]. Therefore, researchers like Hussain *et al.* [13] advocate using social media data to examine public sentiments due to the possibility of acquiring more representative samples with the right spatiotemporal granularity often at a lower cost from social media platforms than surveys. Social media is a suitable data source for this project as around 82% of internet-using adults in the UK have a profile on social media nowadays with roughly consistent representation from all socio-economic groups and genders [14]. One of the largest social networking platforms is Twitter with over 211 million daily active users around the world in the third quarter of 2021 which makes it a valuable data source for conducting sentiment analysis on COVID-19 vaccine-related discourse. Moreover, Twitter users have been thus far willing to express their views relatively openly on this social networking platform due to the sense of anonymity they have generally had [15] and the lack of stringent scientific vetting or editorial curation of tweets on the platform [16]. Consequently, Twitter can be a valuable data source for researching public sentiment towards COVID-19 vaccines. Legitimate news events reported by authoritative news organisations worldwide could potentially influence the sentiment towards COVID-19 vaccines among Twitter users [17]. This project is set to analyse the sentiment of UK-originated tweets and the British Broadcasting Corporation (BBC) continues to be the news organisation with the highest reach among UK-based adults, the BBC can be regarded as the most influential authoritative news organisation in the UK.

1.3. The benefit of understanding COVID-19 vaccine sentiments

Sentiment analysis of UK-originated tweets about specific COVID-19 vaccines is one possible avenue for understanding public sentiment towards COVID-19 vaccines in the UK. As sentiment analysis can be conducted retrospectively, this project will focus on the days

following the publication of certain BBC news reports. These news articles were selected owing to their perceived potential to generate positive or negative sentiment towards the three COVID-19 vaccines used in the UK's vaccination programme. By exploring the general sentiment about COVID-19 vaccines at these times, examining the likely effects of the news reports on the public sentiment towards COVID-19 vaccines, and comparing the sentiment towards different COVID-19 vaccines over time, this project may provide useful insights for the UK authorities.

The contribution of this paper is 4-fold:

- To explore the general sentiment about COVID-19 vaccines in the UK
- To chronologically examine the potential effects of news reports on the public sentiment towards COVID-19 vaccines
- To compare the sentiments toward different COVID-19 vaccines in line with these news reports
- To compare the sentiment towards COVID-19 vaccines over time

Many studies have researched sentiment analysis of the public opinion on COVID-19 vaccines, especially on the effect of media on these opinions. However, there are still some research gaps that this study seeks to fill. To the best of our knowledge, no existing study performed a chronological analysis to understand how news reports impact people's sentiments. Particularly, there is a lack of research on understanding public sentiment towards COVID-19 vaccines specifically in the UK context. This study aims to address this gap by analyzing tweets originating from the UK to understand public sentiment towards COVID-19 vaccines over time. Also, there is limited research on the impact of news and events on public sentiment towards vaccines. This study aims to address this gap by chronologically analyzing tweets in relation to specific news and events to understand how they impact public sentiment towards COVID-19 vaccines and how this varies over time. It is common knowledge that there were progress/positive outcomes and news reportage about the various vaccines, but, there were also more troubling and disconcerting outcomes, especially with the emergence of various variants of the virus. Therefore, the main objective of this research is to explore the exert influence of different news reports about COVID-19 vaccines on people's sentiments, chronologically over one year. The research findings provide valuable insights for policymakers and practitioners by providing an understanding of public sentiment towards COVID-19 vaccines, the impact of news and events on public sentiment, the extent of misinformation about vaccines, and how to develop effective communication strategies. The findings can help policymakers and practitioners to develop more effective strategies to increase vaccine uptake, counter misinformation and protect public health.

2. Literature Review

The COVID-19 pandemic has led to a lot of research across the world. Sentiment, Contents, and Retweets: A Study of Two Vaccine-Related Twitter Datasets, published by Blankenship *et al.* [18] in 2018, revealed that leveraging key thought leaders on social media to support health education on vaccination in their tweets might help reach a bigger audience online. The online research focused on how users interacted with the tweets. The research by Deiner *et al.* [19], found that the public's interest and attitude toward vaccine hesitancy may be seen in social media conversations. The opined that users are more likely to interact with negative news about vaccines. The reason for vaccine scepticism as suggested in [20] might be due to how the government or organization that produces the vaccines communicate the vaccine's benefits. Using Semantic network analysis, the study aimed at raising people's vaccine trust amongst a growing vaccine hesitant population, employing significant concepts to better instruct the target audience. The study suggested that the government should also address concerns that might contribute to vaccine distrust. However, despite the fact that the above studies were effective in establishing how public health communication and social media aid people's scepticism, they failed to address the sways in people's opinions.

In times of health crisis, such as the COVID-19 pandemic, newspapers are more vital and indispensable than ever. They inform citizens about events around them and how they can impact their lives. Gesualdo *et al.* [21] in their study tried to answer the question "How do Twitter users react to TV broadcasts dedicated to vaccines in Italy?" The study revealed that social media discussions in response to public news are priceless and might be used to inform vaccine promotion communication strategies. The study advised that the implementation of a mechanism for monitoring the public's mood toward vaccines on social media should be considered by public health organizations.

Using a logistic regression model on sample data of over one million tweets, Chen and Dredze [22] analysed how images on vaccine-related tweets correlate with the likelihood of it being retweeted and, found that posts with images are twice more likely to be retweeted and shared than nonimage posts. And then recommend that the use of images should be factored into the communication strategies of vaccine administration. While this study was carried out before the COVID-19 outbreak, it highlights the impact of communication strategies on public sentiment with regard to vaccines in general. Another study by Nezhad and Deihimi [23] looked at Persian tweets to understand the Iranian people's view towards COVID-19 homegrown and foreign-made vaccines. Using a sample of over 800,000 tweets posted between April and September 2021, they applied a deep-learning sentiment analysis model based on CNN-LSTM architecture. They found a subtle difference in the Persians' views towards homegrown and imported vaccines; foreign vaccines had higher positive perceptions. While this study clearly underscores the need for positive promotion of vaccines on social media, it did not account for the cultural factors that may impact the overall perception and conversations of Persians around the topic of vaccine administration in Iran.

Another COVID-19 sentiment analysis was carried out by Yan et al. [24] on a different social media platform – Reddit, across different cities in Canada, and found three main discussion categories based on topics around Vaccines, vaccine uptakes and vaccine supply. The level of discussion within these topics correlated positively with vaccine acceptance in Canada. This study, just like in [22,23], shows that Social media can be used to better understand sentiments around COVID-19 vaccines and potentially help improve communications about vaccines. This finding is in line with the study by Jang et al. [25], which tracked the attitudes of Twitter users in Canada following the vaccine rollouts. In the study, Jang et al. [25] identified two groups of Twitter users who harnessed negative sentiments to achieve divergent goals; the 'anti-vaxxers', who used negative sentiments to discourage vaccine acceptance, and the 'COVID zero' group, who used negative sentiments to criticise the public health response, while encouraging vaccination. Again, another evidence of the impact of social media communication on COVID-19 vaccine participation. It was also discovered in a study by Monselise et al. [26] that fear was a leading of the top 5 emotions from nearly 8 (eight) million tweets collected in a 60-day window that started from December 16, 2020. This study was done in the United States. It is important to remember that some of those sentiments might have been influenced by election misinformation following November 4 2020, US elections [27].

Furthermore, Nearly a million and half unique tweets from over half a million Twitter users were collected by Lyu, Han and Luli [17] between March 2020 and January 2021 to understand the changes in public concerns and how they might impact the goal of achieving herd immunity. They found that trust was the most predominant emotion over the period and reached its peak in November 2020, following the announcement of the 90% efficacious Pfizer vaccine [28]. This study provided a snapshot of a time during the COVID-19 pandemic when people were, for the first time, required to do physical and social distancing, isolation and quarantine, which had psychological impacts [29]. This means that desperation, fear and hope could have played a huge part in driving public sentiments at that time. According to the study in [30], people's attitudes and emotions towards COVID-19 evolved over time, from positive (at the beginning of the pandemic) to Negative towards the end of 2021. This is further supported by the study

carried out by Niu et al. [31], who attempted to understand the reason for the rapid acceptance of COVID-19 vaccination by the Japanese population at a time when there was a globally diminished confidence in vaccines (January to September 2021), using Twitter comments. They found that negative sentiments outweighed the positive ones, with no increased vaccine confidence, but the communication strategy adopted by the public health authorities helped to create awareness of the danger of COVID-19, which was key to driving up vaccine uptake.

3. Methodology

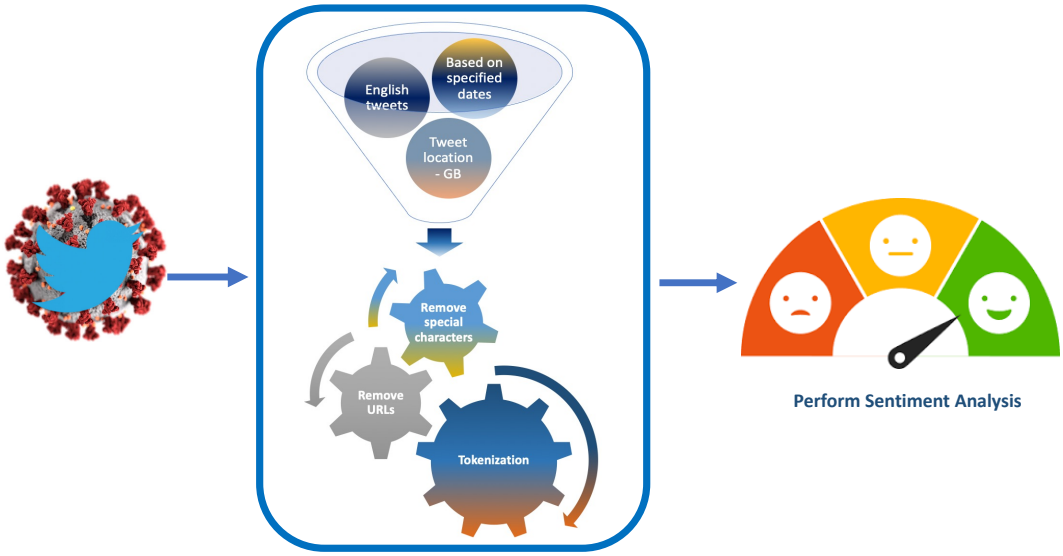


Figure 1. Model Architecture

As can be seen from Figure 1, this study focuses on the extraction and sentiment analysis of tweets (restricted to tweets in English language tweeted from the UK) relating to COVID-19 vaccines, over a period of time. The periods are informed by BBC News reports/breaking news regarding the vaccines. Therefore, the methodological process of this research starts be identifying periods during the pandemic where BBC News broadcast significant news stories about any of the 3 vaccines administered in the UK - Pfizer-BioNTech, Moderna, and Oxford-AstraZeneca. This is then followed by the extraction of tweets that mentioned any of these vaccines for the identified periods.

3.1. Dataset

Six data periods are considered in this research and they are based on BBC News' reportage of significant developments for the UK's adopted COVID-19 vaccines. Each period spans seven days starting from the day the news was reported. The periods and the news headlines are shown in Table 1. The search terms for each of the vaccines are displayed in Table 2. The table shows the terms relating to the three vaccines focused on in this study. It can be seen that some vaccines have more terms than others. These are combinations of terms used to refer to the vaccines to the best of our knowledge.

Figure 2 shows the number of tweets extracted over the period for the 3 vaccines. It can be observed that the number of tweets for AstraZeneca was highest in the first period and consistently decreased. In reverse, Moderna had the lowest number of tweets at the starting period but increased consistently over the period. Pfizer appears to be the vaccine mostly tweeted about between January 2021 and December 2021. We see that from the 3rd to the 6th periods, it has the highest number of tweets.

Table 1. Tweet Extraction Periods and News Titles

Period	News
25 January - 31 January 2021	Moderna vaccine appears to work against variants
2 April - 8 April 2021	COVID 30 blood clot cases found in AstraZeneca recipients in the UK
23 May - 29 May 2021	COVID Pfizer and AstraZeneca jabs work against Indian variant
9 July - 15 July 2021	Heart inflammation link to Pfizer and Moderna jabs
26 November - 2 December 2021	New COVID variant (Omicron): Javid says UK must act quickly over public health risk
8 December - 14 December 2021	COVID Vaccines should work against Omicron variant, WHO says

Table 2. Twitter Search Terms

Vaccine	Search Terms
Moderna	(modernavaccine OR modernajab OR modernaCOVIDvaccine OR modernaCOVID19vaccine OR moderna)
AstraZeneca	(AstraZenecavaccine OR AstraZenecajab OR oxfordvaccine OR oxfordjab OR oxfordCOVIDvaccine OR oxfordCOVID19vaccine OR AstraZenecaCOVIDvaccine OR AstraZenecaCOVID19vaccine OR AstraZenecaoxfordvaccine OR oxfordAstraZenecavaccine OR AstraZeneca)
Pfizer	(pfizervaccine OR pfizerjab OR biontechvaccine OR pfizerbiontechvaccine OR biontechpfizervaccine OR pfizerCOVIDvaccine OR pfizerCOVID19vaccine OR pfizer)

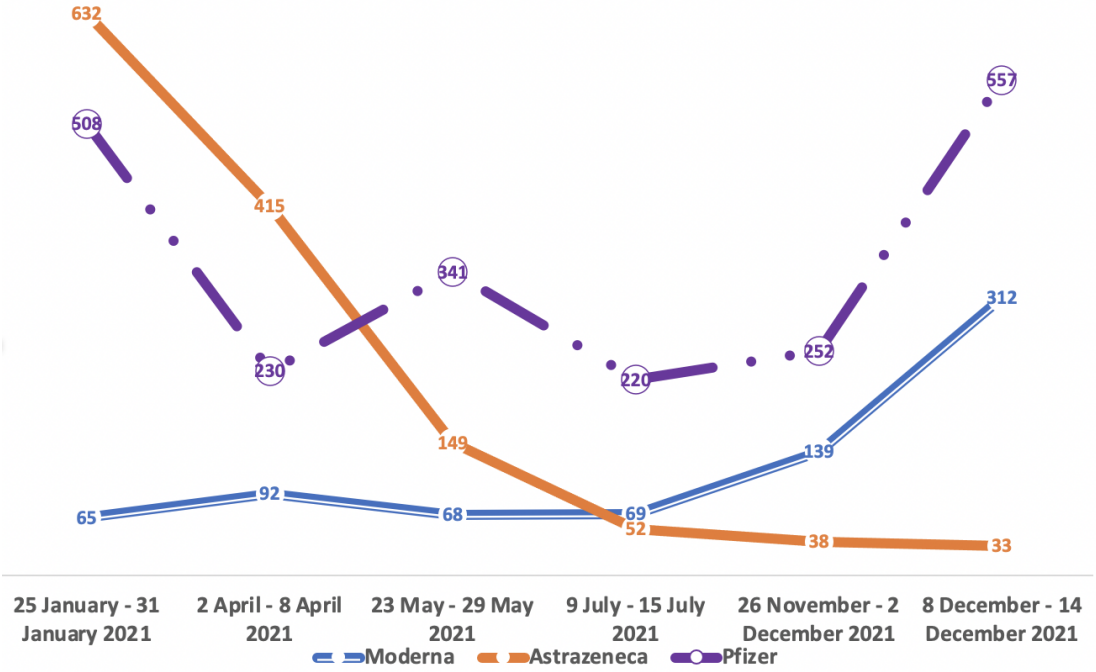


Figure 2. Number of tweets extracted over time

3.2. Data Preprocessing

While extracting the tweets, we made some restrictions and then went further to preprocess the data as follows:

1. We restricted the tweets to English tweets tweeted from the UK within the timeframes as per Table 1, and original tweets (retweets are discarded).
2. Hashtags, usernames, and hyperlinks were removed.
3. Special characters were filtered and white spaces removed.
4. The data was tokenised before passing to the BERT model.

3.3. Sentiment Detection

In this study, we employed the Bidirectional Encoder Representations from Transformers (BERT) model to analyse the sentiments in tweets [32]. The BERT model pretrains deep bidirectional representation from unlabeled texts. It considers the contexts of texts by jointly learning from both the left-right and right-left sequences of the texts. Due to this bidirectional representation of the model, stopword removal, stemming, lemmatisation are not useful when using the model as these will affect the texts construct. For example, if we applied stopword removal to the text - *the dinner was not good*, this will leave us with the text - *dinner good* and the sentiment would have been *positive*. However, the negation *not* changed the sentiment of the text to *negative*. The BERT model was trained on 2,500 million words from Wikipedia Corpus, and Book Corpus of 800 million words. The model adopts the transformer architecture and uses the following two strategies during training:

1. Masked Language Model
2. Next Sentence Prediction

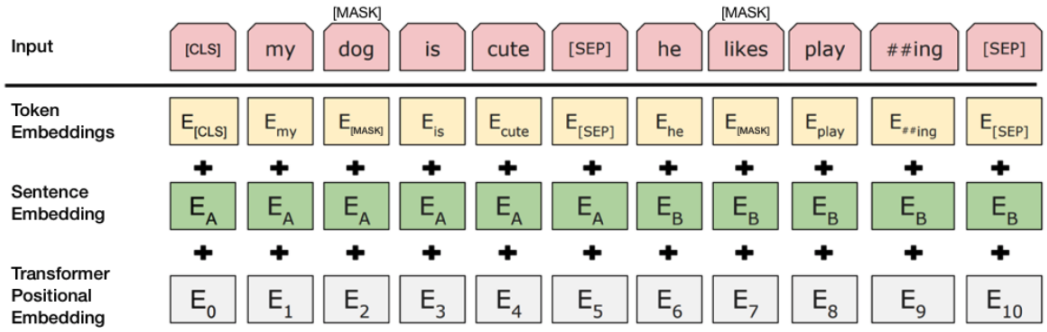


Figure 3. Bert Model Process [33]

The Bert model in Figure 3 presents these strategies. Before word sequences are fed into BERT, a part (15%) of the words is replaced with a *MASK* token. And based on the contexts of the other words (non-masked) in the sequence, the model attempts to predict the masked words. To predict the next sentence (the connectedness between the first and second sentence), the entire input sequence is passed through the Transformer model. The first sentence is the classification sentence [CLS]; all the sentences are separated by the separation token [SEP]. During training, 50% of the time, the second sentence comes after the first, and a randomly sampled sentence 50% of the time. BERT model then predicts if the second sentence is a correct sequence or a random sentence.

As earlier stated, the main objective of this research is to explore the exert influence of different news reports about COVID-19 vaccines on people's sentiments, chronologically over one year. The method employed in this research achieved this objective following similar methods as those stated in section 2 which focused on extracting tweets for sentiment analysis. In our study, the chronological analysis of UK-based COVID-19 vaccine related tweets enable us to uncover how news events about the vaccines affected people's opinions. We adopted the BERT model because several studies have shown that BERT outperforms other models in sentiment analysis tasks. For example, in a study by Devlin et al. [32] BERT was trained on a large corpus of tweets and was able to achieve an accuracy of 85% in sentiment analysis, which outperformed other pre-trained models such as ELMO and

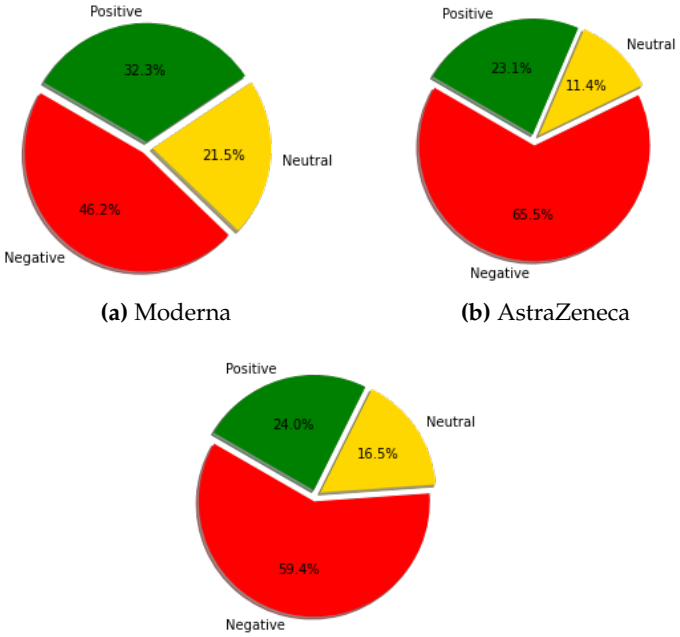
GPT-2, as well as traditional machine learning models such as SVM and logistic regression. BERT's pre-training on a large corpus of makes it more robust and less prone to over-fitting.

4. Results

In this section, we analyse the sentiments contained in tweets towards the three focused vaccines. The periods of this study are based on BBC News reports about various significant vaccine developments from January 2021 to December 2021.

4.1. Period 1: 25 January - 1 February 2021

On the 25th of January 2021, the BBC reported that Moderna COVID-19 vaccine appears to work against more infectious variants of the virus, according to the US pharmaceutical company. Although this news was specifically about Moderna, this vaccine had only 65 tweets compared to the 632 tweets for AstraZeneca and 508 for Pfizer.



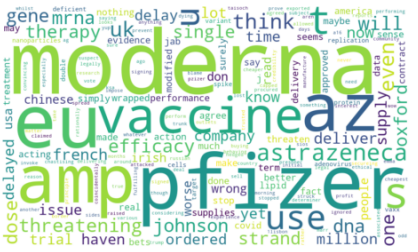
(a) Moderna **(b)** AstraZeneca

(c) Pfizer

Figure 4. Period 1 - Sentiment percentage of tweets per vaccine

From Figure 4, we see that the sentiments are generally negative for the three vaccines. However, it is interesting to see that the percentages of negative tweets for AstraZeneca and Pfizer are above 50%. Moderna has more positive tweets than the others.

Figure 5 shows words that were used in the negative oriented tweets. Although we can see some positive words such as *efficacy, good, and better*, there are lots of negative words in these tweets. For Moderna, we see words such as *threatening, wrong, worse, delayed, and deficient*. AstraZeneca contains negative words such as *failed, threaten, issue, wrong, and dispute*. There are other negative sentiments around the *profitability and nationalsim* where vaccine companies are accused of being *profit* focussed, and Governemnt for *nationalism*. Pfizer possessed some negative terms such as *risk, threatening, problem and failed*.



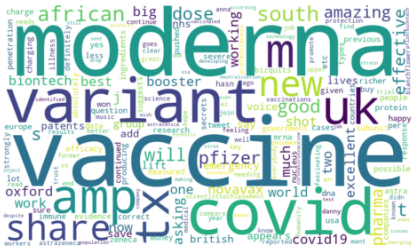
(a) Moderna

(b) AstraZeneca

(c) Pfizer

Figure 5. Period 1 - Words associated with Negative tweets

Over this same period, some of the positives words associated with the vaccines are as follows (see Figure 6):



(a) Moderna

(b) AstraZeneca

(c) Pfizer

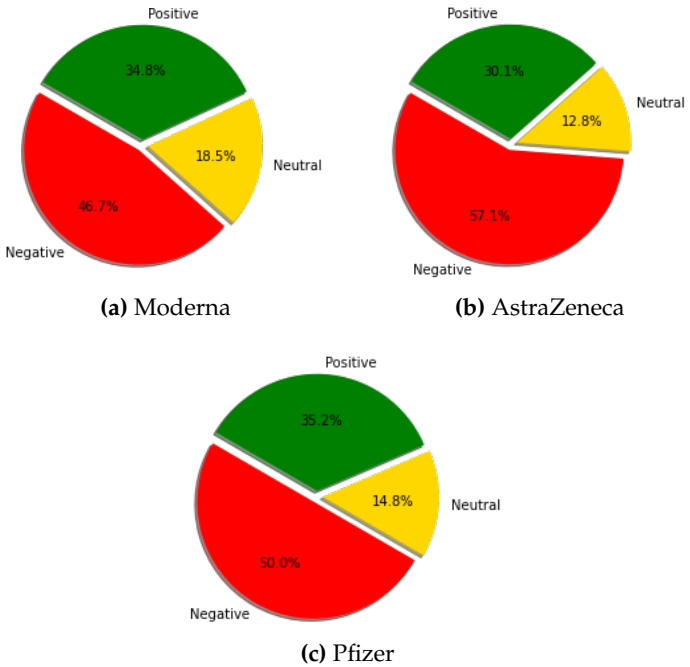
Figure 6. Period 1 - Words associated with Positive tweets

Moderna: *amazing, excellent, working, happy, best.*
AstraZeneca: *great, good, thank, amazing, interesting.*
Pfizer: *great, thank, happy, excellent, fantastic.*

4.2. Period 2: 2 April - 8 April 2021

On the 2nd of April 2021, the BBC reported 30 blood clot cases found in AstraZeneca recipients in the UK. In this period, the number of tweets for Moderna slightly increased from 65 to 92 while those of AstraZeneca and Pfizer decreased from 632 to 415 and from 508 to 230, respectively. This is somewhat surprising as one would expect to see more tweets about AstraZeneca due to the negative news about the blood clot. However, the reason for the declining number of tweets about AstraZeneca could be a result of the fading enthusiasm for the vaccine by the British populace, based on a survey of 5,000 people, as reported by a Reuters article [34]. The article noted rising unease about the possible link to rare adverse side effects of the vaccine but also highlighted overall high confidence in vaccines in the UK. The article further reported that the AstraZeneca vaccine was suspended by over a dozen of European countries due to reports of blood clots and low platelets in a small number of people who received the vaccine.

Overall, for all the vaccines, the percentage of positive sentiments went up slightly while the percentage of negative sentiments decreased, as shown on Figure 7. However, the percentage of negative sentiments for Moderna went up slightly from 46.2% to 46.7% while it's positive sentiment increased from 32.3% to 34.8%. For AstraZeneca, the percentage of negative sentiments went down from 65.5% to 57.1%; while the percentage of positive sentiments went up to 30.1% from 23.1% - this is a significant increase for Astraneneca. The percentage of negative sentiments for Pfizer went down from 59.4% to 50.0%, while the positive percentage went up to 35.2% from 24.0%. Although the sentiments are still generally negative for this period, there's a significant shift in sentiment from negative to positive.



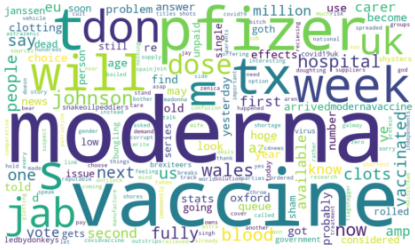
(a) Moderna **(b)** AstraZeneca

(c) Pfizer

Figure 7. Period 2 - Sentiment percentage of tweets per vaccine

Figure 8 shows the word-cloud for negative words associated with the vaccines. Over this period, some of the negative words associated with the vaccines are as follows - we can see some overlaps in the negative words associated with the tweets:

Moderna: *problem, clots, dead, effects, blood.*
AstraZeneca: *risk, severe, effect, clot, blood.*
Pfizer: *effect, death, blood, clot, problem.*



(a) Moderna **(b)** AstraZeneca

(c) Pfizer

Figure 8. Period 2 - Words associated with Negative tweets

(a) Moderna **(b)** AstraZeneca

(c) Pfizer

Figure 9. Period 2 - Words associated with Positive tweets

Over this same period, some of the positives words associated with the vaccines are as follows (see Figure 9):
Moderna: *huge, promise, transparency, funny, thanks*.
AstraZeneca: *good, brilliant, safe, happy, benefits*.
Pfizer: *thank, grateful, lovely, good, safe*.

4.3. Periods 3 to 6

Table 3 presents a summary of sentiment percentages for periods 3 to 6. Generally, it could be seen that the overall sentiments for each of the vaccines are negative. It is

important to note that the sentiment percentages are not synonymous with the number of tweets about the vaccines. The table shows that Moderna received less negative sentiments compared to AstraZeneca and Pfizer. It is also observed that AstraZeneca attracted the most negative tweets. At the positive level, Moderna also attracted more positive tweets that AstraZeneca and Pfizer; while Pfizer received a relatively more positive tweets than AstraZeneca. For all the considered periods, period 3 (23 May - 29 May 2021) with the breaking news - *COVID Pfizer and AstraZeneca jabs work against Indian variant*, received the least negative tweets and the most positive tweets. This is a significant shift in sentiment from period 2 where 30 blood clots cases were found in AstraZeneca recipients. The "good" news reported in period 3, saw Moderna's percentage negative sentiment dropped from 46.7% to 29.4%, AstraZeneca from 57.1% to 45.0%, and Pfizer from 50.0% to 43.7%. On the positive side, Moderna's percentage rose 34.8% to 55.9%, AstraZeneca from 30.1% to 43.0%, and Pfizer from 35.2% to 43.4%. These percentages suggest that the news outbreaks may have swayed people's sentiments towards the vaccines.

Period 4 saw another significant shift in sentiments; this time, to the negative. This period (9 July - 15 July 2021) had the news - *Heart inflammation link to Pfizer and Moderna jabs*. In this period, the percentage of negative sentiments for Moderna rose to 42.0% from 29.4%, AstraZeneca to 57.7% from 45.0%, and Pfizer to 51.8% from 43.7%. The percentages of positive sentiments for the three vaccines also dropped from 55.9% to 40.6%, 43.0% to 26.9%, and 43.4% to 38.2% for Moderna, AstraZeneca, and Pfizer, respectively. There are no significant changes for periods 5 and 6. In general, it could be said that people's sentiments shift in relation to breaking news.

Table 3. Periods 3 - 6: Sentiment percentage of tweets per vaccine

Timeline	Negative (%)			Positive (%)		
	Moderna	AstraZeneca	Pfizer	Moderna	AstraZeneca	Pfizer
23 May - 29 May 2021	29.4%	45.0%	43.7%	55.9%	43.0%	43.4%
9 July - 15 July 2021	42.0%	57.7%	51.8%	40.6%	26.9%	38.2%
26 Nov - 2 Dec 2021	45.3%	57.9%	57.9%	35.3%	36.8%	29.8%
8 Dec - 14 Dec 2021	42.0%	57.6%	52.4%	36.2%	24.2%	29.3

5. Discussion

In summary, this paper contributes to knowledge by exploring the general sentiment about COVID-19 vaccines in the UK; chronologically examining the potential effects of news reports on the public sentiment towards COVID-19 vaccines, by comparing the sentiments toward different COVID-19 vaccines in line with these news reports.

In section 2, we compare the contributions of related existing studies and the result results of the proposed study. The study in [35] revealed that public opinion about COVID-19 vaccinations shifted dramatically over time and across locations. Sentiment analysis can help public health authorities build locally tailored vaccination education initiatives by providing timely insights into public sentiment concerning the COVID-19 vaccine. However, the study only focused on identifying people's sentiment, not considering how external factors such as news affect those tweets. Rahul *et al.* [36], examined sentiment analysis and topic modelling of COVID-19 vaccine-related tweets from November 1, 2020, to December 16, 2020. The study reported a more positive sentiments than negative sentiments from the over 500,000 tweets that were analyzed. In [37], the authors conducted a study to see how the COVID-19 news influenced Twitter sentiment in four different countries: the United Kingdom, India, Japan, and South Korea. The United Kingdom was found to have one of the highest percentages of negative sentiment. Surprisingly, the United Kingdom was the most affected of the four countries. This study, however, only focused on analysing news headlines without the corresponding impact of these on people's sentiments, especially towards COVID-19 vaccines. Gesualdo et al. [21] tried to answer the question "How do Twitter users react to TV broadcasts dedicated to vaccines in Italy?" They revealed that social media discussions in response to public news are priceless

and might be used to inform vaccine promotion communication strategies. While this study correlates with ours, it did not consider a chronological strategy to their analysis. And while their study focused on Italian population, it is also important to conduct a study focused on the UK.

While our study makes important contributions to knowledge and theory, it can also provide valuable insights for policymakers and practitioners in several ways:

- Public sentiment towards vaccines: The findings can provide policymakers and practitioners with an understanding of public sentiment towards COVID-19 vaccines in the UK, which can help them to develop more effective communication strategies to increase vaccine uptake.
- Impact of news and events on public sentiment: The findings can provide policymakers and practitioners with an understanding of how news and events impact public sentiment towards COVID-19 vaccines. This can help them to develop more effective communication strategies to address any misconceptions or concerns that people may have about the vaccine.
- Misinformation about vaccines: The findings can provide policymakers and practitioners with an understanding of the extent of misinformation about COVID-19 vaccines on social media, which can help them to develop strategies to counter misinformation and protect public health.
- Targeted interventions: The findings can provide policymakers and practitioners with insights into vaccine hesitancy and help them to develop targeted interventions to increase vaccine uptake.
- Development of Communication strategies: The findings can provide policymakers and practitioners with insights on how best to communicate the vaccine message to the public, the right timing of communication, and the right channels of communication.

6. Conclusion

COVID-19 vaccines are important for the world to get back on track after the ravaging pandemic. However, it was important to note that many people were sceptical of getting vaccinated. Vaccine hesitancy is a global problem and it is important to understand the reasons for this in order to address it. The paper aimed to understand people's sentiments towards the COVID-19 vaccines in the UK, by examining BBC news reports. In particular, we analysed tweets in relation to three COVID-19 vaccines - Moderna, AstraZeneca, and Pfizer over a twelve-month period using six chronological data periods. We found that overall, the Moderna vaccine is generally perceived more positively than the other two vaccines, while the AstraZeneca vaccine attracted more negative sentiments. These perceptions are largely due to the slightly lower risk of Moderna vaccines compared to the others, and the major blood clot concerns of the AstraZeneca vaccine, respectively.

The study has achieved the objectives of the research. It explored the general sentiments of the British people about the COVID-19 vaccines. We see that the general sentiment about the vaccines over the study period is more negative. A high vaccination rate is thought to be well-received and potentially lead to high vaccine confidence notwithstanding the fears and uncertainties about the pandemic. However, we have seen that this was not the case as various news outbreaks which were sometimes positive and negative at other times swayed people's opinions. The news as reported by the BBC were based on the developments of the pandemic and the vaccines.

For all six chronological period selected for this study, period 1 (25 January - 31 January 2021) with the breaking news - "Moderna vaccine appears to act against variations" had the highest record of negative sentiments. While period 3 (23 May - 29 May 2021) received the fewest negative tweets and the most positive tweets, with the breaking news - "COVID Pfizer and AstraZeneca jabs effective against Indian variant." The study shows that there is a relationship between the news and people's perceptions of the COVID-19 vaccines. The results indicate that news has a significant impact on how people perceived the vaccines,

as seen in the shifts in sentiment percentages. This suggests that the media plays a role in shaping public opinion on vaccines.

In order to address vaccine hesitancy, it is therefore important to provide accurate and balanced information about the vaccines in the media. Based on the result of this study, there are several things that can be done to manage people's sentiment toward COVID-19 vaccines (and other vaccines) or vaccine hesitancy. First, it is important to provide accurate and updated information about vaccines. Second, it is important to address the concerns of the people. The findings of this study would mean various things to various stakeholders. For the government and policymakers, the understanding that news publications affect people's opinions about events, in this case, COVID-19 vaccines, could lead to the implementation of policies that would enable them to monitor the information being conveyed about the events and how people are reacting to it. It would also help them to track vaccine hesitancy and the themes that influence the hesitation, and to implement or adopt better strategies in addressing people's hesitancy. An effective and authoritative information dissemination process would need to be adopted in promoting and strengthening vaccine confidence. Advancing vaccine confidence could be through sustainable engagements with the general public, and partnerships with local authorities, community leaders, influencers, and cultural organisations to promote COVID-19 vaccines. The government would also need to stimulate more responsive, equitable, and accessible programs that reduce barriers to vaccine confidence and uptake. Healthcare practitioners are the most trusted influencers and advisors of vaccination decisions. They can influence people's opinions and sentiments about vaccines, however, they are faced with erratic changes in people's opinions and sentiments mostly due to news reportage and concerns about the vaccines. An understanding of how news outbreaks sway people's opinions and vaccine hesitancy would enable them to implement strategies to manage and support the changing public.

It is recommended that future studies be conducted to investigate the impact of the news on other aspects of people's lives, such as their emotions or economic decisions. In addition, future studies could also explore the impact of fake news on people's sentiments and behaviour. This study has limitations as it only focuses on tweets from the UK. In addition, the study only uses a small sample of tweets as the data is collected over a short period of time. Future studies could focus on covering more timelines and include tweets from other countries to understand how social media users perceive COVID-19 vaccines in different countries.

BBC has been used as a source of information in the research because of its wide reach and diffusive characteristics. The BBC has a large audience, and its content is widely shared and distributed through various platforms. Due to its reach and reputation, the BBC's communicative power can be considered relevant. However, we acknowledge that there are other sources of influence on the sentiment of tweets including social media platforms, newspapers, radio, and television. Additionally, individuals are also influenced by their personal experiences, friends, family, and other people in their social network. Therefore, it would be more accurate to state that among the many sources of information that can reach individuals, the BBC has a relevant weight.

Authors' contributions

Conceptualization by Richard Fuzi and Ebuka Ibeke; Methodology by Olasoji Amujo; Software by Ebuka Ibeke and Olasoji Amujo; formal analysis by Ugo Ogara and Celestine Iwendi; Investigation by Ebuka Ibeke and Celestine Iwendi; Resources and data collection by Olasoji Amujo, Richard Fuzi and Ebuka Ibeke; Writing by: Richard Fuzi, Olasoji Amujo and Ugo Ogara; Validation by: Ugo Ogara and Celestine Iwendi.

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