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iNCOVACC COVID-19 vaccine: A Twitter based Social Media Analysis Using Natural Language Processing, Sentiment Analysis, and Topic Modelling

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ABSTRACT

Most, if not all, the vaccine candidates designed to counteract COVID-19 due to SARS-CoV-2 infection require parenteral administration. Mucosal immunity established by vaccination could significantly contribute to containing the SARS-CoV-2 pandemic, which is spread by infected respiratory secretions. The world has been impacted on many fronts by the COVID-19 pandemic since early 2020 and has yet to recover entirely from the impact of the crisis. In late 2022 and early 2023, China experienced a new surge of COVID-19 outbreaks, mainly in the country's northeastern region. With the threat of new variants like XBB 1.5 and BF.7, India might experience a similar COVID-19 surge as China and needs to be prepared to avoid destruction again. An intranasal vaccine can elicit multiple immunological responses, including IgG neutralization, mucosal IgA production, and T-cell responses. In order to prevent further infection and the spread of COVID-19, local immune responses in the nasal mucosa are required. iNCOVACC is a recombinant vaccine vectored by an adenovirus that contains a SARS-CoV-2 spike protein that has been pre-fusion stabilized. This vaccine candidate has shown promise in both early and late-stage clinical trials. iNCOVACC has been designed for intranasal administration via nasal drops. The nasal delivery system was created to reduce expenses for those living in poor and moderate-income

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countries. The newly introduced intranasal COVID vaccine will be beneficial in mass immunizing the public as it does not need any syringe and can be proven to be an effective method to boost immunity against the SARS-CoV-2 virus. This study uses natural language processing (NLP) techniques to analyze the Indian citizen's perceptions of the newly developed iNCOVACC vaccine in social media. For this study, we have used social media posts (tweets) as data. We have analyzed 125,300 tweets to study the general perception of Indian citizens regarding the iNCOVACC vaccine. Our results have indicated 43.19% of social media posts discussing the COVID-19 nasal vaccine in a neutral tone, nearly 34.29% of social media posts are positive, and 22.5% of social media posts discussions are negative. The general positive feeling that the iNCOVACC vaccine will work and the risks in the new vaccine are the two significant aspects Indian citizens voice out in social media posts about the iNCOVACC vaccine.

1 Introduction

In the last two years, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the cause of coronavirus disease 2019 (COVID-19), has profoundly affected global health, the economy, and social stability (Dhama et al. 2020; Chen et al. 2022). SARS-CoV-2 is a member of the coronavirus family and primarily affects the respiratory system of its host (Akkız 2022). Though the COVID-19 crisis was subdued mainly in the latter part of 2021, the emergence of the Omicron variant and subsequent new Omcrion variants, including BF.7 and XBB 1.5 in late 2022, created a new wave of COVID-19 throughout the world, and it is a matter of concern (Dhama et al. 2022a; Zhou et al. 2022; Dhama et al. 2023). The introduction of the vaccine in mid-2020 has dramatically reduced the effect of COVID-19 and the number of deaths (Coccia 2022). However, the emergence of new variants and their ability to evade the immunity provided by the vaccine created a new issue for scientists and governments worldwide (Praveen et al. 2022). Global health is negatively impacted by the SARS-CoV-2-caused COVID-19 pandemic due to the virus' rapid dissemination and rapid mutation rate, stressing the significance of effective vaccines to prevent future illness and mortality. There are now over 500 vaccinations being researched and developed, with over 150 vaccine candidates undergoing clinical review and 24 vaccines approved for use in humans in times of emergency.

Vaccines capitalize on the unique ability of the human immune system to recognize and recall previously encountered pathogens. An ideal vaccination would stop the disease before it causes serious illness, hospitalization, or death quickly and in various ways. In the aftermath of vaccination, T cells and antibody-making B cells mediate the adaptive immune response (Chakraborty et al. 2022; Sah et al. 2022). Presently, the only way to receive a COVID-19 vaccination is via an intrusive intramuscular (IM) injection, but scientists are hard at work developing a vaccine that may be given via the less invasive nasal or oral routes. Vaccines against COVID-19 that have been approved by the World Health Organization and are given intramuscularly elicit antibody-mediated and cell-mediated immunity to prevent viral replication and offer resistance to the emergence of COVID-19. However, the current IM vaccines are designed to generate a systemic immune response rather than mucosal protection. The protections provided by IM vaccinations may, therefore, not be adequate to deal with virus multiplication and shedding in the upper respiratory tract and may not prevent SARS-CoV-2 infection through the nasal route. Unvaccinated individuals may still be susceptible to infection with SARS-CoV-2 if they do not mount a local secretory IgA antibody immunological response (Alu et al. 2022; Nakahashi-Ouchida et al. 2023).

Inducing sterilizing immunity in the upper airway is not a goal of most vaccinations. Therefore, they primarily defend against lower respiratory tract illnesses. The introduction of vaccines through the nasal route has the potential to not only protect against the clinical manifestations of disease but also to stop the spread of the virus among susceptible people. If anybody wants to stop the spread of viruses, they should get vaccinated in a method that makes their upper airway utterly immune to them (Dhama et al. 2022a; He et al. 2023). An intranasal vaccination has promise because it mimics the natural route of infection, may be administered by the patient, and has the potential to capture a sizeable market share in the long run. Regarding the upper and lower respiratory tracts, intranasal immunization induced strong neutralizing antibody responses and mucosal IgA and T cell responses, essentially eliminating the SARS-CoV-2 infections (Dhama et al. 2022b).

Intranasal vaccination can provide a safe and effective means of eliciting long-lasting systemic and humoral immune responses and mucosal immunity in the upper and lower respiratory tracts because the nasal compartment is the first-line barrier to SARS-CoV-2 entry that must be breached before the virus can spread and disseminate to the lungs. The immunological response prompted by an intranasal vaccine is extensive, including the production of neutralizing IgG, mucosal IgA, and T cells. Prevention of both infection and transmission of COVID-19 requires immune responses at the site of infection (in the nasal mucosa). SARS-CoV-2 vaccinations intranasally protect against acquiring the virus, its replication, it's shedding, and the development and spread of disease (Slomski 2022; He et al. 2023; Nakahashi-Ouchida et al. 2023). Studies have indicated that intranasal delivery of vaccines is

favored over needle injection since it is perceived as less uncomfortable and intrusive to the body, is equally effective, and is associated with fewer side effects (Alu et al. 2022; Slomski 2022; He et al. 2023; Nakahashi-Ouchida et al. 2023).

Previous studies have mentioned the fear of vaccines, and the general mistrust of vaccines resulted in the low intake of vaccines in many parts of the world (Praveen et al. 2021b; Praveen et al. 2021; Chakraborty et al. 2022). In late January 2023, Bharat Biotech developed a new vaccine named iNCOVACC, an intranasal COVID-19 vaccine (Times 2023). Intranasal vaccines are superior to conventional vaccines since the nasal mucosa is often the initial site of infection (Chavda et al. 2021). Furthermore, nasal mucosal vaccination lessens the need for syringes and medical waste, making it a resource-saving and environmentally friendly approach appropriate for a sustainable healthcare paradigm. The mucosal vaccines are also practical for self-help vaccination, which guarantees individual comfort and improves individual compliance, making them suitable for mass immunizations in the general public. China is experiencing a crisis with a surge in COVID-19 cases, and India may soon have a similar situation (Kelleni 2023). To get through this challenging times, the Indian government and health officials must be prepared, and iNCOVACC intranasal COVID vaccine can be promoted among the public to increase immunity among the Indian population.

iNCOVACC contains a SARS-CoV-2 spike protein pre-fusion stabilized and delivered as a recombinant vaccine vectored by an adenovirus that lacks replication. Clinical trials of this vaccine candidate in phases I, II, and III met with positive conclusions. iNCOVACC has been designed for intranasal administration via nasal drops. The nasal delivery device was created to be affordable in low- and middle-income countries (Shahnoor et al. 2023).

Previous research has shown that some people doubt vaccinations and do not accept new methods easily (Praveen et al. 2021). Our study analyzes the Indian citizens' perspective on the new intranasal COVID-19 vaccine. It is crucial to comprehend how the general public perceives the vaccine. Before beginning the process of mass vaccination, this study will assist government officials and policymakers in understanding the difficulties that must be resolved.

2 Materials and Methods

We have used social media posts of Indian citizens to understand ordinary citizens' mental attitudes toward the COVID-19 intranasal vaccine. Governments and policymakers should be aware of the public's views on any health policies they consider implementing since implementing a policy that most citizens do not support will result in not attaining the desired outcomes. In this research, sentiment analysis and topic modeling are two natural language processing (NLP) approaches we employed to analyze the general public's perceptions of India's iNCOVACC COVID-19 nasal vaccine.

For this study, we collected all the tweets concerning Indians talking about the iNCOVACC nasal COVID vaccine. We have scrapped all tweets containing the word 'iNCOVACC' using the Python library Twint. Using the python scrapper we have built, we have scrapped down all the tweets posted by Indians between the 4th week of January 2023 to the 3rd week of February 2023 that contains the word 'incovacc.' For this study, we selected Twitter as our data source. We have gathered tweets from India using the geographical filtering function in the Python library Twint. We have chosen only tweets in the English language for this study. One hundred twenty-five thousand three hundred distinct English tweets were used for the analysis after excluding the duplicated tweets and the tweets from other languages. We select the same amount of tweets for four weeks in 2023 (4th week of January to 3rd week of February 2023) in our corpus to balance out any potential disadvantage resulting from the uneven sample.

Before the analysis, we processed the data through various data-cleaning methods. Data cleaning is essential in the study as it removes unwanted entities from the corpus (Praveen et al. 2021a). Stop words, numbers, punctuation, and hyperlinks that weren't necessary for our data analysis were removed through this method. Stop words in the corpus lack inherent meaning and are hence unnecessary for analysis. Stop words typically refer to articles like 'a' and 'an' and prepositions like 'is,' 'that,' and 'of,' which have no meaning or purpose. Following removing the stop words from the corpus, we also removed other unwanted entities like numbers, punctuations, and hyperlinks. Further, we have performed the stemming and lemmatization of the data for our study. Stemming is the process of reducing the words into their root type by removing the end letters (Praveen and Ittamalla 2020a), such as "pens- > pen" and "likes-> like," and lemmatization is the act of organizing various word kinds into groups to reduce the dimensionality (Praveen et al. 2021c).

2.1 Sentimental analysis

Sentiment analysis is a machine learning technique used for gathering and examining subjective evaluations of various characteristics of a thing or entity in textual data (Praveen and Ittamalla 2020b). The sentimental analysis technique aims to calculate the sentimental score by analyzing the data, which might be a phrase, sentence, or full text (Praveen et al. 2020b). We performed sentiment analysis in our study to comprehend how Indian social media users felt about the iNCOVACC COVID-19 nasal vaccinations. Realizing the general public's opinions regarding a specific concern, such as a particular health policy, can

help governments and policymakers determine whether the general public will support the policy they implement. Using the sentimental analysis technique, the author's tone appears in their text as either positive, negative, or neutral. The Python library TextBlob was utilized for the sentiment analysis process. The TextBlob library analyzes every word in the documents in the corpus using powerful machine-learning algorithms, categorizing the overall sentiments as positive, negative, or neutral (Praveen and Ittamalla 2021a). Each word in the document is scored individually using the Text Blob library. The total score of the document is calculated by a pooling operation (averaging all sentiments), and the final sentiment of each document is determined (Praveen and Ittamalla 2022).

2.2 Topic Modelling

Sentiment analysis lets us comprehend how the general public feels about a health policy. Yet, topic modeling is necessary to understand the variables influencing emotions fully. We performed topic modeling on the data to understand the major aspects of Indian citizens' voices about the newly developed iNCOVACC vaccine. In this study model, we used Latent Dirichlet Allocation (LDA) topic modeling to analyze the principal issues raised by Indian citizens regarding the COVID-19 nasal vaccination. Topic modeling is an information retrieval technique that helps understand the premises based on which the big data corpus is built (Praveen et al. 2020a; Praveen and Ittamalla 2021b). Previous to LDA, latent semantic indexing was used to derive the topics based on which the corpus is built (Praveen et al. 2021). However, the latent semantic indexing method cannot do document-level understanding. Latent Dirichlet Allocation topic modeling works under the assumption that all the documents presented in the corpus are a mixture of the number of topics, where each topic is a multinomial distribution of words (Praveen et al. 2020a). LDA employs machine learning algorithms to understand the latent variables from the unstructured data. To facilitate a better understanding of the topics identified, we used LDAvis.

3 Results and Discussion

3.1 Sentiment Analysis

This research was divided into two phases. In the first phase, sentiment analysis was done to ascertain how individuals feel about iNCOVACC COVID-19 nasal vaccines. The general sentiment of each text in the corpus is evaluated by TextBlob algorithms, which look at each word in the tweet to assess if it is positive, negative, or neutral. For this study, we scrapped 125,300 tweets about Indians talking about iNCOVACC COVID-19 nasal vaccine. For an accurate comparison, we chose an equal number of tweets from each week of the month in the corpus. The sentimental analysis study showed that out of 125,300 tweets, 54129 tweets (43.19%) were neutral about the iNCOVACC COVID-19 nasal vaccine, 42977 tweets (34.29%) revealed positive sentiments and 28194 tweets (22.5%) had negative sentiments. Our study by sentiment analysis showed that about 77.48% of the Indian population's social media posts were either positive or neutral. The results of our research are mentioned in Table 1. Figure 1 and Figure 2 represent the graphical representation of table 1.

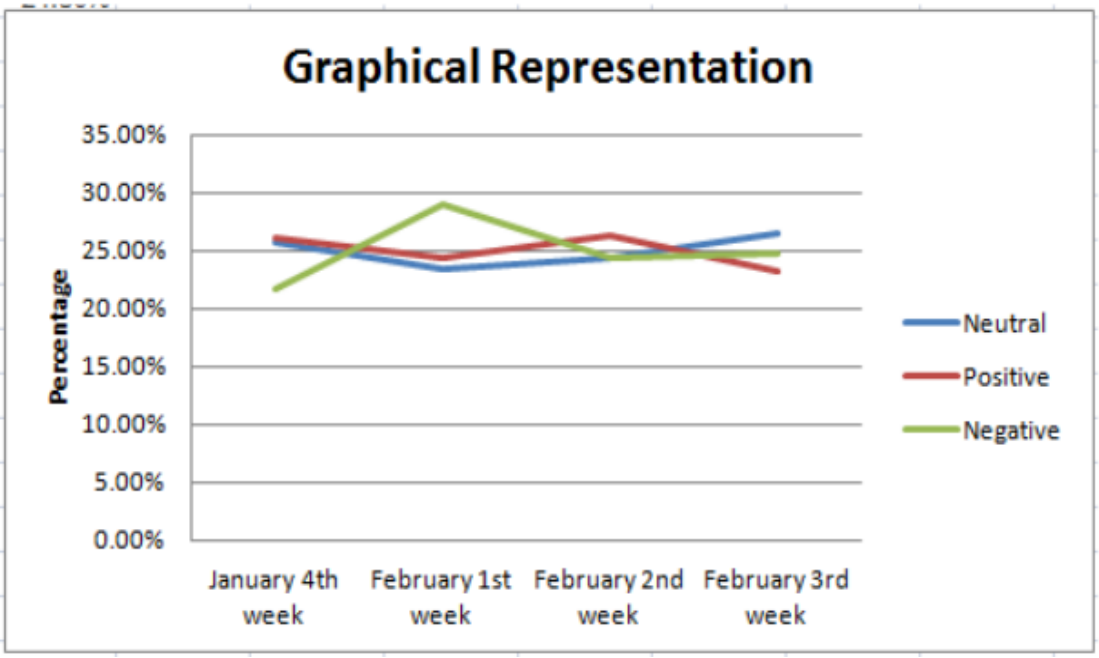

Figure 1 Graphical representation of Table 1 (By percentage)

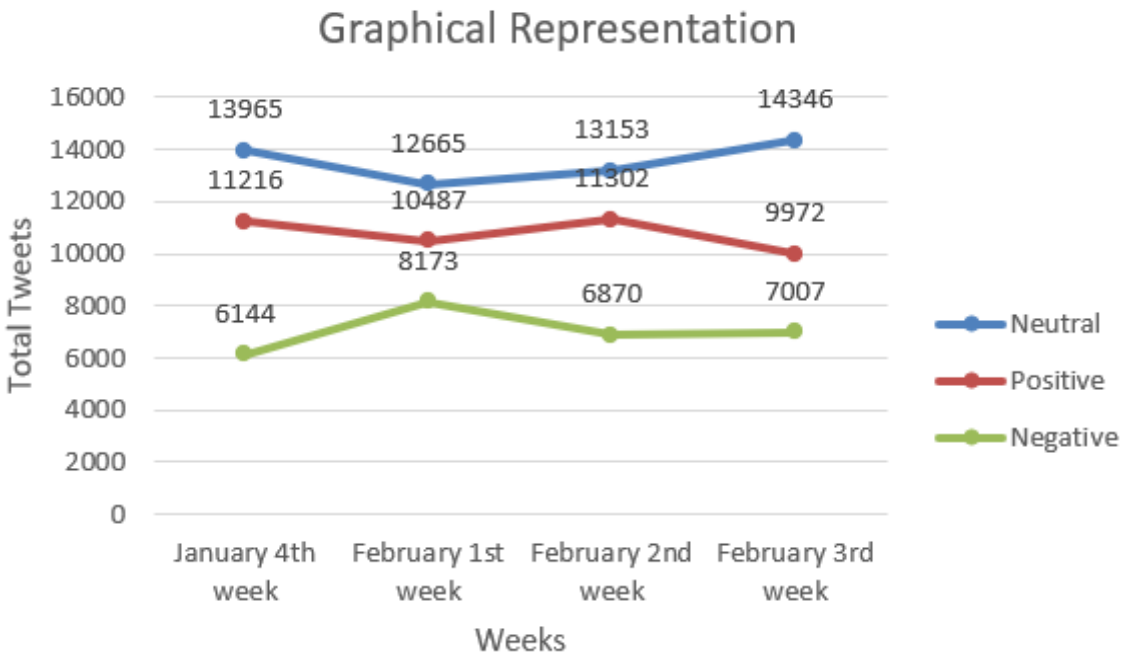

Figure 2 Graphical representation of Table 1 (By Number of Tweets)

Table 1 Sentimental Analysis Research

Week	Total Tweets	Neutral	%	Positive	%	Negative	%
January 4th week	31,325	13965	25.8	11216	26.09	6144	21.7
February 1st week	31,325	12665	23.4	10487	24.4	8173	28.9
February 2nd week	31,325	13153	24.3	11302	26.2	6870	24.3
February 3rd week	31,325	14346	26.5	9972	23.2	7007	24.8
Total	125,300	54,129		42,977		28,194	

3.2 Topic Modeling

Though sentimental analysis provided insight into how the general Indian population felt about the iNCOVACC COVID-19 nasal vaccine and its impacts, it did not aid in our understanding of the critical factors that influence that attitude. We further performed Latent Dirichlet Allocation topic modeling for the tweets about the nasal vaccine to understand the significant aspects the Indian population voices in their social media post about the newly introduced iNCOVACC COVID-19 vaccine. According to the findings of our topic modeling, Indian citizens, while discussing about the iNCOVACC COVID-19 nasal vaccines they discuss various aspects such as the functioning of nasal vaccine, risks of taking a vaccine, availability of the vaccine, fear of infection, safeness for children, registering for this vaccine, whether worth the risk despite of the risks it has, about the need for the vaccine, and general positive feelings about the vaccine.

Many previous studies have used machine learning and deep learning techniques to understand common people's perceptions of vaccines and vaccine hesitancy. Hussain et al. (2021) analyzed over 300,000 Facebook and Twitter posts belonging to the United Kingdom (UK) and the United States (US) related to COVID-19 vaccines. They concluded that nearly 58% of UK social media posts were positive sentiments, and 22% and 17% of UK citizens' posts about vaccines were negative and neutral sentiments, respectively. On the other hand, 56%, 24%, and 18% of the social media posts belonging to the US were made of positive, negative, and neutral sentiments. Lanyi et al. (2022) analyzed over 90,000 social media posts of citizens of the UK. They identified that mistrust towards vaccines, safety aspects towards vaccines, feeling that vaccines are ineffective, and accessibility of the vaccine were some of the key issues that contributed to vaccine hesitancy. Gautam et al. (2022) analyzed over 6000 Indian tweets about the COVID-19 vaccine and concluded that nearly 44.1% of the tweets

Table 2 Topic Modeling

Topic	Top words
Feeling that nasal vaccine work	vaccine, nasal, work, immunity, go, mucosal
Risks in vaccine	vaccine, rinse, nasal, die, people, risk
Availability of the vaccine	reception, appointment, book around, hospital
How it works	nasal, gene, long, enter, production, body
Fear of infection	infection, respiratory, get, covid, much, outrage
Children	child, nasal, vaccine, safe, book, immunity
Registering for the vaccine	intranasal, vaccine, visit, hospital, website, private
Whether worth the risk	approve, get, risk, worth, life, choice
Wondering about the need for the vaccine	need, wonder, covaxin, potus, incovacc, strategic
General positive feeling about the vaccine	great, bharatbiotech, video, proud, world, efficacy

were on a positive tone, 17.6% and 38.2% of tweets were of negative and neutral sentiments, respectively. Villavicenio et al. (2021) have used Naïve Bayes to understand the perception of Filipinos regarding the COVID-19 vaccines. They analyzed 11,974 tweets and concluded that 83.38% were positive. Phrases like "trust science," "vaccine works, and "a dose of hope" were observed several times in the analysis. Ljajic et al. (2022) analyzed 8817 tweets relating to COVID-19, and they concluded that issues such as vaccine effectiveness, the belief that natural immunity is better, a general mistrust over science, vaccines are just an experiment, and conspiracy theories are some factors for vaccine hesitancy. Prabagar et al. (2022) analyzed 400,000 tweets about COVID-19 and concluded that conspiracy theories and the fear of side effects were the most important factors contributing to vaccine hesitancy. From our analysis results, it can be understood that the perception towards the iNCOVACC vaccine is almost as same as that of any previous vaccines.

Conclusion

The study shows that only 34.29% of the Indian population has a positive sentiment toward the COVID-19 nasal vaccines. A previous study analyzing the sentiment of Indians towards the COVID-19 vaccine when the first vaccine for COVID-19 was introduced revealed that 35% of the sentiments of the Indian population were positive. It can be observed that almost the same percentage of Indians who felt optimistic about the COVID-19 vaccine when the first vaccine was introduced also feel positive about the newly introduced iNCOVACC vaccine. Our study also pointed out that 43% of the sentiments about the newly introduced vaccine were neutral. The government, health officials, and policymakers need to introduce advertising and promotion-based initiatives to target 43% of the netural sentiments to convert into positive sentiments. Our topic modeling results show that along with the positive aspects of the vaccines, a large sector of the Indian population also shared their concerns and doubts regarding the vaccine. The risks of taking the newly introduced vaccine, fear of infection on taking the vaccine, whether the vaccine is safe for children, whether it is worth to avail the vaccine despite the risks it has and the need for the new vaccine, despite the availability of the previous vaccines are the concerns shared by Indian population regarding the newly introduced iNCOVACC vaccine. To accomplish the desired outcomes of protective immunity among the citizens of India and protect their health during the COVID-19 pandemic, the Indian governments and policymakers should implement and promote efficient awareness programs and policies through social media and all forms of necessary communications. Strategic planning should be appropriately done to motivate more individuals to come up and take the vaccine.

This worldwide epidemic shows us that the healthcare industry's current regulatory systems cannot expedite the approval of products like vaccinations unless they are under extreme pressure. As vaccine development has not been a priority, it has required a worldwide pandemic to unite worldwide scientists and encourage them to work together on creating a vaccine and other therapies for COVID-19. Healthcare crises of this magnitude necessitate a dedicated regulatory and funding structure to reduce casualties as much as possible. The IM vaccine delivery elucidates a durable systemic IgG response and generates memory B and T cells; a subsequent booster dose administered via the intranasal route recruits memory B and T cells in the upper respiratory tract to provide mucosal protection and prevent the spread of the virus. Most companies developing new COVID-19 vaccines also conduct clinical trials of nasal-based vaccination platforms as part of a booster dosage strategy. We believe the many present initiatives will soon lead to new-generation vaccines and regulatory mechanisms, which will help us overcome the current problem.

The public should be educated about the benefits of intranasal vaccines and the immunological mechanisms that make them superior to those of IM vaccines, and the public should be given

the option of receiving immunizations via either route. In other words, intranasal immunization can prevent virus infection and transmission by inducing sterilizing mucosal and systemic immunity. Intranasal vaccines are expected to aid in the fight against the ongoing COVID-19 pandemic and other possible viral infectious diseases. Pharmaceutical firms may choose to adopt nasal vaccinations and provide comprehensive information on these vaccines due to their benefits and increased adherence. Those who are usually reluctant to get immunizations could be more likely to do so if they were offered these. Vaccine reluctance is a multifaceted problem, but our research can help us better design effective messages to reduce vaccine skepticism and increase vaccination rates. Implicit measures, such as the Implicit Association Test (IAT), could be used to probe people's perceptions of nasal vaccines to tease out their true motivations and biases.

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