Faster than warp speed: early attention to COVD-19 by anti-vaccine groups on Facebook

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ABSTRACT

Background The unprecedented rapid development of COVID-19 vaccines has faced SARS-CoV- (COVID-19) vaccine hesitancy, which is partially fueled by the misinformation and conspiracy theories propagated by anti-vaccine groups on social media. Research is needed to better understand the early COVID-19 anti-vaccine activities on social media.

Methods This study chronicles the social media posts concerning COVID-19 and COVID-19 vaccines by leading anti-vaccine groups (Dr Tenpenny on Vaccines, the National Vaccine Information Center [NVIC] the Vaccination Information Network [VINE]) and Vaccine Machine in the early months of the COVID-19 pandemic (February–May 2020).

Results Analysis of 2060 Facebook posts showed that anti-vaccine groups were discussing COVID-19 in the first week of February 2020 and were specifically discussing COVID-19 vaccines by mid-February 2020. COVID-19 posts by NVIC were more widely disseminated and showed greater influence than non-COVID-19 posts. Early COVID-19 posts concerned mistrust of vaccine safety and conspiracy theories.

Conclusion Major anti-vaccine groups were sowing seeds of doubt on Facebook weeks before the US government launched its vaccine development program 'Operation Warp Speed'. Early anti-vaccine misinformation campaigns outpaced public health messaging and hampered the rollout of COVID-19 vaccines.

Keywords anti-vaccine, COVID-19 vaccine, Facebook, vaccine hesitation, vaccine hesitancy

The rapid amplification of the SARS-CoV-2 pandemic, the cause of COVID-19, has brought unprecedented and inter-connected crises. At a pace never before seen, dubbed by the US Government 'Operation Warp Speed', initial vaccine candidates were proposed within weeks of sequencing the SARS-CoV-2 genome and the first human trials of vaccine candidates soon followed,[1] with multiple safe and efficacious vaccines approved for use within 1 year.[2–4] However, the acceptance of COVID-19 vaccines has faced challenges, including public perceptions.[5,6] One key factor threatening vaccination programs is a lack of public trust of vaccines, in general, and COVID-19 vaccines, in particular. A study of over 13 000 people in 19 countries showed that more than one in four (28%) were less than somewhat likely to accept a COVID-19 vaccine.[7] Research suggests the situation in the USA may be worse. Studies conducted near the time the first COVID-19 vaccines were approved showed that between 50

and 70% of Americans would not accept taking a COVID-19 vaccine,[8–10] including 23% of medical students being unwilling to be vaccinated immediately upon FDA approval,[11] with people of color expressing less intention to be vaccinated than their white counterparts.[12]

Concern about the safety of vaccines, or vaccine hesitancy, is fueled by mistrust of pharmaceutical companies, misinformation and conspiracy theories. Decades of research shows that vaccine hesitancy has led to setbacks in polio eradication as well as outbreaks of previously controlled diseases such as

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Table 1 Anti-Vaccine Facebook group missions statements[a]

Anti-vaccine group	Mission statement
NVIC https://www.nvic.org	The NVIC is dedicated to preventing vaccine injuries and deaths through public education and advocating for informed consent protections in medical policies and public health laws. NVIC defends the human right to freedom of thought and conscience and supports the inclusion of flexible medical, religious and conscientious belief exemptions in vaccine policies and laws.
Tenpenny: a doctor and a voice of reason about vaccines and current events https://www.drtenpenny.com	Dr Sherri J. Tenpenny is an osteopathic medical doctor, board-certified in three medical specialties. Widely regarded as the most knowledgeable and outspoken physician on the adverse impact that vaccines can have on health, Tenpenny has been a guest on hundreds of radio and national television programs (including the Dr Oz Show and the Today Show Australia). She has lectured at Cleveland State University and Case Western Reserve Medical School and has been a speaker at conventions, both nationally and internationally, as a recognized expert on a wide range topics within the field of integrative medicine including breast health, breast thermography, women's hormones, medical uses of iodine and the adverse effects vaccines have on health.
VINE www.vaccinationinformationnetwork.com	VINE—helping parents make an informed choice on behalf of their children. I started the VINE in 1988 and the VINE Facebook page in 2009 to help parents make an informed choice on behalf of their children. Please note that VINE is not a forum for debate.
Vaccine Machine www.TheVaccineMachine.com	The Vaccine Machine refers to the vested interests in medicine, industry and government dedicated to vaccinating our children by any means necessary. We stand in opposition to that machine. We examine the issue of vaccines, vaccination and immunization to uncover establishment lies and misinformation. Our goal is to end compulsory vaccination and immunization.

[a]Collected 1 December 2020.

measles and pertussis (whooping cough).[13] Vaccine hesitancy has also impeded the uptake of H1N1 and HPV vaccines and increased the avoidance of childhood immunizations.[14–16] A main source of vaccine misinformation and conspiracy theories are groups that explicitly oppose vaccinations, i.e. anti-vaccine groups.[17] Among the most accessible and influential channels of anti-vaccine messaging is social media, particularly Facebook.[18–20] Research examining public postings on anti-vaccine group Facebook pages has found that a majority of comments express caution against trusting vaccines, doubts regarding vaccine safety and a need for 'natural alternatives' to vaccination and conspiracy theories implicating the government, public health advocates and pharmaceutical companies in unethical practices.[18] The propagation of anti-vaccine sentiment across social media platforms is well established, and anti-vaccine groups are undermining the rollout of COVID-19 vaccines.[21–25]

The purpose of this study was to examine early anti-vaccine group activity on Facebook in initial response to COVID-19. To chronicle early COVID-19 anti-vaccine activity, we tracked posts on Facebook in the first months of the COVID-19 pandemic. Our aim was to establish an early timeline of anti-vaccine Facebook activity, describe what leading anti-vaccine groups were posting and examine their dissemination and influence.

Methods

Selection of anti-vaccine groups

The methodology of the current study was grounded in previous research that monitored anti-vaccine communications online.[5,26] In earlier research, we had identified the most active anti-vaccine groups on social media. In March 2020, we re-examined the current status of the previously identified anti-vaccine groups on Facebook and found that the most active and influential groups had not changed since 2013; Dr Tenpenny on Vaccines, the National Vaccine Information Center (NVIC) and the Vaccination Information Network (VINE) were then and remain still active and influential. In addition, a new popular group was identified, the Vaccine Machine. These four groups include explicit anti-vaccination mission statements (see Table 1) and typically post misinformation multiple times a week aimed to undermine trust in vaccines, offer alternatives typically promoted as 'natural immunity' and propagate conspiracy theories.[27]

Facebook monitoring and data analyses

We collected all posts to the Facebook pages of the four anti-vaccine groups sampled at staggered time periods in the first months of the COVID-19 outbreak, specifically 1 February 2020 through 31 May 2020. We collected all Facebook
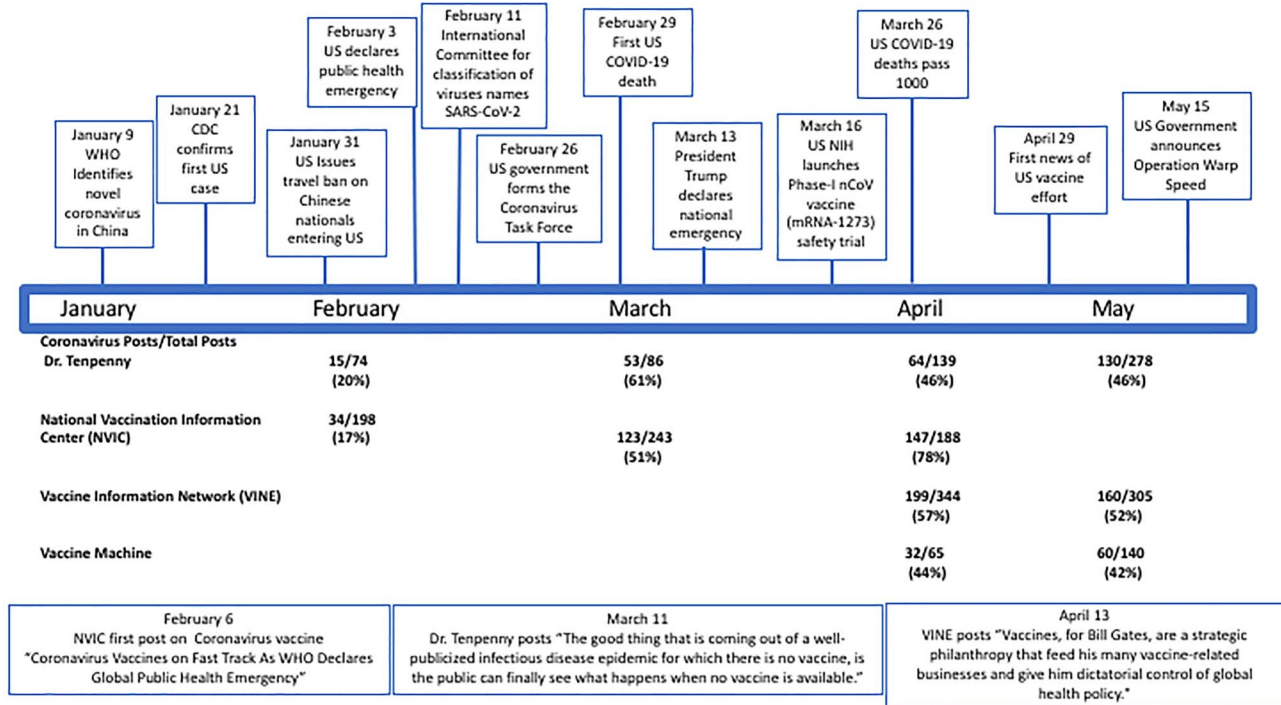
Fig. 1 Timeline of anti-vaccine group Facebook activity and milestones of the COVID-19 vaccine effort, February–May 2020 with selected examples of anti-vaccine group posts.

posts retrospectively, from March back through February, and prospectively, through May 2020 representing a 4-month period for Dr Tenpenny on Vaccines (Tenpenny), a 3-month period (February–April) for the NVIC, and 2 months (April and May) for the Vaccine Information Network (VINE) and the Vaccine Machine. All posts were collected prior to Facebook taking actions in December 2020 to limit the activity of anti-COVID-19 vaccine messaging.[28] Posts were collected by copying and pasting verbatim entries into a text-searchable database. Reposts from other sources were treated the same as original posts. We calculated four numeric values characterizing the extent of dissemination (i.e. number of posts and times shared) and influence (i.e. number of positive reactions [i.e. 'Likes'] and number of comments).

To identify posts concerning COVID-19, we searched the text database for three key terms: 'Coronavirus', 'SARS' and 'COVID'. The use of any one term indicated posts concerning the COVID-19 pandemic. We calculated descriptive statistics for each of the dissemination and influence indicators aggregated at the month level. During the month of April, for which data were available for all four anti-vaccine groups, we conducted contingency table chi-square tests to compare the number of non-COVID-19 and COVID-19 posts. We also performed 2 (type of post: non-COVID-19 versus COVID-19) × 4 (source of post: Tenpenny, NVIC, VINE and Vaccine Machine) factorial analyses of variance with main effects and the interaction terms for the number of posts, number of shares, comments and reactions.

Analyses were further performed for two major anti-vaccine groups, Tenpenny and NVIC, for February, March and April. We examined each indicator of dissemination and influence across all months (i.e. overall) as well as within the months of February, March and April. Contingency table chi-square (χ^2) compared the number of non-COVID-19 and COVID-19 posts. In addition, we compared non-COVID-19 and COVID-19 Facebook posts from Tenpenny and NVIC on the dissemination and influence indicators. For these analyses, we used 2 (non-COVID-19 versus COVID-19) × 2 (Tenpenny versus NVIC) factorial analyses of variance. All statistical tests defined significance as $P < 0.05$.

Results

We extracted a total of 2060 Facebook posts from four anti-vaccine groups; 649 (32%) from VINE, 629 (30%) NVIC, 577 (28%) Tenpenny and 205 (10%) Vaccine Machine. The posts received 213 384 positive reactions, 20 410 comments and were shared 96 809 times. Nearly half ($n = 1017$, 49%) of all Facebook posts concerned COVID-19 and 17% ($n = 358$) specifically concerned COVID-19 vaccines.

Tenpenny and the NVIC were both posting reports concerning COVID-19 in the first days of the pandemic. Figure 1

shows a timeline of COVID-19 posts collected from the anti-vaccine groups in the context of milestones toward developing COVID-19 vaccines. A total of 49 COVID-19 posts from Tenpenny and the NVIC appeared in early February, most of which included the term coronavirus ($n = 45$), with early references also made to SARS ($n = 7$) and COVID ($n = 11$). COVID-19 posts for these two anti-vaccine groups increased each month, with 176 in March and 211 in April. In February, the month which saw the International Committee for the Classification of Viruses name SARS-CoV-2, 20% of Tenpenny's Facebook posts were already referencing COVID-19 as were 17% of NVIC posts. By March, the month that launched the first Phase-I safety trials for a COVID-19 vaccine, the proportion of COVID-19 posts increased to 61% for Tenpenny and 51% for the NVIC. In April, 78% of posts from NVIC were discussing COVID-19, as were 46% from Tenpenny, 57% from VINE and 44% from Vaccine Machine.

Table 2 includes examples of posts from the anti-vaccine groups over the early months of COVID-19. Posts often framed the large financial investments necessary for COVID-19 vaccine development as part of a conspiracy for profit. Along with government and pharmaceutical companies, posts included frequent targets of anti-vaccine groups, including Dr Anthony Fauci of the National Institutes of Health (NIH), Bill Gates of the Bill and Melinda Gates Foundation and Dr Paul Offit of the Vaccine Education Center at the Children's Hospital of Philadelphia. Efforts to sow doubt and create distrust in vaccine safety also appeared early on, including discussions of shielding pharmaceutical companies developing vaccines from product liability and misrepresenting the long-term biologic actions of the vaccines themselves, such as falsely speculating about genetic alterations caused by messenger RNA (mRNA).

Results showed that the anti-vaccine groups were specifically discussing COVID-19 vaccines as early as February, prior to the US government launching its COVID-19 vaccine program, Operation Warp Speed, and months before the first COVID-19 vaccine trials. Initial posts that specifically concerned COVID-19 vaccines were found in the first 2 weeks of February: eight from NVIC and two from Tenpenny. In total, there were 25 COVID-19 posts concerning vaccines in February, 72 in March and 83 in April. Data from all four anti-vaccine groups in April indicated 153 of their 442 (34%) COVID-19 posts specifically concerned COVID-19 vaccines.

Facebook Dissemination and influence of anti-vaccine groups, April 2020

Table 3 shows the number of shares, positive reactions and comments for the Facebook non-COVID-19 and COVID-19 posts from the four anti-vaccine groups in April. Among the 736 Facebook posts, 442 (60%) discussed COVID-19, which had been shared a total of 16 000 times, reacted to 33 645 times and had received 2602 comments. Analyses indicated that there were significant differences for non-COVID-19 versus COVID-19 posts on the number of shares and number of reactions. For number of shares, COVID-19 posts ($M = 48.4$) were shared more than non-COVID-19 posts ($M = 43.4$). By contrast, non-COVID-19 posts ($M = 122.2$) received more reactions than COVID-19 posts ($M = 87.5$). In addition, there were significant differences between the anti-vaccine groups on the three indicators; Tenpenny's posts were shared more often and received more reactions and comments than the other groups. Results also showed that non-COVID-19 and COVID-19 posts interacted with the anti-vaccine groups for shares and reactions, with a non-significant trend for number of comments. The pattern of results showed that NVIC and Vaccine Machine's COVID-19 posts were shared more than non-COVID-19 posts, whereas Tenpenny's and VINE's non-COVID-19 posts were shared more than COVID-19 posts. With respect to number of reactions, NVIC's COVID-19 posts received more reactions than their non-COVID-19 posts, and the other three groups received more reactions for their non-COVID-19 posts. Finally, there was a trend for the interaction for number of comments received, with NVIC's and Vaccine Machine's COVID-19 posts receiving more comments than non-COVID-19 posts, whereas Tenpenny's and VINE's non-COVID-19 posts received more comments than COVID-19 posts.

Facebook dissemination and influence: Tenpenny versus NVIC, February–April 2020

Among the 928 Facebook posts examined for February, March and April from Tenpenny and the NVIC, there were no differences in their number of COVID-19 posts between February and April, $\chi^2 = 1.4$, $P = 0.23$. At the month level, there were no differences in February, $X^2 = 0.3$, $P = 0.55$, or March, $X^2 = 3.1$, $P = 0.07$. However, in April, 78% of posts from NVIC concerned COVID-19 relative to 48% from Tenpenny, a significant difference, $X^2 = 36.1$, $P < 0.001$. Table 4 shows the dissemination and influence indicators for non-COVID and COVID-19 posts from Tenpenny and NVIC.

Across months, COVID-19 posts were shared significantly more than non-COVID posts. In addition, posts from Tenpenny were shared significantly more often than posts from NVIC. The interactions for type and source of post were not significant. In February, the main effects of type of posts and source of posts were both significant, and in February, the interaction was also significant;

Table 2 Sample posts from anti-vaccine Facebook pages during the early months of COVID-19

Source	Content	Sample Post	Date
Tenpenny	Conspiracy theory	The first big mistake in the coronavirus pandemic emerged when the Chinese Communist Party (CCP) tried, but failed, to contain the outbreak in a cloak of silence. The second (and worst) mistake fell at the feet of the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and other institutions that have long promoted the empty marketing point of "global health security". We are quickly learning there is no such thing. In the latter miscalculation, we now know their will not be enough time develop a vaccine in time to slow down, let alone contain, the novel 2019-nCoV virus. Leading vaccine experts, from Novartis' CEO Vas Narasimhan to Jeremy Farrar, the director of the Wellcome Trust, a UK-based health foundation with more than $34 billion in assets to support research, have stated as much in recent interviews with CNBC News and Der Spiegel International, respectively.	Feb. 11
NVIC	Safety/trust	Moderna to use new mRNA technology to develop coronavirus vaccine—the vaccine reaction The recent outbreak of a novel coronavirus that originated in Wuhan, China, has driven pharmaceutical and biotechnology companies to begin developing a vaccine for the mutated virus. Three companies awarded funding for the coronavirus vaccine development. Three research teams have received funding from the Coalition for Epidemic Preparedness Innovations (CEPI), a global public-private partnership launched at the Davos World Economic Forum in 2017, to develop a vaccine for the new strain of coronavirus (2019-nCoV).The first grant was awarded to Moderna, Inc, which has partnered with the National Institute of Allergy and Infectious Diseases (NIAID) within the NIH to develop a vaccine for the Wuhan strain of coronavirus. Some researchers believe that an experimental vaccine previously designed to combat severe acute respiratory syndrome (SARS), which was never licensed, as well as vaccine platforms using mRNA technology, which has not yet been approved by the FDA for vaccine production, are likely to shorten the time needed to fast track a 2019-nCoV vaccine to market. Andrew Pekosz, PhD, professor of molecular microbiology and immunology at Johns Hopkins University's Bloomberg School of Public Health told MarketWatch: 'There's been some really good work on SARS and MERS that is educating this process'. He added: 'You assume that everything that works for SARS and MERS will work for this virus, therefore you just plug in the very specific pieces of the new CORONavirus into these vaccine platforms [and] you should be able to get vaccine candidates very quickly'.	Feb. 17
NVIC	Conspiracy theory	(Repost) 'Do We Need $2.5 BILLION for Coronavirus Vaccine? What Happened to the $2 BILLION Spent on the Zika Vaccine? The White House is asking Congress for AT LEAST (oy vey) $2.5 billion in emergency funds, in part, to develop a vaccine for the Coronavirus outbreak. I have written two recent blog posts about coronavirus which you can find on my homepage. Before we give any governmental agency AT LEAST $2.5 billion dollars we should know how it is going to be spent. Recall the Zika scare from 2016. At that time we were being told by the US governmental agencies (FDA, CDC, and HHS) that somehow a relatively benign virus that has been around for nearly 100 years was suddenly causing birth defects in the form of small-headed babies. There were headlines in the major papers and fear mongering stories that Zika would do the same in the US. My first article about Zika can be found here: https://www.drbrownstein.com/zika-schmika-how-to-waste-2000000000/.The title of the article says it all: "Zika Schmika How to Waste $2,000,000,000". I lamented that President Obama asked Congress for $2 billion dollars to research the "new" problem with Zika. I subsequently wrote three other blog posts stating that Zika would not be a problem in the US and was not the cause of the small-headed babies. I thought giving the CDC $2 billion dollars was a waste of money. Congress ended up giving the CDC over $1 billion dollars to develop a Zika vaccine. My fourth Zika post was titled, "Where is our billion dollars?" Here we are 4 years later and … no Zika vaccine and no more reports of small-headed Zika infections. The reason there are no more reports is because Zika did not cause the problem in the first place. Zika is still occurring around the world and we are still surviving—without an epidemic of small-headed babies. But, we are $1 billion dollars poorer. And, we still have no Zika vaccine. So, should we give the US government AT LEAST $2.5 billion to make a vaccine against COVID-19 (the coronavirus strain currently active)? Right now, the answer should be absolutely not. We simply do not know how deadly this virus is. The information out of China simply cannot be trusted'.	Feb. 27
NVIC	Safety/trust	CORONavirus vaccine clinical trial starting without usual animal data What could go wrong? As they race to test an experimental coronavirus vaccine, researchers are not waiting to see how well it prevents infection in animals before trying it in people, breaking from the usual protocol. 'I do not think proving this in an animal model is on the critical path to getting this to a clinical trial', said Tal Zaks, chief medical officer at Moderna, a Cambridge, Mass.-based biotech that has produced a Covid-19 vaccine candidate at record speed. He told STAT that scientists at the NIH are 'working on nonclinical research in parallel'. Meanwhile, the clinical trial started recruiting healthy participants in the first week of March. That is not how vaccine testing normally happens. Regulators require that a manufacturer show a product is safe before it goes into people, and while it is not enshrined in law, researchers almost always check that a new concoction is effective in lab animals before putting human volunteers at potential risk.	March 13
NVIC	Conspiracy theory	How big pharma will profit from the coronavirus As the new coronavirus spreads illness, death and catastrophe around the world, virtually no economic sector has been spared from harm. Yet amid the mayhem from the global pandemic, one industry is not only surviving, it is profiting handsomely. 'Pharmaceutical companies view Covid-19 as a once-in-a-lifetime business opportunity', said Gerald Posner, author of 'Pharma: Greed, Lies, and the Poisoning of America'. The world needs pharmaceutical products, of course. For the new coronavirus outbreak, in particular, we need treatments and vaccines and, in the USA, tests. Dozens of companies are now vying to make them. 'They're all in that race', said Posner, who described the potential payoffs for winning the race as huge. The global crisis 'will potentially be a blockbuster for the industry in terms of sales and profits', he said, adding that 'the worse the pandemic gets, the higher their eventual profit'.	March 23
NVIC	Trust	The national plan to vaccinate every American—national registry to record everyone's vaccination status Scientists at the NIH are working with a biotech company to quickly start clinical trials of an experimental mRNA vaccine and fast track it to licensure. The FDA has not yet licensed mRNA vaccines that use part of the RNA of a virus to manipulate the body's immune system into stimulating a potent immune response.[2,3] It looks like the coronavirus vaccine will be the first genetically engineered mRNA vaccine to be fast tracked to licensure, just like Gardasil was the first genetically engineered virus-like particle vaccine to be fast tracked to licensure.[4,5] There likely will be lots of questions about whether the fast-tracked coronavirus vaccine was studied long enough to adequately demonstrate safety, especially for people who have trouble resolving strong inflammatory responses in their bodies and may be at greater risk for vaccine reactions.[6–10] However, there is no question about what will happen if the CDC Advisory Committee on Immunization Practices (ACIP)[11,12] recommends that all Americans get the newly licensed coronavirus vaccine. The government has a national vaccine plan. It is a plan designed to make sure you, your child and everyone in America gets every dose of every vaccine that government officials recommend now and in the future.	March 26

(Continued)

Table 2 Continued.

Source	Content	Sample Post	Date
NVIC	Conspiracy theories	Dr Fauci's history in spending billions of government funds on vaccine research with little to show for it The rapidity with which normal life has ground to a halt as a result of coronavirus-related edicts has stunned citizens around the world, generating massive social and economic upheaval. Meanwhile, media coverage of COVID-19 has whipped up unprecedented levels of public anxiety and fear, laying the psychological groundwork for people to eagerly embrace 'magic bullet' medical solutions, no matter how experimental. In the USA, the WHO is now compounding the domestic panic, warning that America could become the new coronavirus 'epicenter'. Across the country, a debate is raging about the nation's medical response and how best to apportion available resources. Many argue, quite reasonably, for the importance of identifying safe, effective and affordable therapies that can provide immediate help to those who are sick. On 22 March, The New York Times reported that there are at least 69 existing drugs or compounds that might be effective in treating the coronavirus. In China, researchers are studying intravenous vitamin C as a potential nontoxic treatment, while a paper published by French researchers on March 20 described promising COVID-19 results from the off-label use of hydroxychloroquine (an antimalarial) and azithromycin (an antibiotic).	March 30
VINE	Safety/trust	Post from Robert F. Kennedy Jr: 'Why are OG villains like Paul Offit and #PeterHotez, the world's top vaccine promoters, frantically warning us about the unique and frightening dangers inherent in developing a #coronavirus vaccine?' Scientists first attempted to develop a coronavirus vaccine after China's 2002 SARS-CoV outbreak. Teams of US and foreign scientists vaccinated animals with the four most promising vaccines. At first, the experiment seemed successful as all the animals developed a robust antibody response to coronavirus. However, when the scientists exposed the vaccinated animals to the wild virus, the results were horrifying. Vaccinated animals suffered hyper-immune responses, including inflammation throughout their bodies, terminating with fatal lung infections. Researchers had seen this same 'enhanced immune response' during human testing of the failed RSV vaccine tests in the 1960s. Two children died. Offit, Hotez and even Anthony Fauci (in an unguarded moment) have warned that any new coronavirus vaccine could trigger lethal immune reactions when vaccinated people come in contact with the wild virus. Instead of proceeding with caution, Fauci has made the criminally reckless choice to fast track his own vaccine (partially funded by Gates) and 7 Gates vaccines without animal studies that could provide early warning of runaway immune response. Gates is so worried about the danger that he says he will not distribute his vaccines until governments agree to indemnify him against lawsuits. On 4 February, when there were only 11 active cases in the USA, Fauci quietly pushed through regulations giving coronavirus vaccine makers full immunity from liability.	April 13
VINE	Safety/trust	Will a COVID19 Vaccine be the First Vaccine to Alter Human DNA to Further Advance Transhumanism? http://ow.ly/21mr50z6Hg6 Transhumanism is a futuristic concept where man and technology blend, resulting in soulless intelligent machines. It is a movement that favors the evolution of a new species of human through the use of integrative circuitry. Referred to as 'human betterment for the post-human era', transhumanists assume that humanity will only be enhanced by machines. No damage. No degradation. No possibility for coercion or domination. In a post-human world, humanity as we know it will be obsolete. In 2012, artificial intelligence pioneer Ray Kurzweil became Director of Engineering and Chief Futurist at Google, hired to work on projects to teach machines to learn. Kurzweil predicts that by 2030 (there is that date again) technological advances will allow tiny nano-bots to be injected into the bloodstream, pass through the blood–brain barrier and integrate into the brain. The human brains can then be connected to 'the cloud', achieving a level of brilliance never thought possible. So, essentially, biological beings will become 'non-biological entities'.	April 13
Tenpenny	Safety/trust	Yes any vaccine developed for covid19 will be liability free The PREP Act provides complete immunity from liability for any loss relating to or resulting from, any product used to prevent or treat illness during a public health emergency. The immunity applies to entities and individuals involved in the development, manufacture, testing, distribution, administration and use of medical countermeasures described in a declaration. The only statutory exception to this immunity is for actions or failures to act that constitute 'willful misconduct'. And as we will see, even willful misconduct may not be punished. For a full explanation of the scope of the act, see below https://www.phe.gov/Preparedness/…/prepact/Pages/prepqa.aspx 'The Public Readiness and Emergency Preparedness Act (PREP Act) added new legal authorities to the Public Health Service (PHS) Act to provide liability immunity related to the manufacture, testing, development, distribution, administration and use of medical countermeasures against chemical, biological, radiological and nuclear agents of terrorism, epidemics, and pandemics. It also added authority to establish a program to compensate eligible individuals who suffer injuries from administration or use of products covered by the PREP Act's immunity provisions. The following is intended to address frequently asked questions from the manufacturing industry, the healthcare community, and state and local government officials about the PREP Act. It is not an exhaustive review of the PREP Act's provisions in all contexts or a protocol for the HHS's implementation of the PREP Act. In addition, other legal protections may be available at the federal, state, and local government level'.	April 14
VINE	Conspiracy theories	'DNA-vaccines are already available and approved for treating various infections, but so far, only for animals in veterinary medicine. All clinical trials for the new vaccine are funded by the Bill and Melinda Gates Foundation'. 'Over the past few weeks, a theory about the involvement of Microsoft founder Bill Gates in the creation and spread of the coronavirus has been actively discussed on the Internet, especially in America. Briefly, the story goes that the Bill and Melinda Gates Foundation has actively funded various developments in microbiology in the past. Since at least 2015, Bill Gates has spoken in public about a coming epidemic, and since the beginning of the coronavirus epidemic, he has been an enthusiast both for the development of vaccines and tracking tools needed to control quarantine violators. Is this a simple coincidence? It is not only hard-working conspiracy theorists who argue in favor of this theory. Donald Trump presidential campaign Roger Stone declared that 'Whether Bill Gates played some role in the creation and spread of this virus is open for vigorous debate … He and other globalists are using it for mandatory vaccinations and microchipping people'. Earlier in an interview with Fox News host Laura Ingraham, US Attorney General William Barr declared that he is 'concerned' about Bill Gates' idea of 'developing digital certificates that would certify that individuals, American citizens, have an immunity to this virus and potentially other viruses going forward to then facilitate travel and work and so forth'.	April 16
Vaccine Machine	Conspiracy theories	Coronavirus 'disappearing' so fast Oxford vaccine has 'only 50% chance of working' Hear this well: did not someone say this was going to happen? 'There is only a 50% chance of the Oxford CORONavirus vaccine working because cases in the UK are declining so fast, one of the scientists behind it has warned. The University of Oxford's Jenner Institute and the Oxford Vaccine Group began developing a COVID-19 vaccine in January using a virus taken from chimpanzees. But with the number of UK CORONavirus cases dropping every day, there may not be enough people to test it on, according to the institute's director Professor Adrian Hill'.	May 24

Table 3 Indicators of dissemination and influence for Facebook posts concerning non-COVID-19 and COVID-19, April 2020

	Tenpenny		NVIC		VINE		Vaccine Machine		Non-COVID versus COVID	Anti-vaccine group	COVID X group interaction
Non-COVID-19	N = 75		N = 41		N = 145		N = 33		F	F	F
	M	SD	M	SD	M	SD	M	SD			
Shares	69.5	67.7	31.7	23.6	22.1	51.8	43.3	59.3	4.1*	7.8**	3.7**
Reactions	180.7	160.2	78.4	69.2	51.0	65.4	156.5	144.1	10.1**	12.1**	3.9**
Comments	24.9	32.5	4.6	6.8	3.8	7.3	14.5	27.2	1.7	11.4**	2.6
COVID-19	N = 64		N = 147		N = 199		N = 32				
	M	SD	M	SD	M	SD	M	SD			
Shares	62.1	67.9	46.1	41.8	18.1	36.9	52.6	85.8			
Reactions	12.2	115.5	93.5	67.1	39.5	55.8	122.3	143.6			
Comments	19.1	35.3	14.1	16.8	3.6	10.4	26.0	47.1			

*P < 0.05.
**P < 0.01.

COVID-19 posts from Tenpenny were shared significantly more often. In March and April, Tenpenny's posts were shared more than NVIC's, and the main effect of type of posts and the type of posts by source interactions were not significant.

With respect to influence indicators, the overall differences between types of posts were not significant (see Table 4). However, both the number of reactions and comments did differ between sources; Tenpenny demonstrated greater numbers of reactions and comments. The interactions were also significant; for Tenpenny, the overall number of reactions and comments for non-COVID-19 posts were greater than COVID-19 posts, whereas reactions and comments on NVIC's COVID-19 posts were greater than their non-COVID-19 posts. In February, only the effects of source were significant; Tenpenny's posts received more reactions and comments. In March, the interaction for number of reactions was significant; Tenpenny received more reactions for non-COVID-19 posts, whereas NVIC received more reactions for COVID-19 posts. For comments in March, only the sources differed: Tenpenny's posts received more comments. Finally, in April, Tenpenny received more reactions and comments than NVIC. However, the interactions were significant; Tenpenny received more reactions and comments for non-COVID-19 posts, whereas NVIC received a greater number of reactions and comments for COVID-19 posts.

Discussion

Main finding of this study

Our analysis of Facebook posts by anti-vaccine groups showed that by April 2020, more than 60% of their posts concerned COVID-19 and 20% specifically discussed COVID-19 vaccines. Two leading anti-vaccine groups, Tenpenny and NVIC, were discussing COVID-19 in early February, with increased activity as the pandemic emerged. Placed in the context of the effort to develop and test vaccines, the anti-vaccine groups examined in this study were sowing doubt about COVID-19 vaccines long before any such vaccine existed. While anti-vaccine groups are typically viewed as fringe and dangerous,[19,23] they are well disguised as legitimate sources of medical information. Perhaps most concerningly and ironically, the US federal government gave NVIC $150 000 and Tenpenny $72 000 COVID-19 relief funds through the Paycheck Protection Program administered by the Trump Administration.[29] Regardless of how or why the US government could knowingly or unknowingly financially support anti-vaccine groups, their doing so legitimizes, supports and effectively underwrites the promotion of vaccine hesitancy that impedes COVID-19 vaccinations.

What is already known on this topic

Previous research reported that public perceptions and concerns about vaccine safety stem from the mistrust of

Table 4 Indicators of dissemination and influence for Facebook posts concerning non-COVID-19 and COVID-19 from Tenpenny and NVIC during February, March and April 2020

	Non-COVID				COVID				Non-COVID versus COVID	Tenpenny versus NVIC	COVID X Group Interaction
	Tenpenny		NVIC		Tenpenny		NVIC				
Overall	N = 167		N = 325		N = 132		N = 304				
	M	SD	M	SD	M	SD	M	SD	F	F	F
Shares	87.3	101.5	30.3	37.4	71.3	82.5	43.9	42.6	7.1**	56.2**	1.3
Reactions	198.7	182.2	79.6	74.6	127.7	104.4	87.1	63.6	2.4	32.7**	4.2*
Comments	21.7	27.2	5.7	8.4	27.8	36.3	14.1	16.5	0.3	24.5**	5.2*
February	N = 59		N = 164		N = 15		N = 34				
	M	SD	M	SD	M	SD	M	SD			
Shares	118.1	134.5	31.4	45.9	124.4	155.9	40.8	47.0	26.7**	71.8**	22.3**
Reactions	223.5	198.9	84.8	90.4	167.6	131.2	71.1	59.2	1.1	31.5**	2.1
Comments	31.6	42.1	6.2	9.3	27.0	19.5	9.9	10.3	0.1	12.8**	0.2
March	N = 33		N = 120		N = 53		N = 123				
	M	SD	M	SD	M	SD	M	SD			
Shares	85.6	87.5	28.3	26.8	67.1	62.8	43.7	42.6	0.1	5.7*	1.4
Reactions	197.8	199.3	73.0	54.8	115.4	76.4	83.7	60.0	3.6	3.6	5.0*
Comments	25.9	31.1	5.5	7.6	20.5	7.7	15.0	17.4	0.1	4.6*	1.5
April	N = 75		N = 41		N = 64		N = 147				
	M	SD	M	SD	M	SD	M	SD			
Shares	69.6	67.7	31.7	23.6	62.0	67.9	46.0	41.8	0.3	60.3**	3.2
Reactions	180.2	160.2	78.3	69.2	128.1	115.5	93.5	67.0	1.9	74.2**	4.1*
Comments	24.8	32.5	4.5	6.8	19.1	35.3	14.1	16.8	1.3	61.5**	8.7**

*$P < 0.05$.
**$P < 0.01$.

pharmaceutical companies, widespread misinformation and conspiracy theories often propagated by anti-vaccine groups.[27] COVID-19 anti-vaccine Facebook activity follows the same fundamental messaging that characterizes typical anti-vaccine rhetoric. Smith and Reiss[23] examined COVID-19 misinformation propagated on a popular anti-vaccine broadcast 'The Highwire with Del Bigtree' and found six common themes: (i) that government and pharmaceutical industry communications about COVID-19 are lying to exaggerate the severity of the new virus; (ii) government is imposing restrictions that infringe on civil liberties; (iii) scientists are 'so-called experts', and anyone can be an expert; (iv) science is not the answer to disease, rather herd immunity is; (v) selectively choosing, or cherry-picking science to support preconceived notions and (vi) vaccines are instruments of government and industry to control, track

and harm people. Examining the early COVID-19 Facebook activity of anti-vaccine groups shows that COVID-19 posts fit these themes, with posts in February 2020 raising concerns about trusting vaccine safety months before there were any COVID-19 vaccines. Anti-vaccine groups emphasized natural immunity, corruption and conspiracies just as they have for past vaccines.[19,27]

What this study adds

Our findings extend previous research that reported early anti-vaccine COVID-19 messaging on Twitter.[8] While all four anti-vaccine groups were posting about COVID-19 as well as COVID-19 vaccines by April, they were not equally influential. For two of the anti-vaccine groups, Tenpenny and VINE, their non-COVID-19 posts had higher indicators

of dissemination and influence than their COVID-19 posts. By contrast, the NVIC and Vaccine Machine demonstrated greater dissemination of COVID-19 posts, and NVIC also demonstrated greater influence of their COVID-19 posts. These results suggest that anti-vaccine messaging, which has been widely shown to impact vaccine interest and uptake,[13] started in the earliest days of the COVID-19 pandemic and ramped up quickly.

Facebook and other social media platforms have the capacity to disseminate accurate information, create influential public health messages and facilitate the rollout of vaccines.[30–32] The Centers for Disease Control and Prevention (CDC) and state departments of health are using Facebook for public health messaging in social networks, albeit with varying levels of success. A study of over 2500 CDC and health department Facebook posts found 7% concerned vaccines and immunization, and most states with lower childhood and influenza vaccination coverage are not utilizing Facebook to promote immunization.[33] A lack of accessible and accurate information fosters skepticism and reduces trust in vaccines,[34] and social media can be a tool to remedy information deficits.

Limitations of this study

We limited our study to four anti-vaccine groups and their activity on only one social media platform. While similar messaging and forms of persuasion have been found across various anti-science and denialism,[35] we cannot know if the Facebook activity for the groups included in this study mirrors the activity of other groups on other platforms. Also, because we collected the dissemination and influence indicators at a single point in time within a month of the postings, our data do not reflect the full extent of potential impact that anti-vaccine groups may have over followers and throughout followers' social networks. We also do not know whether the communications that occurred early in the pandemic had any impact on the subsequent vaccine acceptance or hesitancy. Future research is needed to replicate and clarify the study findings.

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Conflict of interest

No conflict of interest has been declared by the author(s).

References

1 Rawat K, Kumari P, Saha L. COVID-19 vaccine: a recent update in pipeline vaccines, their design and development strategies. *Eur J Pharmacol* 2021;**892**:173751.

2 Polack FP, Thomas SJ, Kitchin N *et al.* Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *N Engl J Med* 2020;**383**:2603–2615.

3 Knoll MD, Wonodi C. Oxford-Astra Zeneca COVID-19 vaccine efficacy. *Lancet* 2021;**397**(**10269**):72–4.

4 Livingston EH, Malani PN, Creech CB. The Johnson & Johnson Vaccine for COVID-19. *JAMA* 2021. doi: 10.1001/jama.2021.2927.

5 Shorey S, Ang E, Yamina A *et al.* Perceptions of public on the COVID-19 outbreak in Singapore: a qualitative content analysis. *J Public Health (Oxf)* 2020;**42**(**4**):665–71.

6 Tanne JH. Covid-19: US cases surge but vaccine distribution is slow. *BMJ* 2021;**372**:n42.

7 Lazarus JV, Ratzan SC, Palayew A *et al.* A global survey of potential acceptance of a COVID-19 vaccine. *Nat Med* 2020;**27**:225–228.

8 Cornwall W. Officials gird for a war on vaccine misinformation. *Science* 2020;**369**(**6499**):14–5.

9 Malik AA, McFadden SM, Elharake J *et al.* Determinants of COVID-19 vaccine acceptance in the US. *EClinicalMedicine* 2020;**26**:100495.

10 Khubchandani J, Sharma S, Price JH *et al.* COVID-19 vaccination hesitancy in the United States: a rapid national assessment. *J Community Health* 2021;**46**(**2**):270–7.

11 Lucia VC, Kelekar A, Afonso NM. COVID-19 vaccine hesitancy among medical students. *J Public Health (Oxf)* 2020. https://doi.org/10.1093/pubmed/fdaa230.

12 Meier B, Dillard A, Lappas C. Predictors of the intention to receive a SARS-CoV-2 vaccine. *J Public Health* 2021; ePub ahead of print. https://doi.org/10.1093/pubmed/fdab013.

13 Larson HJ, Jarrett C, Eckersberger E *et al.* Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: a systematic review of published literature, 2007-2012. *Vaccine* 2014;**32**(**19**):2150–9.

14 Salmon DA, Dudley MZ, Glanz JM *et al.* Vaccine hesitancy: causes, consequences, and a call to action. *Vaccine* 2015;**33**(**Suppl 4**):D66–71.

15 Ruderfer D, Krilov LR. Vaccine-preventable outbreaks: still with us after all these years. *Pediatr Ann* 2015;**44**(**4**):e76–81.

16 Quinn SC, Kumar S, Freimuth VS *et al.* Racial disparities in exposure, susceptibility, and access to health care in the US H1N1 influenza pandemic. *Am J Public Health* 2011;**101**(**2**):285–93.

17 Isaacs D. Vaccine hesitancy and anti-vaccination movements. *J Paediatr Child Health* 2019;**55**(**11**):1293–4.

18 Hoffman BL, Felter EM, Chu KH *et al.* It's not all about autism: the emerging landscape of anti-vaccination sentiment on Facebook. *Vaccine* 2019;**37**(**16**):2216–23.

19 Faasse K, Chatman CJ, Martin LR. A comparison of language use in pro- and anti-vaccination comments in response to a high profile Facebook post. *Vaccine* 2016;**34**(**47**):5808–14.

20 Bradshaw AS, Shelton SS, Wollney E *et al.* Pro-Vaxxers get out: anti-vaccination advocates influence undecided first-time, pregnant, and new mothers on Facebook. *Health Commun* 2020;**10**:1–10.

21 Megget K. Even covid-19 can't kill the anti-vaccination movement. *BMJ* 2020;**369**:m2184.

22 Burki T. The online anti-vaccine movement in the age of COVID-19. *Lancet Digit Health* 2020;**2**(**10**):e504–e5.

23 Smith TC, Reiss DR. Digging the rabbit hole, COVID-19 edition: anti-vaccine themes and the discourse around COVID-19. *Microbes Infect* 2020;**22**(**10**):608–10.

24 Alqudeimat Y, Alenezi D, AlHajri B *et al.* Acceptance of a COVID-19 vaccine and its related determinants among the general adult population in Kuwait. *Med Princ Pract* 2021. doi: 10.1159/000514636.

25 Coustasse A, Kimble C, Maxik K. COVID-19 and vaccine hesitancy: a challenge the United States must overcome. *J Ambul Care Manage* 2021;**44**(**1**):71–5.

26 Warren KE, Wen LS. Measles, social media and surveillance in Baltimore City. *J Public Health (Oxf)* 2017;**39**(**3**):e73–8.

27 Dube E, Vivion M, Mac Donald NE. Vaccine hesitancy, vaccine refusal and the anti-vaccine movement: influence, impact and implications. *Expert Rev Vaccines* 2015;**14**(**1**):99–117.

28 Snyder M. Facebook plans to remove false posts about COVID-19 vaccines. *USA Today* 2020; December 3. https://www.usatoday.com/story/tech/2020/12/03/facebook-instagram-combat-covid-19-vaccine-misinformation/3807389001/

29 Dwoskin E, Gregg A. The trump administration bailed out prominent anti-vaccine groups during pandemic. *Wash Post* 2021 January;**18**:2021.

30 Ahmed N, Shahbaz T, Shamim A *et al.* The COVID-19 infodemic: a quantitative analysis through Facebook. *Cureus* 2020;**12**(**11**):e11346.

31 Chu WM, Shieh GJ, Wu SL *et al.* Use of Facebook by academic medical centers in Taiwan during the COVID-19 pandemic: observational study. *J Med Internet Res* 2020;**22**(**11**):e21501.

32 Docimo S Jr, Jacob B, Seras K *et al.* Closed Facebook groups and COVID-19: an evaluation of utilization prior to and during the pandemic. *Surg Endosc* 2020.

33 Jha A, Lin L, Savoia E. The use of social media by state health departments in the US: analyzing health communication through Facebook. *J Community Health* 2016;**41**(**1**):174–9.

34 Ekezie W, Czyznikowska BM, Rohit S *et al.* The views of ethnic minority and vulnerable communities towards participation in COVID-19 vaccine trials. *J Public Health (Oxf)* 2020. https://doi.org/10.1093/pubmed/fdaa196.

35 Smith TC, Novella SP. HIV denial in the Internet era. *PLoS Med* 2007;**4**(**8**):e256.