



It's not all about autism: The emerging landscape of anti-vaccination sentiment on Facebook



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ABSTRACT

Background: Due in part to declining vaccination rates, in 2018 over 20 states reported at least one case of measles, and over 40,000 cases were confirmed in Europe. Anti-vaccine posts on social media may be facilitating anti-vaccination behaviour. This study aimed to systematically characterize (1) individuals known to publicly post anti-vaccination content on Facebook, (2) the information they convey, and (3) the spread of this content.

Methods: Our data set consisted of 197 individuals who posted anti-vaccination comments in response to a message promoting vaccination. We systematically analysed publicly-available content using quantitative coding, descriptive analysis, social network analysis, and an in-depth qualitative assessment. The final codebook consisted of 26 codes; Cohen's κ ranged 0.71–1.0 after double-coding.

Results: The majority (89%) of individuals identified as female. Among 136 individuals who divulged their location, 36 states and 8 other countries were represented. In a 2-mode network of individuals and topics, modularity analysis revealed 4 distinct sub-groups labelled as “trust,” “alternatives,” “safety,” and “conspiracy.” For example, a comment representative of “conspiracy” is that poliovirus does not exist and that pesticides caused clinical symptoms of polio. An example from the “alternatives” sub-group is that eating yogurt cures human papillomavirus. Deeper qualitative analysis of all 197 individuals' profiles found that these individuals also tended to post material against other health-related practices such as water fluoridation and circumcision.

Conclusions: Social media outlets may facilitate anti-vaccination connections and organization by facilitating the diffusion of centuries old arguments and techniques. Arguments against vaccination are diverse but remain consistent within sub-groups of individuals. It would be valuable for health professionals to leverage social networks to deliver more effective, targeted messages to different constituencies.

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Abbreviations: AIDS, Acquired immunodeficiency syndrome; CDC, Centers for Disease Control and Prevention; DAV, distinctly anti-vaccination; DDT, Dichlorodiphenyltrichloroethane; FDA, Food and Drug Administration; GMO, Genetically modified organism; HPV, human papillomavirus; MMR, measles, mumps, rubella; NASA, National Aeronautics and Space Administration; VAERS, Vaccine Adverse Event Reporting System; WHO, World Health Organization.

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1. Introduction

Vaccines are often hailed as one of the greatest public health achievements of modern medicine, and high levels of vaccination have substantially curbed the rate of vaccine-preventable diseases and early deaths [1,2]. Community protection refers to the concept that if a sufficiently high number of individuals in the population are vaccinated, even those who cannot be vaccinated due to age or existing medical conditions will be protected [3]. However, in the United States (U.S.) only 70% of children 19–35 months receive all recommended immunizations, and over the past decade there

has been a considerable rise in rates of nonmedical exemptions from school immunization requirements [4].

Although opposition to vaccination has existed for centuries [5,6], the Internet, and specifically social media, may be facilitating the spread of anti-vaccination misinformation [7,8]. Unsubstantiated safety concerns presented as scientific information are readily available on the Internet [9]. Previous research suggests that viewing a website providing vaccine-critical information for just 5 to 10 min decreases intention to vaccinate, and that false information appears to spread more rapidly than truth on social media [7,10].

The majority of work examining anti-vaccination rhetoric on social media has been conducted using Twitter or examining the content of comments in response to celebrity posts or the content of Facebook groups [11–17]. Two studies previously examined dialogue on Facebook in response to a specific vaccine-related event. The first analysed posts in a Facebook forum following an Australian documentary about vaccines and autism and found that emotive appeals may override epidemiological evidence [13]. The second study analysed content from Israeli Facebook groups following the 2013 polio outbreak in Israel. Those opposed to the vaccination campaign expressed distrust in the concept of community protection, concerns about the safety of the oral polio vaccine, and distrust in the Ministry of Health [17].

Another previous study using Facebook analysed comments in response to Mark Zuckerberg's Facebook post about taking his child to receive vaccines. Linguistic analysis suggested the language in anti-vaccination comments showed use of analytical thinking, low anxiety, mimicked valid scientific information, and appeared to provide scientific explanations for unscientifically backed perspectives. In contrast, pro-vaccination comments manifested high levels of anxiety and mentioned family and social processes [14].

Finally, a recent study analysed six public anti-vaccination groups on Facebook. Using data collected from 2013 to 2016, the authors discovered that, within these six public groups, the majority of users only “liked” or commented on a couple of posts over the three year period, but a small subset of users were highly active across groups [16].

These previous studies suggest that common themes of anti-vaccine social media posts include skewed scientific information, shifting hypotheses, political arguments centred on parental freedom of choice, lack of trust in the medical community, conspiracy theories, and personal narratives related to negative vaccination experiences [18].

However, research has yet to examine multiple characteristics of the individuals who publish anti-vaccination content on Facebook, a platform with over 2.2 billion monthly active users [19]. Examining the characteristics of these individuals may generate information that will help clinicians tailor interventions [20].

In addition, prior research has not sufficiently leveraged innovative methods such as analysis of photos, images, and videos and social network analysis to better characterize how social media facilitates the transmission of vaccine misinformation [7,20]. Social network analysis can be valuable to understanding actions and connections within online communities [21], and networks can help highlight important people or topics [22].

Therefore, the purpose of this study was to systematically assess individuals known to express anti-vaccination sentiment on Facebook. We (1) coded sociodemographic characteristics of individuals and the anti-vaccination information they convey, (2) conducted social network analysis to examine the connections between these individuals and anti-vaccination topics, and (3) performed in-depth qualitative analysis to identify related themes in these individuals' public posts.

2. Methods

2.1. Sample selection

All study procedures were approved by the University of Pittsburgh Institutional Review Board (PRO17120151). Our data set consisted of 197 individuals on Facebook who posted anti-vaccination comments on a local paediatric clinic's Facebook page. These individuals posted comments in response to a 90-second video produced by the clinic that promoted the human papillomavirus (HPV) vaccine as an anti-cancer vaccine, as recommended by the U.S. Centers for Disease Control and Prevention (CDC) [23]. Nearly one month after the video was posted, it began to receive thousands of comments that were “distinctly anti-vaccination” (DAV), which we defined as being either (1) threatening (e.g. “you'll burn in hell for killing babies”) and/or (2) extremist (e.g. “you have been brainwashed”). The paediatric clinic blocked users posting these messages. This trend lasted for 8 days, after which the number of individuals posting comments dropped to negligible numbers.

We chose to focus on individuals who posted on a single clinic's page, instead of a wide variety of pages, to more precisely investigate the spread of anti-vaccination beliefs across Facebook [24].

2.2. Procedures

We employed a systematic procedure to obtain this sample. First, we collected all comments posted in response to the video over the span of 8 days during which most comments were posted. Second, using the definition described above, two researchers independently assessed a purposeful subsample of 40 comments as to whether comments were DAV. Because there was 100% agreement (Cohen's $\kappa = 1.0$), the remaining comments were single-coded. This resulted in a pool of 795 individuals who posted DAV comments in response to this video. Fourth, we obtained a random sample of 197 profiles in order to feasibly conduct in-depth qualitative assessment. We used stratified random sampling to obtain our sample, first stratifying by the date that each profile was blocked. We then used a random number generator to select 25% of profiles from each day for a period of 8 days. After the final sample was collected, we obtained available demographic information such as age and marital status.

Specific codes were determined using a hybrid process. Given that the DAV comments on the video were not specific to the HPV vaccine, we decided a priori to examine all anti-vaccination content as opposed to only anti-HPV vaccine specific content. Codes were adapted from previous analyses of anti-vaccination Internet content [16,25] and themes previously identified in the literature, such as support for marijuana legalization and belief in conspiracy theories [26,27]. We refined these codes through an inductive approach that involved independent double-coding and identifying exemplar posts (Table 1) [28]. A final codebook was codified, presenting clear definitions and examples of the 26 codes.

Using this codebook, two researchers independently examined all publicly available information that had been posted on each individual's Facebook page over the past 2 years (2015–2017).

Coder training and equilibration proceeded as follows. After double-coding 5% of the individuals ($n = 8$), the 2 researchers met to discuss differences and areas in the codebook that needed clarification. After 3 iterations of this process, coders double-coded 20% of the subsample ($n = 40$). For all categories interrater reliability was considered good to excellent [29], with Cohen's κ ranging from 0.71 to 1.00 and Krippendorff's α ranging from 0.72 to 1.00. Because of this excellent agreement, the coders then independently single-coded the remaining 157 individuals.

Table 1
Codebook for Facebook posts. Adapted: Wolfe, Sharp, & Lipsky (2002) and Smith & Graham (2017).

Variable	Description	Example content
Activism	<ul style="list-style-type: none"> Petition; information about bills or laws; urging people to contact lawmakers; urging people to contact drug companies; urging people to bring information to doctors; take down government or big Pharma; information for reporting adverse vaccine reactions 	<ul style="list-style-type: none"> Information about petitions and protests to SB277 (2015 California law removing personal belief exemptions to vaccine requirements) Instructions on how to file a vaccine reaction with the Vaccine Adverse Event Reporting System (VAERS)
Media, censorship, and “cover up”	<ul style="list-style-type: none"> CDC or doctors in the pockets of big Pharma; big Pharma cover-ups; government cover ups of vaccine effects; physicians paid to vaccinate; vaccination policy is motivated by profit 	<ul style="list-style-type: none"> Pediatricians make over \$100,000 from drug companies each year as a kickback for vaccinating children The CDC destroyed documents of studies linking vaccines to autism and cancer
Homeopathic remedies	<ul style="list-style-type: none"> Homeopathy as an alternative to vaccines; homeopathy as an alternative to medicine; food as medicine 	<ul style="list-style-type: none"> Prescription medications just treat disease symptoms, but plant-based diets cure disease
Vaccination as genocide	<ul style="list-style-type: none"> Vaccination used to kill people; vaccination sterilizes people; vaccination of minorities/third world plot to depopulate 	<ul style="list-style-type: none"> Vitamin B17 cures cancer Flu vaccine contains spermicide and is used for population control Aborticides were found in vaccines that Bill Gates sent to Africa
Moral transgressions	<ul style="list-style-type: none"> Vaccination is evil 	<ul style="list-style-type: none"> The Bible does not support vaccination Forcing vaccination is no different than slavery
Educational material	<ul style="list-style-type: none"> Doctors are uneducated; links to PubMed or “scientific” articles; parents need to educate themselves; parents need to educate doctors and the public; links/testimony from health professionals against vaccines 	<ul style="list-style-type: none"> Links to YouTube videos of physicians such as Andrew Wakefield that are anti-vaccine Photos of vaccine inserts with captions urging parents to educate themselves and physicians about the information in them
Vaccines cause idiopathic illness	<ul style="list-style-type: none"> Vaccines cause rashes, seizures; kids who are not vaccinated get less illness 	<ul style="list-style-type: none"> Mawson Homeschooled Study proves that unvaccinated kids get less childhood illness than vaccinated kids Gardasil causes seizures and paralysis (with pictures of teenagers in wheelchairs)
Vaccines cause autoimmune diseases or cancer	<ul style="list-style-type: none"> Vaccines cause autoimmune diseases, vaccines cause cancer, “evidence” of more vaccines related to higher rates of autoimmune disease and/or cancer 	<ul style="list-style-type: none"> Graphs showing a rise in deaths from cancer in the U.S. over the last 40 years overlaid with graph showing an increase in vaccination rates during those years Vaccinated children are more likely to develop childhood cancers
Vaccines cause autism	<ul style="list-style-type: none"> Vaccination linked to autism 	<ul style="list-style-type: none"> Drug companies have destroyed the results of studies linking the MMR vaccine to autism Rates of autism in the U.S. are increasing, as are the number of vaccines
Vaccines cause death	<ul style="list-style-type: none"> Vaccines cause death; vaccines cause Sudden Infant Death Syndrome (SIDS) 	<ul style="list-style-type: none"> Stories of babies who received vaccines and then were found dead in their crib two days later Figure stating that there have been 0 deaths from measles in the U.S. in the last 10 years but 108 deaths from the measles vaccine
Chemicals and additives	<ul style="list-style-type: none"> Additives in vaccines are dangerous; posts about mercury, aluminum etc; chemicals are dangerous 	<ul style="list-style-type: none"> According to the CDC, vaccines contain aluminum, mercury, fetal bovine serum, monkey kidney cells, and dozens more The amount of aluminum in the Hep B vaccine is 14x the safe amount per the FDA
Number of vaccines	<ul style="list-style-type: none"> Rise in number of vaccines cause of health problems; multiple simultaneous vaccines increase risk 	<ul style="list-style-type: none"> In 1940 children under age 2 got 4 vaccine injections, in 2016 children under 2 got 53 vaccine injections Picture of a baby doll with 20 needles in it, representing how many vaccines a child receives by age 2
Vaccination policy is a violation of civil liberties	<ul style="list-style-type: none"> Parents have the right to choose; against mandatory vaccination 	<ul style="list-style-type: none"> Use of the term “pro-choice” to describe views on vaccination Women’s rights = right to choose what is injected into her child
Cell cultures from aborted fetal tissue are used to grow vaccine viruses	<ul style="list-style-type: none"> Pictures of fetuses used for vaccines; posts about cells from aborted fetuses used to grow vaccines 	<ul style="list-style-type: none"> New vaccines are being developed using body parts from aborted fetuses Cannot be both pro-life and pro-vaccine, as vaccines contain cells from fetuses
Personal stories about harmed individuals	<ul style="list-style-type: none"> Pictures or stories about harmed individuals 	<ul style="list-style-type: none"> Story of Colton, who became paralyzed and then died after receiving the HPV vaccine at age 13 Pictures of babies in the intensive care unit following routine vaccination
Pictures of “scary needles”	<ul style="list-style-type: none"> Pictures of big needles/shots; pictures of people getting shots with big needles 	<ul style="list-style-type: none"> Pictures of health workers holding down a baby while they receive a vaccine Picture of a syringe with a large needle
Pro-marijuana and/or cannabis oil	<ul style="list-style-type: none"> Marijuana should be legal; cannabis oil or marijuana effective at treating illness 	<ul style="list-style-type: none"> Marijuana is more effective than chemotherapy Marijuana is a natural plant that can treat cancer, AIDS, pain, seizures, and other illnesses
Other conspiracy theories	<ul style="list-style-type: none"> Conspiracy related to vaccines; government cover-ups; flat earth conspiracy; JFK assassination conspiracy; 9/11 conspiracy 	<ul style="list-style-type: none"> Polio is not a real disease; symptoms that were called polio were due to DDT poisoning NASA is releasing balloons filled with chemicals across the U.S.

2.3. Measures

We coded 8 variables related to sociodemographic information: age, gender, location, political affiliation, marital status (yes/no), parental status (yes/no), whether employment was listed (yes/no), and whether post-secondary education was listed (yes/no). Age was recorded if the individual listed an age or birthdate on the profile. Gender was inferred from pronouns on the profile (e.g. “send her a friend request”). Location was coded by state or by country for non-U.S. locations. Political affiliation was recorded if an individual had a post in support of a particular political party or candidate (in any country). For both marital and parental status, individuals were coded as married and/or parents if they made reference to a spouse and/or children or if pictures indicated the person had a spouse and/or children.

For each individual, we coded 18 topics related to anti-vaccination content (Table 1). These topics were not mutually exclusive. For example, a post that stated a pharmaceutical company was not reporting data demonstrating that girls who receive the HPV vaccine have an increased rate of seizures could be coded as expressing both “media, censorship, and ‘cover up’” and “vaccines cause idiopathic illness.” We coded both textual and visual content, and if a post contained a link to a video or website, coders included examination of the linked website in their assessments.

2.4. Analysis

First, we conducted a descriptive analysis of all sociodemographic and anti-vaccination variables. Of the 197 individuals, 116 had at least one relevant public anti-vaccination post during the time frame under analysis. We calculated basic descriptive statistics using Stata 15 [30].

Second, we conducted social network analysis to determine if people discussing different anti-vaccination topics led to certain sub-groups organically clustering together. While traditional social networks tend to only assess relationships between people, we used a 2-mode network (also called an “affiliation network”) to describe relationships between not only people but also non-person artefacts (e.g. anti-vaccination topics) [31]. In other words, we studied the connections between people as mediated by discussion topics. We then used modularity to identify potential clusters that could demonstrate how discussion topics were interconnected [32]. Clusters were compared to the five topics of vaccine denial (threat of disease, trust, alternatives, effectiveness, and safety) proposed by the World Health Organization (WHO) regional office for Europe [33]. Visualizations and network descriptive metrics were generated using the Gephi software package [34].

Third, 2 researchers independently conducted a qualitative analysis of public messages posted between 2015 and 2017 using a grounded theory approach [35]. Each researcher developed notes on emergent themes. Researchers then met with a supervising researcher to discuss findings and synthesize themes using a systematic, iterative process that involved open coding, axial coding, and collapsing codes into distinct categories [36].

3. Results

3.1. Descriptive

The majority of individuals identified as female (89%) and/or as parents (78%). A smaller proportion reported an occupation (29%) and/or post-secondary education (24%). The majority of individuals for whom political affiliation could be determined (28%, $n = 55$) identified as supporters of Donald Trump (56%, $n = 31$), a

conservative and the 2016 Republican nominee for President. This was followed by supporters of Bernie Sanders (11%, $n = 6$), a contender in the 2016 Democratic primary and a self-described democratic socialist. Age could only be determined for 2 individuals. Location was mentioned by 136 individuals, most frequently California ($n = 24$), followed by Texas ($n = 9$), Australia ($n = 8$), and Canada ($n = 8$). Only 5 individuals we coded were located in the same state as the organization that posted the pro-vaccination video.

Of the 116 individuals with at least one public anti-vaccination post from 2015 to 2017, posts about “educational material” (73%), “media, censorship, and ‘cover up’” (71%), and “vaccines cause idiopathic illness” (69%) were the most common topics (Table 2).

3.2. Social network analysis

A 2-mode network was constructed with 133 nodes, representing 115 people and 18 topics (Fig. 1). There were 1068 edges, or connections, between people and topics. The network had a density of 0.122 and average degree of 8.03. Modularity analysis found 4 distinct sub-groups. Based on the overarching themes represented in these sub-groups and the topics of vaccine denial provided by the WHO [33], we named these sub-groups (1) trust, (2) alternatives, (3) safety, and (4) conspiracy.

We also assessed betweenness [37], a measure that identifies all of the shortest paths found between any 2 nodes in the network. In this network, “vaccination policy is a violation of civil liberties” had the highest betweenness centrality ($b = 0.135$); it was the topic most discussed by people who discussed only one topic.

3.3. Qualitative analysis

Assessment of qualitative data revealed that many individuals shared the same anti-vaccination stories, articles, and photos when discussing a particular issue (Fig. 2). Usually, these posts were shared from anti-vaccination Facebook groups that market themselves as “pro-information,” “pro-science,” or “pro-vaccine choice.”

In addition to the similarities surrounding anti-vaccination sentiment, qualitative analysis revealed other commonalities in public posts by these individuals. For example, many individuals consistently posted content related to “naturalness,” including attitudes against genetically modified food (anti-GMO), circumcision, and

Table 2

Frequency of anti-vaccination posts by category for profiles with anti-vaccination content ($n = 116$).

Variable	Frequency	
	N	%
Activism	63	54
Media, censorship, and “cover up”	83	72
Homeopathic remedies	77	66
Vaccination as genocide	23	20
Moral transgressions	45	39
Educational material	85	73
Vaccines cause idiopathic illness	80	69
Vaccines cause autoimmune diseases or cancer	57	49
Vaccines cause autism	64	55
Vaccines cause death	70	60
Chemicals	66	56
Number of vaccines	50	43
Vaccination policy is a violation of civil liberties	78	66
Cell cultures from aborted fetal tissue are used to grow vaccine viruses	30	26
Personal stories about harmed individuals	68	57
Pictures of “scary needles”	54	47
Pro-marijuana and/or cannabis oil	36	31
Conspiracy theories	52	45

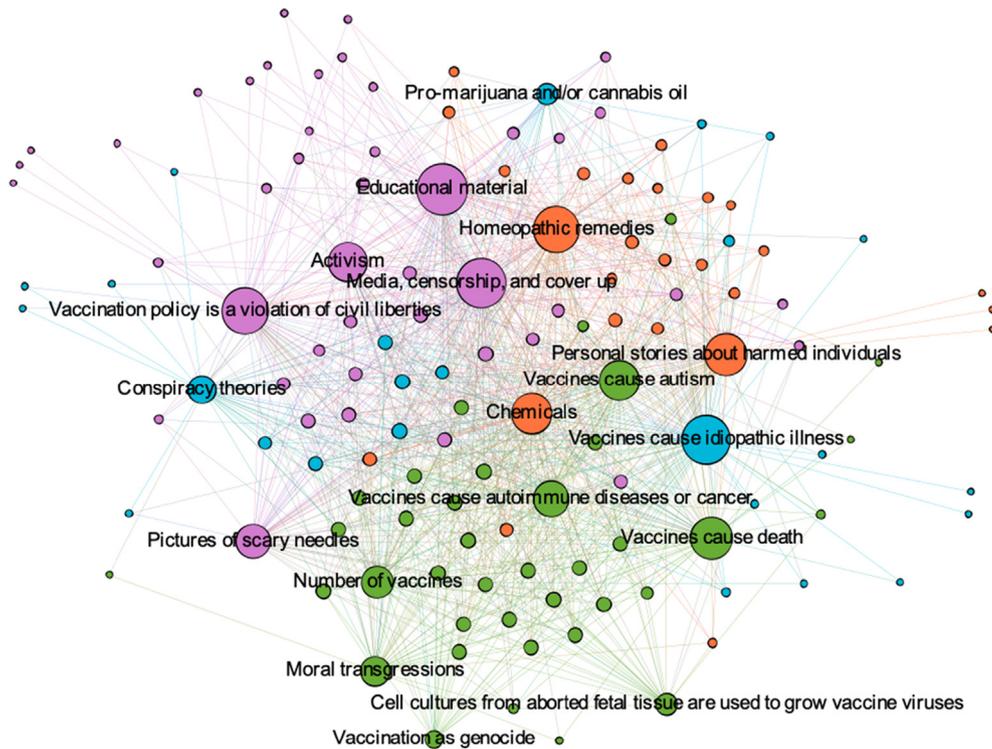


Fig. 1. Visualization of the network representing Facebook profiles discussing vaccine topics. Nodes, or circles, represent profiles and topics of discussion. Edges, or lines, between nodes represent a profile discussing a particular topic. Colours represent 4 different sub-groups: (1) trust – purple; (2) alternatives – orange; (3) safety – green; (4) conspiracy – blue. Size of the nodes represents degree centrality, i.e., larger topic nodes (labeled) are discussed by more people, larger personal nodes discuss more topics. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

water fluoridation. Some of these individuals also expressed vegan activism.

Other individuals expressed views against water fluoridation and GMO in a way that focused on liberty and potential government interference. Many of these individuals posted about government conspiracy related to “chemtrails,” which is a theory that long-lasting condensation trails left by high-flying aircrafts contain chemical/biological agents. They also tended to express anti-abortion and pro-gun sentiments.

4. Discussion

Individuals in our sample mostly identified as female, as parents, and spanned the globe. Posts on these individuals’ Facebook profile pages suggest that many are highly mistrustful of the medical and scientific community. Moreover, while arguments against vaccination were diverse, social network and qualitative analysis found that topics and people tended to cluster into four distinct sub-groups, with many individuals against vaccines holding other shared beliefs.

Although we focused on comments posted on a local paediatric clinic’s Facebook page, we identified individuals from 36 U.S. states and 8 countries, suggesting that, through social media, a local post can gain international attention. Consistent with previous research, individuals in our sample spanned the political spectrum [26,38]. These findings suggest that the online anti-vaccine community is also diverse geographically and politically, and social media may facilitate previously unfeasible connections among these individuals.

In our study, the most commonly coded topic related to anti-vaccination was “educational material.” This refers to content that claims to provide scientific evidence for the negative impact of vaccines. Qualitative analysis revealed that these posts often included

text suggesting that parents are more informed than physicians regarding topics such as the mechanism of action of vaccines and potential complications of vaccines.

The second most common topic was “media, censorship, and ‘cover up.’” Posts in this category quoted from articles suggesting that the government, pharmaceutical companies, and/or physicians consciously and wilfully fail to disclose adverse vaccine reactions. The high prevalence of individuals posting this content suggests that many individuals who currently express anti-vaccination sentiment on Facebook are highly mistrustful of the medical community. This distrust may explain why providing vaccine-hesitant parents with scientific information about vaccines may actually increase reactance and reduce intention to vaccinate [39].

Social network analysis found that topics and people tended to cluster into 4 distinct sub-groups (differentiated by colour in Fig. 1). The “trust” sub-group emphasized mistrust of the scientific community and concerns about personal liberty. The “alternatives” sub-group focused on chemicals in vaccines and the use of homeopathic remedies as an alternative to vaccination. The “safety” sub-group focused on perceived risks and concerns about vaccination being immoral. The “conspiracy” sub-group suggested that the government and other entities hide certain beliefs this sub-group believes to be facts, including that the polio virus does not exist. The presence of distinct sub-groups cautions against a “blanket” approach when developing interventions or educational programming; countering a single theme or argument is not likely to succeed with all anti-vaccine beliefs.

Moreover, the characteristics of these network-defined sub-groups offers empirical support for future work related to the 5 topics of vaccine denial as outlined by the WHO. In 2017, the WHO issued a guide for health authorities on responding to vocal vaccine deniers. Included in this guide are 5 topics of vaccine denial, based on previous communication research and



Fig. 2. Frequent anti-vaccination posts on Facebook profiles and in anti-vaccination groups on Facebook.

experiences of the WHO European Region [33]. These topics are (1) threat of disease (vaccine preventable diseases are eradicated or harmless), (2) trust (questioning the trustworthiness of health authorities), (3) alternatives (suggesting other prevention methods than vaccination), (4) effectiveness (questioning the effectiveness of vaccines), and (5) safety (vaccines cause more risks than benefits). Our network analysis found sub-groups primarily concerned with safety, trust, and alternatives. We also found that topics related to threat of disease and effectiveness tended to cluster together into a sub-group with the overarching theme of conspiracy. Thus, it may be valuable for health authorities to consider this broader classification of conspiracy when addressing vocal vaccine deniers.

Qualitative analysis found that posts related to safety concerns often distorted reputable epidemiological data, consistent with known characteristics of science denialism [40]. For example, many posts included data showing parallels between rates of vaccination and cancer mortality rates to support the claim that vaccines cause cancer. However, the scientifically-established consensus is that immunization against vaccine-preventable diseases, which led to a 29-year increase in life-expectancy, shifted leading causes of death from infectious causes to chronic diseases such as cancer [41]. Therefore, dialogue from health professionals

about vaccination may need to be updated to reflect the ways in which those against vaccination use science denialism.

Consistent with previous media reports [42], qualitative analysis also revealed that many individuals against vaccines hold other shared beliefs, such as concerns about genetically modified organisms and water fluoridation. This presents an opportunity for clinicians to develop interventions aimed at individuals who share these other beliefs. This could be useful because social media may expose individuals who are initially merely vaccine hesitant to content that persuades them to not vaccinate.

Previous research suggests that ideas and information can spread in a manner similar to infectious diseases [43]. Thus, just as vaccination is needed to prevent the spread of infectious disease, interventions are needed to prevent the spread of anti-vaccination messages on social media. Our findings suggest several possible avenues of intervention to increase the level of community protection against the propagation of anti-vaccination messaging on social media. First, media literacy, which teaches individuals about the effect of mass media on attitudes and behaviour [44], may offer a framework to help people better evaluate anti-vaccine content on social media. As noted above, many posts in our sample included data showing parallels between rates of vaccination and cancer mortality rates. Broad investments in media literacy may provide individuals with the tools necessary to critically examine the presentation of these data and associated claims and be more effective than attempts by clinicians to counter individual social media posts [7].

Second, the use of entertainment narratives may be another effective avenue for intervention. Health storylines on television have been shown to influence viewers' knowledge, perception, and behaviour about topics ranging from organ donation to cancer screening [45], but research has yet to examine influence with regard to vaccination. The persuasive power of entertainment narratives likely occurs through identification with characters and decreased reactance from transportation into the narrative [45]. Through these mechanisms, storylines that feature unvaccinated characters who contract a vaccine-preventable disease may highlight disease severity and counter anecdotes shared on social media by anti-vaccination activists.

Third, the identification of distinct sub-groups suggests a valuable opportunity for clinicians to leverage social networks to deliver more effective, targeted interventions. For example, one avenue of intervention for the alternatives sub-group could be the development of health communication campaigns that present vaccines as triggering our natural immune systems [46]. In a similar manner, interventions targeted to the trust sub-group could reframe "liberty" in such a way that vaccinating one's child is seen as a way to let the child be free [46].

Finally, it may be valuable for medical professionals to be more active on social media. Previous studies suggest that only about 5–15% of commentators in online vaccination forums identify as health professionals [13,17]. Our findings could inform the development of toolkits to help clinicians and researchers cultivate trust in the medical community and respond to DAV comments.

The anti-vaccination movement and the growing number of individuals who refuse vaccines for themselves and/or their children is a serious public health crisis. A decade ago, measles was rarely seen in developed countries. Due to declining vaccination rates, in 2018 more than 20 states reported at least one case of measles, and more than 40,000 cases were confirmed in Europe [47,48]. The results from this study can serve as a springboard for the development of tailored health messages and interventions by public health professionals. These campaigns will be imperative to counter the spread of scientific misinformation online, and they have the potential to substantially reduce the burden of vaccine-preventable diseases.

5. Limitations

Our data represented a random subsample of 795 individuals who responded to a single pro-vaccination video. While we purposefully did this to examine the reach of responses to this single video, it should be noted that these results do not necessarily reflect broader discussions of anti-vaccination issues on Facebook. Furthermore, because we relied on self-reported data when coding sociodemographic variables, we could not ensure authenticity of information. We also classified each profile as an individual, though a profile could represent multiple individuals, or a fabricated individual. However, both self-report and difficulty in characterizing individuals are known limitations of using social media data [49]. In addition, we only coded publicly available information: we were not able to code what individuals might be sharing to their Facebook friends privately. Finally, although we aimed to minimize subjectivity through multiple rounds of analysis and the use of a supervising researcher, interpretation of posts using qualitative analysis can be subjective.

6. Conclusions

Examining the content of individual Facebook profiles posting anti-vaccination content provided valuable insight into sociodemographic characteristics, content of Facebook posts, and how these individuals connect with one another. Individuals from around the globe who are opposed to vaccination are connecting via social media, suggesting the need for clinicians and researchers to develop interventions to combat the propagation of misinformation about vaccines on social media. Those opposed to vaccination often misrepresent data and skew risk perception when spreading their messages on Facebook, suggesting that media literacy or entertainment narratives may be effective avenues for intervention. Moreover, while current arguments against vaccination are varied, they remain consistent within sub-groups of individuals. Thus, it may also be valuable for interventions or educational programming to use social networks to deliver targeted messaging tailored to specific anti-vaccination beliefs. Future research should focus on the development and evaluation of these interventions.

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References

- [1] Centers for Disease Control and Prevention. Ten great public health achievements—United States, 1900–1999, *MMWR Morb Mortal Wkly Rep*, 1999; 48:241–3.
- [2] Zhou F, Shefer A, Wenger J, Messonnier M, Wang LY, Lopez A, et al. Economic evaluation of the routine childhood immunization program in the United States, 2009. *Pediatrics* 2014;133:577–85. <https://doi.org/10.1542/peds.2013-0698>.
- [3] Doherty M, Buchy P, Standaert B, Giaquinto C, Prado-Cohrs D. Vaccine impact: benefits for human health. *Vaccine* 2016;34:6707–14. <https://doi.org/10.1016/j.vaccine.2016.10.025>.
- [4] Omer SB, Richards JL, Ward M, Bednarczyk RA. Vaccination policies and rates of exemption from immunization, 2005–2011. *N Engl J Med* 2012;367:1170–1. <https://doi.org/10.1056/NEJM1209037>.
- [5] Kinch M. *Between hope and fear: a history of vaccines and human immunity*. New York: Pegasus Books; 2018.
- [6] Baker JP. The pertussis vaccine controversy in Great Britain, 1974–1986. *Vaccine* 2003;21:4003–10. [https://doi.org/10.1016/S0264-410X\(03\)00302-5](https://doi.org/10.1016/S0264-410X(03)00302-5).
- [7] Chou W-YS, Oh A, Klein WMP. Addressing health-related misinformation on social media. *JAMA* 2018. <https://doi.org/10.1001/jama.2018.16865>.
- [8] Stahl J-P, Cohen R, Denis F, Gaudelus J, Martinot A, Lery T, et al. The impact of the web and social networks on vaccination. New challenges and opportunities offered to fight against vaccine hesitancy. *Méd Mal Infect* 2016;46:117–22. <https://doi.org/10.1016/j.medmal.2016.02.002>.
- [9] Betsch C, Brewer NT, Brocard P, Davies P, Gaissmaier W, Haase N, et al. Opportunities and challenges of Web 2.0 for vaccination decisions. *Vaccine* 2012;30:3727–33. <https://doi.org/10.1016/j.vaccine.2012.02.025>.
- [10] Betsch C, Renkewitz F, Betsch T, Ulshöfer C. The influence of vaccine-critical websites on perceiving vaccination risks. *J Health Psychol* 2010;15:446–55. <https://doi.org/10.1177/1359105309353647>.
- [11] Chakraborty P, Colditz JB, Silvestre AJ, Friedman MR, Bogen KW, Primack BA. Observation of public sentiment toward human papillomavirus vaccination on Twitter. *Cogent Med* 2017. <https://doi.org/10.1080/2331205X.2017.1390853>.
- [12] Dunn AG, Surian D, Leask J, Dey A, Mandl KD, Coiera E. Mapping information exposure on social media to explain differences in HPV vaccine coverage in the United States. *Vaccine* 2017;35:3033–40. <https://doi.org/10.1016/j.vaccine.2017.04.060>.
- [13] Nicholson MS, Leask J. Lessons from an online debate about measles–mumps–rubella (MMR) immunization. *Vaccine* 2012;30:3806–12. <https://doi.org/10.1016/j.vaccine.2011.10.072>.
- [14] 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;34:5808–14. <https://doi.org/10.1016/j.vaccine.2016.09.029>.
- [15] Schmidt AL, Zollo F, Scala A, Betsch C, Quattrocioni W. Polarization of the vaccination debate on Facebook. *Vaccine* 2018;36:3606–12. <https://doi.org/10.1016/j.vaccine.2018.05.040>.
- [16] Smith N, Graham T. Mapping the anti-vaccination movement on Facebook. *Inform Commun Soc* 2017;1–18. <https://doi.org/10.1080/1369118X.2017.1418406>.
- [17] Orr D, Baram-Tsabar A, Landsman K. Social media as a platform for health-related public debates and discussions: the Polio vaccine on Facebook. *Isr J Health Policy Res* 2016;5:34. <https://doi.org/10.1186/s13584-016-0093-4>.
- [18] Kata A. Anti-vaccine activists, Web 2.0, and the postmodern paradigm – an overview of tactics and tropes used online by the anti-vaccination movement. *Vaccine* 2012;30:3778–89. <https://doi.org/10.1016/j.vaccine.2011.11.112>.
- [19] Statista. Most popular mobile social networking apps in the United States as of February 2018, by monthly users (in millions); 2018 [accessed March 5, 2019]. <<https://www.statista.com/statistics/248074/most-popular-us-social-networking-apps-ranked-by-audience/>>.
- [20] Dredze M, Broniatowski DA, Smith MC, Hilyard KM. Understanding vaccine refusal: why we need social media now. *Am J Prev Med* 2016;50:550–2. <https://doi.org/10.1016/j.amepre.2015.10.002>.
- [21] Chu K-H, Wipfli H, Valente TW. Using visualizations to explore network dynamics. *J Soc Struct JOSS* 2013;14.
- [22] Wasserman S, Faust K. *Social network analysis: methods and applications*. New York, New York: Cambridge University Press; 1994.
- [23] Gilkey MB, Zhou M, McRee A-L, Kornides ML, Bridges JFP. Parents' views on the best and worst reasons for guideline-consistent HPV vaccination. *Cancer Epidemiol Biomarkers Prev* 2018;27:762–7. <https://doi.org/10.1158/1055-9965.EPI-17-1067>.
- [24] Moorhead SA, Hazlett DE, Harrison L, Carroll JK, Irwin A, Hoving C. A new dimension of health care: systematic review of the uses, benefits, and limitations of social media for health communication. *J Med Internet Res* 2013;15:e85. <https://doi.org/10.2196/jmir.1933>.
- [25] Wolfe RM, Sharp LK, Lipsky MS. Content and design attributes of antivaccination web sites. *JAMA* 2002;287:3245–8. <https://doi.org/10.1001/jama.287.24.3245>.
- [26] Hornsey MJ, Harris EA, Fielding KS. The psychological roots of anti-vaccination attitudes: a 24-nation investigation. *Health Psychol* 2018. <https://doi.org/10.1037/hea0000586>.
- [27] Kahan DM. Vaccine risk perceptions and ad hoc risk communication: an empirical assessment. *CCP Risk Percept Stud Rep No 17*; Yale Law Econ Res Pap #491; 2014. <https://doi.org/10.2139/ssrn.2386034>.
- [28] Colditz JB, Chu K, Emery SL, Larkin CR, James AE, Welling J, et al. Toward real-time infoveillance of Twitter health messages. *Am J Public Health* 2018;108:1009–14. <https://doi.org/10.2105/AJPH.2018.304497>.
- [29] Krippendorff K. Reliability in content analysis. *Hum Commun Res* 2004;30:411–33. <https://doi.org/10.1111/j.1468-2958.2004.tb00738.x>.
- [30] StataCorp. *Stata Statistical Software: Version 15*; 2018.
- [31] Borgatti SP. Two-mode concepts in social network analysis. *Comput Complex* 2012;29:12–24. https://doi.org/10.1007/978-1-4614-1800-9_179.
- [32] Girvan M, Newman MEJ. Community structure in social and biological networks. *Proc Natl Acad Sci USA* 2002;99:7821–6. <https://doi.org/10.1073/pnas.122653799>.

- [33] World Health Organization. How to respond to vocal vaccine deniers in public. Copenhagen; 2017.
- [34] Bastian M, Heymann S, Jacomy M. Gephi: an open source software for exploring and manipulating networks. *lcwsm* 2009;8:361–2.
- [35] Strauss A, Corbin J. *Basics of qualitative research: techniques and procedures for developing grounded theory*. 3rd ed. Thousand Oaks, California: SAGE Publications; 2007.
- [36] Colditz JB, Ton JN, James AE, Primack BA. Toward effective water pipe tobacco control policy in the United States: synthesis of federal, state, and local policy texts. *Am J Heal Promot* 2017;31:302–9. <https://doi.org/10.4278/ajhp.150218-QUAL-736>.
- [37] Freeman LC. A set of measures of centrality based on betweenness. *Sociometry* 1977;40:35. <https://doi.org/10.2307/3033543>.
- [38] Berezow A, Campbell H. *Science left behind: feel-good fallacies and the rise of the anti-scientific left*. New York: Public Affairs; 2012.
- [39] Nyhan B, Reifler J, Richey S, Freed GL. Effective messages in vaccine promotion: a randomized trial. *Pediatrics* 2014;133:e835–42. <https://doi.org/10.1542/peds.2013-2365>.
- [40] Diethelm P, McKee M. Denialism: what is it and how should scientists respond? *Eur J Public Health* 2008;19:2–4. <https://doi.org/10.1093/eurpub/ckn139>.
- [41] Jones DS, Podolsky SH, Greene JA. The burden of disease and the changing task of medicine. *N Engl J Med* 2012;366:2333–8. <https://doi.org/10.1056/NEJMp1113569>.
- [42] Berezow A. “March Against Monsanto” is now an anti-vaccine, conspiracy movement. *Am Counc Sci Heal* 2016 [accessed March 5, 2019]. <<https://www.acsh.org/news/2016/09/19/march-against-monsanto-now-anti-vaccine-conspiracy-movement-10186>>.
- [43] Bauch CT, Galvani AP. Social and biological contagions. *Science* 2013;342:47–9. <https://doi.org/10.1126/science.1244492>.
- [44] Buckingham D. *Media education: literacy, learning, and contemporary culture*. Malden, MA: Blackwell Publishing; 2003.
- [45] Hoffman BL, Shensa A, Wessel C, Hoffman R, Primack BA. Exposure to fictional medical television and health: a systematic review. *Health Educ Res* 2017;12:551–66. <https://doi.org/10.1093/her/cvx034>.
- [46] Amin AB, Bednarczyk RA, Ray CE, Melchiori KJ, Graham J, Huntsinger JR, et al. Association of moral values with vaccine hesitancy. *Nat Hum Behav* 2017;1:873–80. <https://doi.org/10.1038/s41562-017-0256-5>.
- [47] WHO. Measles cases hit record high in the European Region 2018 [accessed March 5, 2019]. <<http://www.euro.who.int/en/media-centre/sections/press-releases/2018/measles-cases-hit-record-high-in-the-european-region>>.
- [48] Centers for Disease Control and Prevention. Measles cases and outbreaks 2018 [accessed December 20, 2018]. <<https://www.cdc.gov/measles/cases-outbreaks.html>>.
- [49] Hunter RF, Gough A, O’Kane N, McKeown G, Fitzpatrick A, Walker T, et al. Ethical issues in social media research for public health. *Am J Public Health* 2018;108:343–8. <https://doi.org/10.2105/AJPH.2017.304249>.