It's Not All About Autism: the Emerging Landscape of Anti-Vaccination Sentiment on Facebook

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Abstract

Introduction: The anti-vaccination movement has been present since the early 1700s. Previous research suggests that social media may be fueling the spread of anti-vaccination messaging. Therefore, the purpose of this thesis is to (1) highlight major events in the history of the anti-vaccine movement, (2) present a stand-alone journal article from a systematic analysis of individuals known to express anti-vaccination sentiment on Facebook, and (3) integrate the conclusions presented in the article into a broader historical framework.

Methods: A literature review was conducted for the historical overview. For the journal article, our data set consisted of 197 individuals with Facebook accounts who posted anti-vaccination comments on a prominent local pediatric clinic's Facebook page. For each individual, we systematically analyzed publicly available content using quantitative coding, descriptive analysis, social network analysis, and an in-depth qualitative assessment.

Results: Throughout history**,** the anti-vaccination movement has consistently sued fiery rhetoric and vivid imagery to spread its messages, which often center on concerns of liberty and safety. Analysis of Facebook profiles found that more individuals posted content related to mistrust in the medical community, liberty, and belief in homeopathic remedies compared to those who posted that vaccines cause autism. Among 136 individuals who divulged their location, 36 states and 8 countries outside the U.S. were represented. In a 2-mode network of individuals and topics, modularity analysis revealed 4 distinct sub-groups: (1) liberty, (2) naturalness, (3) illness, and (4)

conspiracy. Qualitative analysis found that individuals often share posts from Facebook groups that market themselves as pro-science.

Conclusion: Individuals on Facebook frequently posted anti-vaccine content that echoed historical concerns. Our findings suggest social media outlets facilitate anti-vaccination connection and organization, thus assisting in the amplification and diffusion of centuries' old arguments and techniques. These findings are significant for public health in that they will inform the development of updated messaging around vaccination, and suggest the importance of understanding the history of the anti-vaccination movement when developing these messages. These findings also suggest a valuable opportunity for public health practitioners to leverage social networks to deliver more effective, tailored interventions to different constituencies.

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Preface

I would like to thank the many people who have facilitated my growth as a public health professional. First, I would like to express my deepest gratitude for the opportunities afforded to me by Dr. Brian Primack and my coworkers at the Center for Research on Media, Technology, and Health (MTH). Dr. Primack, I am forever indebted to you for your mentorship, support, and encouragement. To the entire MTH team, words cannot express how thankful I am for the advice, knowledge, and friendship I have received throughout my four years there. I am truly privileged to be a member of this extraordinary team, and I look forward to many more years working with you all.

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1.0 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 deaths from infectious diseases (Centers for Disease Control and Prevention, 1999; Zhou et al., 2014). However, an increasing number of individuals refuse vaccines for themselves or their children (Callender, 2016; Larson, Jarrett, Eckersberger, Smith, & Paterson, 2014; The SAGE Working Group on Vaccine Hesitancy, 2014). In the United States, only 70% of children aged 19–35 months have all of the recommended immunizations, and from 2009 to 2012 the rate of nonmedical exemptions from school immunization requirements rose by 19% (Dredze, Broniatowski, Smith, & Hilyard, 2016; Omer, Richards, Ward, & Bednarczyk, 2012; E. Wang, Clymer, Davis-Hayes, & Buttenheim, 2014). Furthermore, between 2009 and 2016, the percent of kindergarteners with religious or philosophical-belief exemptions increased in 12 of the 18 states that allow for these exemptions (Olive, Hotez, Damania, & Nolan, 2018).

While opposition to vaccination has existed for centuries, social media may be facilitating the diffusion of these messages. Since the early 2000s, the Internet has become a major source for misinformation on vaccines because of the availability of unsubstantiated safety concerns presented as scientific information (Betsch et al., 2012; Brewer, Chapman, Rothman, Leask, & Kempe, 2017; Ward, Peretti-Watel, & Verger, 2016). Previous research suggests that viewing a website that provides vaccine-critical information for just five to 10 minutes increases the

perception of risk of vaccinating and decreases intention to vaccinate (Betsch, Renkewitz, Betsch, & Ulshöfer, 2010).

Previous research examining anti-vaccination rhetoric on social media has primarily focused on Twitter (Chakraborty et al., 2017; Du, Xu, Song, & Tao, 2017; Dunn, Leask, Zhou, Mandl, & Coiera, 2015; Dunn et al., 2017; Massey et al., 2016; Radzikowski et al., 2016; Salathé & Khandelwal, 2011; Shapiro, Surian, Dunn, Perry, & Kelaher, 2017; Tomeny, Vargo, & El-Toukhy, 2017; J. Wang, Zhao, Ye, & Zhang, 2018). This focus is likely due to the "public-facing" nature of Twitter, with an estimated 88% of users allowing their posts to be viewed publicly (Beevolve, 2014). Twitter and individual developers also maintain dedicated tools that facilitate automatic downloading and processing of content from the platform (Denecke et al., 2013; Hanson, Cannon, Burton, & Giraud-Carrier, 2013). Moreover, research on other social media platforms—such as Facebook and MySpace—has been mostly limited to examinations of comments on a particular post or content on public pages, such as Facebook groups (Ache & Wallace, 2008; Faasse, Chatman, & Martin, 2016; Keelan, Pavri, Balakrishnan, & Wilson, 2010; Nicholson & Leask, 2012; Orr, Baram-Tsabari, & Landsman, 2016; Smith & Graham, 2017; Venkatraman, Garg, & Kumar, 2015).

Thus, more research is needed to characterize the *individuals* who publish anti-vaccination content (Dredze et al., 2016). Theories such as the Health Belief Model, Theory of Planned Behavior, Transtheoretical Model, and Social Cognitive Theory highlight the necessity of understanding individual perceptions of illness, risk, and barriers to action when designing behavior change interventions (Bandura, 2004; Glanz et al., 2017; Prochaska & Velicer, 1997; Yang, Barker, Goodman, & Park, 2018). In addition, health and risk communication theories emphasize the importance of crafting messages tailored to defined audience segments (Covello,

Peters, Wojtecki, & Hyde, 2001; Vijaykumar, 2008). Guided by these conceptual frameworks, examination of individuals who post anti-vaccination content on Facebook and the arguments they propagate will provide the basis for developing more effective, targeted public health interventions.

Therefore, our study systematically analyzed data from individuals known to express anti-vaccination sentiment on Facebook. These individuals were identified as being anti-vaccine through comments they posted in response to a video promoting the human papillomavirus (HPV) vaccine on the Facebook page of Kids Plus Pediatrics, a prominent pediatric practice in Pittsburgh, Pennsylvania. On August 23, 2017, Kids Plus Pediatrics posted a 90-second video that promoted the HPV vaccine as an anti-cancer vaccine, an approach recommended by the U.S. Centers for Disease Control and Prevention (CDC) and the National Cancer Institute (NCI; Gilkey, Zhou, McRee, Kornides, & Bridges, 2018). In September 2017, a Facebook user shared the video to an anti-vaccine Facebook group, after which the video received more than 10,000 comments from individuals opposed to vaccination. These comments 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 no grip on reality; you have been brainwashed"). Over the course of eight days, 795 individuals posted these types of comments.

For our study, we analyzed the Facebook profiles of a 25% subsample (n=197) of these individuals. Specifically, we (1) coded sociodemographic characteristics of these individuals and the anti-vaccination information they conveyed, (2) conducted social network analysis (SNA) to examine the connections between these individuals and anti-vaccination topics, and (3) performed an in-depth qualitative analysis to identify related themes in posts authored by these individuals.

In addition, research has yet to synthesize anti-vaccination rhetoric on Facebook within a historical framework. Thus, in the first chapter of this thesis, I will provide an in-depth review of the history of the anti-vaccination movement and previous research on anti-vaccination messaging on social media. The second chapter is a stand-alone journal article, which at the time of this thesis writing is currently under review for publication in *The American Journal of Preventive Medicine*. Following the journal article is the third and final chapter, which presents the thesis conclusions.

2.0 Literature Review

As the British politician Edmund Burke once said, “those who don’t know history are doomed to repeat it.” It is relatively easy to dismiss anti-vaccination beliefs as illogical, but history suggests they are deeply rooted in political, spiritual, and philosophical arguments that are relatively consistent over time. Although many individuals view the anti-vaccination movement as a contemporary phenomenon fueled by Andrew Wakefield’s 1998 *Lancet* article, the anti-vaccination movement has been present since before Edward Jenner developed the first vaccine.

This literature review integrates the history of vaccine development and policy with the anti-vaccine movement and provides an overview of previous research examining the anti-vaccination movement on social media. While this review is not intended to be comprehensive, it does aim to highlight major events that place the current anti-vaccination activities in historical context.

2.1 History of the Anti-Vaccination Movement

2.1.1 Variolation

For centuries, smallpox devastated societies around the globe. Its introduction by conquistadors in the Western Hemisphere is believed to have been instrumental in the fall of the Aztec empire, and during the 18th century in Europe, nearly 400,000 people died each year from the disease (Barquet & Domingo, 1997). Variolation, or the inoculation of non-immune individuals

with pustules from a current victim of smallpox, may have been practiced in China as early as 1000 CE (Kinch, 2018). Variolation resulted in individuals contracting a mild form of the disease, with a case-fatality rate approximately 10 times less than naturally-contracted smallpox (Riedel, 2005). The process gained the attention of Lady Montagu, wife to the British ambassador to the Ottoman Empire. In 1718, she had her son inoculated by a Greek woman, and upon returning to Britain she advocated widely for the procedure (Kinch, 2018). Initially, the medical community was resistant, viewing the procedure as "Eastern medicine" (Kinch, 2018). However, due to the advocacy of Lady Montagu, the Princess of Wales, and several members of the Royal College of Physicians, the use of variolation became widely adopted by wealthy and educated segments of the population (Kinch, 2018).

In 1721 a smallpox epidemic occurred in Boston, affecting half of the city's 12,000 citizens (Beall OT, 1954). As the epidemic began, the Reverend Cotton Mather reached out to the medical community about variolation. Only one physician, Dr. Zabdiel Boylston, was receptive to the idea (Niederhuber, 2014). Opposition to the variolation program was led by Dr. Williams Douglass, one of the few physicians at the time to actually hold a medical degree. In addition, Benjamin Franklin's brother, James Franklin, launched *The New England Courant*, a newspaper devoted to countering variolation (Niederhuber, 2014). This was perhaps one of first reported instances of tabloid journalism, and it set the stage for the continued use of mass media to amplify anti-vaccination sentiment.

Similar to the anti-variolation arguments in Britain at the time, opponents in Boston expressed concern about variolation as "Eastern medicine" (Niederhuber, 2014). Opponents of variolation also expressed concerns about safety and claimed that variolation violated religious law (Niederhuber, 2014). At one point, a protestor launched a grenade through Mather's bedroom

window, with a note that read, “COTTON MATHER, you Dog. Dam You: I’ll inoculate you with this, with a Pox to you” (Kinch, 2018, p. 25). However, Mather and Boylston continued to inoculate individuals. They also conducted a statistical analysis and found that the case-fatality rate among variolated individuals was seven times lower than those who contracted the disease naturally (Beall OT, 1954). These data quieted opposition and the practice became more widely accepted. Furthermore, this data-driven effort by Cotton Mather influenced the rapid adoption of variolation in both Europe and the British colonies during the latter half of the 18th century (Riedel, 2005).

2.1.2 The Smallpox Vaccine

Based on the observation that dairymaids who contracted cowpox were then immune from smallpox, Edward Jenner hypothesized that deliberately inoculating an individual with cowpox could provide protection against smallpox (Riedel, 2005). Thus, in 1796, he collected matter from the cowpox lesions of a dairymaid and inoculated an 8-year old boy. Although the boy developed a mild fever and aches, when Jenner inoculated him with matter from a smallpox lesion three months later, the boy did not develop smallpox (Riedel, 2005). This led Jenner to conclude that his procedure had been effective, and in 1797 he coined the term “vaccination” when describing the procedure in a small, self-published booklet (Riedel, 2005).

By 1800, the procedure had spread throughout Europe, and about 100,000 people had been vaccinated (Barquet & Domingo, 1997). In 1840 Great Britain banned the practice of variolation, and in 1853 began mandating vaccination for infants up to 3 months of age. In 1867, this mandate was extended to 14 years of age with cumulative penalties for noncompliance (Durbach, 2000). In response to these laws, in 1853 the Anti-Vaccination League formed in London, and in 1867

the Anti-Compulsory Vaccination League of Great Britain formed with a mission focused on infringement of personal liberty and freedom of choice (Wolfe & Sharp, 2002). One of the leaders of this movement, William Tebb, stoked anti-vaccination sentiment by using false data that purported that smallpox vaccinations had killed more than 48,000 people in England and Wales (Kinch, 2018).

Following an anti-vaccination demonstration in Leicester that attracted more than 100,000 people, in 1885 Great Britain appointed a royal commission to investigate smallpox vaccination safety and efficacy (Wolfe & Sharp, 2002). There was some legitimacy to these concerns about safety because production was largely unregulated (Kinch, 2018). The commission released a report in 1896 supporting the recommendation for smallpox vaccination; however, the report recommended the abolition of cumulative penalties as a way to appease the anti-vaccination community. In 1898, Parliament passed a new Vaccination Act that eliminated cumulative penalties and allowed parents who did not believe in the safety or efficacy of vaccines to obtain an exemption (Wolfe & Sharp, 2002).

In 1800, U.S. President Thomas Jefferson established the National Vaccine Institute and appointed Dr. Benjamin Waterhouse as vaccine agent (Barquet & Domingo, 1997). In 1813, the U.S. Congress passed the Act to Encourage Vaccination. As part of this act, Dr. James Smith was appointed national vaccine agent and maintained a supply of cowpox scabs to mail around the country (Lanzarotta & Ramos, 2018). In 1822, Dr. Smith mistakenly mailed smallpox scabs as opposed to cowpox, resulting in his dismissal as U.S. vaccine agent and repeal of the act (Lanzarotta & Ramos, 2018). Although smallpox vaccination continued in the U.S. throughout the 19th century, it did so in a decentralized manner.

In 1809, Massachusetts became the first state to require proof of smallpox vaccination for children to attend school, and other states soon followed suit (Kinch, 2018). In fact, vaccination in the early 19th century proved so efficacious at controlling outbreaks that, due to complacency, vaccination levels declined by mid-century (Wolfe & Sharp, 2002). This caused a resurgence of smallpox in the 1870s, which prompted increased efforts by state and local governments to enforce existing vaccination laws. These efforts, combined with the 1879 visit of William Tebb, motivated the formation of the Anti-Vaccination Society of America (Wolfe & Sharp, 2002). Regional leagues began popping up around the country as well, and these leagues were successful in repealing compulsory vaccination laws in six states (Wolfe & Sharp, 2002). In the Midwest, Lora Cornelia Little, whose son Kenneth died in 1896 a year after receiving his smallpox vaccine, began a passionate campaign against vaccines using her son as an example and appealing to growing concerns about state overreach (Kinch, 2018). She used the *Truth Teller*, a periodical focused on homeopathy and alternatives to medical interventions, to promote her claims (Kinch, 2018). For example, she wrote an article titled "Know the Facts About Vaccination" that included false statistics and testimony from non-medical professionals decrying vaccine safety (American Medical Association Propaganda Department, 1922). She also promoted mail-order treatments for a variety of medical conditions ranging from diphtheria to writer's cramp (American Medical Association Propaganda Department, 1922). In addition, John Pitcairm Jr., the founder of Pittsburgh Plate Glass and an avid believer in homeopathy, used his finances and influence to bring credence to the anti-vaccination movement and to spread its message (Kinch, 2018).

Despite the growth of the anti-vaccination movement, by the end of the 19th century smallpox in the U.S. was largely restricted to the urban poor (Kinch, 2018). Unfortunately, actions taken to try to improve vaccination among this population sometimes fueled anti-vaccination

beliefs. For example, during a smallpox outbreak among the homeless in 1893–1894 in New York City, individuals trained to give vaccines were paid 30 cents for each person they vaccinated, resulting in instances of vaccinating the same person multiple times to make a profit (Kinch, 2018). This incident lent support to claims by anti-vaccine advocates that the primary motive behind vaccination was profit as opposed to health.

In 1902, an outbreak of smallpox in Cambridge, Massachusetts, prompted the city to enforce the state law requiring vaccination of all residents (Parmet, Goodman, & Farber, 2005). When Reverend Henning Jacobson refused to be vaccinated, he was convicted and fined (Parmet et al., 2005). In 1905, his case, *Jacobson v. Massachusetts*, was heard by the U.S. Supreme Court. The Court upheld Massachusetts' mandatory vaccination law, writing that states may limit individual freedoms in the name of public health (Parmet et al., 2005). This ruling was followed in 1922 by *Zucht v. King*, in which the Supreme Court upheld a San Antonio, Texas ordinance requiring school children to be vaccinated against smallpox. Writing for the majority, Justice Louis Brandeis cited the previous ruling in *Jacobson v. Massachusetts*, and stated how the Court "had settled that it is within the police power of a state to provide for compulsory vaccination" (Brandeis, 1922).

In 1948, the success of the smallpox vaccine in developed countries prompted the World Health Assembly within the World Health Organization (WHO) to formally issue a proclamation to eliminate smallpox from the Earth (Kinch, 2018). Throughout the 1960s and 1970s, the WHO launched a coordinated, global effort, and in 1977 the last naturally acquired case of smallpox occurred in Somalia (Hajj Hussein et al., 2015). In 1980, the World Health Assembly certified the world to be free of naturally occurring smallpox, marking the first and only instance of global

eradication of an infectious disease through vaccination (The Immunization Action Coalition, 2013).

2.1.3 The Polio Vaccine

In the first half of the 20th century, epidemics of poliomyelitis were regular, annual occurrences with up to 20,000 cases of paralytic polio reported in the U.S each year. On April 12, 1955, the Salk polio vaccine, which utilized a formalin-inactivated virus (IPV), was declared safe and effective and licensed following a placebo-controlled trial (Offit, 2005). The vaccine drastically reduced the instance of paralytic polio, from 13.9 cases/100,000 in 1954 to 0.8 cases/100,000 in 1961 (Baicus, 2012). However, two weeks after mass vaccination began in 1955, five children became paralyzed after receiving the polio vaccine (Offit, 2005). An investigation found that each of these children had received a vaccine produced at Cutter Laboratories in which the virus had not been properly inactivated (Offit, 2005). Although the vaccine was immediately recalled, 380,000 individuals had already been vaccinated from this batch, and ultimately 94 individuals and 166 of their close contacts developed polio due to this inactivation failure (Baicus, 2012).

Following this incident, the National Institutes of Health (NIH) expanded its division of Biologics Control, and later that year, Congress passed the Polio Vaccination Assistance Act, marking the first federal involvement in immunization since the early 1800s (The Immunization Action Coalition, 2013). Although the Salk vaccine proved to be very effective at curbing polio, the Cutter incident eroded trust in the pharmaceutical industry.

In 1963, the Sabin polio vaccine, a live-attenuated vaccine that could be given orally (OPV), was licensed (Baicus, 2012). The OPV was quickly adopted by the U.S. and countries

around the world due to lower cost, ease of administration, and development of better intestinal immunity (Bandyopadhyay, Garon, Seib, & Orenstein, 2015). In rare instances, individuals developed vaccine-associated paralytic polio following administration of the OPV. The live virus can also mutate, leading to polio outbreaks from altered viruses. Thus, in 1997 the CDC recommended switching back to the IPV vaccine (Baicus, 2012). Globally, the WHO has also advocated for the use of the IPV, although OPV is still used for routine immunization (Baicus, 2012).

In 1994, the WHO declared the Western Hemisphere polio free, followed by Europe in 2002 (The Immunization Action Coalition, 2013). In 1988, the World Health Assembly passed a resolution to globally eradicate polio by the year 2000, but this goal has yet to be achieved (The Immunization Action Coalition, 2013). As of 2015, wild-type polio only existed in Pakistan, Nigeria, and Afghanistan. Globally, in 2012–2013 there may have been more cases of vaccine-related polio paralysis from OPV than wild-type polio (Bandyopadhyay et al., 2015).

Unfortunately, vaccine-related polio paralysis and infection from altered viruses have fueled reports from the anti-vaccine community that polio is actually caused by the vaccine, as opposed to a virus (Dutta, 2008). Moreover, in developing countries, mistrust of vaccines is often tied to theories of the "Western plot" to sterilize non-White communities (Warraich, 2009). Religious opposition by Islamic fundamentalists has thwarted polio vaccination efforts in Pakistan, Afghanistan, and Nigeria (Warraich, 2009). Workers have been beaten or even killed, as religious leaders spread claims that the vaccines are contaminated with HIV or chemicals being used to sterilize the population (Warraich, 2009).

2.1.4 The Diphtheria, Tetanus, and Pertussis (DTP) Vaccine

In the 1940s, the diphtheria, tetanus, pertussis (DTP) vaccine, which combined diphtheria and tetanus toxoid with the whole-cell pertussis vaccine, came into widespread clinical use (The Immunization Action Coalition, 2013). By the 1970s, concerns about potential adverse reactions to the vaccine, particularly related to the whole-cell pertussis formulation, reached a tipping point in Great Britain and Japan. In Great Britain, these concerns were fueled by the 1974 publication of a case series that described over 30 children with severe neurological impairment following DTP immunization and the subsequent media attention on stories of children with profound disability that parents believed were caused by the vaccine (Baker, 2003). In 1975, concerned parents in Great Britain joined together to form the Association of Parents of Vaccine-Damaged Children (Baker, 2003). Overall, confidence in administering the vaccine decreased: a 1977 survey revealed almost half of general practitioners were unsure about giving the vaccine unless a parent specifically requested it (Baker, 2003). As a result, vaccination rates plummeted, and in the late 1970s there were 3 epidemics of pertussis in Great Britain.

Although the Joint Committee on Vaccination and Immunization affirmed the safety of the vaccine in 1974, initially the British government did nothing to restore public confidence (Baker, 2003). It was not until 1982 that public health officials used media channels to promote a major immunization campaign. As a result of this campaign, newspapers such as the London *Times* increased their coverage of the recent pertussis epidemics with headlines such as “more babies die” and “whooping cough cases at new record level” (Baker, 2003). This shift, from emotionally charged headlines about the potential dangers of the DTP vaccine to emotionally charged headlines about the dangers of pertussis, was likely influential at increasing immunization rates (Baker, 2003). However, it was met by strong resistance from the anti-vaccination community, who

accused the media of fear mongering and biased coverage (Baker, 2003). Similarly, in 1974, the Japanese media intensified reports of two infants who tragically died after receiving the DTP vaccine (Kinch, 2018). Although mandated pertussis vaccination had been extremely successful in curbing the disease—with no childhood deaths from pertussis in Japan in 1972—the subsequent uproar caused the Japanese government to suspend mandatory pertussis vaccination (Kinch, 2018).

By the late 1970s, the anti-DTP movement gained global traction, spreading to the United States, Soviet Union, and Australia (Baker, 2003). In the U.S., concern over the vaccine was amplified by a 1982 Washington, D.C., television station broadcast titled *DPT: Vaccine Roulette*, which featured young children with severe neurological impairments purportedly caused by the vaccine (Baker, 2003; Kinch, 2018). When concerned parents contacted the station following the broadcast, they were provided with the phone numbers of other individuals who called in, effectively igniting a grass-roots movement (Kinch, 2018). Following this broadcast, Dr. Harris Coulter and Barbara Loe Fisher founded the National Vaccine Information Center. Although the name of this organization made it sound unbiased, its purpose was to disseminate information that supported the growing anti-vaccination movement (Kinch, 2018). A few years later, Dr. Coulter and Ms. Fisher published *DPT: A Shot in the Dark,* which used heart-wrenching anecdotes to feed concerns over the DTP vaccine (Kinch, 2018).

Overall, the U.S. medical community remained in support of vaccination. Unfortunately, many physicians were caught off guard by the rapidly increasing resistance and were not sufficiently prepared with the objective facts and skills needed to addresses the complexity of the risks and benefits of the DTP vaccine (Kinch, 2018). Consequently, the American Academy of Pediatrics, the American Medical Association, and the CDC launched an aggressive media campaign that helped steady immunization rates (Baker, 2003).

The major consequence in the U.S. was a significant rise in litigation. By 1986, there were over 250 annual lawsuits related to the DTP vaccine, in contrast to only 2 lawsuits in 1978 (Freed, Katz, & Clark, 1996). Despite numerous population-based studies that found no link between the vaccine and neurological events, this stream of lawsuits led two of the three manufacturers of the vaccine to cease production, resulting in a vaccine shortage (Freed et al., 1996). In response to both concerns about vaccine shortages and growing parental activism, Congress passed the National Childhood Vaccine Injury Act in 1989, which established the Vaccine Adverse Event Reporting System (VAERS), the National Vaccine Injury Compensation Program (NVICP), and the National Vaccine Program Office (Mariner, 1992). The VAERS allows health professionals and members of the general public to submit reports describing adverse reactions to vaccines, and the NVICP provides compensation for individuals injured by vaccinations on a "no fault" basis (Centers for Disease Control and Prevention, 2015). The National Childhood Vaccine Injury Act also mandated promotion of safer vaccines, which allowed the NIH to sponsor multiple clinical trials of an acellular pertussis vaccine. This accelerated the development of the DTaP (the "a" stands for "acellular") vaccine, which was licensed in 1991 by the U.S. Food and Drug Administration (FDA: Fine, 2003)

The National Childhood Vaccine Injury Act also commissioned the Institute of Medicine (IOM) to review data on adverse vaccination events. In 1991 and 1994, the IOM released two comprehensive reviews on adverse events anecdotally tied to the DTP and MMR vaccines. The reports found insufficient evidence to indicate a causal relationship between vaccines and the vast majority of adverse events, specifically regarding the pertussis vaccine and neurological damage (Baker, 2003; Freed et al., 1996). In 2011, the IOM issued another report concluding that few health problems are caused by vaccines (The Immunization Action Coalition, 2013).

2.1.5 The MMR Vaccine

In 1971, the combined measles, mumps, rubella (MMR) vaccine was licensed by the FDA (Hajj Hussein et al., 2015). In the 1980s, concerns arose over a possible link between the Urabe strain of mumps vaccine virus and aseptic meningitis. The 1994 IOM review noted above concluded that there may be evidence for this association, and in the 1990s Japan, Canada, Great Britain, and the United States began to use a MMR vaccine with a different strain of mumps vaccine virus (Fullerton & Reef, 2002).

Concerns over the MMR vaccine were dramatically magnified in 1998, when Andrew Wakefield claimed to have uncovered a link between the vaccine and autism (Hajj Hussein et al., 2015). In his paper, published in the *Lancet*, Wakefield described 12 children who developed symptoms of autism following MMR vaccination (Hajj Hussein et al., 2015). Investigative journalism by Brian Deer revealed numerous methodological problems with the manuscript, as well as two major conflicts of interest that Wakefield failed to disclose: (1) he was being financed by a British attorney who was developing an MMR vaccine lawsuit, and (2) he had filed for patents to introduce his own MMR vaccine as an alternative (Deer, 2011). In 2010, the *Lancet* publicly retracted the paper (Deer, 2011), but the consequences lasted. Wakefield's claims had been amplified by television interviews and publicity aggressively encouraged by his employer. Furthermore, unlike the DTP controversy, which took years to spread globally, the Internet facilitated the rapid transmission of Wakefield's claims (Kinch, 2018).

Despite being stripped of his medical license due to ethical violations, Wakefield continued to aggressively tout his opinions and findings. He wrote a book, gave dozens of public lectures, and developed a following particularly among wealthy Americans and celebrities including actress and model Jenny McCarthy and actor Charlie Sheen, both of whom have children with autism

(Kinch, 2018). In 2016, Mr. Wakefield wrote and directed the documentary *Vaxxed* about his claims around harms of vaccination. Initially scheduled to be screened at the Tribeca film festival, outrage from other filmmakers and the medical community caused the founder of the festival, Robert DeNiro, to withdraw the film (Kinch, 2018) (p. 241). Nonetheless, Wakefield moved to Texas and began a traveling tour of the documentary.

Moreover, in 1999 the U.S. government released a report which suggested that thimerosol, a preservative used in some vaccines, might expose infants to more mercury than previously thought (Gross, 2009). Thimerosol is not used in any formulation of the MMR vaccine, but the combination of the Wakefield article and this report ignited the theory that autism might be related to vaccine-induced mercury exposure. Jenny McCarthy became particularly vocal about this theory and spearheaded the "Green our Vaccines" movement, which advocated for the removal of "toxins" from vaccines (Stern & Markel, 2005). Media outlets again played a prominent role in disseminating this misinformation. For example, in 2008 McCarthy appeared on CNN for a vaccine-autism "debate" to promote her claim that her son's autism was due to mercury in vaccines; however, no scientists were present to provide the perspective of the scientific and medical community (Gross, 2009).

2.1.6 The HPV Vaccine

In 2006, the FDA approved Gardasil, the first vaccine specifically designed to prevent cancer by protecting against four of the most prevalent strains of HPV (types 6, 11, 16, and 18; Brookes, 2016). In 2014, the FDA approved Gardasil 9, which protects against five additional strains of the virus (Brookes, 2016). In the U.S., routine HPV vaccination is recommended for girls and boys ages 11–12, and females and males ages 13–26 who have not been vaccinated

previously (Markowitz et al., 2014). On October 5, 2018, the FDA approved the vaccine for men and women ages 27–45 (Grady & Hoffman, 2018). Despite evidence supporting the safety and efficacy of the vaccine, vaccination rates among adolescents remain low (Walker et al., 2018).

A 2014–2015 survey found that 28% of U.S. parents reported they had "refused or decided not to get" the HPV vaccine for their child, and 8% reported they had "delayed or put off the HPV vaccine." In this sample, refusal of the vaccine was associated with lower perceived vaccine effectiveness and higher perceived harms from the vaccine (Gilkey, Calo, Marciniak, & Brewer, 2017). Specifically, parents expressed concern about long-term side effects and an increased likelihood of their child becoming sexually active after receiving the vaccine (Gilkey et al., 2017). Previous research suggests that other barriers to action include receiving misinformation from notable public figures, lack of access to healthcare, and concern that the vaccine will increase the likelihood of risky sexual behavior (Perkins, Pierre-Joseph, Marquez, Iloka, & Clark, 2010). Despite multiple studies that have found no association between the HPV vaccine and paralysis, autoimmune disorders, or postural orthostatic tachycardia syndrome, concerns about safety persist (Arana et al., 2017; Arnheim-Dahlstrom, Pasternak, Svanstrom, Sparen, & Hviid, 2013; Cartmell et al., 2018). These fears are often stoked by media coverage of adolescents supposedly harmed by the vaccine (Dunn et al., 2015; Keelan et al., 2010).

In Japan, media coverage and policy surrounding the HPV vaccine have followed an almost identical course to that of the DTP vaccine 40 years prior. In 2010, Japan made the HPV vaccine free for girls ages 12–16 years, and in April 2013 the government added the vaccine to the country's recommended immunization schedule (Hanley, Yoshioka, Ito, & Kishi, 2015). Unconfirmed reports of side effects by the media led the government to withdraw its recommendation for the vaccine just three months later (Hanley et al., 2015). Following this

change, the HPV vaccination rate for 12-year-old girls in Japan fell from 70% in 2012 to just 0.1% in 2014 (Tanaka, Ueda, Yoshino, & Kimura, 2017). Despite the Vaccine Adverse Reactions Review Committee's 2014 conclusion that there was no evidence to support a causal relation between the HPV vaccine and reported adverse reactions, the Japanese government has yet to reinstate the vaccine into the national immunization program (Hanley et al., 2015). This is potentially problematic, as in the absence of a formal recommendation by the government the out-of-pocket costs for patients are prohibitively expensive. Additionally, many providers are hesitant to give the vaccine unless a parent asks directly for it (Sawada et al., 2018).

2.1.7 Current Vaccination Policy in the U.S.

In 1995, the Immunization Practices Advisory Committee, the American Academy of Pediatrics, and the American Association of Family Physicians issued the first unified vaccination schedule (The Immunization Action Coalition, 2013). Since then, the schedule has been updated annually.

Acknowledging the value of the childhood immunization schedule in achieving herd immunity and disease prevention, al l 50 of the United States have passed legislation requiring children to be up to date on immunizations in order to attend school (E. Wang et al., 2014). Herd immunity 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 (E. Wang et al., 2014). The threshold for herd immunity depends on the transmissibility of the infectious agent, but is between 80%–94% of a population for current vaccine-preventable diseases (Doherty, Buchy, Standaert, Giaquinto, & Prado-Cohrs, 2016). However, only 70% of children ages 19–35 months receive all recommended immunizations, and

over the past decade there has been a rise in rates of nonmedical exemptions from school immunizations requirements (Omer et al., 2012). All but three states—California, West Virginia, and Mississippi—allow exemptions for religious or other personal beliefs (National Conference of State Legislatures, n.d.). This is potentially problematic given recent research suggesting that states with higher rates of nonmedical exemptions have lower MMR vaccination coverage (Olive et al., 2018). For example, the California law prohibiting non-medical exemptions was passed in response to a 2015 measles outbreak at Disneyland, in which 45% of children treated for measles were unvaccinated (Zipprich, J., Winter, K., Hacker, J., Xia, D., Watt, J., Harriman, 2015).

2.2 Anti-Vaccination on Social Media

2.2.1 Anti-Vaccination Information Online

As noted, the news media have often played a substantial role in propagating anti-vaccination sentiment. However, the advent of the Internet, specifically social media, has facilitated the spread of information including anti-vaccination material. Since the early 2000s, the Internet has become a major source for misinformation on vaccines (Betsch et al., 2012; Brewer et al., 2017; Ward et al., 2016). This is especially concerning given previous research that found viewing a website providing vaccine-critical information for only five to 10 minutes increases the perception of risks associated with vaccinating and decreases intention to vaccinate (Betsch et al., 2010).

Previous work examining social media and anti-vaccination rhetoric has mainly focused on Twitter (Chakraborty et al., 2017; Du et al., 2017; Dunn et al., 2015, 2017; Kang et al., 2017;

Massey et al., 2016; Radzikowski et al., 2016; Salathé & Khandelwal, 2011; Shapiro et al., 2017; Tomeny et al., 2017). For example, an examination of the sentiment of articles posted in vaccine-related tweets (Twitter-based messages, which are a maximum of 280 characters) found differences in the framing of anti-vaccination as compared to pro-vaccination messages. In this study, articles with negative sentiment (i.e., anti-vaccination) framed messages around institutional distrust in organizations such as the CDC and the pharmaceutical industry, and centered on children (Kang et al., 2017). This is in contrast to the positive (i.e., pro-vaccination) articles, in which messages were related to trust in scientific evidence and focused on parents (Kang et al., 2017). Other studies have specifically examined sentiment toward HPV on Twitter, and these studies have found associations between the release of mainstream news articles about the HPV vaccine and Twitter content and sentiment (Chakraborty et al., 2017; Du et al., 2017).

While most previous studies have examined content on Twitter, several studies have examined other social media sites such as MySpace, Pinterest, YouTube, and Facebook (Ache & Wallace, 2008; Faasse et al., 2016; Guidry, Carlyle, Messner, & Jin, 2015; Keelan et al., 2010; Nicholson & Leask, 2012; Orr et al., 2016; Smith & Graham, 2017; Venkatraman et al., 2015). On MySpace, researchers in 2008 found 303 blogs related to HPV and HPV vaccination. The researchers classified 43% of these blogs as negative based on their use of press releases from vaccine-critical organizations to support their views that vaccination is dangerous (Keelan et al., 2010). When gender could be identified, 71% of bloggers were women, although 60% of blogs critical of immunization were authored by men (Keelan et al., 2010). An analysis of 800 “pins” on Pinterest related to four vaccination-related keywords found 74% of these pins were anti-vaccine, and only 3.7% of pins linked to an external website directed the user to an official medical website (Guidry et al., 2015). On YouTube, an analysis of videos related to HPV found only about 25%

portrayed HPV vaccination in a negative manner (Ache & Wallace, 2008). A similar analysis of YouTube videos in the context of vaccines and autism found that anti-vaccination videos on YouTube, compared with pro-vaccination videos, were longer and more likely to feature speakers with medical degrees (Venkatraman et al., 2015). This study also found anti-vaccination videos on YouTube made appeals to "naturalism," emphasized the right to refuse vaccines, and emphasized the perceived need for more time between administration of different vaccines (Venkatraman et al., 2015).

With regard to Facebook, currently the most popular social media platform among those who use social media (Statista, 2018), previous studies have examined the content of posts and comments on public pages and/or groups. Two studies examined dialogue on Facebook in response to a specific vaccine-related event. The first analyzed posts in a Facebook forum following an Australian documentary about vaccines and autism and found emotive appeals may override epidemiological evidence (Nicholson & Leask, 2012). These researchers also noted that posts seem to indicate that parents see the risk of autism as greater than the risk of infectious disease prevented by vaccines (Nicholson & Leask, 2012). The second study analyzed content from Israeli Facebook groups following the 2013 polio outbreak in Israel. Those opposed to the vaccination campaign expressed distrust in the concept of herd immunity, concerns about the safety of the oral polio vaccine, and distrust in the Ministry of Health (Orr et al., 2016). Only about 13% of commenters in the group were physicians, although these individuals were responsible for 40% of posts (Orr et al., 2016).

Another study analyzed 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 (Faasse et al., 2016). These findings are notable because the content and tone of these anti-vaccination comments may be preferentially appealing to vaccine-hesitant parents (Faasse et al., 2016).

Finally, another study analyzed 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 (Smith & Graham, 2017). The researchers also found that approximately 70% of users were female and that posts were often shared outside of the group, suggesting a broader reach beyond membership of the group (Smith & Graham, 2017).

Therefore, it appears that common techniques used on social media by those opposed to vaccines include skewing scientific information, shifting hypotheses, engaging in political arguments centered on parental freedom of choice, promoting untrustworthiness of the medical community, posting about conspiracy theories concerning censorship by the government and pharmaceutical companies, and sharing personal narratives related to negative vaccination experiences (Kata, 2012; Ward et al., 2016). In addition, by increasing the ease of finding like-minded people, social media may magnify anti-vaccination rhetoric and serve as a catalyst to facilitate anti-vaccination behavior (Brewer et al., 2017; Dredze et al., 2016; Dunn et al., 2017; Tomeny et al., 2017).

However, research has yet to examine multiple sociodemographic characteristics of individuals who post anti-vaccination content and the information they convey on their individual social media pages. This represents an important gap in the literature, because examining data at the level of the individual may facilitate practical interventions by generating information that will help preventive medicine practitioners tailor messaging to specific groups of individuals.

3.0 Journal Article

3.1 It's Not All About Autism: The Emerging Landscape Of Anti-Vaccination Sentiment On Facebook

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3.2 Abstract

Introduction. Social media may be fueling the spread of anti-vaccination messaging, which can facilitate anti-vaccination behavior. 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 analyzed publicly-available content using quantitative coding, descriptive analysis, social network analysis, and an in-depth qualitative assessment. Data were collected and analyzed in 2018. 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: (1) liberty, (2) naturalness, (3) illness, and (4) conspiracy. For example, a comment representative of conspiracy is that poliovirus does not exist and pesticides caused clinical symptoms of polio. An example, from the naturalness sub-group is that eating yogurt cures HPV. Deeper qualitative analysis of all 197 individuals' profiles found that these individuals also tended to post material against other oft-debated health-related practices, including water fluoridation and circumcision.

Conclusions. Social media outlets may facilitate anti-vaccination connection and organization. Arguments against vaccination are diverse but remain consistent within sub-groups of individuals. It would be valuable for prevention professionals to leverage social networks to deliver more effective, targeted messages to different constituencies.

KEYWORDS: Facebook, social media, anti-vaccination, health communication

3.3 Introduction

High levels of vaccination have substantially reduced the rate of vaccine-preventable diseases and early deaths.[1,2] However, an increasing number of individuals refuse vaccines for themselves and/or their children.[3–5] For example, during a 2015 outbreak of measles in California, 45% of individuals treated were unvaccinated.[6]

The typical threshold for herd immunity is between 80%-90% of a population.[7] However, only 70% of children 19-35 months receive all recommended immunizations, and over the past decade there has been a substantial rise in rates of nonmedical exemptions from school immunization requirements.[8]

Unsubstantiated safety concerns presented as scientific information are readily available on the Internet.[7,9,10] Previous research suggests that viewing a website providing vaccine-critical information for just 5 to 10 minutes increases the perception of risk of vaccinating and decreases intention to vaccinate.[11]

The majority of work examining anti-vaccination rhetoric on social media has been conducted using Twitter.[12–21] However, it would be valuable to also investigate spread via Facebook, which has a broader reach. As of April 2018, Facebook had 2.2 billion monthly active users, and approximately 40% of United States (U.S.) adults report using Facebook as a resource for health information.[22,23]

In addition, while prior research has examined themes of anti-vaccination posts and comments on social media,[2425–31] more research is needed to characterize the individuals who publish anti-vaccination content.[32] Examining data at the level of the individual will facilitate practical interventions by generating information that will help preventive medicine practitioners tailor messaging to specific groups of individuals.

Finally, prior research has not sufficiently leveraged social network analysis (SNA) to better characterize how the Internet facilitates the transmission of vaccine misinformation.[32] SNA can be valuable to understanding actions and connections within online communities,[33] and networks can help highlight important people or topics.[34]

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 SNA 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.

3.4 Methods

3.4.1 Sample Selection

Our data set consisted of 197 individuals on Facebook who posted anti-vaccination comments on a prominent local pediatric clinic's Facebook page. These individuals posted comments in response to a 90-second video promoting the Human Papilloma Virus (HPV) vaccine as an anti-cancer vaccine, as recommended by the United States (U.S.) Centers for Disease Control and Prevention (CDC).[35] 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 no grip on reality; you have been brainwashed"). 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, in order to more precisely investigate the spread of anti-vaccination beliefs across Facebook.[22,36]

3.4.2 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. We selected this time period because of the posting pattern noted above. 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 κ=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 profiles in order to feasibly conduct in-depth qualitative assessment. This resulted in our final dataset of 197 individual Facebook profiles.

Specific codes were determined using a hybrid process. Some codes were adapted from previous analyses of anti-vaccination Internet content[25,37] and themes previously identified in the literature, such as support for marijuana legalization and belief in conspiracy theories.[38–40] We supplemented and refined these codes through an inductive approach that involved independent double-coding and identifying exemplar posts (**Table 1**).[41] A final codebook was then codified, presenting clear definitions and examples of each of the 26 codes.

Using this codebook, two researchers independently examined all publicly available posts on the individual's Facebook page over the course of two years (2015-2017).

Coder training and equilibration proceeded as follows. After double-coding 5% of the individuals (n=8), the two researchers met to discuss differences and areas in the codebook needed clarification. After three iterations of this process, coders double-coded 20% of the subsample (n=40). For all categories interrater reliability was considered good to excellent,[42,43] with Cohen's κ ranging 0.71-1.00 and Krippendorf's α ranging 0.72-1.00. Because of this strong agreement, the two coders then independently single-coded the remaining 157 individuals.

Data were collected and analyzed in 2018. All study procedures were approved by the University of Pittsburgh Institutional Review Board (PRO17120151).

3.4.3 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 if in the U.S. or by country for a non-U.S. location. 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.

3.4.4 Analysis

First, we conducted a descriptive analysis of all sociodemographic and anti-vaccination variables. Of the 197 individuals, 116 had at least one relevant anti-vaccination post during the time frame under analysis. We calculated basic descriptive statistics using Stata 14.[44]

Second, we conducted SNA using the Gephi software package[45] to help understand the relationships between individuals and anti-vaccination topics. 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 artifacts (e.g. anti-vaccination topics).[46] We used modularity to identify potential clusters that could demonstrate how discussion topics were inter-connected.[47]

Third, two researchers independently conducted a qualitative analysis of posts between 2015 and 2017 using a grounded theory approach.48 Each researcher developed notes on emergent themes, particularly other topics that appeared frequently alongside anti-vaccination posts. 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.[49]

Table 1 Codebook for Analyzing Facebook Posts.

VARIABLE	DESCRIPTION	EXAMPLE CONTENT
Activism	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	• 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"	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	• 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	Homeopathy as an alternative to vaccines; homeopathy as an alternative to medicine; food as medicine	• Prescription medications just treat disease symptoms, but plant-based diets cure disease • Vitamin B17 cures cancer
Vaccination as genocide	Vaccination used to kill people; vaccination sterilizes people; vaccination of minorities/third world plot to depopulate	• Flu vaccine contains spermicide and is used for population control • Aborticides were found in vaccines that Bill Gates sent to Africa
Moral transgressions	Vaccination is evil	• The Bible does not support vaccination • Forcing vaccination is no different than slavery
Educational material	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	• 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	Vaccines cause rashes, seizures; kids who are not vaccinated get less illness	• 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	Vaccines cause autoimmune diseases, vaccines cause cancer, "evidence" of more vaccines related to higher rates of autoimmune disease and/or cancer	• 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	Vaccination linked to autism	• 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	Vaccines cause death; vaccines cause Sudden Infant Death Syndrome (SIDS)	• Stories of babies who received vaccines and then were found dead in their crib two days later

Table 1 Continued

		• 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 vaccines
Chemicals and additives	Additives in vaccines are dangerous; posts about mercury, aluminum etc; chemicals are dangerous	• 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	Rise in number of vaccines cause of health problems; multiple simultaneous vaccines increase risk	• 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	Parents have the right to choose; against mandatory vaccination	• 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	Pictures of fetuses used for vaccines; posts about cells from aborted fetuses used to grow vaccines	• 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	Pictures or stories about harmed individuals	• 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"	Pictures of big needles/shots; pictures of people getting shots with big needles	• 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	Marijuana should be legal; cannabis oil or marijuana effective at treating illness	• Marijuana is more effective than chemotherapy • Marijuana is a natural plant that can treat cancer, AIDS, pain, seizures, and other illnesses
Other conspiracy theories	Conspiracy related to vaccines; government cover-ups; flat earth conspiracy: JFK assignation conspiracy; 9/11 conspiracy	• 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.

Adapted from Wolfe, Sharp, & Lipsky (2002) and Smith & Graham (2017)

3.5 RESULTS

3.5.1 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 (n=55) identified as supporters of Donald Trump (56%), followed by supporters of Bernie Sanders (11%). Age could only be determined for 2 individuals. Location was mentioned by 136 individuals. The most frequent locations represented were 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 originally posted the pro-vaccination video.

Of the 116 individuals with at least one anti-vaccination post from 2015-2017, posts about "educational material" (73%), "media, censorship, and 'cover up'" (71%), and "vaccines cause idiopathic illness" (69%) were the most commonly posted topics (**Table 2**).

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

3.5.2 Social Network Analysis

A 2-mode network was constructed with 133 nodes, representing 115 people and 18 topics (**Figure 1**). There were 1068 edges, or connections, between people and topics. The network had a density of 0.122, average degree of 8.03, and average path length of 2.11. Modularity analysis found 4 distinct sub-groups. Based on the overarching themes represented, we named these sub-groups (1) liberty, (2) naturalness, (3) illness, and (4) conspiracy.

We also measured betweenness,[50] a measure that identifies all of the shortest paths found between any two nodes in the network. In this network, "vaccination policy is a violation of civil liberties" had the highest betweenness centrality (b=0.135). This means that it was the topic most discussed by people who discuss only one topic.

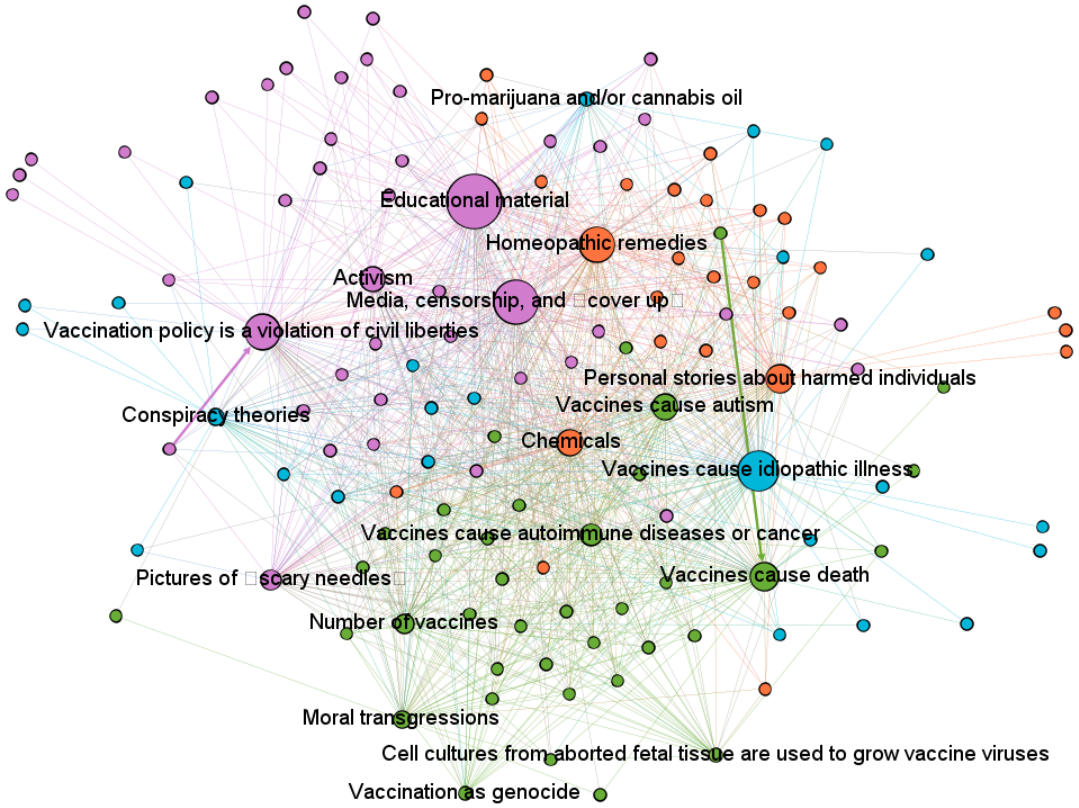

Figure 1 Visualization of the network representing Facebook profiles discussing vaccine topics.

Nodes, or circles, represent profiles and topics of discussion. Edges, or lines, between nodes represent a profile discussing a particular topic. Colors represent 4 different sub-groups: (1) liberty — purple; (2) naturalness — orange; (3) illness — green; (4) conspiracy — blue. Size of the nodes represents degree centrality.

3.5.3 Qualitative Analysis

Assessment of qualitative data revealed that many individuals shared the same anti-vaccination stories, articles, and photos when discussing a particular issue (**Figure 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 posts by these individuals. For example, many individuals consistently posted content related to "naturalness." These individuals also tended to convey attitudes against genetically modified food (anti-GMO), circumcision, and water fluoridation (i.e. added chemicals). Some of these individuals also expressed vegan activism.

Other individuals posted about these topics, but in a way that emphasized the importance of liberty and potential government conspiracies. These individuals also often expressed views against water fluoridation and GMO, but they additionally tended to suggest that government interference might be behind these issues. 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.

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

3.6 Discussion

Systematically assessing individual profiles that express anti-vaccination sentiment on Facebook allowed us to (1) identify sociodemographic characteristics of these individuals, (2) distinguish various anti-vaccination themes represented, (3) understand the relationship between individuals and anti-vaccination topics, and (4) explore other commonly held beliefs expressed by these individuals on Facebook.

Although we focused on comments posted on a local pediatric clinic's Facebook page, we identified individuals from 36 U.S. states and 8 countries, suggesting that, through social media, a local post can easily gain international attention. Thus, social media clearly facilitates connections that were previously unfeasible.

Our findings were consistent with previous research suggesting that the anti-vaccine movement spans the political spectrum.[38,39,51,52] However, some supporters of Donald Trump mentioned supporting him because they believe him to be anti-vaccination, an observation also noted in a recent study examining anti-vaccination tweets.[53]

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. This supports the findings of a recent study suggesting that those who believe they know more than doctors about autism are more likely to endorse vaccine misinformation.[54]

The second most common topic was "media, censorship, and 'cover up.'" Posts in this category quoted from articles implicating that the government, pharmaceutical companies, and/or

physicians consciously and willfully fail to disclose adverse vaccine reactions. These assertions are consistent with vaccine denial as outlined by the World Health Organization.[55] This distrust may explain why providing vaccine-hesitant parents with scientific information about vaccines may actually increase reactance and reduce intention to vaccinate.[56]

Although the anti-vaccine movement has long been tied to concerns around autism,[57] in our sample individuals expressed more concern about vaccines causing other idiopathic illnesses and death from SIDS. Additionally, 49% of posts claimed that vaccines cause autoimmune disorders or cancer. Qualitative analysis found that these posts often cited reputable epidemiological data but through the lens of "science denialism," which suggests that scientific consensus is often the result of conspiracy, using fake experts, referencing only sources that confirm one's beliefs, expecting 100% certain results, and false logic.[58]

For example, many posts included data showing parallels between rates of vaccination and cancer mortality rates. 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.[59] Therefore, dialogue from health professionals about vaccination may need to be updated to reflect these concerns and the ways in which those against vaccination use science denialism.

While arguments propagated against vaccination are diverse, SNA found that topics and people tended to cluster into 4 distinct sub-groups (differentiated by color in **Figure 1**). The "liberty" sub-group emphasized cover-up of "the truth" about vaccines. The "naturalness" sub-group focused on concerns over chemicals in vaccines and the use of homeopathic remedies as an alternative to vaccination. The "illness" sub-group focused on vaccine safety 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; these included that the Earth is flat.

The identification of these sub-groups suggests a valuable opportunity for public health practitioners to leverage social networks to deliver more effective, targeted interventions. For example, one avenue of intervention for the naturalness sub-group could be the development of health communication campaigns that reframe the idea of "purity" and present diseases as "unnatural" and vaccines as "natural."[60] In a similar manner, interventions targeted to the liberty and cover-up 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.[60] Similarly, the presence of distinct sub-groups caution 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.

Qualitative analysis 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 prevention specialists 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.

Interestingly, many posts in our sample were shared from organizations whose names suggest the presentation of unbiased information—such as the "National Vaccine Information Center"—which are in fact overwhelmingly anti-vaccine. Media literacy, which teaches individuals to understand, analyze, and evaluate media messages,[61,62] may provide a framework to help people better decipher this information. More research is needed, however, to explore if media literacy is a successful tool for social media messages about vaccination.

Dredze et al (2016) suggest that effective health communication about vaccines requires not only understanding the various beliefs held by vaccine refusers but also uncovering which persuasive strategies used by them are most effective.[32] Our findings suggest that anti-vaccination individuals on Facebook use factors seen in health and risk communication theory, such as narrative bias, to spread their messages.[55,63] Thus, it may be beneficial for public health and medical professionals to mirror these strategies when designing campaigns to promote vaccination. For example, one possible intervention related to narrative bias could be the use of entertainment narratives. Health storylines on television have been shown to influence viewers' knowledge, perception, and behavior,[64] likely through identification with characters and decreased reactance from transportation into the narrative.[65] Vaccination is in some ways a victim of its own success; as vaccination becomes more commonplace, there are fewer individuals to highlight disease severity. However, storylines that feature characters who are unvaccinated and have serious health problems from a vaccine-preventable disease may effectively counter the anecdotes shared on social media about harmed children.

Finally, it may be valuable for preventive medicine 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, and these individuals often post epidemiological data despite evidence that emotional appeals seem to be more persuasive.[26,28] Our findings could inform the development of toolkits to help clinicians and researchers respond to DAV comments. These tools may increase the ability of scientists and clinicians to counter the spread of scientific misinformation online, which could lead to substantially improved outcomes.

3.6.1 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 still 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.[66] 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.

3.7 Conclusions

Examining the content of individual Facebook profiles posting anti-vaccination content provided valuable insight into sociodemographic characteristics, content of Facebook posts, and how they connect with one another. Individuals from around the globe who are opposed to vaccination are connecting via social media. Current arguments against vaccination are varied but remain consistent within sub-groups of individuals. Moreover, posts by these individuals about vaccination often presented information consistent with characteristics of science denialism. These findings suggest the need for prevention specialists to leverage these social networks to develop and deliver more effective, targeted interventions to different constituencies.

Future research should focus on a more rigorous investigation of the relationship between anti-vaccination topics and other themes associated with science denialism and the effectiveness of interventions targeted to these distinct sub-groups.

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BH conceptualized the study, performed data acquisition, data analysis, wrote the initial draft, revised the article, and read and approved the final version of the manuscript. EF and KC conceptualized the study, assisted with data analysis, revised the article, and read and approved the final version of the manuscript. AS performed data analysis, assisted in writing the initial draft, revised the article, and read and approved the final version of the manuscript. CH and TW conceptualized the study, revised the article, and read and approved the final version of the manuscript. BP assisted with design of the study and data analysis, revised the article, and read and approved the final version of the manuscript.

3.9 References

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4.0 Thesis Conclusions

Systematically assessing profiles of individuals who express anti-vaccination sentiment on Facebook allowed us to (1) identify sociodemographic characteristics of these individuals, (2) distinguish various anti-vaccination themes represented, (3) understand the relationship between individuals and anti-vaccination topics, and (4) explore other commonly held beliefs expressed by these individuals on Facebook. Furthermore, analyzing major events in the history of the anti-vaccine movement alongside these findings provides an opportunity to integrate them into a broader historical framework.

Individuals in our sample mostly identified as female and as parents. Although we focused on those who commented on the Facebook page of a pediatric clinic in Pittsburgh, PA, only five of the 136 individuals who disclosed their location were from Pennsylvania. We identified individuals from 36 U.S. states and eight countries, suggesting that, through social media, a local post can easily gain international attention. Consistent with previous research (Berezow & Campbell, 2012; Centers for Disease Control and Prevention, 2014; Hornsey, Harris, & Fielding, 2018; Lewandowsky, Gignac, & Oberauer, 2013), individuals in our sample also identified with candidates across the political spectrum. Although the majority of profiles for whom political affiliation could be determined were in support of Donald Trump, others supported Bernie Sanders, Jill Stein, or identified as a Libertarian. Our findings suggest that the online anti-vaccine community is diverse geographically and politically, and social media may facilitate connections among these individuals that were previously less feasible.

In our study, the most commonly posted 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 these posts often included text suggesting parents are more informed about vaccines than health professionals. This supports the findings of a recent study suggesting that those who believe they know more than doctors/scientists about autism are more likely to endorse misinformation about a link between vaccines and autism (Motta, Callaghan, & Sylvester, 2018).

The second most common topic was "media, censorship, and 'cover up.'" Posts in this category quoted from articles implicating that the government, pharmaceutical companies, and/or physicians consciously and willfully fail to disclose adverse vaccine reactions. Similar to how the anti-vaccine community in Great Britain accused the media of fear mongering and biased coverage when newspaper headlines focused on pertussis epidemics in the early 1980s, posts in this category also accused the media of being alarmist about outbreaks of disease and not adequately focusing on the dangers of vaccines.

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 and scientific community. This is consistent with the main topics of vaccine denial as outlined by the WHO, most notably questioning the trustworthiness of health authorities (World Health Organization, 2017). This distrust may explain why providing vaccine-hesitant parents with scientific information about vaccines may actually increase reactance and reduce intention to vaccinate (Nyhan, Reifler, Richey, & Freed, 2014).

We also found that many of the "activism" posts we coded opposed California's 2015 law prohibiting nonmedical exemptions for school age children. Despite this opposition, outcomes research suggests the law successfully decreased the percentage of students living in a county with a vaccination rate below 90% (the rate needed for herd immunity from measles) from 33% in 2014

to 1% in 2016 (Olive et al., 2018). Given that individuals who are opposed to vaccination believe the risks to be far greater than the benefits, stricter legal mandates may be necessary to increase immunization rates to levels that are consistent with herd immunity. This method is supported by Rothchild's Behavior Management Model, which posits a legal approach may be necessary to facilitate behavior change when perceived benefits are low and perceived costs are high (Rothschild, 1999).

Many individuals today associate the anti-vaccine movement with concerns about autism (Larson, Cooper, Eskola, Katz, & Ratzan, 2011). However, in our sample more individuals expressed beliefs that vaccines cause idiopathic illness and death (specifically SIDS) as compared to the belief that vaccines cause autism. In addition, 49% of individuals posted that vaccines cause autoimmune disorders or cancer. Qualitative analysis found that these posts often cited reputable epidemiological data but through the lens of "science denialism." Science denialism has several characteristics, including suggesting that scientific consensus is the result of conspiracy, using fake experts, referencing only sources that confirm one's beliefs, expecting 100% certain results, and using false logic (Diethelm & McKee, 2008). Therefore, dialogue from health professionals about vaccination, which often focuses on a perceived link between vaccines and autism, may need to be updated to reflect these other concerns and the ways in which those against vaccination use science denialism.

While arguments against vaccination were diverse, SNA found that topics and people tended to cluster into four distinct sub-groups. The "liberty" sub-group emphasized cover-up of "the truth" about vaccines. The "naturalness" sub-group focused on concerns over chemicals in vaccines and the use of homeopathic remedies as an alternative to vaccination. The "illness" sub-group focused on vaccine safety 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; these included that the Earth is flat. The identification of these sub-groups, each with a different primary rationale for opposing vaccines, suggests a valuable opportunity for public health practitioners to leverage social networks to deliver more effective, tailored interventions.

Qualitative analysis revealed that many individuals against vaccines hold other shared beliefs, such as concerns about genetically modified organisms and water fluoridation. Future research could focus on investigating how these individuals identify themselves (i.e., do they identify more as anti-vaccine, or more as pro-naturalness), and performing further SNA to examine how these profiles connect through these associated themes. In addition, as many of these shared beliefs were often related to concerns about liberty or naturalness, this finding also suggests value in designing interventions that address these broader concerns.

Dredze and colleagues (2016) suggest that effective health communication about vaccines requires not only understanding the various beliefs held by vaccine refusers but also uncovering which persuasive strategies used by them are most effective. Our findings suggest individuals against vaccination use several factors seen in health and risk communication theory to spread their messages on Facebook. Specifically, they makes use of vivid imagery, such as photographs of children and needles, and disseminate personal stories about harmed children (Chen & Dredze, 2018). They also cite sources trusted within the anti-vaccine community (e.g., independently practicing physicians, non-governmental sources) and prime their audience to trust studies that report negative outcomes by highlighting the fact that no medical procedure, vaccination included, is 100% safe (World Health Organization, 2017). They also skew risk perception by emphasizing the lack of individual benefits of vaccines, encouraging distrust of medical and scientific

institutions, and promoting vaccines as a risk of human origin as compared to the natural risk of infectious disease (Covello et al., 2001). Given the effective use of these tactics by the anti-vaccination community, it may be beneficial for public health and medical professionals to mirror these when designing campaigns to promote vaccination.

As discussed, our analysis of individuals who express anti-vaccination sentiment on Facebook suggest the anti-vaccine community is not a homogenous population and social media may be facilitating connections across the globe. These findings also suggest that while arguments against vaccines are diverse, they broadly cluster into concerns related to liberty, naturalness, illness, and/or conspiracy theories. Qualitative analysis revealed that those opposed to vaccination often misrepresent data and skew risk perception when spreading their messages on Facebook.

Previous research suggests that social media may influence the formation of vaccine hesitancy (Betsch et al., 2012; Schmidt, Zollo, Scala, Betsch, & Quattrociocchi, 2018). Integrating the findings from our study into a broader historical framework suggests this influence may be due to social media facilitating the amplification and diffusion of centuries old anti-vaccination arguments and techniques. In the 18th century, many in Europe and the American colonies were against variolation, a precursor to vaccination, because they viewed it as unnatural and as "Eastern medicine" (Kinch, 2018). In the 19th century, opponents of smallpox vaccination frequently cited concerns about civil liberties and safety. Similarly, many individuals in our sample had posts asserting perceived dangers of "Western medicine," that vaccines are not natural, and that mandatory vaccination is a violation of civil liberties. Thus, although arguments against vaccines today may have a slightly different focus, they manifest similarities to arguments from centuries past. Moreover, many of the images that were shared on multiple Facebook profiles in our sample bore a striking resemblance to 1721 anti-variolation headlines in the *New England Courant* and

19th century anti-vaccine newspaper cartoons. The use of fear-evoking images, distortion of data, and personal narratives appears to remain consistent across centuries.

Understanding this history can help public health practitioners more effectively recognize and counter these sentiments. For example, many posts in our sample were shared from the Facebook page for the National Vaccine Information Center. While banning certain organizations like these from creating social media accounts may help curb the spread of this information, knowing that this organization was founded in the 1980s suggests that such an approach may not be effective at countering the anti-vaccination movement more broadly. Furthermore, our analysis of Facebook posts found that many of these individuals often cite historical events such as the Cutter Laboratories IPV inactivation failure when claiming that vaccination is not safe. According to the Trust Determination Model, successful risk communication is facilitated by factors such as caring, honesty, and openness (Peters, Covello, & McCallum, 1997). Thus, it may be effective for public health professionals to be more open about this historical events when discussing risks associated with vaccination (Covello et al., 2001).

In addition to the implications discussed above, these findings suggest several possible avenues for intervention. First, media and health literacy education, which teaches individuals about the effect of mass media on attitudes and behavior (Buckingham, 2003; Hobbs & Frost, 2003), may offer a framework to help people better decipher content on social media related to naturalness, illness, and conspiracy that may influence them not to vaccinate. For example, many posts in our sample included data showing parallels between rates of vaccination and cancer mortality rates. 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 (Jones, Podolsky, &

Greene, 2012). Media and health literacy education, particularly among adolescents and young adults, may provide individuals with the tools necessary to critically examine the presentation of these data and associated claims.

Second, the use of entertainment narratives may be another effective avenue for intervention, particularly with regard to distrust in the medical community and concerns about vaccine safety. Health storylines on television have been shown to influence viewers' knowledge, perception, and behavior (Hoffman, Shensa, Wessel, Hoffman, & Primack, 2017). Social Cognitive Theory suggests characters with whom the viewer identifies are most likely to be influential, and the Extended Elaboration Likelihood Model posits when viewers identify with characters and are transported into the narrative, reactance is decreased because the message is not perceived as an obvious attempt at persuasion (Moyer-Gusé, 2008). Together with the Trust Determination Model, these concepts suggest entertainment narratives related to vaccination may provide a mechanism to reach those who are vaccine-hesitant and distrustful of the scientific community. Furthermore, narratives that feature sympathetic characters who are unvaccinated and suffer consequences from a vaccine-preventable disease could address doubts over the seriousness of vaccine-preventable diseases. These narratives could also focus on concerns other than autism, and may be effective at countering anti-vaccination anecdotes shared on social media.

Third, SNA results and our analysis of the persuasive tactics utilized by individuals who are anti-vaccine suggest more effective dissemination of tailored pro-vaccination messages on social media may be another avenue of intervention. Social marketing uses concepts from commercial marketing in the development of health education programs (Andreasen, 1994). A key component of social marketing is the selection of a carefully chosen target audience, and the development of messages specific to that audience. Each sub-group we identified can be thought

of as a unique target audience, and it may be useful to "market" the behavior of vaccination with messages that specifically address the concerns of that sub-group. For example, messages that reframe the idea of purity and present diseases as disgusting (e.g images of measles virus) and vaccines as triggering one's natural immune system may be effective for the naturalness sub-group (Amin et al., 2017). In a similar manner, messages targeted to the liberty and cover up sub-group could reframe liberty in such a way that vaccinating one's child is seen as a way to break away from the crowd and let the child be free (Amin et al., 2017). Furthermore, dissemination of these messages may be more effective if public health professionals successfully mirror tactics used by the anti-vaccine community, such as emotive appeals (Nicholson & Leask, 2012; Orr et al., 2016).

Fourth, our findings could inform the development of toolkits and a pro-science social media network to help clinicians and researchers respond to distinctly anti-vaccination comments. It may also be beneficial to encourage key social media players such as Facebook and Twitter to address the spread of threatening and/or extremist claims on these platforms.

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 over 20 states reported at least one case of measles, and over 40,000 cases have been confirmed in Europe (Centers for Disease Control and Prevention, 2018; WHO, 2018). The results from this thesis 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.

Appendix Kids Plus Pediatrics Video

Kids Plus Pediatrics. At Kids Plus, we're thrilled to provide the HPV vaccine. In this video, our providers tell you why.

https://www.facebook.com/KidsPlusPediatrics/videos/10159486951555389/. Posted August 23, 2017.

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