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Roles for Health Care Professionals in Addressing Patient-Held Misinformation Beyond Fact Correction

Southwell, Brian G, PhD; Wood, Jamie L, PhD; Navar, Ann Marie, MD, PhD

ABSTRACT (ENGLISH)

Most patients trust their health care professionals,1 but many also turn to sources outside of the examination room for medical information. Although many resources provide accurate information (e.g., government health agencies, professional organizations, and patient advocacy groups), not all information that patients find is accurate. Patients may encounter medical misinformation from a variety of online sources, which can have important health consequences. Health care providers can play a critical role in addressing medical misinformation but have not yet had the opportunity to address medical misinformation fully. (Certain disciplines have made progress, such as pediatricians in mitigating vaccine misinformation.) Effectively addressing misinformation requires more than attempts to simply discredit misperceptions. Encountering patient-held misinformation offers an opportunity for clinicians to learn about patient values, preferences, comprehension, and information diets. Systematically training health care professionals to address patient-held misinformation with empathy and curiosity, acknowledging time and resource constraints, will be a crucial contribution toward future mitigation of medical misinformation.

FULL TEXT

Most patients trust their health care professionals,1 but many also turn to sources outside of the examination room for medical information. Although many resources provide accurate information (e.g., government health agencies, professional organizations, and patient advocacy groups), not all information that patients find is accurate. Patients may encounter medical misinformation from a variety of online sources, which can have important health consequences.

Health care providers can play a critical role in addressing medical misinformation but have not yet had the opportunity to address medical misinformation fully. (Certain disciplines have made progress, such as pediatricians in mitigating vaccine misinformation.) Effectively addressing misinformation requires more than attempts to simply discredit misperceptions. Encountering patient-held misinformation offers an opportunity for clinicians to learn about patient values, preferences, comprehension, and information diets. Systematically training health care professionals to address patient-held misinformation with empathy and curiosity, acknowledging time and resource constraints, will be a crucial contribution toward future mitigation of medical misinformation.

PATIENT EXPOSURE TO MISINFORMATION

Despite recent efforts by social media platforms to reduce or counter medical misinformation (e.g., https://bit.ly/3f4vBeE), patients can find a wide range of inaccurate medical information online with minimal effort. Some misinformation appears on Web sites advertising or selling alternative "natural" products and literature.2 Some misinformation lies in social media posts or carelessly written articles on various sites. A variety of misinformation about remedies, causes, and policy accompanied the arrival of the coronavirus disease 2019 pandemic, for example. At the same time, the potential consequences of medical misinformation also vary. Inaccurate claims that reach large audiences and encourage people to engage in damaging behavior are different from technically inaccurate but relatively inconsequential claims.3

Despite agreement as to the existence of problematic misinformation, patients and providers also face challenges in reliably characterizing high- and lowquality health information. One might attempt to judge information by assessing

the scientific quality of research reported, transparency regarding research sponsorship, and the extent to which research limitations are described. (For examples of questions to raise, see https:// bit.ly/2D74fqY.) Effectively applying such a checklist approach, however, requires a baseline scientific understanding beyond what can be expected of most patients. Such questions best serve as a prompt for patient consultation with a health care professional rather than as a stand-alone tool for patients to use.

MITIGATING THE EFFECTS OF MISINFORMATION

We need to improve patient relationships with health care professionals, meaning we need tools and approaches for improving different types of patient-professional conversations about inaccurate medical claims. Here we can learn from a specific category of such efforts: those developed to address patient hesitancy about vaccines. Leask et al.4 developed a guide for health professionals to consider in addressing parental vaccination concerns. They emphasize a stance that offers parents assistance in decision-making rather than attempting to persuade parents directly or discredit specific information sources. Such an approach prioritizes offering informed advice on how to think about vaccine decisions rather than discrediting specific information sources. Importantly, we also know that in some instances even health care professionals themselves can offer inaccurate information.5 Leask et al.4 point to the opportunity for health care professionals to elicit parent concerns during such encounters and to acknowledge, listen, and empathize while pointing to appropriate information sources. Building on such an approach at Duke University with support from the ABIM Foundation and Craig Newmark Philanthropies, we have developed training for clinicians to address misinformation that emphasizes empathy and listening while acknowledging time limitations.

Developing the capacity to listen to concerns, preferences, and values, as well as to monitor available information environments for inaccurate claims, requires effort. Although some have called for fact checking and social media response efforts by medical organizations to address medical misinformation, investing in scalable efforts to build individual relationships with patients will be crucial. Consider, for example, the experience of the US Centers for Disease Control and Prevention's effort to monitor travelers to the United States during the 2014 to 2015 Ebola outbreak. (For more information, see https://bit.ly/ 2CAM2lJ.) Evidence suggests that a key factor in traveler intention to adhere to requirements was trust-namely, the extent to which travelers trusted program staff with whom they talked at a US airport about the monitoring program. Interpersonal trust is most likely in situations in which people directly encounter a health care professional in person (at least virtually) rather than in situations in which people are presented with information in other ways. Trust involves relationships and not just facts.

To participate in a conversation (about information or what turns out to be misinformation), patients need to feel empowered to raise an idea that their health care provider may perceive as controversial or problematic. Rather than expect patients to raise concerns without prompting, health care providers should invite conversations about potential misinformation with their patients. For example, inviting patients to share what may be affecting their treatment choices with an open-ended question (e.g., "What have you already heard or learned about your treatment/condition?") could open useful conversational space.

Understanding misinformation as a force in a patient's life also calls for assessment of the patient's own lived context. Often patients' experiences or experiences of friends and family affect how they relate to medical information. Having a relative who experienced a medical error may lead a patient to be less trusting of the health care system in general and more likely to believe misinformation focused on the "dangers" of traditional therapies. Some patients may have less trust in the health care system and physicians because of health inequities and historic mistreatment.6 Religious or spiritual beliefs also can affect patients' beliefs about their bodies and may affect therapeutic choices, from choosing natural alternatives to declining therapies.

Providers should recognize that patients will continue to seek medical advice from the Internet, peers, and family members. Directing patients away from alternative sources altogether is unlikely to succeed. Mitigating the effects of misinformation requires providers to empower patients with accurate sources of information to meet patients' own needs for self-education. Patient educational materials should include information about trusted resources.

Although research on the effects of medical misinformation is increasing, we know relatively little about how to address it through clinician intervention. Just as research has helped determine optimal techniques for shared

decision-making between patients and providers, we need a systematically developed evidence base for addressing misinformation in a clinical setting.

A PATH FORWARD

Health care professionals can address patient encounters with medical misinformation by leveraging opportunities to listen to patients, monitor existing electronic information environments, and guide patients toward enhanced understanding of peer-reviewed medical evidence, perhaps in concert with initiatives to enhance news and information literacy.7 Doing so will involve more than issuing corrective pronouncements about fallacies. Health care professionals will need to invest time in understanding what misinformation patients describe and value and work cooperatively with patients to prioritize credible sources. ÂfPU

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All authors contributed equally to this editorial.

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CONFLICTS OF INTEREST

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Sidebar

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DETAILS

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Content Themes and Influential Voices Within Vaccine Opposition on Twitter, 2019

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ABSTRACT (ENGLISH)

Objectives. To report on vaccine opposition and misinformation promoted on Twitter, highlighting Twitter accounts that drive conversation. Methods. We used supervised machine learning to code all Twitter posts. We first identified codes and themes manually by using a grounded theoretical approach and then applied them to the full data set algorithmically. We identified the top 50 authors month-over-month to determine influential sources of information related to vaccine opposition. Results. The data collection period was June 1 to December 1, 2019, resulting in 356 594 mentions of vaccine opposition. A total of 129 Twitter authors met the qualification of a top author in at least 1 month. Top authors were responsible for 59.5% of vaccine-opposition messages. We identified 10 conversation themes. Themes were similarly distributed across top authors and all other authors mentioning vaccine opposition. Top authors appeared to be highly coordinated in their promotion of misinformation within themes. Conclusions. Public health has struggled to respond to vaccine misinformation. Results indicate that sources of vaccine misinformation are not as heterogeneous or distributed as it may first appear given the volume of messages. There are identifiable upstream sources of misinformation, which may aid in countermessaging and public health surveillance. (Am J Public Health. 2020;110:S326-S330. https://doi.org/10.2105/AJPH. 2020.305901)

FULL TEXT

Headnote

Objectives. To report on vaccine opposition and misinformation promoted on Twitter, highlighting Twitter accounts that drive conversation.

Methods. We used supervised machine learning to code all Twitter posts. We first identified codes and themes manually by using a grounded theoretical approach and then applied them to the full data set algorithmically. We identified the top 50 authors month-over-month to determine influential sources of information related to vaccine

opposition.
Results. The data collection period was June 1 to December 1, 2019, resulting in 356 594 mentions of vaccine opposition. A total of 129 Twitter authors met the qualification of a top author in at least 1 month. Top authors were responsible for 59.5% of vaccine-opposition messages. We identified 10 conversation themes. Themes were similarly distributed across top authors and all other authors mentioning vaccine opposition. Top authors appeared to be highly coordinated in their promotion of misinformation within themes.
Conclusions. Public health has struggled to respond to vaccine misinformation. Results indicate that sources of vaccine misinformation are not as heterogeneous or distributed as it may first appear given the volume of messages. There are identifiable upstream sources of misinformation, which may aid in countermessaging and public health surveillance. (Am J Public Health. 2020;110:S326-S330. https://doi.org/10.2105/AJPH. 2020.305901)
Vaccine opposition is a threat to global health,1 with digital and social media a primary source of misinformation and means of organizing vaccine opposition.2,3 Misinformation has reached a critical level, with provaccine and vaccine-opposing communities increasingly polarized.4 "Anti" messaging is increasing in communities that appear to be largely unaffected by traditional health promotion strategies and scientific information.5 In 2000, measles was declared eradicated in the United States as the result of an effective vaccination campaign; however, in 2019, the Centers for Disease Control and Prevention announced 1282 confirmed cases of measles, the highest since 1992.6 Vaccine opposition also has policy implications: dozens of state bills have attempted to supplant established population health practice by prioritizing personal liberties and appealing to ideology, rather than evidence.7 Misinformation erodes trust in science and public health authorities and is associated with a decrease in vaccination rates, risking further outbreaks and cases of vaccine-preventable disease.8 There are economic implications as well: treating measles outbreaks costs approximately $32 000 per case,9 and, in 2017, the reported cost to treat 1 child's case of tetanus was more than $800 000.10 Despite the established and evolving threat to public health that vaccine opposition poses, there has been no systematic, sustained effort to identify, track, and routinely report on it in the United States.

In 2019, public health nonprofit The Public Good Projects commenced Project VCTR (Vaccine Communication Tracking and Response) to identify and track vaccine-related communication on digital and social media. This study examines discourse on Twitter, given that the platform is a primary source of online vaccine misinformation.11,12 The aims of this study were to (1) determine the volume of conversation around vaccine opposition, (2) explore specific themes in conversation regarding vaccine opposition with a focus on vaccine-related misinformation, and (3) identify accounts that are drivers of vaccine opposition. We compared content themes employed by influential vaccine opposition accounts with general themes in vaccine-opposition discourse to identify message frames top authors use to drive conversation.

METHODS

We obtained data through a partnership with a media monitoring platform that collected 100% of publicly available Twitter tweets and retweets containing keywords identified by The Public Good Projects. The initial data collection process was based on a lengthy keyword search query using English-language Boolean operators to identify information related to vaccination conversation on Twitter in the United States from June 1 to December 1,2019. Keywords were selected based on a review of previously published scientific, gray, and white literature (Appendix A, available as a supplement to the online version of this article at http:// www.ajph.org) and deductive determinations based on familiarity with online vaccine conversation.

Initial data collection followed 2 processes: keywords could either be "standalone" or "co-occurring." Standalone keywords function so that any mention of a specific word would collect that post. The initial query consisted of 129 standalone words and 129 hashtag equivalents. Terms could also be co-occurring, meaning that a post was collected if 2 terms were present. Shortened forms of "vaccination" were collected if they also included a health condition treated by vaccines or terms referenced in vaccine discourse. The co-occurring search query consisted of 333 health condition- or vaccine-related words and hashtag equivalents, paired with 3 shorthand vaccine terms and hashtag equivalents. We employed 60 exclusion terms to exclude content related to animal vaccinations or

medication instructions. Keywords can be found in Appendix B (available as a supplement to the online version of this article at http://www.ajph. org).

Identifying Vaccine Opposition

We gathered Twitter data continuously throughout the data collection period. With data collection ongoing, we selected a random sample of 1000 tweets from the total sample ofvaccine-related conversation (0.9% of the data collected at the time, in line with research conducting similar analyses13) and manually coded to identify messages in opposition to vaccines (step 2, Figure 1). In this process, retweets were not manually coded, given that they are often identical to the original tweet, and analysts focused on coding as many unique posts as possible. These messages were differentiated from those in the total sample, which contained all messages referencing vaccines, whether positive, neutral, or in opposition. Posts referencing vaccine hesitancy (i.e., those who do not vaccinate because of lack of access or those who do vaccinate but have questions) were not considered vaccine opposition. These posts generated an additional list of keywords specific to vaccine opposition, which were then added to the full keyword query that generated the total sample, allowing for messages to be identified and analyzed separately as vaccine opposing. All analysis in this study was conducted on posts containing terms related to vaccine opposition.

Theme Generation

We then categorized vaccine-opposing posts into themes. Using a 5-step interpretive process, 2 coders (E. B. and S. D. R.) manually coded 1000 randomly selected posts (step 3, Figure 1).14 Approximately 200 posts were cross-coded between analysts. Discrepancies were re-examined until reaching agreement on more than 90% of posts. Themes were created, compared, and combined until data saturation was achieved, defined as a theme comprising less than 1% of conversation. For this study, 74.8% of data pertaining to vaccine opposition were coded into a theme. Each theme was assigned its own unique list of keywords that identified a post as having met the criterion ofthat theme. To test the validity of each theme's keywords, keywords were turned into queries, as described previously. We reviewed 100 randomly selected posts automatically categorized to each theme. If 90% of automatically categorized posts were accurately coded, that theme's keyword query was approved and applied to the total sample. Theme definitions and sample keywords can be found in Appendix C (available as a supplement to the online version of this article at http://www.ajph.org). Applications ofsupervised automatic coding for qualitative analysis have been explored as a practical way of applying lessons from big data sets to public health.13,15

To identify misinformation promoted within themes around vaccine opposition, analysts reviewed 200 posts receiving the most engagement within each theme (step 4, Figure 1). Misinformation was organized into categories, with each category defined by unique keywords. These keywords allowed all posts within the theme to be automatically tagged if they contained a category of misinformation. Analysts manually verified the top 200 posts within each misinformation category, and keywords were amended to ensure that at least 90% of posts were tagged with the correct misinformation category. The operational definition of "vaccine misinformation" was considered any information that contrasted with the Centers for Disease Control and Prevention's Immunization Safety Office.16

Top Authors

As with other studies examining Twitter data for vaccine-related information,17,18 this study made use of metadata accompanying posts to perform social network analyses. We sorted accounts publishing messages by the number of engagements received to determine which accounts had the most influence in the vaccine opposition conversation (termed "top authors"). Engagement was defined as a like, comment, or share of a post. Analysts identified the top 50 authors each month. Defining engagement in this way allowed for discovery of accounts with the most frequent interactions, specific posts receiving the most interactions, and themes most commonly employed across these posts. Previous research has also examined the top 50 Twitter authors as a way of measuring trends.19 Top authors were manually examined to ensure they were promoting vaccine opposition, versus mocking or reporting on vaccine opposition. Results compare conversation from top authors with overall vaccine opposition conversation with top authors removed ("top authors" vs "non-top authors"). We used the %2 test to determine statistically significant differences between top authors and non-top authors for each theme.

RESULTS

From June 1 to December 1, 2019, we collected 356 594 Twitter posts mentioning vaccine opposition. We identified 129 unique Twitter accounts as top authors within at least 1 of the 6 months, generating 212 018 total engagements and 772.9 million potential impressions (the number of followers of the original author plus the followers of individuals who shared their content). Of those 129 accounts, 15 were top authors for at least 5 months, during which time they generated 124 243 engagements, which was 58.6% of the 212 019 engagements with top authors' content.

We identified 10 themes within posts about vaccine opposition, with the top 5 themes each comprising over 10% of mentions. (Table 1):

Negative health impacts were shown in 55.4% of mentions from top authors and 49.2% of the general opposition (non-top authors). Within this theme, misinformation around deaths attributable to vaccines and vaccine-caused autism was present in 66.5% and 43.8% of top author posts, respectively. Within general opposition, deaths were mentioned in 14.5% of posts and autism in 26.3%. Across references to death, top authors predominantly shared a journal article citing deaths reported to the Vaccine Adverse Event Reporting System from 1997 to 2013 to claim vaccines cause child death.20 Other misinformation related to health impacts included associations between vaccines and paralysis (5.9% top authors; 0.5% general opposition) and seizures (5.7% top authors; 0.8% general opposition).

Pharmaceutical industry mentions appeared in 16.9% of posts from top authors and 18.9% of general opposition. Vaccines were most often framed as a conspiracy by "Big Pharma" to increase sales revenue. Merck was referenced in 58.1% of posts from top authors, compared with 38.7% by general opposition, because of its manufacturing of the Gardasil vaccine.

Policies and political debates related to vaccination followed, in 15.0% of conversation from top authors and 17.7% from general opposition. Posts in this theme predominantly focused on the National Childhood Vaccine Injury Act, which eliminated potential financial liability of vaccine manufacturers from injury claims (27.2% top authors; 6.6% general opposition) and California's Senate Bill 276 which tightened vaccine exemptions (23.9% top authors; 17.5% general opposition). Political discourse regarding vaccines frequently mentioned the government's role in vaccine injury claims and allegations that the government deliberately conceals negative vaccine side effects.

Vaccine ingredients comprised 13.8% of conversation from top authors and 17.2% of general opposition, with posts mentioning heavy metals or ingredients disclosed in vaccine package inserts. Aluminum was the most frequent ingredient referenced, within 44.5% of posts from top authors and 6.4% of the general opposition, followed by mercury (34.1% top authors; 6.9% general opposition) and aborted fetal tissue (9.3% top authors; 2.6% general opposition).

Vaccine research was found within 15.5% of posts from top authors and 5.6% of general opposition. Posts most often criticized vaccine research or institutions conducting research or promoted pseudoscience as fact. The most frequently referenced studies were related to the human papillomavirus vaccine and its association with negative health impacts after vaccination.21 A commonly shared article was retracted in 2019 and is now found on vaccine opposition Web sites (29.0% top authors; 8.9% general opposition).22,23 This was followed by research about the influenza vaccine, highlighting studies showing associations with other respiratory infections, renal failure, and suppressed immune responses (20.0% top authors; 7.3% general opposition).24-26

Five of the identified themes amounted to approximately 7% or less of the total conversation:

Disease prevalence focused on measles outbreaks, with 83.2% of top author posts and 17.4% of general opposition posts mentioning measles or the measles, mumps, and rubella vaccine. Vaccine opponents frequently cited stories about vaccine-driven epidemics, such as the vaccine-derived poliovirus, to suggest the dangers of vaccines (19.5% top authors; 3.8% general opposition).27

Family members typically included mention of individuals who believe they have experienced negative health impacts attributable to vaccination, often from a parent sharing a vaccine adverse health event of their child (70.7% top authors; 57.2% of general opposition).

School conversation focused on policies related to mandatory vaccinations for enrollment.
Religion included references to any religion and most often discussed religious exemptions to mandatory vaccines (46.7% top authors; 44.5% general opposition).
Natural alternatives to vaccines included misinformation about the use of homeopathic alternatives to vaccination and "vaccine detox."

DISCUSSION

This study showed that major talking points used by vaccine opponents originated from a handful of accounts. A total of 129 accounts on Twitter appeared to be driving more than half of all conversation regarding vaccine opposition, and 15 accounts appeared hyperinfluential, generating a majority of engagements on top authors' posts. When top authors' posts were compared with other posts, misinformation themes were similar. While there were statistically significant differences in the proportions of most themes, this may have been attributable to the sample size; when themes were ranked by use, the most common themes used by top authors and all other authors were nearly identical.

When we examined themes for specific talking points, top authors promoted similar misinformation within each theme. For example, within conversation about negative health impacts, references to deaths and autism were mentioned in 67% and 44% ofposts by top authors, respectively. In posts made by non-top authors, these 2 conditions were both mentioned in approximately 15% of posts. Throughout all themes, results showed how vaccine opponents can manipulate facts and their sources. It can be challenging for even experienced public health researchers to verify each claim made by a vaccine opponent, particularly given the amount, variety, and often misleading nature. For example, information taken from the Vaccine Adverse Event Reporting System, a database created by federal health agencies to monitor vaccine reactions, is used by vaccine opponents as "proof" of the government admitting that vaccines cause child death. Critically important context, such as the fact that an adverse event can be reported even ifit is uncertain or unlikely that a vaccine caused it or the role of statistical significance or reporting bias in epidemiology, is lost. Misinformation is a complex issue involving not just what is said but also the intent behind it.

The finding that top authors share the same misinformation suggests that vaccine opponents rely on highly networked communities driven by leaders driving particular narratives.28,29 Influential vaccine opponents most likely select their messages based on the receptivity to those messages. By contrast, public health continues to repeat the same vaccination recommendations in the same manner, despite research demonstrating that these messages arrive in an echo chamber, received by those at little risk of vaccine hesitancy.2,4 The public health community should think critically and pivot messaging based on themes that receive the most engagement among those likely to be vaccine hesitant.

This study suggests that not only are vaccine opposition talking points discoverable but also that they can be quantified; there are only a handful employed at a given time. This aligns with research showing that a majority of Facebook advertisements opposing vaccination were funded by 2 groups.30 If these groups are passively monitored, as suggested by other researchers, public health may be able to counter the growing influence of vaccine opposition by quickly identifying and countering talking points.4

Limitations

The study had limitations. Tweets were collected containing keywords identified (Appendix B). Tweets about vaccines that did not contain these terms were not collected. It is possible that posts were miscoded, particularly for those sarcastically referencing vaccine opposition. Analysts manually checked each theme to ensure at least 90% fidelity and amended keywords to capture sarcasm when possible. In addition, engagement and shared talking points were used as measures of influence, and there are likely other unexplored means of quantifying the influence of individuals in social networks. Furthermore, it is possible that engagements with top author posts were critical of vaccine opposition, rather than supportive. To address limitations, the methodology for automatic coding was tested and checked during this study, and previous research on automatic sentiment analysis for vaccine opposition on Twitter was consulted.31,32

Although outside the scope of this study, research should explore the impact of seasonality on vaccine opposition. The data collection period spanned back-to-school season, flu season, and the legislative cycle. Seasonality was likely a contributing factor to misinformation. In addition, variables such as time or day of the week could be useful in understanding message spread.

Public Health Implications

Results highlighted common vaccine-related misinformation used by vaccine opponents. It will continue to be difficult for public health to effectively counter vaccine opposition without a greater understanding of opposition actors and narratives. It is also important to note that, while this study examined vaccine opposition collectively, pro- and antivaccination beliefs are better represented as a spectrum, not as distinct states.33 Additional research should segment audiences that may be susceptible to specific messages highlighted in this study. In doing so, researchers can identify ways of utilizing and sharing retrospective, real-time, and predictive media data to create messaging that effectively and quickly reaches individuals who are vaccine hesitant. /4JPI-I

CONTRIBUTORS

E. Bonnevie conceptualized the study, oversaw data collection and analysis, and led writing. A. K. GallegosJeffrey and S.D. Rosenberg analyzed the data. J. Goldbarg, E. Wartella, andJ. Smyser conceptualized the study and provided a critical review of the article. All authors approved the final version to be published.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

HUMAN PARTICIPANT PROTECTION

No human participants were involved in this study. Institutional review board approval was sought from IntegReview, and the study was found to be exempt from review.

Sidebar

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Erika Bonnevie, Jaclyn Goldbarg, Allison K. Gallegos-Jeffrey, Sarah D. Rosenberg, and Joe Smyser were with The Public Good Projects, Alexandria, VA, at the time the work was conducted. Ellen Wartella is with The Northwestern School of Communication, Evanston, IL.

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DETAILS

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Crowdfunding Cannabidiol (CBD) for Cancer: Hype and Misinformation on GoFundMe

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ABSTRACT (ENGLISH)

Objectives. To use crowdfunding campaigns to better understand how cannabidiol (CBD) is represented (and misrepresented) as cancer-related care. Methods. We analyzed CBD-related crowdfunding campaigns (n = 155) created between January 2017 and May 2019 in multiple countries on GoFundme.com. Results. More than 81.9% of campaigns fundraised CBD for curative or life-prolonging reasons, and 25.2% fundraised for pain management. Conclusions. Most campaigns seeking funds for CBD for cancer-related care on GoFundMe are for curative or life-prolonging purposes and present CBD definitively asan effective treatment option. In general, campaigners supported their funding requests with anecdotal claims of efficacy and referenced sources of information that were either not evidence-based or that misrepresented existing evidence. Public Health Implications. Misinformation

around CBD for cancer is widespread on medical crowdfunding campaigns. Given the potential adverse impact, crowdfunding platforms, like GoFundMe, must take steps to address their role in enabling and spreading this misinformation. (Am J Public Health. 2020;110:S294-S299. https://doi.org/ 10.2105/AJPH.2020.305768)

FULL TEXT

Headnote

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Methods. We analyzed CBD-related crowdfunding campaigns (n = 155) created between January 2017 and May 2019 in multiple countries on GoFundme.com.

Results. More than 81.9% of campaigns fundraised CBD for curative or life-prolonging reasons, and 25.2% fundraised for pain management.

Conclusions. Most campaigns seeking funds for CBD for cancer-related care on GoFundMe are for curative or life-prolonging purposes and present CBD definitively asan effective treatment option. In general, campaigners supported their funding requests with anecdotal claims of efficacy and referenced sources of information that were either not evidence-based or that misrepresented existing evidence.

Public Health Implications. Misinformation around CBD for cancer is widespread on medical crowdfunding campaigns. Given the potential adverse impact, crowdfunding platforms, like GoFundMe, must take steps to address their role in enabling and spreading this misinformation. (Am J Public Health. 2020;110:S294-S299. https://doi.org/ 10.2105/AJPH.2020.305768)

Health misinformation is an increasing problem forpublic health. Misinformation -understood here as any claim that is misleading or false based on the best current scientific evidence-has spread since the rise of social media, with substantial negative consequences.1,2 For example, diseases such as measles are reemerging in part because of misinformation about vaccine safety.3 Public health efforts to vaccinate those at risk are undermined by antivaccination misinformation on social media, which policymakers have acknowledged as a challenge. In Samoa, the effects of this misinformation have been deadly; approximately 63 persons died from measles there in December 2019 amid a large outbreak made possible by increased resistance to vaccination spurred by misinformation.4

While misinformation around vaccine safety is a prominent example of the challenges and impacts of health misinformation, this problem is not limited to vaccines and infectious diseases. Other forms of health misinformation surrounding a wide range of health issues are spread through online pathways. These include exposure to health misinformation on social media platforms such as Facebook, Instagram, Reddit, and Twitter; viewing ofonline advertisements for businesses selling products directly to consumers; and visiting "fake news" Web sites specifically peddling both health misinformation and intentional disinformation about the safety and efficacy of health products and procedures. These sources of health misinformation are easy to inadvertently access, as when individuals search symptoms or treatments of common conditions online and are then exposed to Web sites that appear credible but offer misinformation on the efficacy of alternative treatments and misrepresent the safety and efficacy of conventional treatments.5 More generally, search engine results, such as those provided by Google, can contain misinformation and can have an impact on public perceptions of an issue.6

One product now capturing widespread interest and, potentially, serving as a focus of health misinformation, is cannabidiol (CBD). CBD, a cannabinoid found in the cannabis plant, is commonly described online as a cure-all for numerous conditions or ailments.7 CBD is popular and under a so-called "health halo" because of the suggestive efficacy from its categorization as a natural health product.8 CBD is currently marketed, sold, and used for minor conditions and purposes such as pain relief and skin health, as well as more serious conditions such as Alzheimer's disease, attention deficit hyperactivity disorder, autism, anxiety, schizophrenia, menstrual pain, insomnia, eczema, erectile dysfunction, posttraumatic stress disorder, Crohn's disease, arthritis, and depression.7,9,10 However, there is little or no robust clinical evidence to support the use of CBD for any of these purposes.11 At this time, only Epidiolex-a CBD medication to prevent seizures-is accepted by US regulatory entities as having sufficient evidence

of efficacy.12

Commercial businesses have cashed in on CBD's popularity, making available more than 500 CBD products.13 CBD-infused cosmetic products are available as shampoos, makeup, bath bombs, moisturizers, toothpaste, and soap.10 Food establishments and companies are presently offering CBD in a range of food products and beverages. The claimed effects ofCBD-infused products vary by product and manufacturer. For example, a CBD shampoo from Emera claims that CBD "naturally integrates with the body's endocannabinoid system to help reduce common dry hair conditions."14 These offerings are not limited to small or fringe companies as even the Coca-Cola Company is exploring introducing a wellness drink infused with CBD.15 Prominent celebrities are also entering the CBD business. Gwyneth Paltrow, the founder and owner of the controversial wellness brand Goop, is a business partner with a company that sells CBD called MedMen.13 Speaking to the benefits of cannabis, Paltrow comments: "[I]t can really be an alternative pain management system, and, in some cases, helpful for depression."16 Other celebrities such as Whoopi Goldberg and Willie Nelson have launched their own cannabis and CBD products for uses such as menstrual cramp relief, hormone balancing, increasing insulin sensitivity, reducing inflammation, and skin care.17,18 A particularly concerning form of misinformation around the efficacy of CBD is its representation as effective for cancer-related care. There is little evidence that CBD is an effective treatment of cancer and limited evidence for the side effects of cancer treatment, such as pain relief or nausea from chemotherapy.19,20 Nonetheless, numerous natural health Web sites and CBD companies make unsupported claims about the efficacy ofCBD for cancer treatment and therapeutic care. In December of2019, the US Food and Drug Administration sent notices to 15 CBD companies for misleading health claims on their Web sites and CBD products.21 Of these 15 companies, 12 had products or blogs claiming CBD as an effective cancer treatment. For example, Mr. Pink Collections, a Beverly Hills, California, CBD supplier, shared articles and social media posts with statements representing CBD as a "natural deterrent to cancerous cells" and claiming that it "arrests cancerous growth."22 Similarly, Koi CBD, another California-based CBD company, claims under a Web page titled "8 Proven Benefits ofCBD" that "CBD relieves pain and inflammation" and "inhibit[s] the invasion of lung and colon cancer."23

Limited research is available to determine how this misinformation is being received by people with cancer and incorporated into their cancer treatment regimens, how this misinformation is being replicated and spread by patient consumers of CBD, and the effects of this misinformation. As both public and private insurance generally do not provide coverage for CBD treatment, especially for cancer-related care, many would-be CBD users seek financial support for this intervention. Thus, a useful means of gaining insight into the understanding of potential users of CBD for cancer-related care is through analyzing medical crowdfunding campaigns appealing for help paying for CBD. Crowdfunding allows users to fundraise costs ofmedical treatment and share their campaigns on social networks, such as Facebook, to appeal for donations. To receive donations, campaigners need to share the details of their proposed treatment and rationale for seeking it. Unsolicited campaign descriptions allow for exploration into patient testimonials and explanations for treatment choices, as has been demonstrated by other analyses of crowdfunding data.24 Thus, the content of campaigns for those fundraising for CBD for cancer-related care can provide insight into why people with cancer are seeking this substance and whether they are well- or misinformed about its safety and efficacy, and help guide policy responses.

METHODS

We retrieved crowdfunding campaigns on GoFundMe.com on October 28, 2019, using targeted word searches for CBD term variants and "cancer" on a database ofcampaign data. This database, initiated in April 2019, was created using the GoFundMe.com sitemap to identify campaign URLs for data scraping. Continuously scraped data included the campaign title, description and updates, funding received, funding requested, geographic location of the campaigner, and number of Facebook shares. We selected GoFundMe because this platform is by far the largest host of medical crowdfunding campaigns worldwide.25 Terms searched with "cancer" included "cannabidiol," "CBD," "Rick Simpson Oil," and "RSO." Rick Simpson Oil is a cannabis oil product with both CBD and tetrahydrocannabinol (THC) and is used for cancer treatment purposes. We added it after an initial review of campaigns for cancer treatment with CBD included specific references to this form of CBD.

The initial search retrieved 955 campaigns. After we removed duplicate campaigns (n = 94) and campaign categories irrelevant to medical uses (n = 170), 691 campaigns remained. We excluded campaigns created before January 2017 to ensure campaigns were relevant to current CBD public discourse and debate, leaving 434 campaigns. The first author (M. Z.) reviewed each campaign to determine inclusion. Campaigns were included if they were crowdfunding CBD treatment of cancer-related care in humans. The second author (J. S.) reviewed campaigns flagged for inclusion. After reviewing each campaign, 155 remained for analysis. Campaigns were excluded for not crowdfunding for CBD (n = 231), not using CBD for cancer-related care (n = 24), using CBD for a nonhuman animal (n = 15), CBD for business ventures and legal issues (n = 8), or not available in English (n = 1). The first and second authors independently reviewed half of the included campaigns and met to develop an initial coding framework. After discussing observed themes, an initial coding framework captured efficacy claims (curative or life prolonging; pain, symptom, and side-effect management; unspecified) and treatment regimen classification (complementary to mainstream treatment, elective exclusive of mainstream treatment, no other mainstream options rationale, or unspecified). After presenting the coding structure to the third author (T. C.), a third code was added to capture CBD efficacy presentation (definitive, possible, or not stated). The first author independently coded each campaign and recorded the specific cancer type and stage. Campaign codes flagged as unclear were reviewed by the second author and any disagreement was resolved through discussion orby the decision of the third author. The second and third authors each audited 50% of campaigns to ensure consistent coding.

RESULTS

The 155 included campaigns raised $904 750.39 (median = US $3015.00) from 12 362 donors (median = 39) and requested $2 748 785.96 (median = $7698.42). The campaigns were shared 67 641 times on Facebook, or averaged 442.1 shares per campaign (median = 262). Campaign host locations were the United States (n = 107), the United Kingdom (n = 28), Canada (n = 11), unknown (n = 3), Australia (n = 2), Ireland (n = 2), Germany (n = 1), and France (n = 1). Most commonly, campaign beneficiaries were patients described as experiencing stage 4 or terminal cancer (n = 71; 45.8%), with others facing unspecified stages (n = 66; 42.6%) and stages 1 to 3 (n = 18; 11.6%).

Campaigns using CBD for curative or life-prolonging reasons were observed in 127 campaigns, raising $757 551.52 (average = $5964.97; median = $3421.95) from 11 006 donors (average = 88 per campaign; median = 42) and shared 61 088 times on Facebook (average = 488.7; median = 272). These campaigns requested $2394 720.35, for an average request of $19 157.76 (median = $8500.00). Campaigns typically fundraised for CBD alongside other conventional or complementary cancer treatments. Most of these campaigns (n = 72; 56.7%) presented CBD as definitively effective in curing cancer or prolonging the recipient's life (Table 1). For example, a campaigner diagnosed with late-stage cancer stated that CBD "will kill the cancer entirely and also help deal with the after effects of other treatments." Often campaigns referenced the experience of others or themselves to justify these definitive efficacy statements. For example, one campaigner wrote

[After doing much research since the beginning of our Mothers diagnosis she read on about Cannabis oil and Rick Simpson's oil and about people healing themselves of tumours and cancer by ingesting very high levels of THC and CBD and all of the 66 different Cannabinoids to help eat and kill cancer cells.

Numerous campaigns reference research or statistics that allegedly prove CBD to be a viable cancer treatment, such as one campaigner from Colorado: "There have been amazing studies on CBD oil. Helps fight cancer . . . this approach I feel is way better than pumping your veins full of poison, at least this is natural."

A smaller group of campaigners raising funds for curative or life-prolonging reasons presented CBD as a treatment that may possibly cure or prolong their lives (n = 47; 37.0%). These campaigns, while still fundraising CBD for curative purposes, are more limited in their claims. Frequently, they are motivated by hope rather than certainty that CBD will cure their cancer or improve their health. For example, one campaigner raising funds for a family member with limited treatment options wrote: "One treatment we have recently become aware ofis CBD oil and although not scientifically proven, has shown signs to many people with cancer, of having remarkable reduction in the disease process." Eight campaigns raising funds for curative or life-prolonging reasons did not have enough information for

categorization.
We observed crowdfunding CBD for pain, the side effects of treatment, or other symptoms in 39 campaigns, raising $159 702.56 (average = $4094.94; median = $1970.80) from 2013 donors (average = 51.6; median = 28) and shared 11 008 times on Facebook (average = 282.3; median = 205). These campaigns requested $486 609.09 (average = $12 477.08; median = $5000.00). Many of these campaigns sought to utilize CBD to lessen the side effects of conventional treatments such as radiation or chemotherapy orto use alongside other complementary cancer treatments. Reported uses ranged from stimulating appetite, general pain relief, assisting with sleep, countering nausea, or general recovery purposes. Most campaigners presented the efficacy of CBD for pain or symptom management purposes as definitively effective (n = 30; 76.9%). For example, one campaigner described CBD countering the effects of chemotherapy: "There is literally nothing else that helps more to get him through rough times like that. It truly helps him with appetite and pain." Another campaigner wrote: "Although CBD isn't a cure it's certainly something we've found to massively alleviate the symptoms and help to make him comfortable."
A small number of these campaigns represented CBD as only possibly effective for pain and side-effect management (n = 7; 17.9%). For example, one campaigner who had not yet tried CBD wrote: "I have been reading up on the effectiveness of CBD oil for cancer sufferers and would like to take this to aid my recovery." Two campaigns did not have enough information for categorization.
Proposed uses of CBD for cancer-related care fell into 4 distinct categories: complementary to mainstream treatment (n = 97; 62.6%), elective exclusive of mainstream treatment (n = 28; 18.1%), no other mainstream options rationale (n = 22; 14.2%), or unspecified (n = 8; 5.2%; Table 2).
The most commonly observed category, complementary to mainstream treatment, refers to campaigns in which campaigners propose using CBD complementary to evidence-based cancer treatments to cure, prolong life, enhance the effectiveness of cancer treatment, or deal with side effects of cancer or cancer treatment. For example, a campaigner used CBD both to supplement chemotherapy and manage its side effects: "We started alternative therapies such as CBD immediately in June 2018 alongside what the oncologist prescribed. I'm pretty sure she wouldn't be here today without the oil."
Elective exclusive of mainstream treatment refers to campaigners using CBD on its own or as part of an alternative treatment regimen in place of mainstream treatment options and against medical opinion. These campaigns signify the choice to forgo conventional treatment. For example, the campaign of a terminally ill man living with cancer for the past 4 years wrote
We pulled together a huge benefit 4 years ago when he was given 6 months to live after refusing chemo and radiation, both industry recommended "fixes." [Name] decided to fight it holistically and with the original donation amounts rendered then, purchased CBD oil and it has prolonged his 'due date' to God for more than 3.5 years!
The no other mainstream options rationale category refers to campaigns in which CBD use is for curative or pain-relief purposes when no other evidence-based curative options are available. Those in this category are not opting out of traditional cancer treatments but rather have been told that no curative options exist, leading them to try CBD as an alternative. For example, a campaigner in the United Kingdom wrote
We are raising money for alternative treatment as her particular tumor is non-responsive to chemotherapy. Alternative treatments are very expensive and not coveredby insurance. We will order a customized CBD Oil, a strength not sold over the counter.
The majority of such cases are terminally ill patients trying something that could potentially cure orprolonglife.
Finally, we labeled 8 campaigns "unspecified," given that not enough information was available to categorize them.
DISCUSSION
Our results suggest that most campaigners seeking funds for CBD for cancer-related care purposes on GoFundMe are for curative or life-prolonging purposes and presented definitively as an effective treatment option. Campaigners support their funding requests with anecdotal claims of efficacy and reference sources of information that are either not evidence-based or that misrepresent existing evidence. This demonstrates that misinformation around CBD for cancer is widespread on GoFundMe.

The spread of CBD efficacy misinformation is compounded by sharing on social networks. Campaigns for curative or lifeprolonging purposes were shared more than 60 000 times or approximately 488.7 times (median = 272) per campaign. These shares may influence the treatment decisions of others who may, in turn, share misinformation about CBD. Campaign hosts must write compelling and sympathetic narratives considered worthy of donations by potential donors-an issue described previously.26 30 The financial success of the campaigns demonstrates the perceived credibility of claims of CBD's efficacy for cancer-related care. The campaigns were very successful and averaged $5946.97 (median = $3421.95) raised per campaign, indicating at least a minimum level of acceptance of campaign claims by donors. Campaign success also shows the power of crowdfunding narratives to persuade readers that unproven medical treatments are valid options.

CBD is primarily used as complementary to evidence-based treatment in our sample. Most campaigns were not relying on CBD as their sole or primary treatment option, but instead incorporating CBD into mainstream options such as chemotherapy or radiation to extend life expectancy or for pain relief. An additional 22 instances were of cases in which the campaign beneficiary did not have any standard treatment option available and thus was trying CBD as a last option. This is a somewhat positive finding because ofthe lack of evidence of CBD's efficacy for cancerrelated care. However, even incorporated as a complementary treatment, there are concerns. People with life-threatening illnesses are appealing for and spending substantial amounts ofmoney on CBD for purposes that are not evidence-based. Raising funds for CBD as a potentially curative or lifeprolonging treatment without appropriate evidence represents a context in which misinformation exploits hope in a particularly vulnerable group, spreads misinformation, and wastes resources. In addition, there is potential for CBD interaction with medications, and the side effects of CBD are still not fully known.10,13

We classified a sizable portion of campaigns using CBD as exclusive of mainstream treatment (n = 28). While these campaigns represent a smaller portion of the campaigns retrieved (18.1%), they are especially alarming. Most of our sample were persons with advanced stages of cancer, with approximately 45% describing a stage 4 or terminal cancer diagnosis. These campaigners were forgoing routine care to use CBD on its own or as part of an alternative treatment regimen for curative or life-prolonging treatment. Forgoing evidence-based treatment leads to potentially treatable cancer worsening and opportunities for positive outcomes diminished. The claims made by those within this category particularly heighten the risk of misinformation to others by advocating against cancer treatments such as chemotherapy or radiation in favor of "natural" or alternative treatment regimens incorporating CBD.

This study provides an example in which unproven cancer treatments are promoted on GoFundMe without intervention by this crowdfunding platform. It adds to crowdfunding research literature examining fundraising for scientifically unsupported or unproven treatments, such as unproven stem-cell interventions,31,32 homeopathy,24 and naturopathy, hyperbaric oxygen therapy, and long-term antibiotics for Lyme disease.33 The evidence presented provides a strong rationale to encourage or require GoFundMe to intervene by restricting the most problematic campaign types observed in our study. Researchers have proposed crowdfunding platforms to act as gatekeepers to deter campaigns for scientifically unsupported treatments.34 While all these campaigns include misinformation about the known efficacy of CBD for cancer-related care, campaigns making definitive statements about CBD's efficacy and promoting CBD as an alternative to available and evidence-based care are particularly dangerous. Unsubstantiated hype and inaccurate claims can cause people to forgo effective treatment and spread treatment misconceptions and distrust of conventional treatments, undermining public health systems.

GoFundMe directly enables and profits from the sharing of this misinformation and thus is responsible for ensuring content on its platform does not harm others. Facebook shares increase public exposure to misinformation and can inspire donations and the creation of new campaigns. While current mechanisms are in place to report campaigns, such as the "report fundraiser" button, these mechanisms are insufficient as they focus on fraudulent campaigns and do not include blocking the sharing of misinformation. GoFundMe should devote resources to identify campaigns with misinformation shortly after posting to their Web site, particularly those with implications for life-saving treatment decisions. Identifying campaigns at the early stages is crucial as this limits the spread of misinformation. Any activities to identify campaigns with misinformation should be transparent. To improve transparency and improve

trust around these interventions, GoFundMe should share the process of campaign identification and report results, such as the number of campaigns identified as spreading misinformation. Relying on potential donors to report campaigns with misinformation is an inadequate response.

Crowdfunding platforms such as GoFundMe can work with recognized cancer institutions to determine acceptability of proposed fundraising asks. Other social media platforms have partnered with reputable health organizations to determine which content is appropriate or not. In 2019, Facebook announced that they would partner with the US Centers for Disease Control and Prevention to identify sources of vaccine misinformation.35 GoFundMe can take similar action with cancer and potentially other diseases or conditions about which misinformation is spread. If GoFundMe chooses not to take these actions on its own, then greater regulatory involvement preventing the hosting and spread of medical misinformation around CBD for cancerrelated care and beyond will be justified.

PUBLIC HEALTH IMPLICATIONS

CBD is associated with substantial misinformation. There are critical misconceptions about the current evidence base and acceptable uses, such as in the case of cancer. Crowdfunding platforms spread this misinformation. Campaign content is not checked for validity, and claims surrounding CBD efficacy for purposes such as curative or life-prolonging cancer treatment are shared widely on social media. This misinformation is dangerous; consequences include unnecessary financial strain and the delay and, in some cases, exclusion of evidence-based cancer treatment. GoFundMe must intervene to address its role in enabling and spreading this misinformation. ÂfPU

CONTRIBUTORS

AH authors reviewed the data, identified coding structure, and edited the article. M. Zenone wrote the article and coded data.J. SnyderandT. Caulfieldauditedcodeddata.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

HUMAN PARTICIPANT PROTECTION

Ethics approval was not required for this study because the data used were publicly available and posted without an expectation ofprivacy.

Sidebar

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DETAILS

Subject:	Cannabidiol; Public health; Cannabinoids; Cancer; Cancer therapies; Social networks; Pain; Funding; Vaccines; Pain management; Celebrities; Crowdfunding; Marijuana; Alzheimers disease; Menstruation; Measles; Websites; False information
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Contrasting Misinformation and Real-Information Dissemination Network Structures on Social Media During a Health Emergency

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ABSTRACT (ENGLISH)

Objectives. To provide a comprehensive workflow to identify top influential health misinformation about Zika on Twitter in 2016, reconstruct information dissemination networks of retweeting, contrast mis- from real information on various metrics, and investigate how Zika misinformation proliferated on social media during the Zika epidemic. Methods. We systematically reviewed the top 5000 English-language Zika tweets, established an evidence-based definition of "misinformation," identified misinformation tweets, and matched a comparable group of real-information tweets. We developed an algorithm to reconstruct retweeting networks for 266 misinformation and 458 comparable real-information tweets. We computed and compared 9 network metrics characterizing network structure across various levels between the 2 groups. Results. There were statistically significant differences in all 9 network metrics between real and misinformation groups. Misinformation network structures were generally more sophisticated than those in the real-information group. There was substantial within-group variability, too. Conclusions. Dissemination networks of Zika misinformation differed substantially from real information on Twitter, indicating that misinformation utilized distinct dissemination mechanisms from real information. Our study will lead to a more holistic understanding of health misinformation challenges on social media. (Am J Public Health. 2020;110:S340-S347. https://doi.org/10.2105/AJPH.2020.305854)

FULL TEXT

Headnote

Objectives. To provide a comprehensive workflow to identify top influential health misinformation about Zika on Twitter in 2016, reconstruct information dissemination networks of retweeting, contrast mis- from real information on various metrics, and investigate how Zika misinformation proliferated on social media during the Zika epidemic. Methods. We systematically reviewed the top 5000 English-language Zika tweets, established an evidence-based definition of "misinformation," identified misinformation tweets, and matched a comparable group of real-information tweets. We developed an algorithm to reconstruct retweeting networks for 266 misinformation and 458 comparable real-information tweets. We computed and compared 9 network metrics characterizing network structure across various levels between the 2 groups.
Results. There were statistically significant differences in all 9 network metrics between real and misinformation groups. Misinformation network structures were generally more sophisticated than those in the real-information group. There was substantial within-group variability, too.
Conclusions. Dissemination networks of Zika misinformation differed substantially from real information on Twitter, indicating that misinformation utilized distinct dissemination mechanisms from real information. Our study will lead to a more holistic understanding of health misinformation challenges on social media. (Am J Public Health. 2020;110:S340-S347. https://doi.org/10.2105/AJPH.2020.305854)

Social media have become real-time sources of information on various fields, including health and medical-related topics.1'2 Contents on a social media platform, such as Twitter, are mainly user-generated, and the lack of effective fact-checking mechanisms makes social media susceptible to propagations of misinformation. Infiltration and proliferation of health-related misinformation on social media, especially during health emergencies, is a serious threat to people and the entire society.3 Misinformation about vaccines,4-6 Zika,7 tobacco, vaping, and marijuana products8 are a few examples that demonstrate the health-related misinformation problem on social media.

While social media can be an effective tool to enhance people's health literacy, 9,10 they are also a rich resource to study the public's perspectives and reactions toward various topics.11 14 Infosurveillance systems aim to strengthen

the capacity of the public health community by closely monitoring online discussions of health topics15-18 and detecting misinformation.19 State-of-the-art analyses of (mis)information dissemination on social media mainly seek 2 purposes: (1) analyzing the information cascade20,21 and (2) identifying misinformation.22-26 In the first direction, computational modeling is used to investigate the virality and spread of (mis)information. In the second direction, different attributes, mainly context-based, are examined to identify misinformation.23,24,27-33 Nevertheless, developing such systems based on textual content is challenging.34 The content can be altered to appear real to avoid being detected by automated algorithms.35 We suggest that content is only 1 aspect ofthe comprehensive health misinformation challenge on social media. Therefore, relying on textual content alone is not adequate. There is an emerging need to understand health misinformation from more aspects, including the content, the users who are involved, and the social media environment as an interconnected entity.

One of the key approaches to investigate an infectious disease outbreak is to track the trajectory of the epidemic. In this study, we defined the dissemination of a particular piece of (mis)information as a dynamic process in which the original post (e.g., a tweet) is propagated by retweeting in an information-dissemination network (colloquially referred to as "network" hereafter). Retweeting shows that the user recognizes the importance of the original post and is willing to disseminate the piece of information. Therefore, we focused on retweeting as the information dissemination method.35

We use the 2016 Zika epidemic as a case study when health agencies had prominent presence on social media to share the latest findings and guidelines. However, uncertainty about this epidemic and overlapping events such as the 2016 US presidential election and the Olympics in Rio de Janeiro, Brazil, opened the door for misinformation. In this study, we first established an operational definition of health-related misinformation and identified the most popular Zika misinformation tweets. We then developed an algorithm to infer and reconstruct information dissemination networks of top Zika misinformation and comparable real-information tweets. Afterward, we applied network analyses to extract network structure metrics for both groups. We investigated how network structures differed quantitatively. This study leverages our understanding on the mechanism of health misinformation dissemination on social media and how it might have outcompeted real information. Eventually, the insights from this project will help with the development of more effective health communication strategies on social media against various misinformation.

METHODS

We chose the entire year of 2016 (January 1-December 31,2016) as the sampling period for this study. This time period covered the major milestones in Zika epidemic timeline, including the World Health Organization's (WHO's) initial warning of Zika across the Americas, the official declaration of the public health emergency of international concern, and the end of the public health emergency of international concern. Using Zika as the keyword, we collected a total of 3.7 million Englishlanguage tweets in and retweets published in 2016 via the Gnip application programming interface through our university's data science program. This data set was complete, including all English-languge Zika discussions on Twitter in 2016. Therefore, our data set provided a more comprehensive and unbiased view of the public discourse of Zika on Twitter in 2016.

Misinformation Identification and Relevant Information Matching

We ranked all original Zika tweets on the basis of the number of received retweets, from highest to lowest. Following this descending order, we selected the top 5000 most retweeted tweets as the sample pool. Then we established an operational definition of misinformation such that the information in the tweet was not evidence-based. We used peer-reviewed journal articles and conference proceedings, government and health agencies' (e.g., Centers for Disease Control and Prevention and WHO) reports and statistics, and fact-checking Web sites to evaluate the validity of the tweet. After we identified misinformation in the top 5000 pool, we identified another group of comparable tweets with real information based on theirposting time and number of retweets. A detailed description of how this definition was operationalized, assurance of reliability, and examples are provided in Appendix A (available as a supplement to the online version of this article at http://www.ajph.org).

We acquired metadata of each original tweet as well as all its retweets, including posting date and time, user names

involved, and followees-followers information. We used them to track information dissemination, construct networks, and conduct subsequent analyses.

Constructing Dynamic Information Dissemination Networks

Because Twitter did not explicitly publicize who-retweeted-whom information, we developed an algorithm based on posting or retweeting time and friends-follower relationship to infer and reconstruct the network of retweeting. A detailed technical report on this algorithm is in Appendix B (available as a supplement to the online version of this article at http://www.ajph.org).

We also investigated the temporal dynamics of information dissemination by calculating times to receive 50%, 75%, 90%, 95%, and 100% of all retweets in real and misinformation groups. This demonstrated the temporal variability within and between the 2 groups and gave the networks a temporal aspect as well.

Computing and Interpreting Important Network Metrics

Once the network was constructed for each tweet, we computed and compared important network metrics highly relevant to information dissemination both within and between the 2 groups. In this study, we extracted total of 9 metrics: network reach (REA), network influence (NIF), diameter (DIA), density (DEN), modularity (MOD), Wiener index (WEI), structural virality (VIR), top out-degree centrality (OUT) score, and top betweenness centrality (BET) score. These metrics quantified and characterized network structures from different aspects and across network levels. Here we provide a succinct description of these metrics; more detailed technical explanations are in Appendix C (available as a supplement to the online version of this article at http:// www.ajph.org):

* REA of a network measured the number of unique vertices (i.e., unique user accounts in this network).
* NIF (also known as network size) represented number of all vertices. If each user name retweeted exactly once, then REA should equal NIF. A larger difference between REA and NIF indicated that some user names in the network had retweeted more than once.
* DIA was the shortest distance between the 2 most distant vertices in the network.
* VIR measured average distance between all pairs of vertices in the network.
* DEN measured proportion of potential relationships that actually existed in the network.
* WIE was sum of the shortest paths between all pairs of vertices.
* MOD measured likelihood of dividing a network into potential clusters (i.e., subgroups), within which vertices were highly connected, but loosely connected among subgroups. MOD was a locallevel network metric.
* OUT measured how much influence a single vertex had in terms of generating retweets to further spread information. We calculated the entire OUT distribution and presented the largest OUT value of all retweeters in a network.
* BET quantified the importance of the vertex in terms of the connectivity of the network. Larger BET indicated a more critical role in maintaining network stability. We showed the largest BET value.

In summary, these network metrics comprehensively characterized different aspects of networks at multiple scales, from overall global network level (REA, NIF, DIA, VIR, DEN, and WIE) to local cluster level (MOD) and all the way down to individual vertex level (OUT and BET). Although there were other network metrics, these 9 metrics were especially critical for information dissemination from original posting user account to other retweeting vertices in the network.

Network and Statistica! Analyses

We compared network metrics between the 2 groups by using the Kolmogorov- Smirnov test to identify any significant differences in distributions of these metrics. We performed data retrieving, processing, and network reconstruction in Python version 3.7.3 (Python Software Foundation, Beaverton, OR). We carried out network and statistical analyses in R version 3.5.0 (R Foundation, Vienna, Austria) with additional packages. All input data and codes are freely available upon request.

RESULTS

We focused on the most popular tweets about Zika in this study. We defined popularity as number of retweets received of a given tweet. We considered a tweet to be popular if it was retweeted at least 50 times. About 5000

tweets in our data set had retweets above this cut off. Among the top 5000 most retweeted Zika tweets in 2016, we identified and verified a total of 400 tweets that contained misinformation. Among them, 266 tweets included adequate metadata to reconstruct the information dissemination networks. Not all metadata were available because of data loss, including user accounts banned by Twitter, content removed by Twitter, or the user actively retracted the original post for various reasons. The comparison group ofreal information contained a total of 458 tweets that occurred within similar dates of posting of misinformation tweets and had similar number of retweets of misinformation. To avoid potential selection bias, we did not make a 1-to-1 match of real Zika tweets.

Temporal Variability in Information Dissemination Dynamics

There was substantial temporal variability in the retweeting dynamics between misinformation and real-information groups (Figure 1). It took a significantly shorter time for misinformation to receive 50% of all retweets (T50 = 334 min for misinformation; T50 = 448 min for real information; P <.001 according to the 2-sided t test). The difference was minimal to receive 75% of all retweets (T75 = 916 min for misinformation; T75 = 898 min for real information; P = .93). Interestingly, it then always took a significantly longer time for misinformation to receive 90% of retweets (T90 = 2580 min vs T90 = 1795 min; P = .03), 95% of retweets (T95 = 4739 min vs T95 = 2824 min; P = .001), and all retweets (T100 = 34 869 min vs T100 = 22 340m; P< .001). Misinformation attracted at least half of all retweets within a relatively short period of time to make it more viral. Afterward, misinformation might be deliberately retweeted to keep their visibility over a longer time span. Based on these observations, we chose the time until the last retweet to construct the network, as it provided the most complete view of retweeting activity.

Network Metrics of Real vs Misinformation Groups

We reconstructed retweeting networks for each tweet in real and misinformation groups. Examples of dynamic network structures are provided in Figure 2 for both misinformation and real information.

The distributions of important network metrics of both groups are presented in Table 1. For demonstration purpose, we scaled all network metrics between 0 and 1 with feature scaling. Actual numeric summary statistics are shown in Table 1. None ofthese distributions approximated normal distribution, showing high skewness and kurtosis as well as possible multimodality. This indicated large withingroup variability of network structures. All network metrics' distributions differed significantly (P <.05) between real and misinformation groups, according to the Kolmogorov-Smirnov test. Therefore, real and misinformation networks presented a lot of heterogeneities, both within and between groups.

The DEN was significantly higher in the misinformation group as retweeters were more likely to engage in retweeting misinformation if their friends (whom they followed) tweeted or retweeted so. Note that this network was the original follower-followee network from which information dissemination network was inferred. The difference and relationship between these 2 networks are detailed in Appendix B. The reason that we used the original network only for density is discussed in Appendix C.

The DIA was also significantly higher in the misinformation group. In general, the smaller the diameter, the fewer layers the information passed through the network to reach the outermost retweeter. Misinformation attracted more grass-roots users one after another, as opposed to more hierarchical, cascade-like dissemination in the realinformation group.

The VIR, which focused on average path length, was also significantly higher in the misinformation group, indicating that vertices were generally farther apart in the network. This finding reinforced our previous finding that misinformation involved more direct user-to-user, or small cluster-to-cluster information dissemination than hierarchical dissemination through layers in the realinformation group.

The NIF and REA were similar metrics in which REA focused on unique retweeters. The misinformation group had both significantly smaller REA and NIF. In addition, about 30% of misinformation tweets had a same vertex retweeted at least twice, which was substantially higher than in the realinformation group (< 10%). This could be an intentional propagation strategy to disseminate (mis)information on social media. However, the risk ofsuch strategy was that Twitter might detect it and take actions. Therefore, having multiple user names to retweet the same content together would be a more effective way for information dissemination than having the same user name to retweet

the same content multiple times.
For the WIE, the misinformation group had significantly smaller values on average. This indicated that misinformationretweeting networks could have more starlike local clusters, which reduced the WIE. This was also consistent with our previous finding that the misinformation network had more local clusters and a larger MOD value. However, this finding seemed to contradict the previous finding that, on average, DIA was actually larger in the misinformation group. The actual distribution of WIE in the misinformation group was the key to solve this dilemma (Table 1). For the misinformation group, the WIE distribution had more than 1 prominent peak (i.e., multimodal). While some Zika misinformation networks had overall smaller WIEs, a few networks had very large WIEs. From an actual (mis)information propagation perspective, this implied that propagators exploited 2 seemingly contrasting strategies: first, using a star-like network with a very small WIE (much less frequently observed in the real-information group); second, using chain-like dissemination network with a large WIE. In addition, there were hybrids of these strategies to disseminate misinformation farther out. For example, propagators of misinformation might create an initial burst of retweets, shown as local stars in the network, which attracted more grass-roots users to help pick up the trend and retweet one after another. However, we did not observe such a sophisticated arrangement in the realinformation group.
At the local network level, we saw higher modularity more frequently in the misinformation group, indicating that users who retweeted misinformation tended to form smaller, local clusters to disseminate the information. Therefore, Zika misinformation was more difficult to tackle with traditional mitigation strategies. Multiple smaller clusters reduced the risk of removal of some clusters, as other clusters served as alternative routes for information dissemination. By comparison, the real-information group had relatively smaller MOD. MOD in the misinformation group was more heavily skewed to the left, compared with that in the real-information group (Table 1).
At the individual vertex level, distribution of OUT in the misinformation group also had a strong multimodal pattern, indicating that many misinformation tweets involved a user with an extremely large outbound degree (centrality score >200; Table 1) who might serve as potential online influencer or propagator. On the other hand, distribution of OUT in the real-information group was similar to a normal distribution. OUT of the misinformation group was more heavily right skewed in comparison with the realinformation group. The vast majority ofusers in the misinformation group were not influential in relaying information.
For BET, top BET users in the realinformation group had a significantly smaller BET score than that in the misinformation group (127 vs 1003). Therefore, these top BET users in the misinformation group were more important than their counterparts in the real-information group to maintain network stability, as higher BET score indicated a more critical role in information pass-through. While top OUT users could be identified relatively easily by their superficial activity of attracting many retweets, the top BET user, on the other hand, was much more difficult to detect unless constructing the network and performing centrality calculation for all vertices. Nevertheless, from a misinformation mitigation perspective, targeting top BET users could be a more effective way to stall or even completely shut off misinformation propagation than focusing on top OUT users.
To summarize, the misinformation group had distinct distributions of all of these network metrics from the real-information group, indicating significantly different dissemination network structures. Data mining of information dissemination networks could help health professionals and the general public better understand the dissemination process ofhealth misinformation. In addition, these quantitative metrics could be utilized by health informaticians to develop more accurate infosurveillance and misinformation detection systems.

DISCUSSION

We developed an analytical framework to investigate health misinformation dissemination on social media. We provided an operational definition of health misinformation and constructed an algorithm to explicitly track how health (mis)information is disseminated on social media through retweeting networks.
We need to point out that our current knowledge about health topics evolves through time as more and more clinical, epidemiological, and other evidence becomes available-hence, the idea of "evidencebased." The terms "real information" and "misinformation" should be used with caution because our current understanding might be falsified

in the future. Timing of the discussion should be considered especially during an emerging health crisis such as the Zika epidemic. For example, we found that The Economist, a generally reliable source of information, tweeted in December 2016 that Zika is harmless to adults (the post was deleted) when there had already been clear evidence to show the causal relationship between Zika virus infection and Guillain- Barré syndrome in adults. Had the tweet appeared in early 2016 when the causal relationship was not yet established, it would not have been deemed as misinformation. As a consequence, an important follow-up of this study is to increase the health literacy in the society such that people learn how to check the validity ofhealth information and why it is misinformation, and frequently update their knowledge about the health issues, instead of merely being told whether a piece of information is real or not.

We will further investigate user activity and attributes to identify bots and examine their effectiveness in dissemination of real and misinformation on social media. The example of a real-information dissemination network (Figure 2) is suspected to be facilitated by bots. In addition, we checked user verification status and only a small fraction were verified users. The real-information group had a higher user-verification rate (2%) than did the misinformation group (1.2%). This observation agrees with other studies showing a strong presence of established news agencies and health organization on Twitter during the Zika outbreak in 2016.

Other work is currently under way to investigate users' activity through time and how this temporal dynamic reveals misinformation infiltration. In this study, we constructed a network G of a given tweet at the end of all retweeting activities. As we showed large temporal heterogeneity both within and between groups (Figure 1), our algorithm is able to construct a dynamic network Gt at given time t. If we detect a sudden rise in retweeting dynamics at time t, we can then construct a specific network by time t to explicitly identify which user is causing the burst of retweets, quantify the user's centrality scores, and work at the individual vertex level to further address the health misinformation epidemic on social media.

Public Health Implications

This study provided solid evidence on health misinformation dissemination patterns on Twitter, one of the most utilized social media platforms. Our analytical framework is universally developed and can explore other public health issues on social media. For example, we have studied genetically modified organism misinformation spreading on Sina Weibo, the largest Chinese social media platform. Other emerging and controversial health topics, including the current COVID19 pandemic, are also being investigated with this framework.

Another key public health implication of this study is to extract important features of health misinformation, which are not directly identifiable from its content alone. We showed the importance to treat misinformation (pathogen), users (hosts), and social media (environment) as an interconnected entity-the Infodemiology Triad. Misinformation, like real pathogens, is not leaving no trace behind. This study substantially increased our understanding of misinformation dissemination dynamics. Furthermore, the rich data set can be used in conjunction with other features of misinformation (e.g., content, linguistic, and account-based) to build a comprehensive health-misinformation detector. In subsequent work, we will use state-of-the-art machine-learning methods to build such a classifier for public health use.

Conclusions

We investigated health-related real and misinformation disseminated on social media during a health emergency from a dynamic network perspective. We discovered that the 2 groups had distinct network structures, indicating their different dissemination patterns. Our work has shed light on developing more accurate health misinformation detectors. ÂfPU

CONTRIBUTORS

Q. Xu, Y. Ge, S. Krishnan, and S. Chen formulated the study idea. A. Bagarvathi collected the data. L. Safarnejad andS. Chenperformed analyses and developed the article. Y. Ge and S. Chen supervised the project. All authors contributed substantially in this project.

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CONFLICTS OF INTEREST

The authors have no conflict of interest in this study.

HUMAN PARTICIPANT PROTECTION

This study used secondary online social media data in the public domain for analysis. No actual human participants were involved.

Sidebar

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DETAILS

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Adapting and Extending a Typology to Identify Vaccine Misinformation on Twitter

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ABSTRACT (ENGLISH)

Objectives. To adapt and extend an existing typology of vaccine misinformation to classify the major topics of discussion across the total vaccine discourse on Twitter. Methods. Using 1.8 million vaccine-relevant tweets compiled from 2014 to 2017, we adapted an existing typology to Twitter data, first in a manual content analysis and then using latent Dirichlet allocation (LDA) topic modeling to extract 100 topics from the data set. Results. Manual annotation identified 22% of the data set as antivaccine, of which safety concerns and conspiracies were the most common themes. Seventeen percent of content was identified as provaccine, with roughly equal proportions of vaccine promotion, criticizing antivaccine beliefs, and vaccine safety and effectiveness. Of the 100 LDA topics, 48 contained provaccine sentiment and 28 contained antivaccine sentiment, with 9 containing both. Conclusions. Our updated typology successfully combines manual annotation with machine-learning methods to estimate the distribution of vaccine arguments, with greater detail on the most distinctive topics of discussion. With this information, communication efforts can be developed to better promote vaccines and avoid amplifying antivaccine rhetoric on Twitter. (Am J Public Health. 2020;110:S331-S339. https://doi.org/10.2105/AJPH.2020.305940)

FULL TEXT

Headnote

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discussion across the total vaccine discourse on Twitter.
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At present, one of the greatest risks to human health comes from the deluge of misleading, conflicting, and manipulated information currently available online.1 This includes health misinformation, defined as any "health-related claim of fact that is currently false due to a lack of scientific evidence. "2(p2417) Vaccination is a topic particularly susceptible to online misinformation, even as the majority of people in the United States endorse the safety and efficacy of vaccines.2,3 The reduction of infectious diseases through immunization ranks among the greatest health accomplishments of the 20th century, yet as the 21st century progresses, vaccine misinformation threatens to undermine these successes.4 The rise in vaccine hesitancy-the delay and refusal of vaccines despite the availability of vaccination services-may be fueled, in part, by online claims that vaccines are ineffective, unnecessary, and dangerous.5 While opposition to vaccines is not new, these arguments have been reborn via new technologies that enable the spread offalse claims with unprecedented ease, speed, and reach.2,6
Combating vaccine misinformation requires an understanding ofthe prevalence and types ofarguments being made and the ability to track how these arguments change over time. One of the earliest inventories of online vaccine misinformation comes from Kata's 2010 content analysis of antivaccine Web sites.7 In this work, 8 Web sites were labeled for 6 "content attributes": alternative medicine; civil liberties; conspiracies and search for truth; morality, religion, and ideology claims; safety and effectiveness concerns; and misinformation. All Web sites shared content from more than 1 area: 100% promoted safety concerns and conspiracy content, 88% also promoted civil liberties and alternative medicine content, and 50% also promoted morality claims.7 Misinformation and antivaccine arguments were nearly synonymous, with 88% of Web sites relying on outdated sources, misrepresenting facts, selfreferencing "experts," or presenting unsupported falsehoods.7
Since 2010, both the Internet and the nature of vaccine misinformation have changed profoundly. The static Web sites Kata analyzed have been supplanted by interactive social media platforms as the primary channels for antivaccine information dissemination.8 Unlike Web sites, which feature a single perspective, social media platforms were designed to encourage "dialogue" and feature a plurality of perspectives.9 Social media also introduces new challenges, as opportunistic actors including automated bots and state-sponsored trolls flood channels with information designed to manipulate, provoke, or scam genuine users.10
Recognizing these changes, scholarly efforts to characterize vaccine misinformation on social media have taken many forms. These include content analyses of vaccine posts on platforms including Twitter,11 Facebook,12 Instagram,13 Pinterest,14 and YouTube.15 Although research questions varied-often tied to specific vaccines (e.g., human papillomavirus, influenza), temporal events (e.g., outbreaks, policy changes), or claims (e.g., debunked claim that vaccines cause autism)-the presence of misleading antivaccine content is near universal. The universality of Kata's broad categories endures, with many of these studies highlighting antivaccine content, questioning vaccine safety concerns, and promoting conspiracy theories.
More recently, computational advances have made big data and machine-learning methods popular. A common approach has been to use automated classification schemes to label posts by vaccine sentiment, either broad

categorical analyses (e.g., sorting content into positive, negative, and neutral) or into topical categorization schemes (e.g., sorting content by topics such as safety, efficacy, and cost).16 18 Other applications have included mapping semantic networks,19 detecting network and community structures,20 using topic modeling to infer areas of discussion,21 23 classifying images,24 and using machine-learning classifiers to infer geographic and demographic information.25 Topic modeling has been particularly successful in surveillance of content shared by social media users and can be deployed in a variety of contexts, from monitoring key topics in human papillomavirus vaccine discussions on Reddit to identifying topical links between content posted by Russian Twitter troll accounts.22,23 A new study used latent Dirichlet allocation (LDA) topic modeling to track 10 key influenza vaccine-related Twitter topics over time and measure how they correlated with vaccine attitudes.26 The strength of automated approaches is in the ability to quickly analyze millions of messages; however, the results tend to be tied to specific data sets and often lack the broad applicability and simplicity of Kata's framework.

While these studies have expanded scholarly knowledge, big questions remain: What is the prevalence of both pro- and antivaccine content on social media platforms? What topics dominate the general vaccine discourse? And what topics are spreading misleading vaccine information? To answer these questions, we introduce a new typology, building upon Kata's 2010 work, but updating it for Twitter and introducing automated approaches to replicate our findings at scale. We chose Twitter as one of the key platforms sharing vaccine misinformation, but also as the most accessible for research.27 Twitter may not be reflective of the attitudes held by the general public, but as a communication channel it plays a powerful role in amplifying vaccine messages and can foster online communities with shared interests. The resulting typology categorizes major themes and amplification strategies in the discourse of both vaccine opponents and vaccine proponents on Twitter. We believe this is a necessary first step toward developing a comprehensive survey of online vaccine discourse and foundational to developing successful efforts to fight misinformation.

METHODS

Our analysis followed 3 stages: first we conducted a manual content analysis on a subsample ofvaccine-relevant tweets; then we utilized LDA, a type of probabilistic topic modeling, to infer the major topics of discussion in the total vaccine discourse; and, finally, we conducted a second manual content analysis of representative tweets from each of the 100 topics generated in stage 2.

Data

Our data set contained 1.8 million vaccine-relevant tweets collected between 2014 and 2017 through the Twitter public streaming keyword application programming interface. Tweets were English language, contained vaccine keywords (substrings "vax" or "vacc"), and had been filtered by using a machine-learning classifier trained to exclude tweets not relevant to vaccination (e.g., metaphors).28

Content Analysis

Our first aim was to adapt Kata's typology to Twitter data by conducting a content analysis of 10000 randomly selected vaccine-relevant tweets (Figure 1). We designed our approach to comply with an emerging set of best practices to ensure rigor and accuracy.29 Tweets had been manually annotated for vaccine sentiment as part of an earlier project.30 Two independent annotators (A. M., K. P.) then coded each nonneutral tweet into 1 or more thematic categories. On a random sample of 100 antivaccine tweets, annotators agreed 88.75% of the time on primary codes (Scott's p = 0.85; 95% confidence interval [CI] = 0.78, 0.93). On a random sample of 100 provaccine tweets, annotators agreed only 48% of the time for primary codes (Scott's p = 0.38; 95% CI = 0.26, 0.49), suggesting a much harder task. To address low reliability, a third team member (A.J.) reconciled discrepancies for both data sets and assigned final codes for each tweet.

The antivaccine codebook (see the box on p. S334) included adapted versions of5 of Kata's 6 original content categories.7 The final attribute, misinformation, was widespread across all categories and was not coded separately. We did not identify a provaccine equivalent to Kata's typology during our literature search and chose to develop our own. The annotation team created a set ofdeductive codes to mirror Kata's categories, using examples from the data set to justify each new code. For instance, "safety and efficacy" was determined to be the provaccine

counterpart to antivaccine concerns about vaccine safety. In this way, we developed codes for pro-science, provaccine policy, criticizing antivaccine beliefs, and safety and effectiveness. Morality-based provaccine content (e.g., vaccinate to protect others) did not emerge as distinct theme. More common were tweets promoting vaccines without an underlying argument, prompting our fifth theme, "vaccine promotion."

Latent Dirichlet Allocation Topic Modeling

To infer distinctive topics of conversation across the entire sample of vaccine-relevant tweets, we used LDA, a widely used type of probabilistic topic model designed to identify underlying topics in a text data set by identifying groups of words that often co-occur (for more details on probabilistic topic models see Blei31).32 LDA is increasingly common in health informatics research as a method to assess large text-based data sets (see also Walter et al.23 and Chan et al.26). LDA assumes that each document (in this case, a tweet) contains an underlying mixture of topics and that each topic can be captured by an underlying mixture of words. We trained LDA with 100 topics on a subset of 1 million tweets, then inferred the topics on the remaining 800 000 tweets by using the trained model. In training the model, we preselect the number of topics we expect to find and then optimize the model for the most likely arrangement of words in each topic and topics in each document. We used the implementation of LDA from the MALLET topic modeling toolkit and used the default parameter settings unless otherwise noted.33 Every tweet receives scores reflecting probabilities for all underlying topics; the highest scoring topic is then taken as the primary topic for that tweet. For each topic, we aggregated tweets with the highest topic probabilities (87%- 95%). After excluding topics that returned fewer than 100 tweets or non-English content, the new data set contained 26 542 tweets, with an average of 285 tweets per topic (Figure 1).

Integrating the Typology

To understand how LDA topics fit within the updated typology, we conducted a second content analysis, randomly selecting up to 20 of the most relevant tweets from each LDA topic (Figure 1). LDA outputs provide keywords for each topic, but these can sometimes include co-occurring words that may not be truly conceptually related; therefore, it is important to assess highly representative full-length tweets (for topic keywords see Appendix A, available as a supplement to the online version of this article at http://www.ajph.org). Three annotators (A.J., A. M., K. P.) independently labeled each tweet for vaccine sentiment and theme. Across 100 randomly selected tweets, we observed 79% agreement on vaccine sentiment (Fleiss's k = 0.69; 95% CI = 0.59, 0.78) and 82% agreement on content labels for nonneutral tweets (Fleiss's k = 0.78; 95% CI = 0.66, 0.89). Topics were then arranged by sentiment and divided into categories: majority pro- or antivaccine (>70%nonneutral), neutral and pro- or antivaccine (20%-70% nonneutral), majority neutral (<20% nonneutral), or both (> 20% both provaccine and antivaccine; Table 1).7,9 In addition, we used this space to incorporate labels for Twitter-specific information including hashtags, @mentions, and retweet campaigns.

RESULTS

First we present results from the content analysis, then we present results integrating LDA and manual coding.

Prevalence of Vaccine Themes

Of the 10 000 messages annotated in subsample 1, 22% (n = 2241) were antivaccine, 17% (n = 1744) were provaccine, and the remaining 61% (n = 6015) were neutral or not relevant (Table 2). Among antivaccine tweets, safety concerns was the single most common theme (59%; n = 1320) followed by conspiracies (41%; n = 930), civil liberties (11%; n = 248), morality claims (5%; n = 105), and alternative medicines (2%; n = 50). Most tweets (68%; n = 1666) were labeled with a single topic. Co-occurrence was most common between safety concerns and conspiracies (n = 411).

For provaccine tweets, vaccine promotion (37%; n = 648) was the most common theme, followed by criticizing antivaccine beliefs (31%; n = 538) and safety and effectiveness (30%; n = 523). Fewer messages were pro-vaccine policy (5%; n = 92) and pro-science (5%; n = 85). Most tweets (89%; n = 1550) had a single label. The most common cooccurrence was between criticizing antivaccine beliefs and vaccine safety and effectiveness (n= 182).

Characterizing Latent Dirichiet Allocation Topics

Of the 100 LDA topics, 28 topics included significant antivaccine content, 48 included provaccine content, and 33

were neutral or not relevant (Table 1). Within each of these categories, we recognized a spectrum: 10 topics were majority antivaccine, 9 combined antivaccine and neutral content, 9 included both provaccine and antivaccine content, 20 combined provaccine and neutral content, and 18 were majority provaccine.

Although the proportions of nonneutral tweets and nonneutral topics were significantly different ($X^2 = 23.50$; $P < .001$) the distribution of themes was roughly equivalent (Table 2). For provaccine topics, the same 3 topics-safety and efficacy, vaccine promotion, criticizing antivaccine beliefs -were the most represented, with slightly greater representation of provaccine policy among topics ($P = .03$; Fisher's test). For antivaccine topics, we observed no significant differences between the distributions of themes ($X^2 = 5.54$; $P = .24$).

Topics that were primarily antivaccine consisted entirely of conspiracy and safety concerns (5 topics each, 50%). Conspiracy claims tended to focus on governmental and pharmaceutical fraud, while safety concerns included claims of vaccine-induced idiopathic illnesses and vaccines as poison. Among these 10 topics, we found the highest concentration of retweet activity in the data set, with 3 topics dominated by nearly verbatim retweets (possibly indicating bot-like activity). Other amplification strategies included use of antivaccine hashtags and @messages to celebrities and public officials for attention. Topics that combined antivaccine and neutral content (n = 9) included conspiracies (4 topics, 44%) and safety concerns (3 topics, 33%), but also civil liberties (2 topics, 22%). In these topics, neutral news content appeared alongside antivaccine claims and sometimes political content.

Majority provaccine topics (n = 18) included all 5 themes. Vaccine promotion efforts included a mix of event promotion, philanthropy efforts, and vaccine recommendations. Safety and efficacy topics emphasized the risks of not vaccinating, benefits of vaccines, or simply proclaimed #vaccineswork. Antivaccine-critical topics shamed antivaccine parents as crazy, stupid, and neglectful parents-sometimes relying on satire or parody. Pro-science topics included celebrations of vaccines as a major public health accomplishment but also included defending science against "fake news." Like antivaccine-critical topics, some of these claims relied on humor. Provaccine policy topics included discussion of vaccine mandates. Topics that combined provaccine and neutral content (n = 20) also included all 5 themes but included topics that were more controversial or polarizing like political discussions and influenza vaccine topics.

The 9 topics that combined significant provaccine and antivaccine sentiment highlighted areas of overlap in the discourse. This included debated topics in which users repeated and refuted arguments, such as differing interpretations of epidemiological evidence or the legality of mandates. It also included arguments with parallel structure; antivaccine arguments that claim vaccine science is "bad science" appeared alongside provaccine arguments describing vaccine opposition as pseudoscience. These conversations included more neutral hashtags (e.g., #immunity, #vaccine) and reliance on @messages to directly contact other users.

DISCUSSION

The sheer volume ofvaccine information on Twitter presents major challenges for researchers trying to systematically address misleading information. With this analysis, we introduce an innovative approach to estimate the prevalence of vaccine themes and classify major topics, providing a comprehensive assessment ofthe vaccine discourse on Twitter. We found a slightly greater proportion of antivaccine messages than provaccine messages (22% to 17%), with many more messages neutral on vaccines-findings in line with previous work.17 However, topic modeling demonstrated that distinctive topics ofconversation tend to be nonneutral, with a greater diversity of topics containing provaccine content from all 5 thematic areas, while topics containing antivaccine content concentrated on safety concerns and conspiracy theories. Neutral tweets represented most of the data set, but topic modeling demonstrated how they can serve as the foundation for both provaccine and antivaccine arguments, with a roughly one third of all topics mixing both neutral and polarized content.

Although very different in tone and sentiment, provaccine and antivaccine messages were more structurally similar than we anticipated. Because LDA analysis depends on word choice and language structure to identify coherent topics, that 9 topics included significant proportions of both provaccine and antivaccine content suggests use of similar language and rhetorical strategies. This does not necessarily mean that vaccine opponents and proponents were directly engaged; indeed, previous work has highlighted echo-chamber effects that limit exposure between

outside viewpoints at work in vaccine communities on Twitter.34 However, the 2 communities may be indirectly influencing each other's arguments, as evidenced by similar use of semantic strategies.

The Twitter features that allow for the spread of antivaccine content have likely also reshaped how provaccine content spreads. The prevalence of straightforward vaccine promotion content suggests that Twitter is a useful platform to easily share recommendations, remind patients to get vaccinated, and provide links to events. The increased visibility of the antivaccine movement has also likely shaped the ways Twitter users use the platform to defend vaccines. This is most clear in use of the platform to debunk antivaccine conspiracies, vent anger, or otherwise shame, blame, or complain about antivaccine parents. However, many debunking efforts tended to focus on a narrow set of outdated antivaccine claims suggesting that those most critical of antivaccine arguments are responding to an abstract idea of the antivaccine population and not engaging with antivaccine topics directly on Twitter. Defending vaccines also manifested in more subtle ways, like the #vaccineswork hashtag, where users felt the need to tweet in support of vaccines, making visible a sentiment that until recently many viewed as standard. This response is mirrored in the broader "defense of science" debates happening on Twitter as users see antivaccine arguments as part of a broader antiscience trend.

In addition to characterizing topics, we were able to observe how different arguments aligned with misinformation and amplification strategies. While antivaccine arguments are using many of the same strategies Kata detailed in 2010, including presenting unsupported falsehoods and misrepresenting scientific evidence, we saw some newer strategies that are tailored to Twitter. With strict character limits, tweets do not allow for contextualization, making it much easier to mislead by using sensational falsehoods or manipulations of real data. Some antivaccine claims are presented as facts, mimicking the language of mainstream news or science. In these instances, source credibility may be more important for users to gauge validity. Although both vaccine opponents and proponents have successfully utilized hashtags, we found @messaging and retweet campaigns were more common in antivaccine topics. Political language also appeared in both pro- and antivaccine content.

We identified a Twitter-specific amplification strategy that relied on massive retweet campaigns, suggesting evidence of concentrated effort by 1 or a group of actors. These campaigns may be driven by genuine users but could also indicate networks of automated accounts. Unlike previous studies that have characterized users as likely bots,30 focusing on messaging led us to look for evidence of bot-like behavior, of which these massive retweet campaigns were the most egregious.10 Topics consisting largely of retweets were among the most clearly misleading or political, including claims that shaken baby syndrome was a cover-up for vaccine injury and stories of an alternative medicine doctor mysteriously found dead after "exposing the truth" about vaccines. This suggests that amplification and automation have been successfully used to artificially inflate the appearance ofantivaccine and political topics.

Limitations

This research is not without limitations. LDA methods have their own drawbacks: researchers must preselect the number of topics to be inferred, , setting too many or too few topics can produce different results, and the resulting topics can be too specific or too broad depending on selected parameters.35 For these reasons, LDA is best at providing broad overviews of content, not nuanced analysis of specific topics. More broadly, by focusing our analyses on text only, we cannot ascertain the identity of the user, network features, the source of the linked content, or the impact of embedded images, which undoubtedly influence how information is perceived.

In the manual analysis, intercoder reliability for provaccine annotations was quite low; we believe this reflects the high level of similarity between our chosen categories. Vaccine opponents typically level specific claims against vaccines, but vaccine proponents tend to use very general language in support of vaccines, making it difficult to select a specific provaccine code. Future research is needed to refine this coding strategy. The challenges from the first round of annotation were largely absent during the second round of annotation, suggesting that annotators improved over time or that the nonrandom distribution of tweets from topic models aided in comprehension.

Public Health Implications

This updated typology was designed to distill relevant information from across the entire vaccine discourse on

Twitter quickly and accurately. Mapping the proportion of tweets was necessary first step, but we believe understanding how these themes play out in online conversation can better inform communication efforts on how users engage with vaccine topics on Twitter. At this stage, our findings remain quite general but lend themselves to several specific recommendations, particularly for provaccine messaging. While vaccine proponents are already using the platform to debunk specific antivaccine claims, these are often not the same claims promoted in antivaccine topics. Rather than address rumors directly and risk amplifying them further, it may be more beneficial for vaccine advocates to continue to emphasize the safety and efficacy of vaccines in general terms. Similarly, engaging with a bot-driven narrative only further amplifies the message. It is also important to communicate to the Twitter users eager to defend vaccines that the humor used to criticize antivaccine tweets and anti-science tweets may inadvertently mislead and furtherprovoke.36 This updated typology serves as a proof of concept. Future research efforts should explore specific communication strategies and extend similar approaches to map vaccine discourse and associated misinformation on additional platforms. Â1PU

CONTRIBUTORS

A. M.Jamison designed the content analysis portion ofthe study, lead the manual annotation team, and wrote the article. D. A. Broniatowski designed the computational portion of the study and provided critical revision of the article. M. C. Smith performed the computational analysis. K. S. Parikh and A. Malik served as annotators for the content analysis and assisted with codebook development. M. Dredze aided in data collection and provided critical revision ofthe article. S. C. Quinn provided health communication context and provided critical revision of the article.

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Sidebar

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Correction as a Solution for Health Misinformation on Social Media

Vraga, Emily K, PhD; Bode, Leticia, PhD

ABSTRACT (ENGLISH)

Scholars (including in this issue of AJPH) have debated which interventions limit the spread of health misinformation on social media, including promoting high-quality information, removing misinformation from platforms, and inoculating people against misinformation by bolstering news, information, and health literacy. Unfortunately, these preventative solutions cannot eliminate health misinformation, necessitating strategies that respond to misinformation to limit its pernicious influence on public attitudes and behaviors. Corrections-the presentation of information designed to rebut an inaccurate claim or a misperception -are an important treatment for misinformation. Despite the relative stickiness of misinformation, corrections are typically effective in reducing beliefs in health misinformation, although they are less so as issues become more polarized or beliefs become embedded in an individual's self-concept.

FULL TEXT

Scholars (including in this issue of AJPH) have debated which interventions limit the spread of health misinformation on social media, including promoting high-quality information, removing misinformation from platforms, and inoculating people against misinformation by bolstering news, information, and health literacy. Unfortunately, these preventative solutions cannot eliminate health misinformation, necessitating strategies that respond to misinformation to limit its pernicious influence on public attitudes and behaviors.

Corrections-the presentation ofinformation designed to rebut an inaccurate claim or a misperception -are an important treatment for misinformation. Despite the relative stickiness of misinformation, corrections are typically effective in reducing beliefs in health misinformation, although they are less so as issues become more polarized or beliefs become embedded in an individual's self-concept.1,2

CORRECTION ON SOCIAL MEDIA

On social media, in contrast to individually directed private communication, there are two targets for any corrective message: (1) the person sharing the misinformation, and (2) the community of individuals seeing the misinformation or the correction. These two targets may have different levels of resistance to correction. Someone posting misinformation is likely quite committed to that position, and cognitive dissonance makes it difficult for that poster to alter his or her beliefs after publicly sharing them. However, even people sharing misinformation can be corrected, especially when correction comes from a close tie.3

The second target of a correction on social media is the audience-those who witness a correction on social media but are not directly targeted or engaged in the interaction. This can occur, for example, when individuals see someone who is sharing misinformation being corrected by another user or an expert organization; it could also extend to corrective messages offered in response to commonly held misperceptions without targeting a misinformation post directly. Those watching from afar are likely less affected by cognitive dissonance, as their identity is not directly under threat, and thus more amenable to correction. We refer to this phenomenon as "observational correction."4,5 Research has consistently documented the ability of observational correction to reduce health misperceptions, including correction from a variety of sources- algorithms within the platform, expert organizations, and other social media users-on different platforms and on a wide range of health topics.4-6

BEST PRACTICES

Research has identified a number of best practices for engaging in observational correction on social media. First, citing highly credible factual information with links to expert sources is important, especially for users offering corrections.1,6 Expert sources themselves are more effective in correcting misinformation than users are, and engaging in such corrections on social media does not appear to negatively affect their credibility.5 Sharing

corrections that counter personal or political interest can enhance trust and thus effectiveness, so considering trusted sources among a target audience is essential.

Second, offering a coherent alternative explanation for the misinformation boosts the power of corrections.1,2 Corrections can state what is false and provide an explanation for why it is false (which may include the origins of the misinformation) to have stronger impacts. For example, you could debunk the myth that cutting sugar from your diet will cure cancer by explaining that sugar and diet are linked to cancer risk, but not to its treatment.

Third, multiple corrections reinforce the message, leading to reduced misperceptions.1,5 Repetition is a classic communication strategy and may be necessary when users correct.5

Finally, misinformation should be corrected early, before misperceptions are entrenched.4 Once misperceptions are ingrained and associated with one's identity, motivated reasoning to protect those beliefs becomes more likely, leading people to dismiss corrective information. Although early corrections may prevent misperceptions from being created, they should avoid drawing attention to uncommon misperceptions and must be transparent about the amount of expert consensus and evidence that exists on a topic.7

We offer one example of best practices for observational correction in the context of COVID-19 in Figure 1, wherein Tito's Vodka rapidly responds to an individual claiming she or he used their vodka to make hand sanitizer. The Tito's Vodka correction includes an unusual source debunking against their self-interest, citing a credible expert in the health domain, explaining why the myth is inaccurate, and repeating the accurate information.

REMAINING QUESTIONS FOR RESEARCH

There is substantial evidence that correcting health misinformation on social media is a fruitful strategy for reducing misperceptions among both those sharing misinformation and the community seeing the interaction. However, more research is needed to determine the efficacy of this strategy and to understand its limits.

First, we must consider the related questions of who engages in correction and how to encourage more people to respond to misinformation. Observational correction depends on a critical mass of trusted, willing, and informed correctors, but in general people are reluctant to confront others on social media and may not be equipped with the skills and information necessary to do so. Research should investigate how to develop appropriate social norms or interventions to encourage corrections on social media. Ideally, corrections would come from across the population, representing different demographics, backgrounds, and attributes; this may require targeted interventions to encourage groups who are currently less likely to engage in corrections. Likewise, relevant experts, professionals, and organizations could be incentivized to engage in corrections.

Second, calculated judgments about which misinformation should be prioritized in correction efforts are needed. If the myth being addressed is sufficiently rare or the account comparatively obscure, efforts to debunk the misinformation may heighten awareness of the myth unnecessarily.1 The potential of the misinformation to cause harm, the vulnerability and size of the audience for the post, and the level of evidence and expert consensus on the issue7 should be part of this calculation, but more research is needed into exactly where correction can do the most good.

Third, false corrections-that is, people claiming to correct when they are actually providing misinformation-merit attention. Not everyone correcting misinformation on social media is doing so accurately or in good faith. Right now, we have little understanding of the effects of false corrections. We also need to know more about how people respond when a correction generates debate about the truth.

Fourth, greater coordination between scholars and social media platforms could make correction more effective. This could include platforms working to highlight the visibility of comments that provide debunking materials; for example, prioritizing comments that link to credible health organizations or trustworthy news media sources. Beyond working with researchers to test interventions, platforms might also make appropriately anonymized data available to researchers, allowing greater investigation into the frequency, scope, and type of misinformation and correction occurring on social media.

Finally, many elements of observational correction may vary by platform or by circumstance. Among these are the tone of the correction, whether the correction comes before or after the misinformation, whether it relies on logic- or

fact-based appeals, what sorts of visuals it uses, and what types ofpopularity or credibility cues are available. Each of these is likely to affect how the corrective information is perceived and whether it is accepted by the audience of users witnessing it.

Health misinformation on social media will not be resolved with any single intervention, but encouraging users, experts, and platforms to correct misinformation as they see it on social media may be part of the solution.

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CONFLICTS OF INTEREST

There are no conflicts of interest to disclose.

Sidebar

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Who Is Susceptible to Online Health Misinformation?

Scherer, Laura D, PhD; Pennycook, Gordon, PhD

ABSTRACT (ENGLISH)

Although everyone has the potential to be misled by false information, online misinformation is not an equal opportunity aggressor. Some of us are more likely to believe misinformation than are others and serve as vectors by sharing it on social media. To effectively combat misinformation on social media, it is crucial to understand the underlying factors that lead certain people to believe and share false and misleading content online. A growing body of research has tackled this issue by investigating who is susceptible to online misinformation and under what circumstances. This literature can help shape future research and interventions to address health misinformation. We provide a brief overview of what we know about who is susceptible and what we still have to learn.

FULL TEXT

Although everyone has the potential to be misled by false information, online misinformation is not an equal opportunity aggressor. Some of us are more likely to believe misinformation than are others and serve as vectors by sharing it on social media. To effectively combat misinformation on social media, it is crucial to understand the underlying factors that lead certain people to believe and share false and misleading content online. A growing body of research has tackled this issue by investigating who is susceptible to online misinformation and under what circumstances. This literature can help shape future research and interventions to address health misinformation. We provide a brief overview of what we know about who is susceptible and what we still have to learn.

THEORETICAL PERSPECTIVES

One dominant perspective, which is sometimes referred to as the deficit hypothesis, is that people who believe misinformation do not have sufficient knowledge or literacy to discriminate between true and false information. Although health researchers often focus on health literacy, other types of literacy deficits are relevant, such as digital literacy, media literacy, and science literacy. Brashier and Schacter recently argued that the reason older adults share fake news on social media more frequently than do younger adults is not because of cognitive declines but because older adults have lower digital literacy than do younger adults. Older adults may be less savvy at identifying reliable online news sources, advertised (vs editorial) content, and manipulated photographs.1 Accordingly, some interventions have sought to address misinformation susceptibility by improving digital literacy (and related skills). For example, Guess et al. recently reported that a brief digital media literacy intervention improved detection of fake news headlines in both the United States and India.2

Another perspective is that people tend to be susceptible to misinformation that is consistent with their preexisting beliefs or worldview.3 Considerable research has shown that people tend to preferentially believe information that is consistent with their other preexisting beliefs.3 However, recent research has found that people may not be as influenced by their preexisting attitudes as previously thought. Specifically, in one study, individuals who had a more reflective cognitive style, as measured by the Cognitive Reflection Test, were better able to discern between true and false news content than were people who were more intuitive.4 Importantly, this occurred regardless of whether the news headlines were consistent or inconsistent with the participants' political ideology. Individuals' tendency to engage in greater reflective thought is also associated with their ability to detect COVID-19 misinformation.5 Moreover, other work has found that those who are worse at discerning between true and false information tend to overclaim their own knowledge and to be receptive to "pseudoprofound" statements (i.e., they rate random sentences filled with buzzwords but devoid of intended meaning as being profound).6 Evaluating these findings altogether, experts have speculated that receptivity to misinformation is related to being more "reflexively

openminded."6 That is, people who are susceptible to misinformation fail to even consider that the content is inaccurate, regardless of their underlying political ideology or preexisting beliefs.

Accordingly, a recent study showed that a simple accuracy nudge that primes people to think about whether headlines are true is sufficient to increase the quality of COVID-19-related news content that people indicate they would share on social media.5 A Twitter field experiment employing a similar intervention has also reported promising results.7 These findings support the idea that people fall for misinformation because they fail to think about the accuracy of content that they come across on social media, not because they are exercising politically motivated reasoning or are simply confused about what is and is not true.

To summarize, there are three currently dominant (albeit not entirely mutually exclusive) theoretical perspectives addressing why certain people are susceptible to online misinformation: (1) being confused about what is true versus false, suggesting that knowledge or various literacies are a primary factor; (2) having strong preexisting beliefs or ideological motivations that lead to motivated reasoning and therefore a desire to believe and share misinformation; and (3) neglecting to sufficiently reflect about the truth or accuracy of news content that is encountered on social media.

QUESTIONS FOR FUTURE RESEARCH

There are, of course, other individual characteristics that may be particularly relevant to accepting health-related misinformation that are not as neatly characterized under these perspectives. An important element is trust in health experts and health science. Trust is multifaceted: people can possess varying levels of (dis)trust in doctors, medical science, scientists, and health care systems. Each type of distrust may make an individual more susceptible to health misinformation. More research is needed on different facets of trust and their implications for believing misinformation. Other individual characteristics that have not yet been adequately studied in relation to misinformation susceptibility include traits such as the need for autonomy and one's orientation toward medicine. For example, a medical-maximizing orientation (i.e., the tendency to want active, aggressive approaches to health care) was recently found to be robustly associated with susceptibility to COVID-19 misinformation, a finding that warrants further explanation and exploration.5

A key unanswered question is whether susceptibility to misinformation is a generalized trait or is context dependent. The people who believe misinformation about politics may be the same people who believe misinformation about health5-however, there may be important differences between people who believe one or the other type of misinformation, and this issue has not been systematically investigated. For that matter, health misinformation spans many different health topics, and it is unclear whether people who believe misinformation about a particular health topic, such as vaccines, also tend to believe misinformation about other health topics (e.g., misinformation about cancer treatments, COVID-19). No research has explicitly addressed this question, but an answer to it could provide insight into the extent to which findings in one content area can inform other areas. Such knowledge would help to streamline the development and testing of interventions. For example, if we knew that similar people believe misinformation about health and politics and science, then we could more confidently extend interventions from one domain to others.

ADDRESSING SUSCEPTIBILITY

Although content moderation on social media platforms is clearly needed, we also need scalable interventions that can efficiently reach and effectively influence the people who are susceptible to believing and sharing health misinformation. These might be interventions to improve digital literacy or misinformation awareness in online environments. We envision a targeted public health campaign, and the first thing that any campaign needs is an excellent understanding of its audience: who they are, what motivates their beliefs and behaviors, and what is likely to persuade them. To understand our audience and deliver effective messages, we need to identify the characteristics ofpeople who are particularly susceptible to misinformation. Identifying who is susceptible to misinformation will also help us understand why they are susceptible. Understanding misinformation susceptibility in this way could help us make great strides in addressing it through targeted public health interventions. ÂfPU

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CONTRIBUTORS

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CONFLICTS OF INTEREST

The authors have no conflicts ofinterest to disclose.

Sidebar

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DETAILS

Subject:	Accuracy; Media literacy; Science; Intervention; Social networks; Older people; Cognition &reasoning; COVID-19; Editorials; Medical research; Public health; False information; Digital broadcasting; Coronaviruses; Digital literacy; Mass media effects; Internet; Social media; Equal opportunity; Digital media
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Facebook Pages, the "Disneyland" Measles Outbreak, and Promotion of Vaccine Refusal as a

Civil Right, 2009–2019

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ABSTRACT (ENGLISH)

Objectives. To understand changes in how Facebook pages frame vaccine opposition. Methods. We categorized 204 Facebook pages expressing vaccine opposition, extracting public posts through November 20, 2019. We analyzed posts from October 2009 through October 2019 to examine if pages' content was coalescing. Results. Activity in pages promoting vaccine choice as a civil liberty increased in January 2015, April 2016, and January 2019 (t[76]= 11.33 [P< .001]; t[46] = 7.88 [P< .001];and t[41] = 17.27 [P<.001], respectively). The 2019 increase was strongest in pages mentioning US states (t[41] = 19.06; P< .001). Discussion about vaccine safety decreased (r_s [119] = -0.61; P< .001) while discussion about civil liberties increased (r_s[119] = 0.33; Py< .001]). Page categories increasingly resembled one another (civil liberties: r_s[119] = -0.50 [P<.001]; alternative medicine: r_s[84] = -0.77 [P<.001];conspiracy theories: r_s[119] = -0.46 [P< .001]; morality: r_s[106] = -0.65 [P< .001];safety and efficacy: r_s[119] = -0.46 [P< .001]). Conclusions. The "Disneyland" measles outbreak drew vaccine opposition into the political mainstream, followed by promotional campaigns conducted in pages framing vaccine refusal as a civil right. Political mobilization in state-focused pages followed in 2019. Public Health Implications. Policymakers should expect increasing attempts to alter state legislation associated with vaccine exemptions, potentially accompanied by fiercer lobbying from specific celebrities. (Am J Public Health. 2020;110:S312-S318. https://doi. org/10.2105/AJPH.2020.305869)

FULL TEXT

Headnote

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Conclusions. The "Disneyland" measles outbreak drew vaccine opposition into the political mainstream, followed by promotional campaigns conducted in pages framing vaccine refusal as a civil right. Political mobilization in state-focused pages followed in 2019.

Public Health Implications. Policymakers should expect increasing attempts to alter state legislation associated with vaccine exemptions, potentially accompanied by fiercer lobbying from specific celebrities. (Am J Public Health. 2020;110:S312-S318. https://doi. org/10.2105/AJPH.2020.305869)

Facebook connects billions of people globally,1 enabling individuals to share information on pages organized around common interests. Facebook can therefore be used to spread health-related information2 and misinformation3-5 quickly and widely, affecting public discourse6,7 and potentially driving real-world behaviors. These community

dynamics could also allow malicious actors to mobilize vulnerable communities for their own purposes.8 For example, Facebook has been linked to recent outbreaks of violence around the world.9

The dynamics of health misinformation on Facebook pose a threat to vaccination programs. Social media exposure is theorized to amplify vaccine skepticism,10 exposing billions of users to misinformation about vaccines, increasing hesitancy and delay,11-13 eroding trust in health care providers and public health experts,12,14 and reducing vaccination rates, with repeated exposures potentially exacerbating this hesitancy.15

In addition to amplifying misinformation, the group structure of social media platforms may concentrate it,7 polarizing communities.6 Tightly knit communities that collectively refuse to vaccinate lack herd immunity-meaning that a small number of disease exposures can lead to deadly outbreaks -and damage herd immunity for the broader population. In 2019, the US Centers for Disease Control and Prevention reported outbreaks of measles in several US states and worldwide, all of which struck communities with low vaccination rates (https://www. cdc.gov/measles/cases-outbreaks.html). Finally, some have raised concerns that the COVID-19 "infodemic" could trigger vaccine refusal.16 Public health communicators must therefore attend to rationales for vaccine refusal and how this misinformation might affect real-world behaviors.

Rationales for vaccine refusal vary widely and often contradict one another.17 One emphasizes vaccine harms, health risks, or safety concerns associated with vaccination. Another frames vaccination as a civil liberties issue, asserting parental rights to determine medical care. Others embrace conspiracy theories (emphasizing scientific, governmental, and pharmaceutical malfeasance) or alternatives to Western medicine such as naturopathic cures or dietary supplements. Historically, these different rationales have been associated with different social groups.18 On the surface, social media seem to reflect this community structure, with specific Facebook pages corresponding to these audiences.

On the other hand, recent outbreaks and legislative proposals around the world19 suggest that vaccine opposition may be coalescing around a common narrative, emphasizing civil rights and freedom from elitist government overreach. Because coalescence could facilitate organized political action around vaccine opposition, we sought to test this hypothesis, examining how the discourse of vaccine opponents on social media has changed over time. Here, we report the results of a retrospective observational study characterizing the content of 204 public Facebook pages, emphasizing different vaccine opponent narratives. Using a set of 284 266 posts from October 2009 through October 2019, we quantified changes in the popularity of these narratives. Finally, we examined the proportion of messages associated with different communities, testing the hypothesis that pages expressing a specific group affiliation nevertheless post vaccine refusal content from a wide range of different perspectives.

METHODS

We conducted 3 analyses. First, we categorized Facebook pages opposing vaccination and measured the volume of posts in each category. Second, we described the topics of discourse within each page type over time and tested the hypothesis that pages in each category preferentially shared posts reflecting an underlying group identity. Third, we measured whether content across page types was coalescing over time.

Data Collection

Using a method initially developed for identifying online community structure,20 we identified a cluster of Facebook pages expressing vaccine opposition. We first identified a seed set of pages promoting content opposing vaccination, then added additional pages if they "liked" these seed pages and vice versa. This expanded list was then cross-checked to eliminate false identifications, and we iterated this process by using snowball sampling20-22 until no more pages were added. We identified 303 Facebook pages pertaining to vaccines, sampled on March 25, 2019. Using data from CrowdTangle,23 a public insights tool owned and operated by Facebook, we downloaded all public posts for these pages on November 21, 2019. After removing 22 (7%) non-English pages, 214 (71%) of the remaining pages, involving 1 414 081 "fans" as of March 25, 2019, expressed vaccine opposition. We successfully downloaded all 288 175 posts from 204 of these pages (95%; we were unable to download posts for some pages, and 1 page, with 3 511 posts, was excluded because of a coding error), with a total of1 397 086 (99%) fans.

Analysis

Which online communities are most active? Using information contained in pages' title and "about" sections, we categorized pages into 5 high-level non-mutually exclusive content categories derived from Kata's24 typology of vaccine-opposing content: (1) safety and efficacy, (2) alternative medicine, (3) civil liberties, (4) conspiracy theories, and (5) morality. We did not use the sixth category, misinformation, because misinformation appeared across all pages. Two independent annotators (A. M. J. and E. S.) agreed in 76.7% of instances (Cohen's k = 0.66; 95% confidence interval [CI] = 0.58, 0.74, indicating "substantial" agreement).25 Discrepancies were reconciled discursively and final codes reflect consensus. We also identified pages containing the name of a US state (e.g., "Michigan for Vaccine Choice"). We then enumerated fans and monthly post volume for each page category.

Raw post counts (Appendix A, Figure A, available as a supplement to the online version of this article at http://www.ajph.org) suggest qualitative changes in activity surrounding (1) January 2015: the "Disneyland" measles outbreak26; (2) April 2016: the release of Vaxxed, a film directed by a discredited former physician; and (3) January 2019: a US measles epidemic. We used the t test to examine changes in post frequency in different page categories before and after these events (see Appendix A, Figures B and C, for additional evidence for these specific events).

What content is most likely to be posted in these pages? We combined the message text and, if applicable, link text, and link description into a single document for each post after removing all URLs. Using the MALLET software package (AK McCallum, Amherst, MA) with Bayesian hyperparameter optimization,27 we inferred 100 topics for these documents using a Latent Dirichlet Allocation28 model fit to all 288 175 posts through November 20, 2019. Two authors (D. A. B. and A. M. J.) independently matched each of the resulting topics to 1 of 6 content or 2 design ("emotive appeals" or "content aspects") attributes listed in Kata's typology24 after manually inspecting the top 10 keywords and 50 posts for each latent Dirichlet allocation topic (Cohen's k = 0.67; 95% CI = 0.58, 0.77). We merged the conspiracyoriented attributes "profit," "collusion," "protection," and "coverup" attributes because ofoverlapping content; both annotators independently reported inability to distinguish among these attributes. In addition, we added new attributes reflecting novel content: within "alternative medicine," dieting and lifestyle; within "civil liberties," politics, political rallies, and events; and a "miscellaneous" category with design attributes specific to social media platforms (e.g., hashtags). Disagreements between annotators were reconciled discursively and final codes reflect consensus.

Next, we averaged the document-specific probability distributions for all documents in each month to generate monthly distributions over topics for 284 266 (99%) posts from October 2009 through October 2019. (We excluded data from before October 2009 [33 posts; 0.01%] because they had fewer than 20 posts per month, making probability distribution calculations unreliable. In addition, we excluded November 2019 [3876 posts; 1%] because we only had partial data for that month.) We generated similar average monthly distributions for each page category. We examined how these category-specific distributions increased or decreased in popularity29 using Spearman's rank correlations to account for floor and ceiling effects. Finally, we segmented the data into the same 4 time periods as described previously.

Are rationales for vaccine opposition coalescing around common topics? For each page type, we calculated the average monthly proportions of category-consistent topics compared with post proportions in all other pages (e.g., civil liberties topic proportions in civil liberties pages compared with civil liberties topics in all other pages). We tested the hypothesis that pages had higher proportions of category-consistent content. Next, we examined how these proportions changed over time. Finally, we calculated the Kullback-Leibler divergence-a standard metric of probability distribution similarity-between the category-specific monthly topic distribution for each Facebook page category and the average distribution for all posts in October 2019, the last full month in our sample. We examined whether the Kullback-Leibler divergence for each page category decreased over time, which would indicate that the distribution ofposts within that page category was becoming more similar to the reference.

RESULTS

Out of204 Facebook pages in our sample, 90 (44%) were categorized as "civil liberties," 90 (44%) as "safety and efficacy," 61 (30%) as "conspiracy theories," 16 (8%) as "alternative medicine," and 7 (3%) as "morality" (43 pages [21%] had 2 annotations; see Appendix A, Table A). A total of 53 (26%) pages contained the name of a US state in

their title. After applying a logarithmic transform to correct for skewed data, we did not detect statistically significant differences in the number of fans (F[6197] =0.14; P = .99) orposts (F[6197] = 0.36; P = .90) per page by page type (Appendix A, Figures D and E).

Measles Outbreaks, Movies, and Legislative Mandates

Figure 1 shows several statistically significant nonlinear increases in post volume in the time period between October 2009 and October 2019. Compared with previous months, overall monthly post volume increased during the period between January 2015 (the "Disneyland" measles outbreak) and March 2016 (r[76] = 12.16; P< .001). A second increase occurred in the period between April 2016 (the release of Vaxxed) and December 2018 (t[46] = 3.63; P< .001). This second increase seems to have occurred in pages promoting "civil liberties" (t[46] = 9.46; P< .001) but not associated with any specific states. By contrast, post volumes in other pages decreased slightly (t[46] = -2.93; P = .005). Finally, compared with the period between April 2016 and December 2018, a statistically significant increase occurred in January 2019 (the 2019 US measles epidemic; t[41] = 13.47; P< .001). These changes cannot be attributed to linear increases in the overall Facebook user base (Appendix A, Figure F).

This increase seems to be primarily associated with activity in civil liberties pages, but also pages mentioning a US state in their title. Because there was statistically significant overlap between these categories (38 [72%] of the 53 state pages were categorized as "civil liberties"; x2[1] = 22.09; P< .001), we examined them separately. Civil liberties pages mentioning states (t[41] = 17.31; P< .001), civil liberties pages not mentioning states (t[41] = 12.85; P< .001), and pages mentioning states but not civil liberties (t[41] = 21.45; P <.001) all experienced statistically significant increases in post volumes. Pages mentioning states contained a total of 67 036 (24%) posts, with 33 498 (50%) posts in pages mentioning just 6 states: Michigan, Oregon, Georgia, New Hampshire, Delaware, and Vermont (raw counts in Appendix A, Table B). Pages mentioning neither states nor civil liberties did not experience a statistically significant change in post volumes (t[41] = -1.67; P = .10).

Political Mobilization and Celebrity Spokesmen

Appendix B (available as a supplement to the online version of this article at http:// www.ajph.org) shows the proportion of all topics in our data set, aggregated into attributes and typology categories (see Appendix A, Table B, for topic descriptions). Results show that posts in our sample were roughly equally likely to be about conspiracy theories (21%), civil liberties (20%), and safety and efficacy (19%). Figure 2 shows that the monthly share ofposts pertaining to safety and efficacy decreased overall (rs[119] = -0.61; P< .001), driven by a decrease in posts about immunity to specific diseases (e.g., indicating that vaccines are ineffective, cause diseases, or otherwise weaken the immune system; rs[119] = -0.71; P< .001). This decrease coincided with the "Disneyland" measles outbreak (t[76] = -4.51; P< .001) and the launch of Vaxxed (t[46] = 2.94; P = .005). By contrast, the share ofposts pertaining to civil liberties has grown overall (rs[119] = 0.33; P< .001), with discrete increases associated with both the 2015 (t[76] = 5.41; P< .001) and 2019 (t[41] = 6.38; P< .001) measles outbreaks but a decrease in between (t[46] = -3.20; P = .003). These changes are largely attributable to posts opposing vaccine mandates ("totalitarianism"; rs[119] =0.45; P< .001), which follow the same pattern: increases in 2015 (t[76] = 5.75; P< .001) and 2019 (t[41] = 5.91; P< .001), with a decrease in between (t[46] = -2.54; P = .01). Furthermore, we saw discrete increases in posts advocating political mobilization ("politics") in both 2015 (t[76] = 3.78; P< .001) and 2019 (t[41] = 5.23; P< .001), and with a statistically significant decrease in between (t[73] = 3.52; P< .001).

The share of posts reflecting "content aspects" also increased statistically significantly (rs[116] = 0.29; P = .001), driven primarily by posts about Vaxxed (rs[119] = 0.79; P< .001), with statistically significant increases corresponding to the lead-up (t[76] = 6.17; P< .001) and launch (t[46] = 5.79; P< .001) of Vaxxed, but with a statistically significant decrease afterward (t[41] = -4.01; P< .001). Concurrently, posts referring to the movie's producer have steadily increased (rs[119] = 0.82; P< .001), as have those referring to a political activist and attorney with whom he frequently collaborates (rs[119] =0.73; P< .001). By contrast, posts referring to a candidate for public office in New York City who opposes vaccines (rs[119] = -0.40; P <.001) and the founder of a nonprofit who advocates for "parents of vaccine-injured children" (rs[119] = -0.67; P< .001) have both decreased over time.

Coalescence of Rationales Across Pages

As expected, pages categorized as promoting civil liberties (t[119] = 12.67; P< .001) and conspiracies (t[119] = 6.67; P <.001) posted statistically significantly more content reflecting their corresponding topic categories than did other pages. By contrast, we did not detect statistically significant differences between pages categorized as about safety and efficacy (t[119] = -0.50; P = .62) and morality (t[106] = -1.90; P = .06) and their corresponding categories. Pages pertaining to alternative medicine had statistically significantly less alternative medicine content than did other pages (ř[84] = -8.90; P< .001).

All page types displayed an overall decreasing trend in the Kullback-Leibler divergence between each month's topic probability distribution and the average distribution for October 2019 (civil liberties: rs[119] = -0.50 [P< .001]; alternative medicine: rs[84] = -0.77 [P< .001]; conspiracy theories: rs[119] = -0.46 [P< .001]; morality: rs[106] = -0.65 [P< .001]; safety and efficacy: rs[119] = -0.46 [P< .001]). Thus, each Facebook page category is hosting increasingly similar content. For example, pages pertaining to safety concerns contained equal proportions of posts about safety concerns as those that did not pertain to safety concerns (Figure 3). Even pages pertaining to conspiracy theories, which seem to have experienced a relative increase starting in 2017, are converging.

DISCUSSION

Our results demonstrate how the vaccine opponent discourse has increased in volume and evolved over time, with 3 distinct phases:

1. vaccine opposition becomes mainstream,
2. popular media spokesmen target civil liberties pages, and
3. civil liberties pages promote state-level political mobilization.

Phase 1

The "Disneyland" measles outbreak brought national attention to mainstream vaccine opposition. Before this date, measles outbreaks in the United States had garnered comparatively little media attention. This outbreak sparked a national debate and the enactment of legislation to curb personal belief exemptions in California. During this period, the volume of posts on all vaccine opponent pages increased, and civil liberties discourse, in particular, became widespread.

Phase 2

The launch of Vaxxed coincided with an increase in posts to non-state-specific civil liberties pages. However, the proportion of civil liberties topics discussed decreased whereas the proportion of posts about the movie increased. This suggests that these pages may have been used as vehicles to disseminate content advertising the movie, possibly having established a linkage between the civil liberties discourse and the personalities driving this movie's agenda. This interpretation is supported by a decrease in civil liberties content in civil liberties pages, such that these pages more directly mirrored the content of other pages (Figure 3). This coincided with an increase in references to the movie's producer and collaborator during the same time period (Figure 2d, in particular, shows a large spike in January 2017). Fans of civil liberties pages may have been explicitly targeted as audiences for this movie.

Phase 3

The year 2019 gave rise to a sharp increase in posts to pages mobilizing Facebook fans for political purposes. This effect is especially pronounced in US state pages, which have seen increases in civil liberties discourse, but also vaccine safety concerns and alternative medicine. Michigan, Oregon, Georgia, New England, and Delaware seem to have been especially targeted. Notably, several of these regions were sites of measles outbreaks in 2019, a focus of legislative debate regarding vaccines, or both. For example, Georgia's House Bill 615 would "authorize certain minors to receive vaccinations without parental consent" (http://www.legis.ga.gov/ Legislation/ en-US/display/20192020/HB/ 615). Finally, among nonstate pages, only civil liberties pages experienced a similar increase whereas other topics declined in volume.

These findings were replicated in the topic analysis, which showed that both 2015 and 2019 saw a sharp increase in the civil liberties discourse, attributed largely to increased discussions about political mobilization and totalitarianism. By contrast, discussion of safety and efficacy has decreased, suggesting that vaccine opponents increasingly oppose vaccination as a matter of political principle rather than because of any particular concern about harms.

Emergence of a Common Vaccine Opponent Narrative

All categories of vaccine pages appear to increasingly reflect the same proportion of topics regardless of the stated purpose of the page. Furthermore, a large and increasing proportion of these messages reflect civil liberties and especially totalitarianism and political mobilization. This raises questions regarding to what extent there may be coordinated action driving content to these pages, with common ideological, political, or commercial commitments.

Limitations

A labeling error by 1 annotator led us to inadvertently exclude 1 page (1% of posts)- that claimed to promote "understanding of" or "truth about" vaccines, but actually opposed vaccines-from our sample. Beyond this 1 error, we utilized trained annotators with subject matter expertise to achieve reliable results.

In general, Facebook pages reflect "the official profiles for entities, such as celebrities, brands or businesses"30 constituting a limited snapshot of Facebook's dynamic network structure. By contrast, Facebook groups are designed for people to "share their common interests and express their opinion."30 Pages often point to eponymous groups, suggesting similar content; however, future work should conduct a more extensive comparison. Furthermore, private groups are inaccessible to ethical researchers whereas all pages are public. Although some content may have been removed before data collection, these removals appear limited-only 10 pages did not return any posts-compared with the millions of fans and hundreds of thousands of posts in our sample.

Public Health Implications

Health communicators frequently focus their efforts on debunking misinformation and promoting the health benefits of vaccination to the public. By contrast, vaccine opponents increasingly use the language of civil liberties-such as "vaccine choice"-to frame their efforts.

There is scientific consensus regarding the safety and efficacy of vaccination. Nevertheless, a civil liberties frame implies a legitimate debate about vaccination. This frame is known to increase hesitancy and delay-and, therefore, the likelihood of outbreaks-even among those who believe that vaccines are safe and effective.8 Furthermore, this frame puts the impetus for making what would otherwise be a routine procedure on vulnerable parents. Finally, framing vaccination as an individual choice shifts attention away from the social rationales for vaccination, including that herd immunity is a key factor in protecting the most vulnerable patients-the immunocompromised and the elderly.31

A freedom-of-choice frame has previously been adopted by vaccine opponents in other countries19 and by the tobacco industry when seeking to advance its business interests: this frame had been used to oppose government regulation by deflecting blame from corporate responsibility onto individual consumers.9 Vaccine opponents may similarly be using this frame to deflect attention from internal contradictions and significant internal disagreements regarding specific safety concerns or conspiracy theories. For example, some vaccine opponents claim that vaccines cause the diseases that they actually prevent, whereas others claim that vaccines are unnecessary because associated illnesses were already declining. Given the shifting rationales for vaccine refusal, a "civil liberties" framing fundamentally recontextualizes vaccination, making it into a value-laden political issue, rather than a debate over scientific or medical facts.

To the extent that public health communications emphasize verbatim facts over the gist, or bottom-line meaning,32 34 of vaccination, vaccine opponents and proponents may be talking past one another, with proponents unable to convince opponents about the value of vaccination and conflating vaccine opposition with ignorance-a linkage that strengthens the claim that public health and medical officials are elitist. Thus, this framing presents health communicators with a danger and an opportunity. The danger is that public health practitioners, often with limited human and fiscal resources, cannot devote the sheer attention necessary to maintain a constant social media presence. Furthermore, they may wish to avoid the appearance of communications that could be judged to be partisan or political. By contrast, by empowering members of the public to make their own choices about vaccination, public health communicators must be equally empowered-but only if provided with adequate resources-to communicate the appropriate and compelling social context for vaccination decisions.

Our results suggest that vaccine opponents are becoming increasingly organized with considerable political clout.

Public health agencies and advocates must therefore build strong relationships with state policymakers so that they may take an active stance when proposed laws or exemptions would further threaten the public's health. Finally, legislation is shaped by public opinion. Thus, continued protection ofthe public health will require sustained research into effective messages for communicating fact-based rationales for vaccination that are nevertheless targeted and tailored. These messages must be responsive to the contextual factors, specific values, and gists motivating vaccine refusal.

CONTRIBUTORS

D. A. Broniatowski designed the study, collected and analyzed data, conducted the statistical analyses, and wrote the first draft of the article. A. M. Jamison assisted with study design, critically revised the article, and conducted the qualitative analysis. N. F. Johnson, N. Velasquez, R. Leahy, and N. Johnson Restrepo collected and labeled data and critically revised the article, M. Dredze critically revised the article. S. C. Quinn critically revised the article and assisted with study design.

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CONFLICTS OF INTEREST

D. A. Broniatowski has received an honorarium of$500 from the United Nations Shot@Life Foundation-a nonprofit organization that promotes global childhood immunization. M. Dredze holds equity in Sickweather and has received consulting fees from Bloomberg LP and Good Analytics N. F. Johnson, N. Velasquez, R. Leahy, and N. Johnson Restrepo occasionally act as consultants to outside companies, but they do not and have not acted in this capacity with any company related to the content of this article, nor more generally in public health or on the topic ofvaccines. None ofthe organizations or companies listed here had any role in the study design, data collection and analysis, decision to publish, or preparation of the article.

HUMAN PARTICIPANT PROTECTION

The data used in this article are from publicly available online sources, the uses ofwhich are deemed exempt by the George Washington University institutional review board (180804).

Sidebar

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DETAILS

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Using a Global Pandemic as a Teachable Moment to Promote Vaccine Literacy and Build Resilience to Misinformation

Vanderpool, Robin C, DrPH; Gaysynsky, Anna, MPH; Chou, Wen-Ying Sylvia, PhD, MPH

ABSTRACT (ENGLISH)

Vaccination against infectious disease has been recognized as one of the "Ten Greatest Public Health Achievements" of the 20th century, given the substantial impact immunizations have had globally across a range of diseases, including polio, influenza, pneumonia, measles, mumps, rubella, viral hepatitis, pertussis, and oncogenic human papillomarvirus.1 Populationlevel vaccination programs have resulted in significant declines of new cases of disease, decreased morbidity and mortality, lower health care costs, and improved productivity.1 However, despite the proven clinical and cost effectiveness of vaccination, vaccines have not yet achieved their full potential, as rates of immunization among children and adults remain suboptimal, leading to a resurgence ofsome infectious diseases (e.g., measles).

FULL TEXT

Vaccination against infectious disease has been recognized as one of the "Ten Greatest Public Health Achievements" of the 20th century, given the substantial impact immunizations have had globally across a range of diseases, including polio, influenza, pneumonia, measles, mumps, rubella, viral hepatitis, pertussis, and oncogenic human papillomarvirus.1 Populationlevel vaccination programs have resulted in significant declines of new cases of disease, decreased morbidity and mortality, lower health care costs, and improved productivity.1 However, despite the proven clinical and cost effectiveness of vaccination, vaccines have not yet achieved their full potential, as rates of immunization among children and adults remain suboptimal, leading to a resurgence ofsome infectious diseases (e.g., measles).

Bringing increased attention to vaccination now is especially important as the world continues to combat COVID-19, a novel infectious disease that is easily transmissible and has an uncertain disease course, disproportionately affects elderly and ethnic/ racial minority populations, provides fertile ground for misinformation, and has become politicized. As an uncertain population anticipates the development of a COVID-19 vaccine to help return society to some semblance of normalcy, priming the public for vaccine acceptance is an urgent public health priority. With daily lives interrupted and vaccine discussions dominating news headlines, government hearings, and social media discourse, this urgency should be used as a teachable moment to promote vaccine literacy, address hesitancy, and build resilience to misinformation specific to a COVID-19 vaccine and about vaccination more generally. These efforts require us to reengage the public, community leaders, health care providers, public health practitioners, policymakers, and health agencies in addressing the challenges associated with bolstering vaccine-related knowledge, attitudes, and behaviors.

The fact that lack of access to vaccines is a critical driver oflow immunization rates in many communities is undeniable; however, when individuals do have access, lack of vaccine confidence becomes a primary barrier to uptake. In fact, recent polls suggest that many Americans do not plan to get a COVID-19 vaccine when one becomes available. Therefore, we specifically focus on strategies and research ideas for addressing vaccine literacy and hesitancy. Given the speed at which a vaccine for COVID-19 is being produced, adequate information about vaccine development and implementation as well as safety and efficacy may be challenging for individuals to gather and process. Proactive and coordinated communication efforts (e.g., public awareness campaigns) emphasizing the phases of vaccine development, Food and Drug Administration oversight, and adverse event reporting systems could increase confidence in vaccine safety and effectiveness.2

In addition to increasing knowledge about vaccines, efforts to promote vaccine literacy should support the public's

ability to critically evaluate health information, strengthen numeracy skills, and instill an appreciation of the complexity of scientific research.3 Strategies for cultivating vaccine literacy could include tailored patient- and parent- provider communication during clinical encounters, targeted media campaigns, peer-to-peer vaccine education, school-based health and science courses, and community-delivered educational programs (e.g., churches, social services, cooperative extension programs).4

Although increasing the public's knowledge about vaccines will be vital, perhaps the greatest challenge facing vaccine literacy efforts is the proliferation of vaccine misinformation online. For years, public health experts and vaccine advocates have tried to reverse the damage caused by reports of an unfounded link between autism and childhood vaccines, only to have these efforts undermined by the massive amount of vaccine misinformation circulating online. Misinformation has become an especially acute problem in the context of COVID-19 because there are still many unanswered questions about the disease, making it easy for rumors to take root in the absence of scientific certainty.

Alarmingly, antivaccination groups are taking advantage of this situation to actively mislead the public and engage in divisive discourse on social media, even before the development of a COVID-19 vaccine. As evidenced by recent media reports, these activists are using social media to propagate rhetoric related to personal freedoms, to try to preempt possible COVID-19 vaccine mandates, to amplify fear and distrust of vaccines, to discredit those involved in vaccine development (e.g., pharmaceutical companies, philanthropists, government scientists), and to encourage parents to skip routine vaccination appointments during the pandemic. These online disand misinformation efforts are especially worrisome, as research has shown that fewer children have been getting routine vaccines since COVID-19 was declared a national emergency.5

Notably, exposure to misinformation cannot simply be undone through fact checking, correcting, or debunking efforts: a large body of research has shown that retractions are rarely successful at eliminating reliance on misinformation, a phenomenon known as the "continued influence" effect.6 Mitigating the effects of exposure to vaccine misinformation requires the development and testing of novel strategies beyond traditional vaccine education efforts. These strategies could include inducing skepticism about disinformation agents modeled after previous efforts to discredit the tobacco industry and developing tools to help the public identify credible information sources (e.g., creating a symbol to indicate that a Web site or social media account is credible and has been vetted). Other innovative ideas include combatting online conspiracy theories by partnering with former members of conspiracist communities to offer insights on the group's beliefs and disseminate evidence-based health information to current members. Mobilizing the provaccine majority to counter online misinformation may also be considered a testable strategy to assuage exposure to misinformation. Social media platforms could also proactively monitor, flag, and remove content or accounts that promote harmful health information and reconfigure platform features that amplify misinformation.

Although strengthening knowledge of vaccines, addressing misinformation, and reinforcing literacy skills are all necessary, they are not sufficient to fully address vaccine hesitancy and uptake. Cognitive, emotional, social, cultural, and contextual factors also shape overall vaccine attitudes and behaviors.2,7 Examples of these factors include political ideology, religious beliefs, online information silos dominated by singular viewpoints, medical mistrust, stances on government involvement in individual health decisions, and disease risk perceptions. Vaccine literacy efforts must therefore acknowledge that hesitancy is not always driven by a lack of knowledge and address these drivers by creating and delivering messages that align with individuals' values, acknowledge their concerns, and emphasize the health and economic benefits of vaccination for individuals, their families, and their communities. Potentially effective strategies include reinforcing healthpromoting social norms, engaging social media and key opinion leaders and influencers to advocate vaccines, and ensuring the provision of strong and consistent vaccine recommendations from health care providers. However, we recognize that many of these proposed intervention strategies have limitations (e.g., limited efficacy among individuals with entrenched beliefs, insufficient reach); therefore, communication efforts should be combined with policy-based approaches- such as school and workplace immunization requirements- that establish vaccination as the default option for individuals and families and

disincentivize individuals from refusing vaccinations.

As we collectively face the public health consequences of the COVID-19 pandemic, we need to proactively and thoughtfully develop, test, and implement timely communication interventions to increase vaccine confidence. It is challenging enough to promote uptake of vaccination under normal circumstances, but it is particularly vital in anticipation of a future COVID-19 vaccine and the contentious discourse and pervasive misinformation that currently surrounds this topic. Going backward in the progress made against vaccine-preventable diseases is not an option; routine vaccination ofchildren and adults cannot be compromised or delayed. We should seize the attention being given to the COVID-19 pandemic and ubiquitous discussions of a vaccine as an opportunity to explore new intervention strategies to reinforce our commitment to a vaccine-literate and vaccineprotected public. >4jPI-l

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CONTRIBUTORS

R. C. Vanderpool conceptualized the editorial and wrote the first draft. A. Gaysynsky and W-Y.S. Chou contributed additional concepts and participated in further writing and revision.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

Sidebar

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DETAILS

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HPV Vaccine Searches on Pinterest: Before and After Pinterest's Actions to Moderate Content

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ABSTRACT (ENGLISH)

Objectives.To compare how human papillomavirus (HPV) vaccination was portrayed on Pinterest before and after the platform acted to moderate vaccine-related search results to understand (1) what the information environment looked like previously and (2) whether Pinterest's policy decisions improved this environment in terms of sources and content. Methods. In this quantitative content analysis, we compared 2 samples of 500 HPV vaccine-focused Pinterest posts ("pins") collected before and after Pinterest's actions to provide more reliable vaccine-related information. Pins were based on search results and were analyzed using the Health Belief Model. Results. The majority of preaction search results leaned toward vaccine skepticism, specifically focused on perceived vaccine barriers. Few pins were published by public health-related Pinterest accounts. Postaction search results showed a significant shift to HPV vaccination benefits, and the number of pins by government or medical accounts increased. However, the proportion of pins in search results containing HPV content of any type was significantly lower. Conclusions. Pinterest's efforts to moderate vaccination discussions were largely successful. However, the ban also appeared to limit HPV vaccination search results overall, which may contribute to confusion or an information vacuum. (Am J Public Health. 2020;110:S305-S311. https://doi.org/10.2105/AJPH.2020.305827)

FULL TEXT

Headnote

Objectives.To compare how human papillomavirus (HPV) vaccination was portrayed on Pinterest before and after the platform acted to moderate vaccine-related search results to understand (1) what the information environment looked like previously and (2) whether Pinterest's policy decisions improved this environment in terms of sources and content.

Methods. In this quantitative content analysis, we compared 2 samples of 500 HPV vaccine-focused Pinterest posts ("pins") collected before and after Pinterest's actions to provide more reliable vaccine-related information. Pins were based on search results and were analyzed using the Health Belief Model.
Results. The majority of preaction search results leaned toward vaccine skepticism, specifically focused on perceived vaccine barriers. Few pins were published by public health-related Pinterest accounts. Postaction search results showed a significant shift to HPV vaccination benefits, and the number of pins by government or medical accounts increased. However, the proportion of pins in search results containing HPV content of any type was significantly lower.
Conclusions. Pinterest's efforts to moderate vaccination discussions were largely successful. However, the ban also appeared to limit HPV vaccination search results overall, which may contribute to confusion or an information vacuum. (Am J Public Health. 2020;110:S305-S311. https://doi.org/10.2105/AJPH.2020.305827)
Human papillomaviruses (HPVs) repre- i sent the most common sexually trans- j mitted diseases. They are the primary cause of , warts and cancers of the genital areas, as well as several other cancers.1,2 Since 2006, a vaccine against most HPV infections that can lead to cancer has been introduced in more than 80 countries.3 Recent estimates indicate that 70% to 90% of HPV-related cancers may be prevented through universal HPV vaccination.4 Despite the potential benefits of HPV vaccination, there are several challenges that hinder vaccine uptake.3 Many individuals have negative attitudes toward the vaccine5 or are concerned about vaccine safety.6 Others believe it is for females only or that being in a monogamous relationship prevents individuals from getting HPV.7,8
While individuals likely learn about the HPV vaccine from a variety of sources, searching for health information online is increasingly common. Although the specific influence of social media on medical decision-making remains understudied, research supports an association between online health information searches and medical decision changes.9 Visiting antivaccination Web sites for 5 to 10 minutes can increase perceptions of vaccination risks and decrease intentions to vaccinate.10 In addition, HPV vaccine uptake may be lower in states where vaccine misinformation and conspiracies made up higher proportions of Twitter exposure,11 suggesting that negative representations of vaccines may influence vaccine acceptance. Recent studies have demonstrated that Pinterest is home to a large volume of health information,12-14 including significant amounts of antivaccine content.12,15 These studies prompted Pinterest to take action in 2019 to improve the available information about vaccines on its platform.16 In this study, we examined the content of pins resulting from searches for HPV vaccine information on Pinterest and how their efforts to mitigate vaccine-related misinformation have affected the information environment.
HEALTH MISINFORMATION ON SOCIAL MEDIA
Despite widespread scientific agreement about the value ofvaccines,17 misinformation about vaccines is common. Campaigns that question the safety and efficacy ofvaccination often outweigh official narratives on Twitter.18,19 Likewise, analyses of videos about the HPV vaccine on YouTube20 and portrayals of vaccination on Pinterest12 both found that antivaccination posts elicited more engagement, echoing research suggesting that mothers who oppose childhood vaccination communicate more about the issue on social media.21 These antivaccination posts often pair logical and seemingly factual language with fewer anxiety-related words than provaccination posts, heightening their appeal.22 While concerns about health misinformation on social media are widespread,22,23 vaccine misinformation deserves special attention, given its potential for compromising herd immunity and putting vulnerable populations not eligible to receive vaccinations at risk.
Human Papillomavirus Vaccine on Pinterest
In2018,29%ofadults in the United States reported using Pinterest, with usage particularly high among women (41%) and adults aged 18 to 49 years (34%).24 In addition, 80% of mothers and 38% of fathers in the United States use the platform.25 As mothers continue to be the primary care coordinators for children26 and make most health care decisions for their families,27 Pinterest's demographics make it particularly well suited for examining HPV vaccination messages.
In response to calls for social media platforms to take proactive approaches to manage misinformation, Pinterest

instituted a series of policy changes. In early 2019, Pinterest first disabled searches for pins that contained certain vaccine-related information, regardless of the results' reputability.28 In late summer of 2019, Pinterest announced that it would only show information about vaccines from public health organizations.16 As a consequence, the search results for HPV vaccine content have deviated from the broader body ofposts on this topic, making it critical to adopt a "search as research" approach to understand the information that the public receives when they seek HPV vaccinerelated information in Pinterest.29

To date, to our knowledge, no other studies have examined the content that Pinterest displays when people search for the HPV vaccine or evaluated Pinterest's effort to reduce vaccine misinformation in that content. Therefore, this study offers 2 advancements to our understanding of health information on Pinterest. By comparing how HPV vaccination was portrayed in search results before the platform took action to moderate vaccine-related content (the "preaction" time period) versus after these actions (the "postaction" time period) this study shows (1) what the information environment looked like previously and (2) whether Pinterest's policy decisions improved the search environment in terms of the sources and the content of pins.

Health Belief Model

The Health BeliefModel (HBM) provides a useful theoretical framework for analyzing media messages about vaccination.30,31 The HBM posits that motivation for adopting healthy behaviors is determined by perceptions of susceptibility, severity, benefits, barriers, self-efficacy, and cues to action. In the context of HPV vaccination, perceived susceptibility refers to beliefs about the likelihood of contracting HPV vaccine-preventable diseases. Perceived severity is the assessment of the seriousness of contracting HPV vaccine-preventable diseases. Perceived benefits are assessments ofthe effectiveness of the HPV vaccine and associated positive consequences of avoiding HPV-related diseases. Perceived barriers about the HPV vaccine include safety concerns and any perceptions that inhibit someone from getting the vaccine (e.g., fear of needles, cost). Perceived self-efficacy is individuals' assessments of their ability to get the HPV vaccine. Lastly, cues to action are defined as external triggers prompting people to get the vaccine for themselves or their children.31 Broadly, we consider "pro-HPV vaccine" pins those that highlight the susceptibility and severity of contracting HPV-related diseases, promote the benefits of the HPV vaccine and selfefficacy, and offer cues to action to get the vaccine. Conversely, those highlighting barriers-including visuals likely to elicit fear (e.g., include a large needle, fearful expression, perceived vaccine adverse effects)-are considered to be "anti-HPV vaccine" content.

A large body of research demonstrates the utility of the HBM in predicting vaccination and other preventive behaviors such as health screenings,32,33 making it an appropriate framework for examining whether Pinterest's policy changes had the effect of improving vaccine-related content in alignment with the best available medical evidence. Given that Pinterest took actions designed specifically to boost the prominence of high-quality official sources of vaccine information, we hypothesized the following:

1. A greater proportion of official sources regarding HPV vaccine-related posts will appear in the postaction period as compared with the preaction period.

2. The postaction period will have (1) a greater proportion ofHBM constructs that support HPV vaccination and (2) a smaller proportion of HBM constructs that oppose HPV vaccination (compared with the preaction period).

Notably, Pinterest removed engagement indicators in the postaction period. However, we hypothesized the following:

3.In the preaction period, posts with (1) HBM constructs that oppose HPV vaccination will receive more engagement, and (2) HBM constructs that support HPV vaccination will receive less engagement than posts without these constructs.

METHODS

We conducted a quantitative content analysis of2 samples of500 HPV vaccine- related Pinterest posts. The first sample was collected October 2, 2018, before Pinterest's actions to moderate vaccine-related search results; the second was collected December 2, 2019, following Pinterest's actions to moderate vaccine-related search results. For both searches, we cleared the limited browsing history of the computer used (a brand-new computer that had

not been used except to install basic programs for future use), used procedures to access Pinterest without being logged in to the platform, and used the same computer and procedure for both searches to ensure that algorithms for an existing account or user would not influence the search.

We collected both samples via a form of manual systematic random sampling, in which every third pin from the search results was selected, and this process was carried out for each time period until 250 posts were reached for each of 2 search terms, "HPV vaccine" and "HPV vaccination," for a total of 500 posts per time period. Consistent with the "search as research" approach, the sample is representative of the search results yielded by Pinterest, although not ofthe overall body of posts that people have created on the platform.

We manually coded all posts (n = 1000) for engagement (i.e., the total number of saves and comments each were counted and included), account characteristics (e.g., individual, commercial, health-related, and government), and whether the post linked to an external Web site (yes or no; if yes, the type of Web site). We also recorded visual characteristics (e.g., primarily image, primarily text, mix of image and text, infographic, drawing, or video), and the presence of fear visuals (e.g., large needle, mask, orthreat sign, such as a skull and crossbones). Furthermore, we coded pins for the presence of HBM constructs (e.g., perceived benefits of and barriers to the HPV vaccine, perceived severity ofand susceptibility to HPV, as well as perceived self-efficacy and cues to action). Examples for the HBM constructs present in search results are included in Appendix Figures A through F (available as supplements to the online version ofthis article at http://www.ajph.org).

Intercoder Reliability

After a period of training, 3 coders (J. P. D. G., H. M. M., and Y. Q.) independently coded 20% of posts (n = 200). After pretesting and subsequent coding protocol changes, intercoder reliability using Krippendorffs a ranged from 0.70 to 1.00, with an average of 0.77, meeting the standard for reliability. One coder coded 600 additional posts, and each ofthe remaining coders coded 150 more.

Statistical Analyses

We carried out descriptive analyses for all variables. We assessed differences between time periods with the %2 test. We used the Mann-Whitney U test to check for differences in Pinterest engagement between posts with (vs without) a range of dichotomous variables. We conducted all analyses with SPSS version 26 (IBM, Somers, NY).

RESULTS

The purpose of this study was to analyze HPV vaccine-related search results on Pinterest, comparing results before and after Pinterest's 2019 actions on vaccine-related searches. All of the preaction pins mentioned HPV or the HPV vaccine in some way, but only 40.6% of the postaction sample did, despite our explicitly using the search terms "HPV vaccine" or "HPV vaccination." Some pins in the postaction sample (n = 500) focused on a non-HPV vaccine (e.g., influenza; measles, mumps, and rubella [MMR]; 18.6%), while others mentioned vaccines in general (29.2%) or made no mention of vaccines (11.6%). Within the postaction sample, 74.0% of pins from the "HPV vaccination" search (n = 250) mentioned the HPV vaccine or the virus itself, compared with only 7.2% of the "HPV vaccine" pins (n = 250).

In the preaction period, most visuals (64.4%) primarily consisted ofan image. The remaining pins were 9.4% primarily textbased, 16.4% a mix of image and text, and 3.6% an infographic. In the postaction period, the proportion of visuals consisting primarily of an image was lower (36.0%), while the proportions of primarily text-based (15.6%), a mix of image and text (29.2%), and infographic (10.0%) pins were higher. The %2 test showed that all of these differences were significant (Table 1).

Regarding information sources, most pins (79.2%) in the preaction period originated with individuals, while only 3.2% were published by official medical entities (e.g., hospitals), and no pins originated with government entities (e.g., public health departments, the Centers for Disease Control and Prevention; Table 1). By contrast, in the postaction period, only a quarter of pins (25.8%) originated with individuals, with 46.2% published by official medical entities and 7.6% by government entities. The %2 test revealed that all of these differences were significant (Table 1), supporting our first hypothesis.

Next, we examined the HBM constructs present in HPV-vaccine related search results. In the preaction sample, the

most frequently mentioned HBM construct was perceived barriers (65.6%), with perceived benefits a distant second (13.0%; Table 1). Barriers included adverse effects of the HPV vaccine (55.0%), fear visuals (32.2%), and conspiracy theories (13.8%; Table 1).

Among pins in the postaction sample that focused on HPV or the HPV vaccine, the HBM constructs present were categorically different (supporting our second hypothesis). Perceived benefits were mentioned most frequently (40.2%), followed by perceived severity of HPV infection and its consequences and perceived susceptibility to HPV infection (22.1%; Table 1). By contrast, perceived barriers to vaccination were present in only 11.3% of posts, vaccine adverse reactions in 1.6%, conspiracy theories in 1.2%, and fear appeals in 14.2% of posts. A large needle remained the most common fear visual. The %2 test again showed that all of these differences were significant (Table 1) and broadly provided support for our second hypothesis, as provaccine content increased and antivaccine content decreased in postaction pins.

Finally, we assessed the relationship between message features and engagement in the preaction period. As shown in Table 2, pins mentioning barriers to getting the HPV vaccine were significantly more likely to produce Pinterest engagement than pins that did not mention barriers. Mentioning benefits ofthe HPV vaccine, self-efficacy, and cues to action were each associated with lower median save frequencies (Table 2), supporting our third hypothesis.

DISCUSSION

While Pinterest still tends to be seen as a place to find and share recipes and decorating ideas, several studies demonstrate not only that vaccine posts are present but also that these posts tend to be dominated by vaccine skeptics.10,12 The results of the preaction time period of this study confirm these trends: 65.4% of pins mention specific barriers to getting the HPV vaccine, such as perceived adverse effects of the vaccine and conspiracy theories. Not only do HPV vaccine-skeptic posts dominate this part of the sample, but when they appeared, they also were often associated with higher levels of engagement in the form of saves (Pinterest's main engagement metric). Apart from perceived barriers, HBM constructs were almost entirely absent from the preaction sample. When we considered the high percentage oflisted barriers to getting the HPV vaccine, together with very little mention of the severity of and susceptibility to HPV, it was clear that vaccine skepticism was prevalent in these search results, and more strategic efforts to promote the HPV vaccine in this space were needed.

Another finding of interest for the preaction sample was that the majority of the pinners in the search results were individuals, while only 3% of all pins were confirmed to originate with official medical accounts (e.g., hospitals, medically focused nonprofits), and there was no presence of any pins published by government accounts such as the Centers for Disease Control and Prevention. This is concerning, as it appeared to suggest that the public health experts' voice-often likely to provide trustworthy and reliable health information-was again largely absent on this platform, which was a concern shared by earlier health-focused Pinterest studies.12-15

Pinterest engaged in several strategic efforts over the course of 2019-first disabling searches for certain vaccine-focused terms, and then repopulating these searches with posts originating with reliable public health entities. The postaction sample in this study yielded several encouraging results: more of the posts originated with either public health- or health-related entities, and of the HBM constructs, perceived benefits of the HPV vaccine, as well as severity of and susceptibility to HPV infection, were mentioned in 23.5% and 22.1%, respectively, of the postaction sample (as compared with 3.6% and 5.0% of the preaction sample).

However, a few serious concerns also surfaced. First, in the postaction sample, 60% of all pins did not address the HPV vaccine or the virus in any way, instead focusing on other, often younger childhood vaccines about which information may not be relevant for people searching for HPV vaccine information. We performed additional searches on December 21, 2019, to probe these results. At the time this article was written, keyword searches for "HPV vaccine," "flu vaccine," "MMR vaccine," and "vaccine" yielded identical results (i.e., the same mix of messages focused on diverse vaccine-related issues such as the MMR vaccine, influenza vaccine, HPV vaccine, herd immunity, history ofvaccines, and general advice on how to make vaccines an easier experience for young children (Appendix Figures G-J, available as supplements to the online version of this article at http://www.ajph.org). Although we are not privy to Pinterest's search algorithm, we suspect that the results for the search for keyword

"vaccine" were replicated and provided for the search for any type of"vaccine"-related search, whether that be "flu vaccine," "HPV vaccine," or "MMR vaccine."

In addition, 12.2% of the postaction sample did not discuss vaccines of any kind in their posts. Interestingly, the distribution of HPV- versus non-HPV-related pins appeared to be clearly skewed in 1 direction: pins from the "HPV vaccine" keyword search only yielded 7.2% of HPV vaccine- and virusrelated posts, while pins from the "HPV vaccination" keyword search yielded 74% of HPV vaccine- and virus-related posts. As postaction results were identical for "HPV vaccine" and non-HPV vaccine searches, the low rate of HPV content from the "HPV vaccine" search may be an artifact of how Pinterest has implemented its strategy for reducing misinformation around vaccines more broadly. Of further interest is that a search for keyword "HPV vaccine" produced a warning from Pinterest, but "HPV vaccination" did not (Figure 1). Finally, even when a pin mentioned the HPV vaccine or virus, visuals were often of questionable quality and utility, frequently because the quality of the image was lacking (Appendix Figure K, available as a supplement to the online version of this article at http://www. ajph.org) or because the pin was not designed for Web use (Appendix Figure L) or it was not conveying any kind of clear message or information (Appendix Figure M).

Limitations and Future Directions

There is no current application programming interface available for Pinterest data collection by keyword, so the sampling method, while approximating randomization as closely as possible, couldbe improved.12,14,34 Second, while network analysis on Pinterest is in its infancy, future studies should consider using both current (posts that are saved from another user, similar to Twitter's "retweeted" posts) and original (posts created by the pinner as original Pinterest content) pinner data to better understand which messages spread fastest and how they spread. Third, a qualitative analysis should be considered to extend this research, as should message-testing studies that focus on correcting misinformation and spreading accurate information on Pinterest. Finally, we did not seek to capture the overall body of Pinterest posts about HPV vaccination, but rather focused on Pinterest as a source of information via its search mechanism. Future work should consider what individual people post to Pinterest and iftheir behaviors have changed in light of Pinterest revising its algorithms to reduce antivaccine content in search results.

Public Health Implications

Overall, Pinterest's efforts to mitigate HPV vaccination misinformation in its search results were partially successful. The information landscape before Pinterest's systematic effort was largely anti-HPV vaccination, with individuals sharing information that highlighted barriers, promoted conspiracy theories, and focused on rare or inaccurate negative side effects of the vaccine rather than the severity of and susceptibility to HPV. Although these trends were not eradicated with Pinterest's efforts, the postaction information available skewed more positively, focusing on the benefits of vaccination and the dangers of HPV infections. The postaction pins originated more often with reputable accounts, without removing individuals' ability to communicate by creating their own pins.

However, the way in which the content restrictions were implemented also appeared to limit HPV vaccination content. Many of the pins that emerged when we searched for "HPV vaccine" were not related to vaccination at all or focused on other, younger childhood vaccinations. This could lead to another type of misinformation if audiences fail to realize when a pin is referring to a different vaccine type, or an information vacuum. Although Pinterest took an important first step with its 2019 actions, it can and should improve the curational aspect of vaccine-related searches on its platform.

Health communication and public health professionals as well as advocacy organizations should also do more to fill the information gap related to HPV vaccination on social media. More health professionals should consider expanding their social media activities to include Pinterest, particularly considering Pinterest's largely female user base and the dominant role of women in making health care decisions for their families.27 Second, while more messages in the postaction sample discussed benefits of vaccination and dangers of HPV infection, content could further encourage self-efficacy for or actions to get the vaccine, as self-efficacy is important in achieving behavior change to overcoming perceived health threats.35 Finally, more strategic partnerships between social media platforms like Pinterest and health communication professionals would help create a space where valuable-and

accurate-health information flourishes.

Conclusions

To our knowledge, this research is the first to evaluate Pinterest's actions to moderate content to combat the spread of vaccine-related misinformation. Although Pinterest's efforts represent initial progress toward thwarting messages with potentially harmful information, improved approaches are necessary moving forward. Social media platforms should do more than block harmful content and redirect search results. From a public health perspective, it is imperative that Pinterest users seeking vaccine information receive search results that are not only medically accurate but also relevant to the specific vaccine ofinterest. To achieve more meaningful moderation and promote the dissemination ofaccurate information on Pinterest, a 2-pronged approach is needed: improved strategies for filtering in relevant and vaccine type-specific pins, as well as generating a greater volume ofhigh-quality, reliable content to fill the void left by blocking misleading pins. Public health content creators should provide more well-designed, informative, and effective Pinterest messages and visuals.

CONTRIBUTORS

J.P.D. Guidry contributed to conceptualization, data curation, investigation, methodology, formal analysis, preparation of the original draft, and article review and editing. E. K. Vraga contributed to methodology, review and editing of the article, and formal analysis. L. I. Laestadius contributed to preparation ofthe original draft. C. A. Miller and K. E. Carlyle contributed to methodology and review and editing of the article. A. Occa, X. Nan, and B. F. Fuemmeler contributed to review and editing ofthe article. H.M. Ming and Y. Qin contributed to the investigation.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

HUMAN PARTICIPANT PROTECTION

Institutional reviewboard approval was not neededfor this study because all Pinterest posts were publicly available.

Sidebar

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DETAILS

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Tackling Online Misinformation: A Critical Component of Effective Public Health Response in the 21st Century

Zucker, Howard A, MD, JD

FULL TEXT

As commissioner of health for New York State, I am charged with overseeing the state's response to health crises: Ebola, Zika, measles, and, currently, the COVID-19 pandemic. In each case, I have experienced firsthand how the development and spread of misinformation can make responding to public health crises even more challenging. It has become increasingly evident that our job now is fighting not only the spread ofdisease but also the spread of misinformation about the disease. Although the control of misinformation is most urgent when tackling outbreaks of infectious diseases such as COVID-19, it is also important in many other domains of health, including chronic disease. For example, last year, the Food and Drug Administration released a statement warning consumers not to drink a solution that turns into bleach when "activated" following product directions, because it was being promoted on social media as a treatment for conditions ranging from autism to cancer (https:// bit.ly/3hetir2).

The spread of false and malicious information is not new. However, it has recently become an especially challenging problem for several reasons. First, the sheer speed and scale at which (mis)information spreads is alarming. Whereas it used to take hours, if not days, for information to reach the public, it now takes minutes, if not seconds. And with Americans increasingly getting their news from social media (https://pewrsr.ch/3aGeFdA), the potential reach of false information is enormous and unprecedented. Second, misinformation is especially dangerous today because of declining trust in institutions, including government, medical systems, and the press, which has created a vacuum in which science is pushed to the margins and misinformation more easily takes hold.

The viral spread of misinformation on social media is of significant concern to public health practitioners; once inaccurate information starts circulating, it is incredibly difficult to contain or mitigate its effects. Misinformation spreads because it tends to be driven by emotions, especially fear, and it is very difficult to combat emotions using facts, which is the traditional approach public health employs in response to misinformation. Equally concerning is the fact that even after individuals learn that a piece of information is false, they still tend to believe it, at least to some extent, because of the difficulty of removing information once it has been encoded in memory. This perseverance of false information means it is exceedingly difficult to reverse the harm of misinformation exposure. Using medical terms, one might say misinformation is widely prevalent, incredibly infectious, and highly resistant to currently available treatment.

Although misinformation has received significant attention in the political sphere since the 2016 US presidential election, the public health stakes are equally high, if not higher. Health misinformation threatens to negate much of the progress we have made in the past century to improve population health. In spring 2019, I gave a TEDx presentation focused on this national concern (available at https://www.youtube.com/watch?v=ak-aV6bkedE). Those of us working on the frontlines ofpublic health urgently need research that will help us better surveil, understand, prevent, and mitigate the viral spread of health misinformation online. I congratulate AJPH for responding with this special issue of research examining social media misinformation across an array of health topics. >4jPU

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Twitter Communication During an Outbreak of Hepatitis A in San Diego, 2016–2018

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ABSTRACT (ENGLISH)

Objectives. To examine how and what information is communicated via social media during an infectious disease outbreak. Methods. In the context of the 2016 through 2018 hepatitis A outbreak in San Diego County, California, we used a grounded theory-based thematic analysis that employed qualitative and quantitative approaches to uncover themes in a sample of public tweets (n = 744) from Twitter, a primary platform used by key stakeholders to communicate to the public during the outbreak. Results. Tweets contained both general and hepatitis A-specific information related to the outbreak, restatements of policy and comments critical of government responses to the outbreak, information with the potential to shape risk perceptions, and expressions of concern regarding individuals experiencing homelessness and their role in spreading hepatitis A. We also identified misinformation and common channels of content driving themes that emerged in our sample. Conclusions. Public health professionals may identify real-time public risk perceptions and concerns via social media during an outbreak and target responses that fulfill the informational needs of those who seek direction and reassurance during times of uncertainty. (Am J Public Health. 2020; 110:S348-S355. https://doi.org/10.2105/AJPH.2020.305900)

FULL TEXT

Headnote

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The hepatitis A virus (HAV) is a fecal- orally transmitted virus1 spread primarily through close personal contact with an HAVinfected person and occasionally through consumption of contaminated food and water. Although its incidence has decreased dramatically since the introduction of the hepatitis A vaccine,1 for reasons that are unclear, since late summer 2016 HAV has had an increased presence across the United States. In particular, a large outbreak of hepatitis A in San Diego, California, was officially declared a local public health emergency by the San Diego County public health officer on September 1,2017. The outbreak was notable in both its severity and its rapid spread, with almost 600 cases, 20 deaths, and 400 hospitalizations in San Diego County through early 2018. In addition, since the outbreak, numerous other states reported cases ofhepatitis A, some ofwhich may be linked to the initial outbreak in San Diego.2 An audit by the state later noted that San Diego County's response to the HAV was greatly delayed.3

During situations with a sudden increase in caseload or transmission, a coordinated public health strategy can facilitate communication about risks and appropriate behavioral responses.4 Creating and implementing a coordinated public health strategy requires effective communication deployed in a rapid manner.5 Social media offers a way to provide the public with emergency alerts and real-time updates regarding emergencies.6 Effective communication also requires that public health professionals deftly handle the rising problem of health-related misinformation on social media.7 As questions about how to monitor and assess misinformation during an infectious disease outbreak have emerged among public health professionals, an increased understanding of the context in which health-related misinformation spreads via social media may serve as a starting point for addressing these questions.

At the same time that misinformation on social media has begun to emerge as a possible threat to public health, the United States has experienced several significant infectious outbreaks, including the current COVID-19 pandemic. However, despite the increasing interest in exploring the use of social media message platforms for early disease prediction8 and message content during environmental emergencies,9 research on content and communication during an outbreak spurred by a vaccine-preventable communicable disease outbreak remains limited.10 It is also unclear whether and how real-time patterns of health information diffused via Twitter during an outbreak of a vaccine-preventable infectious disease may differ from other outbreaks or how communication varies if the outbreak originated in a stigmatized population.

We examined both how and what was communicated (and miscommunicated) via social media during the 2016 through 2018 hepatitis A outbreak in San Diego. One example of a misinformation effect on public health is the antivaccine misinformation in social media posts describing childhood immunizations as a cause of autism and the subsequent reductions in herd immunity.11 We address the following research questions (RQs):

RQ1: How did Twitter users communicate about the hepatitis A outbreak?

RQ2: What were the source types (type of individual or organization) and characteristics of Twitter users contributing to the conversation about the hepatitis A outbreak?

RQ3: What themes about the hepatitis A outbreak on Twitter were more likely to be shared and by which source types?

RQ4: Was there misalignment between messaging about the hepatitis A outbreak on Twitter from authorities and members of the public?

RQ5: Was misinformation shared on Twitter during the hepatitis A outbreak?

RQ6: In what ways did users seek or share content about HAV on Twitter?

METHODS

We used the hepatitis A outbreak in San Diego (November 2016 to October 2018) and a grounded theory-based thematic analysis to motivate our research. We first examined qualitative data to identify themes of tweets shared during the outbreak. This approach was guided by principles of grounded theory methods.12 Our primary data were publicly available messages posted to Twitter by official response agencies (e.g., the public health department) and other numerous stakeholders during October 2017 through December 2017-the height of the outbreak.

Data Collection

We used the visualizing information space in ontological networks framework13 to examine the interrelationships between online messages, space, and time. The framework consists of an approach our team developed for visualizing and analyzing Web pages and social media content from a spatiotemporal perspective. We focused exclusively on data collected from Twitter because of the realtime and dynamic nature ofthis platform. We took advantage of the spatial filtering methods provided by the Twitter search application programming interface.

We collected 4401 tweets limited to San Diego County between October and December 2017, coinciding with Governor Jerry Brown's declaration of a statewide emergency and the downward epidemiological curve of new cases.14 We used user profile information with place name dictionaries (gazetteers; Appendix A, available as a supplement to the online version of this article at http://www.ajph.org) to determine that all tweets originated in San Diego County. Of these tweets, we randomly selected 1000 tweets for analysis. After identifying the number of

unique users, we randomly de-duplicated users so they each had only 1 tweet. We decided to randomly select 1 tweet per user to ensure that we did not violate assumptions of independence in observations for our tests of association. We further constrained the sample by removing tweets that (1) were about flu only, (2) were about vaccines for animals, (3) discussed other forms of hepatitis, or (4) were written in a language other than English. This resulted in a final analytical sample of 744 tweets, which represented 17% of all tweets collected; the sample was composed of tweets from unique users, meaning each user appeared in our sample only once.

Data Analytics

We used retrieved tweets and metadata to tabulate information such as the impressions and engagements of each tweet and to establish the frequencies of hashtag use. We also searched metadata fields (e.g., Twitter @handle, display name, number of followers) for relevant search terms. Two researchers (R. E. H. and T. A.) manually coded the message content of the original tweets from the entire data set to identify relevant themes. Using grounded theory, we performed a thematic analysis to identify themes oftweets in our sample. We additionally coded each targeted account with an included tweet in the sample according to its network size (number of followers) and number of accounts followed by the account.

We first analyzed and coded tweets using the constant comparative method.15 Using this approach, we focused on patterns of conceptual and exemplar convergence and divergence in the data. The identification of themes occurred through revisits and recodes of tweets to ensure that themes were substantiated by the data. When reasonable, we reconsidered and revised coding categories in cases that departed from identified themes.16 Over the course of revising thematic categories, we developed a coding scheme for 2 coders (who were not privy to the research questions driving the study) to use to quantitatively examine tweets in our sample. Coders also quantified the number of times a theme was observed (RQ1) and calculated intercoder reliability between both coders for the frequency of themes identified in our sample. Using coding guidelines from previous research,17 coders also coded tweets for source type (RQ2), which we then used to link to themes (RQ3). Building on patterns of misinformation and misalignment between public health messaging and individuals and organizations who were not public health authorities, we developed coding categories for content inconsistent with known public health messaging about hepatitis A vaccinations and contamination or sanitation issues (RQ4) and misinformation (RQ5).

We developed coding procedures for misinformation related to vaccines with guidance from others.18 For example, if a tweet promoted a vaccine-related conspiracy theory (e.g., vaccine policymakers are influenced by profit motives) or trivialized vaccine-preventable diseases (e.g., vaccines are worse than the measles), we coded it as containing misinformation. If a tweet contained any misinformation (related or unrelated to the hepatitis A outbreak), we coded it as having misinformation. To qualify as having no misinformation, a tweet could contain only accurate content. Last, given the unique properties of social media, we developed coding categories to capture the frequency with which users engaged in seeking and sharing information (i.e., in the form of news, statistics, known facts) and opinions (RQ6). Our codebook (Appendix B, available as a supplement to the online version of this article at http://www.ajph.org) contains more information about coding approaches. We examined contingency tables using C2 analysis and magnitude of effect with the j (ϕ) coefficient.

Coders were trained on a training set of tweets and double-coded 20% of the total number of tweets. In instances of coding disagreements, coders discussed discrepancies until resolved. Good intercoder reliability (at least 0.80) was achieved after 3 rounds of double-coding, after which remaining tweets were single-coded. We used Gwet's agreement coefficient,19 as it may address limitations observed in the use of other more commonly used coder reliability statistics, including Cohen's k and Scott's P, which are more sensitive to prevalence.20,21

We conducted the statistical analyses using Microsoft Excel (Microsoft Corp., Redmond, WA) and SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

We report the findings of tweets in our sample (n = 744) that were used for our thematic analysis. The median number of followers for these users was 480.5, and the median number of users they were following was 453.5.

Research Question 1

RQ1 was, How did Twitter users communicate about the hepatitis A outbreak? To answer this question, we identified major themes in our sample of Twitter users (any publicly viewable accounts that could be organizations, excluding accounts of a single person) or individuals (excluding accounts of an organization or cause). Among the 744 messages, we found that a subset related to policy issues (n = 281) and questions regarding general medical information (n = 177). These were followed by themes related to risk perceptions ofhepatitis A (n = 111), concerns regarding individuals experiencing homelessness and their role in spreading hepatitis A (n = 151), specific hepatitis A medical concerns (n = 90), and other (n = 137; Table 1). We did not code themes as mutually exclusive, and intercoder reliability was strong, with an average Gwet's agreement coefficient of 0.87, ranging from 0.80 to 0.96.

Research Question 2

RQ2 was, What were the source types and characteristics of Twitter users contributing to the conversation about the hepatitis A outbreak? Table 2 presents results showing the source types in our sample. The majority of tweets in our sample were shared by individuals (77.2%), and the most common categories for individuals included users who mentioned being a parent (9.1%) and a journalist (11.0%). Aportion of tweets shared by individuals expressed firsthand experience of the hepatitis A outbreak (15.7%) and pointed to the spirituality (8.2%) and political persuasion (25.8%) of the user. The most common types of organizations contributing to the conversation about the hepatitis A outbreak were businesses (65.8%), news organizations (37.7%), and nonhealth advocacy groups (18.2%). We noticed, however, that only a small portion of tweets (1%) was shared by government organizations.

Research Question 3

RQ3 was, What themes about the hepatitis A outbreak on Twitter were more likely to be shared and by which source types? Organizations were more likely to tweet themes related to government and policy ($\phi = 0.09$), particularly news affiliates ($\phi = 0.24$) and content with general medical information, when compared with individuals ($\phi = 0.10$; Table 3). By contrast, individuals were more likely than organizations to share tweets with themes centering on the population experiencing homelessness ($\phi = 0.09$). Individuals with political affiliations were most likely to tweet about policy ($\phi = 0.15$) and homelessness ($\phi = 0.18$). Journalists were most likely to discuss risk perceptions ($\phi = 0.14$).

Research Question 4

RQ4 was, Was there misalignment between messaging about the hepatitis A outbreak on Twitter from authorities and members of the public? We explored the frequency with which tweets in our sample contained any content that was inconsistent with known messaging from the Health Department of San Diego County with regard to hepatitis A vaccination and sanitation or contamination concerns (Table 4). Most tweets contained content that was not relevant to messaging on issues related to hepatitis A vaccination (92.2%; n = 686) and sanitation or contamination (87.1%; n = 648). For tweets that were relevant, the majority discussing HAV vaccination (89.7%; n = 52) were consistent with messaging from the health department. However, we observed a different pattern for relevant tweets discussing HAV sanitation or contamination concerns, with the proportion discussing issues in a manner inconsistent with messaging from the health department (49.0%; n = 47) evenly split with the proportion of tweets aligned with the health department (51%; n = 49).

Research Question 5

RQ5 was, Was misinformation shared on Twitter during the hepatitis A outbreak? Table 4 also shows the results of our examination of misinformation. We detected the presence ofmisinformation shared on Twitter during the outbreak. However, we discovered that only a small proportion of tweets (7.4%) contained any misinformation. Most tweets did not expressly align or misalign with county messaging on selected themes.

Research Question 6

RQ6 was, In what ways did users seek or share content about HAV on Twitter? Our last research question sought to examine different and nonmutually exclusive ways that users engaged with HAV content on Twitter (Table 4). Specifically, we looked at content contained in each tweet that indicated users' engagement as characterized by seeking or sharing information (in the form of news, statistics, or known facts) or opinions. Overall, we found that a higher proportion of information (60.1%) and opinion (45.6%) sharing than information or opinion seeking (5.8%)

occurred among users in our sample.

DISCUSSION

In this descriptive study, we note the similarities of previous research18 to the themes (RQ1) we uncovered surrounding warnings to the public through updates on the progression of the outbreak. We also note that emergent themes related to risk perceptions of the outbreak (e.g., susceptibility and severity related to infection) and perceptions regarding (in)effectiveness of policy and government responses (e.g., response efficacy of recommendations to the public) aligns with concepts of risk-response theorizing.22 Our study also showed that tweets shared by government sources (RQ2) were rare, suggesting a lack of dialogue between government agencies and the public during the outbreak.

Although previous research emphasizes the public's engagement with information from government authorities during times of crisis, scholars have also noted that often crisis communication on Twitter takes the form of a 1-way flow of information rather than an interactive dialogue between government authorities and members of the public.23 This lack of dialogue may have further added to public perceptions of insufficient action on the part of the government during the initial stages of the outbreak and critiques that the county's response was unsatisfactory. In future outbreak scenarios, using the interactive properties of Twitter may help public health authorities more effectively use this communication channel to promote dialogue with affected communities.

Perhaps unsurprisingly, organizations were more likely to tweet themes sharing broad informational content (RQ3), whereas individuals were more likely to share information on risks and advocacy issues (e.g., homelessness). This difference in focus may suggest that a shift away from top-down communication by organizations in our study toward meaningful and engaging dialogue with the public24 did not take place during this outbreak. Without this dialogue, organizations may struggle to address the concerns and informational needs of public audiences, which may create an unintended informational vacuum in which the public seeks desired information elsewhere.25

We also detected some misalignment between messaging about the hepatitis A outbreak on Twitter from authorities and members of the public (RQ4). Although most tweets discussing hepatitis A vaccination were consistent with messaging from the health department, small fractions of tweets with messages that are inconsistent with official public health messaging may be concerning, as even seemingly small pieces of misinformation can be propagated. For example, as Baker discusses, Andrew Wakefield's published article on a vaccine-autism connection gained traction in part through the Internet26 despite later retraction, and in the recent global COVID-19 pandemic, we have observed the power that even 1 piece of dangerous misinformation uttered once by a political leader despite an immediate response by health experts to correct the situation.27

For tweets falling under themes providing general medical information and HAVspecific information, we found references to misinformation regarding vaccine safety, all of this in light of an ongoing outbreak of a vaccine-preventable disease. Although only a small proportion of tweets in our study contained misinformation (RQ5) at the individual level, in the aggregate even a small amount of misinformation can pose potential issues for public health at the population level if it leads to vaccine noncompliance among enough individuals and subsequent reductions in herd immunity. However, more research is needed to establish thresholds of misinformation and when they reach problematic proportions requiring intervention.

Additionally, the context of an outbreak of an infectious disease such as hepatitis A suggests that the level, nature, and spread of misinformation is likely to vary depending on public health concerns. This particular hepatitis A outbreak largely affected a marginalized and socially distant population; however, outbreaks affecting populations such as children may evoke a greater level of concern that generates content and levels of misinformation differing from what we observed. Future research may examine content and proliferation ofmisinformation, as well as outbreaks affecting different populations, to confirm this hypothesis.

Our results also indicate that Twitter users' activities are likely to be dominated by more information- and opinion-sharing efforts than information- and opinion-seeking ones (RQ6). As individuals are likely to engage in information seeking regarding health issues about which they desire more knowledge,28 it is possible that our coding of tweets captured mostly content from users who had already sought information about the outbreak before posting tweets.

Future research may seek to examine how users seek information on Twitter, as it is an important source of public health information, including content about vaccinations.29 Last, findings from our study show evidence of some aspects following a distancing, blame, stigma pattern.30 Some tweets conveyed information that the hepatitis A outbreak was largely confined to individuals experiencing homelessness, and although not true ofall tweets in our sample discussing the individuals experiencing homelessness in San Diego, a portion of tweets referred to this population in derogatory ways in the context of the hepatitis A outbreak.

Limitations

This study contains some limitations. Our sample was not representative of the entire population of tweets about the hepatitis A outbreak during the specified time frame of our study; we examined content only about HAV from Twitter, and we could not draw inferences related to content flow on Twitter or elsewhere or of the offline effects of these tweets. We also could not draw inferences about the potential impact ofmessages offline or attributes of messages that would increase their online reach (e.g., liking, retweeting, mentions), an area ripe for future research. However, we can get a sense of the range of diverse topics, level of public awareness, and early stirrings of misinformation on the issue of HAV. Such findings can help health authorities keep abreast of the information environment during a time-sensitive event and offer a method for detecting unfulfilled informational needs that can serve as a starting point for formative research guiding the design ofeffective messaging. Last, although the hepatitis A outbreak originated in the population experiencing homelessness, our data do not suggest which Twitter users in our sample may be homeless or whether they were obtaining information from Twitter. However, emerging evidence suggests that the use of these platforms among individuals experiencing homelessness may be especially common among youths.31

Public Health Implications

Results of this study may help inform policies or practices that increase services to the population experiencing homelessness and may help reduce the spread of hepatitis A by reconsidering the best way to reach the population most affected by this outbreak. Although our data included sources that were health authorities as well as sources that were individuals acting as advocates and organizations that work with the homeless community, it was not clear whether these sources were attempting to use Twitter to reach individuals experiencing homelessness directly in this context. This may be a missed opportunity, given that a portion of tweets coded under "specific HAV medical concerns" would be of great value if they were read by individuals experiencing homelessness.

By connecting themes and information sources, we saw that the fast-paced spread of a vaccine-preventable disease brought antivaccination argumentation to the forefront. Public health professionals may consider engaging with social media to address the public's risk perceptions and concerns as they arise in real time during an outbreak and tailoring responses that fulfill the informational needs of those who seek direction and reassurance during times of uncertainty. In addition, given the proportion of sources representing journalists and users articulating political viewpoints, it will be vital to ensure that sources in positions of power outside public health exercise care in the content they share about an epidemic and avoid spreading misinformation for commercial or political gain.

Last, public health agencies can use the results of this study to understand whom their messages are reaching, the concerns of these individuals regarding an outbreak, and their reaction to official public health recommendations. Because the containment of infectious disease outbreaks may depend on human behavior (e.g., getting vaccinated, handwashing), such factors can provide insight for how to best engage such individuals with necessary targeted public health messaging if compliance with public health recommendations begins to weaken among certain population groups.

Conclusions

Previous research has found that exposure to misinformation influences vaccine knowledge32 as well as perceptions of vaccine risk compared with perceived susceptibility to diseases that can be prevented by vaccines.33 Our findings illustrate the ongoing need to develop and refine approaches for advancing health-related misinformation surveillance. Such methods can help illuminate the nature and extent of health-related misinformation on social media and provide guidance on how and when public professionals may need to intervene and enact corrective action, issues particularly relevant during the current COVID-19 pandemic.

CONTRIBUTORS

E. Oren and L. Martinez conceptualized, updated, and developed the study design; drafted the article; and supported the creation of the study forms and tools. R. E. Hensley, P.Jain, T. Ahmed, andI. Purnajo contributedto data management and analysis. R. E. Hensley, P. Jain, A. Nara, and M-H. Tsou contributed to updating and developing the study design. P. Jain and T. Ahmed created study forms and tools. All authors contributed to writing the article and approved the final article.

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Note. Any opinions, findings, conclusions, or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the NSF.

CONFLICTS OF INTEREST

None of the authors have any conflicts of interest to declare.

HUMAN PARTICIPANT PROTECTION

No protocol approval was necessary because no human participants were involved in this study.

Sidebar

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DETAILS

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Where We Go From Here: Health Misinformation on Social Media

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ABSTRACT (ENGLISH)

Falsehoods have been shown to spread faster and farther than accurate information,1 and research suggests that misinformation can have negative effects in the real world, such as amplifying controversy about vaccines2 and propagating unproven cancer treatments.3 Health misinformation on social media, therefore, urgently requires greater action from those working in public health research and practice. ASSESS CONSEQUENCES OF MISINFORMATION Little evidence is available regarding the extent to which misinformation exposure online affects health-related behaviors, attitudes, knowledge, and outcomes at the individual or population level, or how exposure to misinformation intersects with existing health disparities.

FULL TEXT

Falsehoods have been shown to spread faster and farther than accurate information,1 and research suggests that misinformation can have negative effects in the real world, such as amplifying controversy about vaccines2 and

propagating unproven cancer treatments.3 Health misinformation on social media, therefore, urgently requires greater action from those working in public health research and practice. We define "health misinformation" as any health-related claim of fact that is false based on current scientific consensus. Many other types of information pose a challenge for health communication, including contradictory or conflicting findings, changing evidence, and information that involves a high degree of uncertainty; however, these issues are outside the scope of this editorial, which focuses on information that is patently false.

Responding to misinformation is challenging for many reasons. For example, psychological factors, including emotions and cognitive biases, may render straightforward efforts to counter misinformation by providing accurate information ineffective. This may be why interventions, such as recommending articles with corrective information, have shown mixed efficacy.4 Another issue concerns the difficulty of identifying and reaching those who are exposed to misinformation. The diversity and volume of social media facilitate the creation and maintenance of information silos by making it easy for users to selfcurate their feeds and find similar content through automated algorithms. These features reduce the likelihood that individuals who are part of a group in which misinformation is circulating will be exposed to content that contradicts the prevailing view of their network.

As accumulating evidence indicates, in domains as varied as childhood vaccines and COVID-19, widespread health misinformation can have potentially devastating consequences, and responses need to be timely, strategic, and evidence based. We outline five understudied research areas that need to be addressed to improve policy and practice in response to health misinformation (Figure 1).

ENHANCE SURVEILLANCE

Much of the research conducted to date has relied on cross-sectional content analysis of social media data,5 and although these types of studies are important, the field needs to move toward a more comprehensive understanding ofthe social media misinformation environment. For example, many studies have focused on Twitter, but other popular platforms, such as WeChat, Tumblr, Reddit, and Pinterest, remain understudied. Additionally, research is needed to better understand nontextual content, including images, memes, and videos found on platforms such as Instagram, TikTok, and YouTube, taking advantage of computer-assisted visual analysis.

Surveillance efforts also need to account for the complex processes affecting diffusion by systematically exploring the spatial, temporal, network, and crossplatform dynamics of misinformation spread. This knowledge would help us identify critical platform, content, and network characteristics that enable or impede the dissemination of misinformation.

UNDERSTAND PSYCHOLOGICAL DRIVERS

We also need to draw on theoretical frameworks from political science, psychology, communication, and other social sciences to examine the role of emotion, cognition, and identity in relation to misinformation and use this knowledge to inform interventions. For example, the human tendency toward confirmation bias may render debunking efforts ineffective, as corrective information may be viewed as inconsistent with a preferred narrative and therefore ignored or denied. In situations in which a strong confirmation bias exists, interventions based on value affirmation might be more effective.

Similarly, although the impact of emotion on misinformation processing has been studied in the context ofpolitics,6 less is known about the role emotions play when it comes to health misinformation-even though health topics can generate strong emotions, including fear and anxiety. A deeper understanding of the psycho-socio-emotional drivers of misinformation acceptance and sharing, and how they differ across various domains (e.g., political vs health information), will be crucial for designing successful interventions.

ASSESS CONSEQUENCES OF MISINFORMATION

Little evidence is available regarding the extent to which misinformation exposure online affects health-related behaviors, attitudes, knowledge, and outcomes at the individual or population level, or how exposure to misinformation intersects with existing health disparities.

Moreover, misinformation may have additional consequences that-although difficult to observe-are equally insidious. For example, misinformation could create the impression that no consensus exists on a topic or that official sources

of information are not credible, which could generate feelings ofapathy, confusion, and mistrust. This could then lead individuals to disengage from health information seeking, avoid health care, or make decisions that are detrimental to their health. Although there are challenges to linking online activity with offline behavior, theoretically informed empirical research is needed to elucidate the full extent of the real-world consequences of misinformation exposure.

FOCUS ON THE MOST VULNERABLE

Research indicates that most people are susceptible to misinformation in some contexts and that typical sociodemographic predictors of health disparities may not govern vulnerability to misinformation. For instance, highly educated individuals may be equally vulnerable to misinformation when it comes to topics that are central to their identity.7 Identifying factors that may increase susceptibility to misinformation (e.g., conspiracy mindset, lack of access to evidence-based health information) would enable better targeting of resources and better tailoring of strategies.

Once we identify who is most vulnerable, methods for strategically intervening with these groups will be needed. For example, interventions could use sources of information that are deemed credible by a particular vulnerable community to increase the likelihood of message acceptance. Research is also needed to understand whether interventions should target the most influential individuals in these vulnerable groups or focus on those who might be less integrated into the group and still amenable to change.

DEVELOP AND TEST EFFECTIVE RESPONSES

An approach centered on simply providing evidence-based health messages or broadly debunking misinformation will likely be insufficient. Interdisciplinary research is needed to develop additional strategies and identify the optimal timing, manner, and forum for responding to misinformation. Although a reactive response will be effective in one situation, a proactive response (such as inoculation) may be vital in a different context. It is also possible that the best response is no response at all, for example, if acknowledging the falsehood in a correction would only "give it oxygen" and further its spread.

Additionally, targeted approaches for reaching misinformed individuals with corrective information are needed. Public health practitioners and health care providers could attempt to identify and penetrate online information silos where misinformation is rampant to offer evidence-based information, direct users to credible sources, or provide countermessaging.

Finally, system-level preventive efforts are also needed, such as legislation requiring social media platforms to remove potentially harmful misinformation or incentives to increase their adoption ofpractices that make it more difficult for users to find and share misinformation. Increasing the public's health, science, and media literacy to decrease vulnerability to misinformation is another important prevention strategy. Such efforts could raise awareness of the techniques (e.g., cherry-picking data) used by agents of misinformation and increase the public's understanding of the inherent uncertainty and complexity of health and science information to induce a healthy skepticism toward claims that are overly simplistic or sensational.

USING RESEARCH TO INFORM POLICY AND PRACTICE

The research priorities we have outlined should inform and improve policy and practice aimed at addressing health misinformation on social media, such as content moderation standards used by platforms and rumor mitigation efforts undertaken by public health agencies. As these policies and interventions are implemented, further research will be needed to evaluate their impact. >4jPI-l

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CONFLICTS OF INTEREST

The authors have no conflicts ofinterest to disclose.

Sidebar

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Limited Role of Bots in Spreading Vaccine-Critical Information Among Active Twitter Users in the United States: 2017–2019

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ABSTRACT (ENGLISH)

Objectives. To examine the role that bots play in spreading vaccine information on Twitter by measuring exposure and engagement among active users from the United States. Methods. We sampled 53 188 US Twitter users and examined who they follow and retweet across 21 million vaccine-related tweets (January 12, 2017-December 3, 2019). Our analyses compared bots to human-operated accounts and vaccine-critical tweets to other vaccine-related tweets. Results. The median number of potential exposures to vaccine-related tweets per user was 757 (interquartile range [IQR] = 168-4435), of which 27 (IQR = 6-169) were vaccine critical, and 0 (IQR = 0-12) originated from bots. We found that 36.7% of users retweeted vaccine-related content, 4.5% retweeted vaccine-critical content, and 2.1% retweeted vaccine content from bots. Compared with other users, the 5.8% for whom vaccine-critical tweets made up most exposures more often retweeted vaccine content (62.9%; odds ratio [OR] = 2.9; 95% confidence interval [CI] = 2.7, 3.1), vaccine-critical content (35.0%;OR= 19.0; 95% CI = 17.3, 20.9), and bots (8.8%;OR = 5.4;95% CI = 4.7, 6.3). Conclusions. A small proportion of vaccine-critical information that reaches active US Twitter users comes from bots. (Am J Public Health. 2020;110:S319-S325. https://doi. org/10.2105/AJPH.2020.305902)

FULL TEXT

Headnote

Objectives. To examine the role that bots play in spreading vaccine information on Twitter by measuring exposure and engagement among active users from the United States.

Methods. We sampled 53 188 US Twitter users and examined who they follow and retweet across 21 million vaccine-related tweets (January 12, 2017-December 3, 2019). Our analyses compared bots to human-operated accounts and vaccine-critical tweets to other vaccine-related tweets.

Results. The median number of potential exposures to vaccine-related tweets per user was 757 (interquartile range [IQR] = 168-4435), of which 27 (IQR = 6-169) were vaccine critical, and 0 (IQR = 0-12) originated from bots. We found that 36.7% of users retweeted vaccine-related content, 4.5% retweeted vaccine-critical content, and 2.1% retweeted vaccine content from bots. Compared with other users, the 5.8% for whom vaccine-critical tweets made up most exposures more often retweeted vaccine content (62.9%; odds ratio [OR] = 2.9; 95% confidence interval [CI] = 2.7, 3.1), vaccine-critical content (35.0%;OR= 19.0; 95% CI = 17.3, 20.9), and bots (8.8%;OR = 5.4;95% CI = 4.7, 6.3).

Conclusions. A small proportion of vaccine-critical information that reaches active US Twitter users comes from bots. (Am J Public Health. 2020;110:S319-S325. https://doi. org/10.2105/AJPH.2020.305902)

Vaccine misinformation-false information not supported by evidence-is believed to be common on social media,1 but much less is known about whether it is commonly encountered and who encounters it. Not all vaccine-critical content posted on social media is misinformation, but misinformation is common in vaccine-critical content.2 Misinformation can undermine confidence in vaccination and encourage hesitancy and refusal,3 which then may influence the number and severity of infectious disease outbreaks.4,5 The potential for misinformation to spread via social media platforms is a pressing question for governments and global agencies.

Information epidemics and the potential impact of poor-quality health information online have been discussed for more than 20 years.6 To understand the effect of misinformation on health behaviors and outcomes, we need to go beyond characterizing misinformation and measuring how quickly it spreads7,8 to measure the composition of what

people are exposed to and engage with online. Information exposure is related to the concept of exposure in individual psychology studies on misinformation, and measures of information engagement are related to the concepts of salience of misinformation and how people choose to express their vaccine attitudes online.9 Because of its openness, Twitter is a convenient platform for estimating information exposure and engagement, but it has limitations. Potential exposure can be measured by observing social network structure, and engagement can be partially measured by observing how users pass on misinformation as retweets.

The Twitter information ecosystem is a complex mix of human and nonhuman actors posting or engaging with information for a range of purposes. Software agents (bots) that post on social media are an important type of nonhuman actor. Although there is evidence of their involvement in vaccination discourse and more broadly in public health on social media platforms,10-12 estimates of the size of their presence and their potential impact vary considerably. On Twitter, bots are accounts that are operated automatically to post, retweet, or reply and may vary in sophistication from simply reposting links to certain (often malicious) Web pages to more sophisticated masquerading of humans aiming to alter the discourse of a topic. A 2017 study estimated that between 9% and 15% of Twitter accounts are bots.13

A study that characterized vaccine-related tweets posted by trolls and bots on Twitter suggested that trolls and bots affect vaccine discourse10 but did not measure whether people ever saw or engaged with those tweets. Related research examining the potential effect of bots and fake news in politics suggested that bots play a minor role in potential influence, with humans more often responsible for spreading misinformation than bots.8,14

Despite the number of studies characterizing vaccine-related content on social media, none have provided reliable estimates ofhow often human social media users see or engage with bots on the topic. We sought to measure exposure to and engagement with vaccine information among active Twitter users in the United States and examine the role that bots might play in spreading vaccine-critical information on the platform.

METHODS

We collected all tweets matching a set of vaccine-related keywords and posted by any Twitter account between January 12, 2017, and December 3, 2019. We labeled tweets as vaccine critical or otherwise by training a machine-learning classifier, and we identified bots among the accounts posting vaccine-related tweets. Although tweets expressing a negative opinion of vaccination are not necessarily misinformation, much of the vaccine-critical content available online is either inaccurate or makes claims unsupported by evidence.2

In parallel, we monitored a sample of active, human-operated Twitter accounts from the United States (users) to track potential exposure and engagement with vaccine-related content. Information exposure is challenging to measure at scale, so we used information about the accounts the users follow as a proxy. Similarly, engagement is multifaceted and could be defined by views, interactions, replies, retweets, quoting, or other actions, and we measured retweets under the assumption that they most closely relate to active engagement.

Study Population

First, we sampled a set of Twitter users from the United States, requiring that these users be well established and active. We sampled accounts ofpeople who had recently posted any tweet and used a heuristic based on previous studies examining users over time to target active and established users via checks on the number of followers, rate of posting, and proportion of retweets (Appendix, section 2 [available as a supplement to the online version of this article at http://www.ajph.org]). A gazetteer, Nominatim (Appendix, section 3), then parsed accounts we judged to be active and well-established human users to infer a home location, and we included those that were in the United States in the analysis.

Vaccine-Related Tweets and Accounts Posting Them

We captured vaccine-related tweets posted by any public Twitter account via continuous keyword filtered requests to Twitter servers. Keywords included all reasonable synonyms and variants for words related to vaccines, vaccination, and immunization (Appendix, section 1). We have previously experimented with coverage ofthis approach and are confident that it covers all public tweets and retweets that match these keywords relative to the current best practice for Twitter surveillance in public health applications.15

We identified bots using Botometer,16 an established and validated method for identifying Twitter accounts likely to be bots (Appendix, section 4.1). Because of daily limits on the service, we collected these intermittently after accounts first posted a vaccine-related tweet during the study period. Bot scores vary between 0 and 1, where scores closer to 1 indicate a higher likelihood that a user is a bot. The typical approach used to identify bots among a population of Twitter accounts is to use a simple threshold, where any account with a score of 0.5 or higher is labeled as a bot.8,13,17

We used a supervised machine-learning method to identify vaccine-critical tweets. We created training data with help from Amazon Mechanical Turk workers, who were asked to label tweets based on whether they were vaccine critical. We sampled 10 000 vaccine-related tweets from 10 000 distinct accounts from the complete set of vaccine-related tweets, and we used labels from multiple workers to train a classifier (Appendix, section 4.2). We then applied the best-performing classifier to all vaccinerelated tweets to label them as vaccine critical or otherwise.

Analysis of Exposure and Engagement

We measured exposure based on the Twitter accounts that users followed. We collected lists of such accounts once per user after we first sampled each user. We counted any vaccine-related tweet or retweet posted by an account that a user was following as a potential exposure. We counted any vaccine-related tweet posted during the study period as a potential exposure if the user followed the account at the time the information was collected.

We measured engagement by identifying vaccine-related tweets that were retweeted by users. We looked for the users' identifiers in the set of 21 million vaccine-related tweets and retweets (Appendix, section 1).

In our primary analysis, we focused on descriptive characterizations of the frequency and distribution ofexposures and engagements for bots relative to human-operated accounts and for vaccine-critical relative to other vaccine-related tweets. Because we did not attempt to infer the demographics of the randomly sampled users, we were unable to measure or adjust for demographic differences.

We conducted a post hoc analysis of the set of users for whom potential exposures to vaccine-critical tweets were at least half of the total number of potential exposures to vaccine-related tweets. For this subgroup of users, we compared engagement with bots and vaccine-critical tweets against their counterpart users for whom vaccine-critical tweets made up less than half of their exposures. Differences are reported as unadjusted odds ratios (ORs) with 95% confidence intervals (CIs).

RESULTS

The study included 53 188 Twitter users in the United States, who we sampled independently from whether they were exposed to or shared vaccine-related content (Figure 1). These users were distributed across the United States; the most common user locations were California (12.3%), New York (9.2%), and Texas (9.1%; Appendix, section 3). Ofthe 5 124 906 scored accounts tweeting or retweeting about vaccines during the study period, 2 121 315 accounts were followed by 1 or more of the 53 188 users.

Potential Exposure to Bots and Vaccine-Critical Tweets

In terms of the frequency of potential exposures, we found that users were potentially exposed toa median of 757 (interquartile range [IQR] = 168-4435) vaccine-related tweets, a median of 27 vaccine-critical tweets (IQR = 6-169), and a median of 0 vaccine-related tweets from bots (IQR = 0-12). The results indicate that for most users, exposure to vaccine-critical content was relatively infrequent and that exposure to bots was extremely infrequent (Figure 2).

Exposure to bots was rare and unevenly distributed across users (Figure 2); 42.0% of users may have been exposed at least once to a vaccine-related tweet originally posted by a bot, because either they followed a bot account that posted a vaccine-related tweet or an account they followed retweeted a vaccine-related tweet posted by a bot account. However, posts from bots made up a small percentage of vaccine-related exposures; the median percentage of exposures originating from bots was 0.0% (IQR = 0.0%-0.5%). Bot accounts were responsible for at least half of the potential exposures to vaccine-related tweets for less than 0.06% of users.

Exposure to vaccine-critical tweets was also relatively rare and unevenly distributed across users (Figure 2). As a proportion of exposures, vaccine-critical tweets made up a median of 3.2% (IQR = 1.4%-9.2%) of all vaccine-related exposures. Vaccine-critical tweets made up at least halfofvaccine-related exposures for 5.8% of users. The results

indicate that although most users may have seen a vaccine-critical tweet, only 1 in 20 users were more often exposed to vaccine-critical content than other vaccine-related content.

Engagement With Bot Accounts and Vaccine-Critical Content

When counting the retweets of any vaccine-related tweets and the posting ofany original vaccine-related tweets together, we found that the median number oftimes a user posted or retweeted about vaccines was 0 (IQR = 0-2) and that 36.7% of users posted or retweeted vaccine-related content at least once during the period. Few users actively engaged with vaccine-related tweets; 1.9% of users engaged with vaccine-related tweets at least once per month on average.

Retweeting bots was uncommon. Just 2.1% of users retweeted a bot at least once during the study period, compared with 27.1% of users who retweeted vaccine-related tweets from human-operated accounts at least once (Figure 3).

Retweeting vaccine-critical content was relatively uncommon. Just 4.5% of users retweeted a vaccine-critical tweet at least once, compared with 26.2% of users who retweeted other vaccine-related tweets at least once (Figure 3).

Engagement with bots and vaccine-critical tweets was unevenly distributed across users (Figure 3). For 2.6% of users, vaccine-critical tweets made up at least half of their vaccinerelated retweets during the study period. Bots made up at least half of the set of vaccine-related retweets for just 0.4% of users.

Users Disproportionately Exposed to Vaccine-Critical Tweets

We further analyzed the 5.8% of users for whom at least half of their potential exposures to vaccine-related content were vaccine-critical tweets. The median potential exposure count among the 3086 users was 30 709 (IQR= 8795-65 091) compared with 750 (IQR = 195-3698) for other users, indicating that users in this subgroup were more often exposed to any type of vaccine-related tweets than their counterparts. The median percentage of exposures to bots among the 3086 users was 6.2% (IQR = 2.2%-9.1%) compared with 0.0% (IQR = 0.0%-0.4%) among other users, indicating that bots made up a greater proportion of what these users may have seen.

Users from this subgroup were more likely to engage with vaccine-related posts in general, suggesting that they were more engaged with vaccines and vaccinations as a topic. In this subgroup, 62.9% (1940 of3086) retweeted vaccine-related content at least once in the study period compared with 36.9% (17 553 of 47 513) of other users (OR = 2.9; 95% CI = 2.7, 3.1). The median number of posts or retweets among the subpopulation was 2 (IQR = 0-6), compared with 0 (IQR = 0-2) from other users.

Users from this subgroup were also more likely to retweet bots and vaccine-critical content than were other users. The percentage of users from this subgroup who retweeted bots at least once was 8.8% (271 of 3081) compared with 1.7% (825 of47 513) of other users (OR = 5.4; 95% CI = 4.7, 6.3). The percentage of users from this subgroup who retweeted vaccine-critical tweets at least once was 35.0% (1081 of 3086) compared with 2.8% (1310 of 47 513) of other users (OR = 19.0; 95% CI = 17.3, 20.9).

These results show that 5.8% of Twitter users in the United States are embedded in communities where exposure to vaccinecritical content is common. These users differ from other Twitter users in the United States in that they tend to engage with the topic more often and are more likely to share vaccine-critical content. Although they are also more likely to share content from bots than other users, bots still accounted for a small proportion ofwhat they read or shared.

DISCUSSION

Twitter users in the United States were frequently exposed to information about vaccines between January 12, 2017, and December 3, 2019. More than a third ofusers also engaged in discussion about the topic by posting or retweeting vaccine information, but this engagement was relatively infrequent for most users. Engagement with any vaccine-related tweets, vaccine-critical tweets, and bots was higher in the 5.8% of users who were embedded in communities where vaccine-critical content was common. The overwhelming majority of the vaccine-related content seen by typical users in the United States is generated by human-operated accounts, not bots. The results show that bots play little to no role in shaping vaccine discourse among Twitter users in the United States.

Comparison With Existing Literature

Consistent with other literature in the area, we found that a small proportion of Twitter users were embedded in communities where vaccine-critical content was shared more than other vaccine content. Compared with other users, these users were more likely to have posted or retweeted about vaccines, and more of the vaccinerelated tweets they posted were vaccine critical. These results indicate that engagement with vaccine-critical information is concentrated in certain communities. This is consistent with the findings of studies examining community structure and information exposure in human papillomavirus vaccines on Twitter,18 20 studies of news media coverage of vaccinations,21 and studies on exposure to and engagement with political fake news.14 Although this study is not directly comparable with studies that characterize vaccine-related posts from bots and trolls,10 our results suggest that conclusions drawn about the importance ofbots in shaping the discourse on social media may be overstated. We found that Twitter users in the United States rarely share vaccine-related content posted by bots. A 2017 study examined follower relationships between human users and bots on Twitter, estimating that between 9% and 15% of accounts are bots, that human users mostly form connections with other human users, and that there is little reciprocity (humans following bot accounts that follow them).13 Although we measured engagement in a more direct way, our results are generally consistent with these findings. Another study examining the spread of low-credibility content suggests that human users retweet articles posted by bots almost as much as they retweet other humans, although it appears that what drives amplification is the volume of retweets the content has regardless of the provenance of those retweets.17 This highlights the importance of estimating exposure and engagement in populations of information consumers rather than speculating about impact by counting posts.

Limitations

The tool we used to detect bot accounts may be imperfect, and some users may have been misclassified. However, we used a standard threshold common to previous studies that show the tool rarely misclassifies accounts.13,16,17 Some bots may have been deleted or suspended after posting about vaccines and before we could capture their bot score. Of the 5.28 million accounts posting about vaccines, we did not score 0.1 million accounts (2.4%) because they became unavailable in the period between identifying the account and checking its score. It is possible that a greater proportion of those accounts were bots compared with the accounts that were included in the analysis. Given the number, this difference could not have affected the conclusions.

We did not investigate the full complexity of the information landscape on Twitter. For example, we cannot draw any conclusions about trolls-human-operated Twitter accounts that use a range of approaches to gain followers and may post misinformation. New studies would benefit from measuring the potential effect of trolls via exposure and engagement with trolls in a robust sample of human users.

Our method for detecting vaccine-critical tweets had a high accuracy but was imperfect, which means that we likely misclassified a small proportion of posts. However, because the classifier was designed to maximize recall over precision (Appendix), we were more likely to overestimate than underestimate the number of vaccine-critical tweets. Measures of potential exposure are approximations based on the structure of the follower network and do not capture changes to the algorithms that Twitter uses to deliver posts to users; therefore, including advertising and recent changes that present tweets from accounts that users do not follow may make potential exposure estimates less reliable. Estimates of potential exposure may have also been affected by an inability to continually update information about who users follow on Twitter. It was only feasible to collect information about who the users followed after they were identified, and users are likely to have followed or unfollowed other users during the study period. However, users are still much more likely to be exposed to tweets ofthe accounts they follow, so the measure of potential exposure is likely to be a reasonable proxy for information consumption.

Public Health Implications

Our results have implications for public health practice and can be used to inform approaches for addressing vaccine misinformation.7,22 Two proposed approaches are (1) tools to help social media platforms identify misinformation (a precursor to removing, hiding, or algorithmically reducing exposure), and (2) interventions designed to empower users to critically appraise the information they see.7 Critical appraisal skills necessary to distinguish between credible information and misinformation vary,23 and tools that could be used to support the

critical consumption of vaccine-related information might offer insights into the techniques and topics used in antivaccine arguments.24,25 Our results suggest that allocating resources to eliminating bots may be less effective than providing tools to improve media literacy and developing personalized communications interventions targeted at communities where vaccine-critical content is most common.26 Strategies that focus on limiting the impact of influential accounts spreading misinformation are warranted-an approach aligned with how public health organizations make decisions about how and when to engage with vaccine-critical content.27

Our analysis also has implications for research practice and reporting. Beyond counting and characterizing the content posted on social media platforms, it is important to consider that not all posts have the same effect. Posts vary in terms of reach and engagement, and phenomena such as echo chambers mean that certain content is shared and consumed mostly in specific communities of often like-minded people. Measuring and separating out the mechanisms ofhomophily, contagion, and external drivers of network dynamics require studies that involve social media users as participants.

How those messages influence vaccination uptake requires them to be considered in the broader context of how vaccination decisions are made. Although experimental studies of the direct impact of vaccination messages online show a capacity to change beliefs and intentions temporarily,30 studies that involve people who choose not to vaccinate their children indicate that core beliefs about health and parenting experiences in the health care system are central.31,32 Given that lack of vaccination tends to be clustered, it is likely that social network structures play a role in the process.

Further studies are needed to better understand the gaps between what can be observed about people online and the decisions they make about vaccination offline. Despite some early examples across several social media platforms,33-35 social media research rarely connects measures of information expression or exposure from social media data to individual attitudes and behaviors measured by surveys or using medical records. We recommend further studies that can reconcile the link between online and offline behavior to improve the translation of social media research.

Conclusions

Active Twitter users in the United States are frequently exposed to vaccine-related content, but most users never or infrequently engage. For nearly all users, bots are responsible for a small proportion of the vaccine-related content users see, and engagement with bots is negligible. Exposure to and engagement with vaccine-critical content tend to be most heavily concentrated in a relatively small subgroup ofusers who are more engaged with the topic overall. Researchers studying health information consumption should consider measuring exposure and sharing in representative populations to better understand the potential effect of what is being posted. Rather than focusing efforts on bots, social media platforms, policymakers, and public health agencies should continue to focus on the known factors influencing vaccinationrelated behaviors. /4JPI-I

CONTRIBUTORS

A. G. Dunn, J. Leask, E. Coiera, A. Dey, and K. D. Mandl conceptualized and designed the study. A. G. Dunn, D. Surian, J. Dalmazzo, and D. Rezazadegan collected, processed, and analyzed the data. A. G. Dunn, M. Steffens, and A. Dyda interpreted the data. All authors drafted the article, provided critical revisions, and finalized the article.

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The authors have no conflicts of interest to declare.

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Sidebar

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A Prologue to the Special Issue:Health Misinformation on Social Media

Chou, Wen-Ying Sylvia, PhD, MPH; Gaysynsky, Anna, MPH

FULL TEXT

This National Cancer Institute-sponsored special issue of the AJPH reflects the growing consensus among national health agencies, public health researchers, and practitioners that online health misinformation, particularly on social media (SM) platforms, presents a critical challenge for public health. The spread ofmisinformation threatens to erode much of the progress that has been made on many fronts, including vaccination, tobacco use, and control of infectious diseases.

This special issue came about in recognition of several key trends that have emerged over the past decade, including (1) Americans are increasingly getting their news and health information from SM; (2) the public's trust in traditional sources ofinformation (e.g., mass media, government agencies, the medical system) is at historic lows; and (3) the online discourse, from politics to health, has become increasingly divisive and partisan. These factors provide a fertile environment where health misinformation can take root and spread, and the potential real-world consequences are alarming. For example, antivaccine views promoted on SM could lead to avoidance of routine vaccinations and community spread of disease, and videos advertising ineffective or dangerous cancer treatments could lead patients to forgo recommended therapies.

Reacting to these trends, we began planning this special issue in 2019. However, shortly after the article submission deadline passed, the world experienced the defining health crisis of our generation-the COVID-19 pandemic-and we witnessed in real time how the proliferation of misinformation hindered pandemic response. Rumors, myths, and conspiracy theories regarding the origins of the disease, its severity and prevalence, vaccine development, prevention measures, and unproven treatments spread online at alarming speed.

The consequences of endorsing such misinformation can be disastrous: the belief that the pandemic is overblown can make people less willing to comply with social-distancing measures and mask requirements, mistrust in vaccine experts can impede vaccination programs' ability to achieve sufficient coverage, and the use of unproven treatments can cause serious injury or even death. The onslaught of misinformation about COVID-19 grabbed news headlines and became a key theme in both public and private discourse during the pandemic, engendering a wider recognition ofthe urgent need to better understand, and more effectively respond to, health misinformation. The contributions in this special issue are, therefore, especially timely.

Our initial call for proposals attracted more than 140 submissions, demonstrating the field's readiness to tackle the challenge of health misinformation. After two rounds of competitive reviews, we selected the articles for publication based on rigor, public health relevance, and diversity of topics and methods. The issue therefore covers a wide array of health topics, including vaccines (Dunn et al., p. S319; Bonnevie et al., p. S326; Jamison et al., p. S331; Broniatowski et al., p. S312; Guidry et al., p. S305), cancer prevention and treatment (Wilner and Holton, p. S300; Zenone et al., p. S294), and infectious disease outbreaks (hepatitis A in Oren et al., p. S348; Zika in Safarnejad et al., p. S340).

The issue also features research across a diverse set of SM platforms. Although most articles examined Twitter (Dunn et al.; Bonnevie et al.; Jamison et al.; Oren et al.; Safarnejad et al.) and Facebook (Broniatowski et al.), a few focused on understudied platforms such as Pinterest (Guidry et al.; Wilner and Holton) and GoFundMe (Zenone et al.).

The articles in this issue also showcase a wide range ofresearch methods, including machine learning and natural language processing (Bonnevie et al.; Dunn et al.; Jamison et al.; Broniatowski et al.), content analysis (Guidry et al.; Wilner and Holton; Oren et al.; Zenone et al.), and network analysis (Safarnejad et al.). These contributions provide an informative set of rigorous and replicable approaches to understanding and responding to misinformation.

More important than the diversity of topics and methods are the practical lessons these studies offer the field of public health. Analyses ofSM content can yield useful findings, for example, in tackling vaccine misinformation. Dunn et al. show that vaccine misinformation on Twitter is not primarily driven by bot activity- suggesting that focusing on specific communities where vaccine misinformation is circulating might be more effective than targeting bot accounts. Bonnevie et al. show that the types of misinformation that vaccine opponents spread are quite limited and that the sources of misinformation are not heterogeneous or distributed; therefore, identifying and countering a small set of arguments and highly influential accounts could be an efficient way to address vaccine misinformation.

The methodology developed by Jamison et al. could be used to help identify prominent themes in SM vaccine discourse and develop counterarguments against misinformation. The longitudinal analysis of antivaccine Facebook pages in Broniatowski et al. points to one such theme: the "freedom of choice" framing of vaccine decisions. The increased focus on civil liberties since 2015 suggests that attempts to counter vaccine misinformation will need to address political arguments, rather than solely providing facts about vaccine safety and efficacy.

Notably, public health practitioners are not the only ones dealing with health misinformation, and the actions of other players, such as SM platforms, need to be studied. Evaluating the impact of Pinterest's 2019 vaccine content moderation policy, Guidry et al. show that although it successfully reduced human papillomavirus vaccine misinformation in search results, it also reduced the amount of human papillomavirus vaccine-related content overall, potentially creating an information vacuum. As SM sites enact new policies, public health organizations and health care providers should be ready to fill any information gaps resulting from these changes. It is not enough to simply remove misinformation; we must ensure that accurate information is widely accessible on these platforms.

Another limitation of SM companies' actions is that they tend to be reactive and focus on the particular topics receiving attention at a given moment, rather than tackling misinformation in a holistic manner. Although Pinterest took action to address vaccine misinformation, the study by Wilner and Holton shows that misinformation about breast cancer is also a significant issue on the platform. These authors found that many pins about breast cancer prevention or treatment contain misinformation, including claims about foods that allegedly prevent or treat cancer, references to unsubstantiated cancer risk factors, and statements downplaying the accuracy and safety of mammograms. However, the subtlety of the misinformation identified (e.g., most claims were exaggerated rather than patently false, inaccurate information was often conveyed through images instead of text) highlights why falsehood detection and content moderation efforts can be challenging.

Zenone et al. also confront a complex case of cancer-related misinformation in their examination of the way cannabidiol is portrayed in fundraising campaigns on GoFundMe. Most campaigns were found to misleadingly present cannabidiol as curative or life prolonging, with many relying on anecdotal evidence to support these claims. The hype and misperception surrounding cannabidiol underscores the need to investigate the realworld harms of

misinformation, especially when the evidence base on a topic is not well established. Furthermore, the study demonstrates the need to expand research beyond prominent platforms, as misinformation can also proliferate on SM platforms that are not primarily considered informationdissemination channels.

The last research articles offer timely case studies on two previous disease outbreaks, with lessons for the COVID-19 pandemic. Oren et al. demonstrate the feasibility and utility of studying tweets to understand the community response to a hepatitis A outbreak. Key themes identified-including risk perception (e.g., susceptibility to and severity of infection), criticisms of the government's response, and stigma against the population perceived to be the source of the outbreak-all have echoes in the current discourse on COVID19. The authors also point to missed opportunities for health organizations to use SM to engage in dialogue with affected communities, rather than using these platforms to simply broadcast information.

Safarnejad et al. analyzed tweets related to the 2015 to 2016 Zika outbreak, finding distinctly different dissemination network structures between misinformation and accurate information. This study highlights the need to go beyond crosssectional content analysis to track how misinformation spreads. It also points to a central challenge in outbreak communication: the evolving nature of the evidence base makes it difficult to identify and counteract misinformation in real time.

As a complement to the empirical research articles, we also solicited commentaries and editorials focusing on critical gaps and priorities in health misinformation research and practice. To begin, Chou et al. (p. S273) outline five priority areas for future research:

1. enhancing misinformation surveillance,
2. understanding the psychological drivers of misinformation endorsement and sharing,
3. identifying real-world consequences of misinformation,
4. intervening with those who are most vulnerable to misinformation and its consequences, and
5. developing and testing effective responses to misinformation.

Scherer and Pennycook (p. S276), Vraga and Bode (p. S278), and Tan and Bigman (p. S281) further expand on some of these priority areas. Scherer and Pennycook present three theoretical perspectives that may explain what makes certain people more susceptible to misinformation and suggest additional factors (such as trust) to be further explored. Vraga and Bode summarize best practices for "observational correction" online-a potentially effective approach that can be scaled up by engaging the public, experts, and SM platforms. Tan and Bigman explore avenues for misinformation research in the context oftobacco control, highlighting the need to enhance misinformation surveillance of new tobacco products; assess the impact of exposure to online tobacco misinformation, especially among vulnerable populations; and develop interventions for tobacco disparity populations.

The final set of editorials offers concrete recommendations for those on the front lines of public health. Southwell et al. (p. S288) highlight the critical role of health care providers, encouraging them to proactively combat misinformation by monitoring the information environment, listening to patients, and helping patients gain a better understanding of medical evidence. Donovan (p. S286) offers recommendations for public health communicators seeking to provide timely, relevant, and local information on COVID-19 and other health issues, including monitoring rumors that are gaining traction, building stronger relationships with journalists, and using channels other than SM (e.g., text messaging) to communicate critical health information.

Vanderpool et al. (p. S284) discuss the need to leverage the attention paid to COVID-19 vaccines to tackle vaccine hesitancy more broadly, advocating efforts to enhance vaccine literacy and improve communication efforts by taking into account people's values as well as the cognitive, emotional, sociocultural, and contextual factors associated with vaccine hesitancy. Finally, Susser (p. S290), an ethicist, cautions the field against adopting the tools that have proven effective for spreading misinformation (e.g., microtargeting) to disseminate evidence-based health information, noting the need to weigh the potential effectiveness of digital influence tools against the risks they raise, such as violations of privacy, disregard for personal autonomy, perpetuation of bias, and lack of transparency and accountability.

In summary, as our knowledge of the (mis)information ecosystem grows, we will need to reexamine traditional health communication theories, standard research designs, and ongoing public health practices. It would be naive to assume that delivering accurate health information earnestly using existing tools, channels, and guidance will be effective. It is time to boldly explore innovative, adaptive, and alternative approaches to both disseminating evidence-based information and mitigating the impact of misinformation. With COVID-19 continuing to cause global suffering and disruptions, understanding and combatting health misinformation is one of the most urgent public health priorities of our time. Á¡PU

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The authors have no conflicts ofinterest to disclose.

Sidebar

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Breast Cancer Prevention and Treatment: Misinformation on Pinterest, 2018

Wilner, Tamar, MA; Holton, Avery, PhD

ABSTRACT (ENGLISH)

Objectives. To quantify and describe the incidence of misinformation about breast cancer on the social media platform Pinterest, a leading source of women's health (e.g., breast cancer) information. Methods. We performed a hand-coded content analysis on 797 Pinterest posts ("pins") mentioning the terms "breast cancer" or "breast" and "cancer," collected in November 2018. Results. From the original sample of 797, 178 (22.3%) made a factual claim about what social media users could do to prevent or treat breast cancer. Of these, more than half-91 (51.1%)-contained misinformation. Therefore, 11.4% of the sample overall contained misinformation related to breast cancer prevention or treatment. Conclusions. Pinterest is a significant vector of misinformation about breast cancer, especially given the platform's overwhelmingly female composition and its visual means of conveying information. Public Health Implications. Health practitioners should be aware of the myths circulating about breast cancer prevention and treatment and be prepared both to dismantle misinformation and to stress reliable health guidance. Meanwhile, Pinterest may wish to widen the criteria it uses for identifying health misinformation on its platform. (Am J Public Health. 2020;110:S300-S304. https://doi.org/10.2105/AJPH.2020.305812)

FULL TEXT

Headnote

Objectives. To quantify and describe the incidence of misinformation about breast cancer on the social media platform Pinterest, a leading source of women's health (e.g., breast cancer) information.
Methods. We performed a hand-coded content analysis on 797 Pinterest posts ("pins") mentioning the terms "breast cancer" or "breast" and "cancer," collected in November 2018.
Results. From the original sample of 797, 178 (22.3%) made a factual claim about what social media users could do to prevent or treat breast cancer. Of these, more than half-91 (51.1%)-contained misinformation. Therefore, 11.4% of the sample overall contained misinformation related to breast cancer prevention or treatment.
Conclusions. Pinterest is a significant vector of misinformation about breast cancer, especially given the platform's overwhelmingly female composition and its visual means of conveying information.
Public Health Implications. Health practitioners should be aware of the myths circulating about breast cancer prevention and treatment and be prepared both to dismantle misinformation and to stress reliable health guidance. Meanwhile, Pinterest may wish to widen the criteria it uses for identifying health misinformation on its platform. (Am J Public Health. 2020;110:S300-S304. https://doi.org/10.2105/AJPH.2020.305812)

Health misinformation presents an increasingly complex problem in online and social media spaces.1 3 Misinformation can be defined as "false or inaccurate information regardless of intentional authorship."4(p282) Online misinformation about cancer is a particularly critical concern because the few extant studies suggest that such misinformation may be widespread.5 The presence of cancer-related misinformation online remains largely undocumented, however.6 Researchers have therefore called for more investigation of the frequency of inaccurate cancer information on social media.7

Breast cancer misinformation online is a particular phenomenon that warrants more analysis. Breast cancer is one of the most common cancers found in US women.8 Health misinformation about breast cancer is ofparticular concern on Pinterest. About 322 million people use Pinterest every month,9 and health and fitness content constitute its third-most-popular subject matter by followers perpin, after travel and education.10 The platform's user base is 70% female, and 42% of all US women use the site.11,12

Pinterest is also composed mostly of visuals. Each "pin," or piece of content, on Pinterest consists primarily of a graphic file. This poses a particular misinformation concern because, compared with text, visuals have greater positive effects on attention and recall.13 In addition, visuals are uniquely able to persuade.14

Among the few studies of misinformation on Pinterest, Guidry et al.15 found that of 800 vaccine-related pins, 74% were antivaccine. Guidry et al.16 found that pins about waterpipe smoking tended to portray the activity in a positive light. Tang and Park17 found that pins about nonmelanoma skin cancer tended to provide scant information about causes, prevention, and treatment.

CLASSIFYING MISINFORMATION

To understand misinformation posts about breast cancer, it is important to analyze sources, types of misinformation, phase, and the presence of conspiracy theories.

Sources

By investigating who the sources of misinformation are, we can attempt to shed light on the motivations of the actors involved, which could then help antimisinformation activists to know what countersteps might work.18

Misinformation Types

Wardle distinguishes 7 types of mis- and disinformation: satire or parody, false connection, misleading content, false context, imposter content, manipulated content, and fabricated content.18 The types are distinguished by some content characteristics but also by the motivations of the creator. We briefly employed this typology but found it to be problematic for several reasons. First, the typology is derived in large part from motivations of the content creator, which we felt we could not ascertain with certainty. Second, even based on content features alone, most of Wardle's misinformation types did not present themselves and thus did not seem relevant in this context. These include misleading content ("misleading use of information to frame an issue or individual") and imposter content ("when genuine sources are impersonated"). We pilot an alternative approach, outlined in Table B (available as a supplement to the online version of this article at http://www.ajph.org).

Phases

In addition, a study of cancer misinformation should seek to understand the "phase" under discussion: whether the information pertains to cancer prevention, cancer treatment, or both. While both forms of misinformation are potentially life-threatening, misinformation on treatment presents more short-term risks, such as people abandoning a more effective treatment for a less effective one.

Conspiracy Theories

Several studies suggest that conspiracy theories are a frequent aspect of health misinformation online.16 Conspiratorial thinking is especially resistant to correction,19 and belief in health-related conspiracies correlates negatively with desirable health behaviors.20 Conspiracy theories on cancer are widespread: a representative survey of US adults found that 37% believe the Food and Drug Administration is bowing to drug company pressure to cover up natural cancer cures.20 It is therefore important to examine the role of conspiracy thinking in breast cancer misinformation online.

PROBLEM STATEMENT

The prevalence, typology, content, and sourcing of misinformation about breast cancer on Pinterest remain understudied. In our current study, we sought to fill this gap with a content analysis of 797 systematically selected pins. We identified the frequency of misinformation within posts, the location of the misinformation within eachpost (i.e., text only, image only, both), the sources linked to by the posts, the types of misinformation used, the phase described, the content of misinformation (e.g., vitamins and minerals, food, mammograms), and the presence of conspiracy theories.

METHODS

We used the software program ParseHub (ParseHub, Toronto, ON, Canada) to search the terms "breast cancer" and "breast + cancer," on November 14, 15, and 16, 2018, fora total of6 searches. We then used ParseHub to automatically scrape links to the pins. We collected a sample of 838 pins, similar to previous research.15,16 This sample size was deemed large enough to perform the required statistical analyses (frequencies and %2s) while still being a manageable amount to code. We saved a screen capture of each pin. We found 41 of the links downloaded not to connect to extant pins, and we discarded these, leaving 797 pins for further analysis.

Codebook

We conducted coding in 2 phases, deductive and inductive. In the deductive phrase, we worked from a codebook presented as Table A (available as a supplement to the online version of this article at http://www.ajph.org). We used 1 variable within this codebook ("phase") to answer the research questions but also as a screener to determine which pins required further coding. This code captures whether each pin made a factual claim about what social

media users could do to prevent or treat breast cancer. From the original sample of 797 pins, 178 (22.3%) met this criterion and were analyzed further. Excluded posts mostly consisted of inspirational messages and promotions for breast cancer-themed products. The further coding for the set of 178 posts included several codes based on Guidry et al.15 These were the type of Web site the pin linked to and conspiracy theory used in the post (if any). We considered a conspiracy theory to be a claim about breast cancer that invoked secrecy by powerful groups or individuals.

In addition, we created variables for the presence of misinformation in the image and in the text. We determined the presence of misinformation by comparing the content of the pins to reputable sources of information on breast cancer, including the Web sites of the Memorial Sloan Kettering Cancer Center (especially its guide to herbs and botanicals21), the World Cancer Research Fund (especially its guide to diet, nutrition, and physical activity22), the National Cancer Institute,23 BreastCancer.org, Susan G. Komen,24 and published academic papers. If a claim in the pin was shown to be false by evidence from 1 of these sites, we coded the text or image in question as containing misinformation. Only 1 false claim was required to code for misinformation, even if the text or image made several claims.

In the inductive content analysis phase, we employed a grounded, qualitative coding approach to discover common themes in the types and content of misinformation in the posts. The first author (T. W.) examined notes made during the deductive analysis and used this to derive a misinformation typology and a typology of topics (Table B).

Coder Training and Intercoder Reliability

Using a random number generator, 80 pins were selected for a pretest, in which both researchers coded. Acceptable Krippendorff alphas were achieved for all quantitative variables, as follows: 0.91 for phase, 0.88 for source, 0.82 forpresence ofmisinformation in the image, 0.82 for presence of misinformation in the text, and 0.80 for presence of conspiracy theory.

RESULTS

Of pins that made a factual claim about breast cancer prevention or treatment, more than half (51.1%) contained misinformation. This means that 11.4% of the sample overall contained misinformation related to breast cancer prevention or treatment. Of those, 28.6% contained misinformation in the image only, 23.1% in the text only, and 48.4% in both. Pins containing misinformation linked overwhelmingly to blogs (71.4% of the time), with much smaller proportions linking to mainstream media Web sites (7.7%), medical Web sites such as hospitals (3.3%), other health-focused Web sites (5.5%), social media sites (2.2%), and other sites (2.2%).

Type of Misinformation

Of posts containing misinformation, we classified 54.9% as exaggerated. Examples included claimed anticancer or cancer prevention effects for probiotics, flaxseed, turmeric, dandelions, pomegranates, green tea, vitamin D, insulin-like growth factor 1 (IGF-1), and a variety of other foods, medicines, and supplements.

We classified another 18.7% of misinformation as no evidence, with examples including claims that antiperspirants cause cancer (and that an "armpit detox" can counteract this supposed effect), and claims about the cancer-fighting powers of various foods and supplements. Meanwhile, we classified 16.5% of misinformation as inaccurate. Common themes here were downplaying of the accuracy and safety of mammograms, sometimes in favor of ultrasounds; false claims that bioidentical hormones do not carry the same cancer risks as synthetic hormones; and mischaracterization of tumor size and lymph node involvement during the various stages of breast cancer. We classified another 4.4% as outdated, in all cases because official guidance on when women should start getting mammograms has changed.

Finally, we classified 2.2% as contraindicated -these had to do with claims on turmeric and colloidal silver, described in more detail in the "Content of Misinformation" section-and we classified 2.2% as error by omission, because, while listing warning signs of breast cancer, they failed to mention obvious candidates including lumps and other changes to the breast.

Phase in Posts

We performed a %2 test of independence to examine the relationship between the presence ofmisinformation and

the post phase (restricting the analysis only to pins that made factual claims about prevention and treatment). There was a significant relationship between these variables (C2 [2;n = 178] = 8.51; Cramer's V = 0.219; P <.05). Bonferroni pairwise comparisons showed that frequencies for posts containing misinformation were significantly different than posts without misinformation for the "both" category at P <.05. For the other 2 phase categories, there were no significant differences. Of posts containing misinformation, 34.1% related to prevention, 41.8% related to treatment, and 24.2% related to both. For posts found to contain no misinformation, 42.5% related to prevention, 49.4% related to treatment, and 8.0% related to both.

Content of Misinformation

Breaking down misinformation posts by topic, 39.6% were about foods that supposedly prevent or treat cancer, or that supposedly cause cancer. Many claims were mild and nonspecific, such as "Mediterranean Diet for Breast Cancer." Others went further-for example, proposing that 10 certain foods "Prevent Breast Cancer Completely." One post asked if readers were taking "this breast cancerpill" (which turned out to be probiotics, on which breast cancer research is at an early stage). Other pins advocated the use of turmeric, which the breast cancer foundation Susan G. Komen says should be used cautiously by people with breast cancer until more about its effects are known.25 Another 19.8% of misinformation pins were about vitamins, minerals, herbs, or supplements. Pins sometimes posed these substances as add-ons for a healthy lifestyle (as in, "This Tree Bark Can Heal Digestive Issues and May Even Fight Breast Cancer," about slippery elm), but sometimes as substitutes for other cancer treatments (as in "One simple pill stops breast prostate and thyroid cancers," about iodine). One pin touted "5 Known Cures for Cancer that the World NEEDS to know!," with the pictured "cure" being colloidal silver (Figure 1). The Memorial Sloan Kettering Cancer Center says colloidal silver cannot cure cancer, and long-term use can cause seizures and kidney damage.26

Next, 9.9% of misinformation pins were about supposed environmental causes of cancer, with antiperspirants being 1 commonly cited culprit, despite the National Cancer Institute saying that no scientific evidence links antiperspirants to breast cancer.27 Other pins blamed soaps, pots and pans, and genetically modified organisms. Meanwhile, 8.8% of misinformation pins were about mammograms, ultrasounds, or thermography. Some of these posts played up the risks and downplayed the benefits of mammography, touting thermography and ultrasounds as alternatives. Others were simply outdated, recommending that women begin annual mammograms at age 40 years, when the American Cancer Society has raised the recommended age to 45 years, with mammograms elective from 40 to 44 years.28 Some of the less-common content of the misinformation pins included the stages of breast cancer (5.5%), symptoms (3.3%), surgery (3.3%), hormone treatment (2.2%), the role of faith in treatment (2.2%), breast selfexaminations (1.1%), benign lumps (1.1%), research organizations (1.1%), and alternative medicine, not including food, vitamins, minerals, herbs, or supplements (1.1%).

Conspiracy Theories

Ofthe misinformation pins, 95.6% did not put forth any conspiracy theories. The few to do so either alleged that information on cancer is being withheld from the public or implied that research organizations are profiting from cancer.

DISCUSSION

These findings suggest that misinformation about breast cancer reaches people through vectors besides the obvious platforms of Facebook and Twitter and does so by using persuasive methods. Misinformation clearly takes advantage ofPinterest's visual nature: in our findings, most of the pins with misinformation used either the image alone, or the image in combination with text, to convey their inaccuracies. We also found that the misinformation pins were more likely than the nonmisinformation pins to relate to prevention and treatment simultaneously, meaning the misinformation could be more influential over patient decision-making.

The results demonstrate the complexity of the misinformation landscape on a single platform, with likely varying implications for health outcomes, confirming earlier observations.4 The finding that most claims were exaggerated rather than "no evidence," "inaccurate," or "contraindicated" is somewhat reassuring; however, we would caution that even treatments based on a germ oftruth can be harmful if used to replace a more established treatment.

One encouraging finding was that conspiracy theories did not appear frequently among the misinformation. This is somewhat surprising given widespread belief in cancer conspiracy theories.20 It is possible that Pinterest's efforts to crack down on health misinformation have led to such posts being taken down before other types of misinformation. Or perhaps Pinterest's users are more concerned with providing helpful tips on what users can do than they are with analyzing the motives of governments and companies. This finding, along with the others, does suggest that Pinterest moderators should be rather expansive in what sort of pins they consider evaluating for misinformation; obvious flags like conspiracy theories may not be present.

As Southwell et al. note, the effects of misinformation are highly dependent on diffusion and exposure.4 The mere presence of this misinformation on Pinterest does not guarantee that these pins were heavily viewed, and questions of misinformation's diffusion on Pinterest-whom it reaches and how its reach compares with that of factual information-warrant further research. However, we note several reasons for concern. First, studies suggest that false and misleading health stories get far more shares on social media than do verified news stories on the same topic.29 Second, hearing about breast cancer-related controversy can provoke online searching.30 As we obtained these results by searching on Pinterest for the most obvious breast cancer-related terms, the results suggest that Pinterest users who hear about breast cancer controversies may well end up seeing similar pins to what we found.

PUBLIC HEALTH IMPLICATIONS

Health providers should be aware that many of their patients use Pinterest, and patients employing Pinterest to find information on breast cancer are likely to have been exposed to misinformation. This misinformation can be particularly persuasive given that it leverages Pinterest's emphasis on visual content, and given that it often appeals to people's desire for information about both prevention and treatment. Thus, the misinformation on Pinterest appeals to both those with breast cancer and those looking to avoid the disease. In addition, many Pinterest users are women aged older than 50 years, creating a particular vulnerability12-given that most breast cancers are found in women aged 50 years or older,31 and that older people may be more susceptible to misinformation.32

Given that a majority of misinformation pins featured exaggerated claims, often about foods and supplements, practitioners should be prepared to discuss the importance of following the most evidence-based health recommendations for both breast cancer prevention and treatment. Much of this informative work may be preemptive, such as clearly and persuasively outlining the benefits of mammograms or of lowering cancer risk with exercise. At the same time, dangerous yet less-shared ideas such as the use of colloidal silver may only need to be directly addressed as patients raise them. For public health advocates, the study suggests information to stress in public health campaigns, such as the need for mammograms and the importance of curbing established breast cancer risk factors. This may begin to counteract misinformation present on Pinterest.

CONTRIBUTORS

The authors jointly designed the study and coded for reliability testing. T. Wilner carried out subsequent coding. The authors jointly wrote the article.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

HUMAN PARTICIPANT PROTECTION

Human participant protection was not needed because there were no human participants involved in this study.

Sidebar

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DETAILS

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Misinformation About Commercial Tobacco Products on Social Media- Implications and Research Opportunities for Reducing Tobacco-Related Health Disparities

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ABSTRACT (ENGLISH)

Misinformation about commercial tobacco products is not new. For decades, major tobacco companies deliberately deceived the public through marketing practices (e.g., brand names or labels such as "natural" and "organic") and public relations campaigns. The tobacco industry's deception of the public provides an important historical context for examining current forms of tobacco product misinformation through social media. The industry's campaigns sought to downplay and deny health harms and addictiveness of combustible cigarettes. These campaigns were aimed at creating doubt about scientific evidence showing how cigarette smoking harmed smokers and those exposed to secondhand smoke.

The tobacco industry's deliberate deception has led to tremendous human suffering and millions oflives lost in the United States and globally every year because of smoking and secondhand smoke exposure. Although the overall prevalence of smoking in the United States has declined over the past 50 years because of comprehensive tobacco-control policies and efforts, targeted marketing campaigns and community sponsorships among disparity populations-including African American communities, sexual and gender minorities, and populations experiencing homelessness-contribute to persistent disparities in cigarette smoking and related health consequences in these populations.

FULL TEXT

Misinformation about commercial tobacco products is not new. For decades, major tobacco companies deliberately deceived the public through marketing practices (e.g., brand names or labels such as "natural" and "organic") and public relations campaigns. The tobacco industry's deception of the public provides an important historical context for examining current forms of tobacco product misinformation through social media. The industry's campaigns sought to downplay and deny health harms and addictiveness of combustible cigarettes. These campaigns were aimed at creating doubt about scientific evidence showing how cigarette smoking harmed smokers and those exposed to secondhand smoke.

The tobacco industry's deliberate deception has led to tremendous human suffering and millions oflives lost in the United States and globally every year because of smoking and secondhand smoke exposure. Although the overall prevalence of smoking in the United States has declined over the past 50 years because of comprehensive tobacco-control policies and efforts, targeted marketing campaigns and community sponsorships among disparity populations-including African American communities, sexual and gender minorities, and populations experiencing homelessness-contribute to persistent disparities in cigarette smoking and related health consequences in these populations.

In recent years, the introduction of alternative forms of nicotine products into the marketplace (e.g., e-cigarettes, heated tobacco products, and smokeless tobacco) has led to a more complex information landscape, as the population health effects of using these products remain inconclusive- leading to intense scientific and public debate.

For example, misinformation from the online marketing of e-cigarettes by manufacturers, retailers, and social media influencers has claimed that e-cigarettes contain only water vapor and are harmless. This misinformation serves to downplay the risks and addictiveness of e-cigarette use and is in part responsible for the youth vaping epidemic of recent years. Conversely, online misinformation that e-cigarettes are just as or more harmful than smoking potentially deters current cigarette smokers who are unable to quit smoking from considering reducing harms by switching to e-cigarettes. Because cigarette smoking is increasingly concentrated among disparity populations, the impact of misperceptions about e-cigarettes' relative harms compared with smoking could lead to widening tobacco-related health disparities in these populations.1

Social media may amplify the transmission of tobacco product misinformation in addition to traditional media. Exposure to and effects of misinformation about tobacco products may be unevenly distributed across population subgroups because of structural determinants, including variations in access to trusted sources of health information, health literacy, and online social networks. Inequalities in misinformation exposure and receptivity may perpetuate and widen tobacco use disparities and related health disparities.2 Tailoring algorithms based on users' online behaviors and preferences may further increase certain users' exposure to misinformation about commercial tobacco products. However, there is limited research on exposure to misinformation about tobacco products on social media and the effects of such exposure on attitudes and use of tobacco products, particularly among disparity populations.

We discuss gaps in research to address misinformation about tobacco products on social media, especially among tobacco disparity populations. In the current information environment, most misinformation is from tobacco companies and user-generated social media posts that are not explicitly linked to tobacco companies. We further consider both explicit misinformation (information that is verifiably false based on current scientific evidence) and implicit misinformation (information that misleads the public about the harms and benefits of tobacco products).3

SOCIAL MEDIA MISINFORMATION SURVEILLANCE

Surveillance of misinformation on tobacco products on social media is needed to keep pace with the introduction of new tobacco products such as e-cigarettes and smokeless tobacco and the spread of false information about such products. For example, a content analysis of 1068 tweets from a corpus of tobacco-related tweets reported that 10% contained claims about tobacco-related health consequences, use patterns, policies, or tobacco industry actions. Of these claims, the researchers coded 18% as explicitly false, with the majority being unverified health consequences of tobacco product use and cessation methods that were not evidence based.4

It is clearly important to conduct surveillance on protobacco misinformation on social media that misleads the public into thinking tobacco products are safe or help smokers to quit successfully, contrary to current evidence. Yet, there is also a need to characterize the prevalence and content of misinformation that exaggerates the harms of e-cigarettes on social media (e.g., posts that e-cigarettes are as harmful as or more harmful than combustible tobacco products or cause cancers). Although evidence suggests that e-cigarette use is not completely harmless, switching completely to e-cigarettes is associated with reducing the risks of short-term health effects compared with continuing cigarette smoking. Social media posts focusing on the harms of e-cigarette use may be a reason for a growing public misperception that e-cigarettes are just as harmful as or even more harmful than combustible cigarettes.5

EXPOSURE TO AND EFFECTS OF MISINFORMATION

Research is also needed to assess whether exposure to and effects of misinformation about tobacco products on social media adversely affect tobacco use and tobacco-related health consequences among disparity populations. Efforts are needed to determine whether disparity populations are specifically targeted by misinformation campaigns about tobacco products in terms ofthe content, sources, and how these social media posts are disseminated. There is limited research on measuring exposure and effects of tobacco product misinformation in the general population, and none has focused on disparity populations.

A randomized experiment to examine the effects ofmisleading tobacco content in YouTube videos found that young adult participants aged 18 to 24 years who viewed misleading information about e-cigarettes and hookahs reported more positive attitudes toward these products than did those who viewed a control video unrelated to health.6 The

majority of participants were non-Hispanic (88%) and White (73%).

Research to assess how misinformation influences tobacco product perceptions and use among tobacco disparity populations will help to determine the need for preventive and corrective interventions and appropriate approaches to intervene for these populations.

PREVENTIVE AND CORRECTIVE INTERVENTIONS

Recent research focused on misinformation corrective strategies, including court-ordered corrective statements, reported that there was an uneven reach of these correctives across education level and socioeconomic status.7 However, there are research gaps in evaluating interventions aimed at debunking misinformation about tobacco products on social media and preventive approaches such as inoculation messages or media literacy training for increasing awareness of and resistance to influence by misinformation. In addition, research has not focused on the effectiveness of corrective approaches among disparity populations. Research is needed to design and implement culturally appropriate and effective preventive and corrective interventions for disparity populations, if warranted based on evidence from research on the exposure and effects of misinformation among these populations. Principles of community-engaged and participatory research provide helpful frameworks to design culturally appropriate preventive and corrective interventions for diverse populations.

In sum, misinformation about tobacco products on social media is a significant factor that may influence public misperceptions and adversely affect the health of populations who are most affected by tobacco product use and widen health disparities. It is critical to apply state-of-thescience approaches from the emerging body of research on health misinformation to conduct surveillance, measure exposure and effects, and design potential interventions to prevent and mitigate the adverse effects of tobacco product misinformation among tobacco disparity populations.

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The authors contributed equally to the editorial.

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Note. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the FDA.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

Sidebar

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DETAILS

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Concrete Recommendations for Cutting Through Misinformation During the COVID-19 Pandemic

Donovan, Joan, PhD

ABSTRACT (ENGLISH)

The COVID-19 pandemic presents multifaceted challenges for the US health care system. One such challenge is in delivering vital health information to the public-a task made harder by the scourge of health misinformation across the information ecosystem (Southwell et al., p. S288 in this issue of AJPH, and Southwell etal.1). I offer concrete recommendations for public health information officers and communication professionals drafting communication

campaigns for health agencies and health organizations to maximize the chance that timely health advisories reach the public. At Harvard Kennedy's Shorenstein Center, the Technology and Social Change Research Project studies how misinformation spreads and what its impact is on politics and society (bit.ly/2YcTX09bit.l). Unlike political disinformation, or fake news, health misinformation can quickly lead to changes in behaviors, which is why health communicators can't wait for tech companies to solve the problem.

For example, research on antivaccination movements shows how celebrities, activists, and discredited physicians gain influence over vaccination policies, while also promoting quackery, misinformation, and conspiracies on social media.3 Although it is difficult to know who has been affected by health misinformation, best strategies to counter it focus on addressing "silent audiences" with direct, careful, and succinct messaging.

FULL TEXT

The COVID-19 pandemic presents multifaceted challenges for the US health care system. One such challenge is in delivering vital health information to the public-a task made harder by the scourge of health misinformation across the information ecosystem (Southwell et al., p. S288 in this issue of AJPH, and Southwell etal.1). I offer concrete recommendations for public health information officers and communication professionals drafting communication campaigns for health agencies and health organizations to maximize the chance that timely health advisories reach the public.

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For example, research on antivaccination movements shows how celebrities, activists, and discredited physicians gain influence over vaccination policies, while also promoting quackery, misinformation, and conspiracies on social media.3 Although it is difficult to know who has been affected by health misinformation, best strategies to counter it focus on addressing "silent audiences" with direct, careful, and succinct messaging.4

Search engines and social media platforms are struggling to control the groundswell of new attention to COVID-19 and are having difficulty matching the right information to the right person at the right time. For example, searching Google, Facebook, Twitter, or YouTube for the phrase "Where can I get tested for coronavirus?" will return different information-or worse, fake news, a predatory scam, or malware (https://politi. co/3g9uzOE).

The pandemic lays bare how the algorithmic design of search engines and social media, which prioritize fresh and relevant content, contributes to confusion by mixing different kinds of information into a single feed: the mundane, the newsworthy, and critical medical recommendations (https://bit.ly/3iQoetq). Additionally, because many platforms are designed with advertising as their backbone, authoritative content from health agencies, health professionals, and local governments is often subsumed by advertising looking to grab clicks.5

The situation is dire. People need timely, relevant, and local information on COVID-19. Likewise hospitals, governments, health agencies, and universities are overwhelmed with inquiries and need to use mass communication to reach everyone. Any communication strategy must use redundancy by getting the same information out across as many different channels as possible.

Here are five recommendations based on our research about medical misinformation at the Shorenstein Center:

1.Domain registrars have reported upward of 120 000 domains with keywords related to coronavirus or COVID-19. Although most of the new domains have no content, scammers are using custom domains to target people seeking information about treatment, the worried well, and those suffering financial hardships because of COVID-19 (https://nbcnews.to/3iT5QQu). Public health and health care organizations with already established and functioning Web sites should not register new domains because it is difficult to gain traction within search engines and social media. Instead, these organizations should make a page dedicated to the particular health emergency, in this case COVID-19, on their already existing Web site and update it regularly, even if there is nothing newsworthy to report. Updates provide fresh signals to algorithms, which will rank it accordingly.

2.Debunking every rumor, every conspiracy theory, and all political punditry exhausts critical resources. Furthermore, there has been a deluge of requests for interviews with medical personnel and public health advocates. Health communicators should establish a monitoring protocol to decide which misinformation is gaining traction and approaching a tipping point, such as when misinformation moves across platforms or someone newsworthy, such as a politician or celebrity, distributes it. We recommend routinely checking the Federal Emergency Management Agency's rumor database (https://bit.ly/ 3kSOKUO) and Google's fact-checking database of recently debunked news stories (https://bit.ly/2Ebnwbg). Scan comments posted to local social media groups and public messaging apps, such as Nextdoor. Keep a log of comments the organization receives via social media accounts, telephone, or e-mail. Importantly, no one should respond to misinformation unless there is good reason to do so and they have a plan for communicating it publicly (https://bit.ly/3j4PKnh). It is recommended not to respond to individuals but rather to debunk major misinformation themes.

3. Keeping up with the demand for new information during this pandemic will require a shift to mass communication strategies. In terms of risk communication, working with journalists is key to fighting misinformation. Building two-way communication bridges between health communicators and local journalists will ensure visibility and trust across professional sectors when communication emergencies happen. This is different from hosting press conferences. It's about creating real relationships, where public health is the shared goal. Helping journalists debunk misinformation and providing key recommendations will raise the credibility and visibility of public health recommendations to broad audiences.

4. If using social media to communicate, which all public health organizations should do, contact the platforms and request free public service advertising. In a crisis like this, online advertising systems can be repurposed to reach local audiences (https:// bit.ly/3gcHpfc). Local television news remains a reliable way to inform many people quickly and locally.

5.Local governments and health agencies should set up text messaging systems and SMS (short message service) push notifications, where possible, to reach people outside social media. Although emergency management strongly advises that governments set up these systems before a disaster, the pandemic is an opportunity to enroll many people. Alternatively, emergency alert systems do not require a signup and could be adapted to reach people in a certain geographic area. For example, New York City has used emergency alerts to request health care workers. Right now, search and social media companies are not designed to deliver authoritative, timely, relevant, and local information. Tech companies are at a crossroads, where the alliances and coalitions built now to tackle the COVID-19 pandemic will shape the future of risk communication on the Internet. It is crucial, therefore, that health communication professionals understand the limitations of social media and actively work to mitigate misinformation to lessen the harms caused by unchecked scams, hoaxes, and conspiracies; the public must be able to access timely, local, and relevant information when they need it most. ÂfPU

Joan Donovan, PhD

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DETAILS

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Ethical Considerations for Digitally Targeted Public Health Interventions

Susser, Daniel, PhD

ABSTRACT (ENGLISH)

Researchers, advocates, and policymakers increasingly worry that the Internet generally, and social media specifically, have become vectors of misinformation, manipulation, and other forms of malign influence.1,2 Unlike older forms of media, such as radio and television, Internet-driven influence differs in its capacity for individualized targeting, the speed with which messages can be transmitted and amplified, and the extent to which the creation and distribution of messages can be automated. While much attention has focused on the effects of such messaging on political discourse, researchers have traced equally concerning impacts on discussions pertaining to health-related issues, such as vaccine safety.3 Searching for ways to respond, public health officials and public health scholars have suggested a range of approaches, including increasing existing efforts to promote information and health literacy, devising strategies for publicly rebutting misinformation, and preparing clinicians and public health officials to address misinformation one on one.4

FULL TEXT

Researchers, advocates, and policymakers increasingly worry that the Internet generally, and social media specifically, have become vectors of misinformation, manipulation, and other forms of malign influence.1,2 Unlike older forms of media, such as radio and television, Internet-driven influence differs in its capacity for individualized targeting, the speed with which messages can be transmitted and amplified, and the extent to which the creation and distribution of messages can be automated. While much attention has focused on the effects of such messaging on political discourse, researchers have traced equally concerning impacts on discussions pertaining to health-related issues, such as vaccine safety.3 Searching for ways to respond, public health officials and public health scholars have suggested a range of approaches, including increasing existing efforts to promote information and health literacy, devising strategies for publicly rebutting misinformation, and preparing clinicians and public health officials to address misinformation one on one.4

Such strategies are uncontroversial. Yet some contemplate going further, asking whether the same tools contributing to these problems-targeted, automated digital messaging-might be utilized to mitigate their negative effects. For example, while acknowledging potential risks, Dunn et al. explore ways "social media data are used to predict or model health-related behaviours and outcomes" and "how these methods might be operationalised in the design of precision behavioural interventions."5 One can imagine public health analogs of YouTube's "redirect method," which identifies users interested in terrorist or extremist videos and redirects them to antiextremist countermessaging.

Though research in this area is preliminary, it raises significant ethical questions that ought to be addressed in advance of further developments.

MANIPULATION AND AUTONOMY

In part, these proposals mirror ongoing debates about the use of so-called "nudging" to promote individual and public health, and they prompt some of the same normative considerations. Nudging involves shaping people's choice environments in such a way that subtly steers them toward individually or socially beneficial decisions. Because such interventions are often designed to bypass people's capacity for conscious deliberation, and function instead by triggering preconscious decision-making heuristics ("cognitive biases"), they are fraught with questions about paternalism and manipulation.

While no consensus has been reached about the extent to which such worries are justified, they highlight morally relevant costs of intervening in people's decision-making that might otherwise be neglected from the cost-benefit calculations public health officials have to make. We value autonomy (i.e., our capacity to make independent decisions), even when it means deciding to make ourselves worse off.Of course, situations can arise in which the potential harm is so grave that preventing it outweighs the cost of violating a person's autonomy (e.g., in cases of suicidal ideation). But such situations ought to be treated as the exception rather than the rule. As researchers and public officials weigh the costs and benefits of utilizing digital influence strategies to promote health-especially precisely targeted (or "personalized") interventions, which I and others argue raise particularly acute manipulation worries2-they ought to seriously contemplate the costs of circumventing people's capacity (and their right) to think and choose for themselves. If they decide to utilize such strategies, they should design interventions that targets can easily contextualize and understand-for example, by clearly indicating who is behind the messaging, why the person seeing it has been targeted, where they can find more information, and how they can opt out of future interventions.

PRIVACY

Privacy concerns arise because targeting individuals with relevant, timely public health messages requires collecting and processing information about them. One reason public health scholars are enthusiastic about the potential for these kinds of interventions is that ubiquitous digital technologies, such as smartphones and fitness trackers, create huge amounts of data that can be used to make predictions about individual and population-level health events. However, privacy scholars and advocates caution that the existence of such information does not entail that it is "up for grabs." People share information about themselves in particular contexts, with the expectation that it will be accessed by specific recipients and used for specified ends.6 Just as technology companies like Facebook and

Cambridge Analytica faced backlash from the public when it learned they used information disclosed through social media to target political advertisements, public health officials ought to exercise caution before using such information to target health messaging, unless they have received clear, explicit, affirmative consent.

BIAS

Researchers have shown, time and again, that the algorithms used to deliver targeted content online are deeply susceptible to unintended, discriminatory bias. Using such tools to mitigate social media-driven misinformation or to promote truthful public health messaging thus raises the possibility ofmissing certain groups or targeting them with inaccurate information. As public health practitioners are unlikely to build message targeting systems themselves, relying instead on platforms like Google's and Facebook's, they ought to carefully consider the risk that their interventions might not reach all intended audiences (and indeed, that they might exclude already marginalized groups). At the very least, public heath campaigns that do utilize ad targeting or other content recommendation platforms should be regularly audited to detect issues before they become widespread.

ACCOUNTABILITY

Finally, questions about accountability come to the fore whenever powerful institutions intervene in people's lives. Such questions are especially urgent in this context because machine learning and artificial intelligence (the computational techniques that power most targeting and recommender systems) are known for their opacity, which derives from the fact that their inner workings are often protected by corporate trade secrecy laws, and their decision-making logics are difficult even for experts with proper access to understand.7 If public health organizations are going to use such tools ethically, they will need to go out of their way to create structures of transparency and accountability. That might involve storing messages for post hoc review, carefully logging who has seen them, and making that information readily available to auditors.

CONCLUSION

Dealing successfully with these ethical questions will require balancing difficult tradeoffs. On one hand, the troves of personal data collected about each of us are incredibly revealing, and the tools for leveraging those data to target digital messages are powerful and readily available. It is easy to understand why researchers and public health practitioners are eager to explore the good they could do with them.

On the other hand, targeted digital public health interventions might also involve considerable ethical costs. The data that power targeting technologies are often collected in ways that disrespect data subjects' privacy. Such technologies are liable to target messages in ways that discriminate against marginalized groups. They create barriers to accountability. And targeted digital public health interventions threaten to influence our decision-making in ways that violate our autonomy. Whether the benefits ofthese interventions outweigh the costs should be determined on a case-by-case basis. To make such determinations, practitioners should consider both the severity of the health risks they are addressing (e.g., promoting healthy diets vs suicide intervention or combating health misinformation during a pandemic) and the extent to which they can minimize potential harms (e.g., whether messaging can be made transparent, and targeting data can be collected in ways that respect people's privacy). Of course, the ethical issues discussed here are not exhaustive-rather, they suggest a place from which discussions about the ethics of targeted digital public health interventions can start. >4jPUI

Daniel Susser, PhD

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Sidebar

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Social Media and Cancer Misinformation: Additional Platforms to Explore

Walsh-Buhi, Eric R, PhD, MPH

ABSTRACT (ENGLISH)

This special issue of AJPH, sponsored by the National Cancer Institute, represents important and exciting research addressing the major issues of misinformation on social media and cancer. There are excellent research articles and editorials included in this issue on topics such as breast cancer prevention and treatment misinformation on Pinterest (Wilner and Holton, p. S300), bots (Dunn et al., p. S319) and human papillomavirus (HPV) vaccine opposition (Bonnevie et al., p. S326) on Twitter, and cannabidiol (CBD)-related misinformation on GoFundMe (Zenone et al., p. S294). Misinformation, defined as false or inaccurate information, regardless of intentional authorship,1 is not a new issue to society or to public health. While misinformation, truth framed as “fake news,” and other efforts to spread false stories have likely been around as long as humans have lived in groups, according to the World Economic Forum (WEF), digital misinformation is becoming pervasive in online social media; in fact, it has been listed by the WEF as a global risk and one of the main threats to society

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Although research on cancer-related misinformation on social media is still in its infancy-that is, we do not have a 50-plus-year history, like with tobacco and health research, to fall back on-this special issue on cancer and social media misinformation contains strong articles focusing on social media platforms such as Twitter (5 research articles), Pinterest (2 research articles), and Facebook and GoFundMe (1 research article each). Readers may notice an absence of studies, however, focusing on other important and popular social media platforms. For example, more work is desperately needed on cancer misinformation on YouTube, Instagram, TikTok, and Reddit.

YOUTUBEAND MISINFORMATION

YouTube is the most popular social media platform in the United States, with almost three quarters of US adults (73%) reporting using the video-sharing site.3 Its popularity is cause for concern as we learn more about how YouTube is vulnerable to cancer misinformation. A preliminary search of PubMed for "YouTube and misinformation and cancer" yielded only 43 results, and many of those results were unrelated to misinformation. One of those research articles, however, reporting on prostate cancer videos on YouTube, noted that 115 videos (or 77% of the analyzed sample) contained potentially misinformative or biased content within the video or comments section, with a total reach of more than six million viewers.4 The influences on and impacts of such misinformation on one of the world's most popular social media platforms remain largely unknown.

INSTAGRAM AND MISINFORMATION

Instagram is another a platform on which more research is needed. With more than one billion monthly active users, Instagram is the third most popular social media platform in the United States, behind YouTube and Facebook.3 Each day, Instagram users upload more than 500 million photos, videos, and stories (a combination ofvideos, text, and photos). A second search conducted on PubMed, similar to the one noted earlier and substituting the term "Instagram" for "YouTube," resulted in fewer research studies on misinformation and cancer (n = 15); and, again, most of those search results were unrelated to misinformation. Major gaps remain in terms of surveilling cancer misinformation on social media, but especially on Instagram, as well as evaluating the influence of misinformation on health, and developing and testing interventions combatting cancerrelated misinformation on Instagram (see Chou et al., p. S273).

TIKTOK AND MISINFORMATION

While other social media platforms, such as Reddit and TikTok, are becoming popular worldwide, very limited research has been published on them and the presence of cancer-related misinformation. A third search on PubMed, as previously noted and with the terms "Reddit" and TikTok," respectively, substituted in place of "Instagram," resulted in five and zero research studies, respectively. The latter could be attributable to the fact that TikTok does not provide open access to its post data via a public application protocol interface (API), as does Twitter. While data are not necessarily easily accessible from these platforms, it is critical that we in public health strive to study cancer-related misinformation across a variety ofplatforms. Now more than ever, partnerships with companies like Google (owner of YouTube), for example, are needed. The reason is simple. TikTok is home to a new generation of social media users: young people. In November 2019, the TikTok app surpassed 1.5 billion

downloads combined on the Apple App Store and Google Play store, ranking above both Facebook and Instagram.5 The most popular group ofTikTok users are adolescents. Relatedly, as noted earlier, two thirds of Instagram users are people younger than 30 years. If we are to meet young people where they are and protect a critical generation from the potential perils of misinformation, then we must focus on the social media platforms these priority populations use.

RESEARCH OPPORTUNITIES AND FUTURE DIRECTIONS

The nature of certain platforms also makes them important for additional study. For example, there are many "healthy lifestyle "-related Instagram accounts. However, we do not know whether information provided via such accounts is accurate regarding healthy diets, or whether the account owners or content creators make unsubstantiated claims about certain foods (e.g., "superfoods") or products (e.g., vaping and tobacco product ads, vaper influencers on TikTok). To know if we should be concerned about misinformation on Instagram and TikTok, we need to explore the content being shared systematically, survey users for their exposure and experiences, or both.

How might we partner with tech companies like Facebook, Instagram, and TikTok? Although much of the existing research focuses on Twitter, because the platform offers greater access to their data via public APIs, companies like Facebook and Instagram have increasingly closed public access to its data for a variety of reasons but largely because of breaches in data privacy and trust regarding use of users' data (see the Cambridge Analytica scandal6). Efforts must be reignited by researchers to forge new relationships with tech companies. One way to do this effectively is by creating "win-win" or mutually beneficial relationships with tech partners. Researchers must take the time to rebuild trust and make their use of social media data beneficial to the platforms or companies themselves. Strategies such as community-based participatory research (CBPR) may be fruitful, for example. CBPR emphasizes that all parties at the table have an equitable footing in asking research questions, conducting the research, and owning the process. In this case, the tech companies serve as the community. CBPR would place tech companies front and center so that their questions are the ones being asked, with help from researchers. This is also important because some companies lack the tools to analyze their own data, even though a rich supply is available (i.e., from academic researchers). In a positive move, certain entities are now serving as third-party platforms for accessing Facebook and Instagram (e.g., CrowdTangle), and such efforts are already opening the door to making a greater proportion of social media data more available and transparent to researchers.

It is also critical that we advocate for additional federal funding to study such areas. As an illustration of current support for social media misinformation research, a brief search of active National Institutes of Health (NIH) funding support for "social media" and "misinformation" yields five results (see Figure A, available as supplement to this article at https://www. ajph.org). If our elected officials are moved to curb the dangers of misinformation, then increases in allocations of the NIH budget, with a particular focus on funding research related to social media platforms utilized by young people and misinformation related to health, is warranted. Such funding allocations are critical as we respond to what the WEF has termed a global risk and one ofthe main threats to society.

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CONFLICTS OF INTEREST

The author has no conflicts of interest to disclose.

Sidebar

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DETAILS

Subject:	Public health; Vaccines; Social networks; Economic summit conferences; Tobacco; User behavior; Cancer; Funding; Internet; Prostate cancer; Breast cancer; Young adults; Prevention; Science; Human papillomavirus; Health care; Health research; Society; Allocations; Medical treatment; Social media; False information; Mass media; Public officials; Digital media; Research
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Location:	Indiana; United States--US
Company / organization:	Name: World Economic Forum; NAICS: 926110; Name: Cambridge Analytica; NAICS: 518210, 541618, 541820; Name: GoFundMe; NAICS: 518210; Name: Indiana University; NAICS: 611310; Name: Pinterest; NAICS: 518210
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Southwell, B. G., PhD., Wood, J. L., PhD., & Navar, Ann Marie,M.D., PhD. (2020). Roles for health care professionals in addressing patient-held misinformation beyond fact correction. American Journal of Public Health, Suppl.Supplement 3, 110, S288-S289. doi:https://doi.org/10.2105/AJPH.2020.305729

Most patients trust their health care professionals,1 but many also turn to sources outside of the examination room for medical information. Although many resources provide accurate information (e.g., government health agencies, professional organizations, and patient advocacy groups), not all information that patients find is accurate. Patients may encounter medical misinformation from a variety of online sources, which can have important health consequences. Health care providers can play a critical role in addressing medical misinformation but have not yet had the opportunity to address medical misinformation fully. (Certain disciplines have made progress, such as pediatricians in mitigating vaccine misinformation.) Effectively addressing misinformation requires more than attempts to simply discredit misperceptions. Encountering patient-held misinformation offers an opportunity for clinicians to learn about patient values, preferences, comprehension, and information diets. Systematically training health care professionals to address patient-held misinformation with empathy and curiosity, acknowledging time and resource constraints, will be a crucial contribution toward future mitigation of medical misinformation.

Bonnevie, E., M.A., Goldbarg, J., M.P.H., Gallegos-Jeffrey, A., Rosenberg, S. D., M.P.H., Wartella, E., PhD., & Smyser, J., PhD. (2020). Content themes and influential voices within vaccine opposition on twitter, 2019. American Journal of Public Health, Suppl.Supplement 3, 110, S326-S330. doi:https://doi.org/10.2105/AJPH.2020.305901

Objectives. To report on vaccine opposition and misinformation promoted on Twitter, highlighting Twitter accounts that drive conversation. Methods. We used supervised machine learning to code all Twitter posts. We first identified codes and themes manually by using a grounded theoretical approach and then applied them to the full data set algorithmically. We identified the top 50 authors month-over-month to determine influential sources of information related to vaccine opposition. Results. The data collection period was June 1 to December 1, 2019, resulting in 356 594 mentions of vaccine opposition. A total of 129 Twitter authors met the qualification of a top author in at least 1 month. Top authors were responsible for 59.5% of vaccine-opposition messages. We identified 10 conversation themes. Themes were similarly distributed across top authors and all other authors mentioning vaccine opposition. Top authors appeared to be highly coordinated in their promotion of misinformation within themes. Conclusions. Public health has struggled to respond to vaccine misinformation. Results indicate that sources of vaccine misinformation are not as heterogeneous or distributed as it may first appear given the volume of messages. There are identifiable upstream sources of misinformation, which may aid in countermessaging and public health surveillance. (Am J Public Health. 2020;110:S326-S330. https://doi.org/10.2105/AJPH. 2020.305901)

Zenone, M., B.A., Snyder, J., PhD., & Caulfield, T., L.L.M. (2020). Crowdfunding cannabidiol (CBD) for cancer: Hype and misinformation on GoFundMe. American Journal of Public Health, Suppl.Supplement 3, 110, S294-S299. doi:https://doi.org/10.2105/AJPH.2020.305768

Objectives. To use crowdfunding campaigns to better understand how cannabidiol (CBD) is represented (and misrepresented) as cancer-related care. Methods. We analyzed CBD-related crowdfunding campaigns (n = 155) created between January 2017 and May 2019 in multiple countries on GoFundme.com. Results. More than 81.9% of campaigns fundraised CBD for curative or life-prolonging reasons, and 25.2% fundraised for pain management. Conclusions. Most campaigns seeking funds for CBD for cancer-related care on GoFundMe are for curative or life-prolonging purposes and present CBD definitively asan effective treatment option. In general, campaigners supported their funding requests with anecdotal claims of efficacy and referenced sources of information that were either not evidence-based or that misrepresented existing evidence. Public Health Implications. Misinformation around CBD for cancer is widespread on medical crowdfunding campaigns. Given the potential adverse impact, crowdfunding platforms, like GoFundMe, must take steps to address their role in enabling and spreading this misinformation. (Am J Public Health. 2020;110:S294-S299. https://doi.org/ 10.2105/AJPH.2020.305768)

Safarnejad, L., PhD., Xu, Q., PhD., Ge, Y., PhD., Krishnan, S., PhD., Bagarvathi, A., PhD., & Chen, S., PhD. (2020). Contrasting misinformation and real-information dissemination network structures on social media during a health emergency. American Journal of Public Health, Suppl.Supplement 3, 110, S340-S347. doi:https://doi.org/10.2105/AJPH.2020.305854

Objectives. To provide a comprehensive workflow to identify top influential health misinformation about Zika on Twitter in 2016, reconstruct information dissemination networks of retweeting, contrast mis- from real information on various metrics, and investigate how Zika misinformation proliferated on social media during the Zika epidemic. Methods. We systematically reviewed the top 5000 English-language Zika tweets, established an evidence-based definition of "misinformation," identified misinformation tweets, and matched a comparable group of real-information tweets. We developed an algorithm to reconstruct retweeting networks for 266 misinformation and 458 comparable real-information tweets. We computed and compared 9 network metrics characterizing network structure across various levels between the 2 groups. Results. There were statistically significant differences in all 9 network metrics between real and misinformation groups. Misinformation network structures were generally more sophisticated than those in the real-information group. There was substantial within-group variability, too. Conclusions. Dissemination networks of Zika misinformation differed substantially from real information on Twitter, indicating that misinformation utilized distinct dissemination mechanisms from real information. Our study will lead to a more holistic understanding of health misinformation challenges on social media. (Am J Public Health. 2020;110:S340-S347. https://doi.org/10.2105/AJPH.2020.305854)

Jamison, Amelia,M.A.A., M.P.H., Broniatowski, D. A., PhD., Smith, M. C., PhD., Parikh, K. S., B.S., Malik, Adeena,B.A., B.S., Dredze, M., PhD., & Quinn, S. C., PhD. (2020). Adapting and extending a typology to identify vaccine misinformation on twitter. American Journal of Public Health, Suppl.Supplement 3, 110, S331-S339. doi:https://doi.org/10.2105/AJPH.2020.305940

Objectives. To adapt and extend an existing typology of vaccine misinformation to classify the major topics of discussion across the total vaccine discourse on Twitter. Methods. Using 1.8 million vaccine-relevant tweets compiled from 2014 to 2017, we adapted an existing typology to Twitter data, first in a manual content analysis and then using latent Dirichlet allocation (LDA) topic modeling to extract 100 topics from the data set. Results. Manual annotation identified 22% of the data set as antivaccine, of which safety concerns and conspiracies were the most common themes. Seventeen percent of content was identified as provaccine, with roughly equal proportions of vaccine promotion, criticizing antivaccine beliefs, and vaccine safety and effectiveness. Of the 100 LDA topics, 48 contained provaccine sentiment and 28 contained antivaccine sentiment, with 9 containing both. Conclusions. Our updated typology successfully combines manual annotation with machine-learning methods to estimate the distribution of vaccine arguments, with greater detail on the most distinctive topics of discussion. With this information, communication efforts can be developed to better promote vaccines and avoid amplifying antivaccine rhetoric on Twitter. (Am J Public Health. 2020;110:S331-S339. https://doi.org/10.2105/AJPH.2020.305940)

Vraga, E. K., PhD., & Bode, L., PhD. (2020). Correction as a solution for health misinformation on social media. American Journal of Public Health, Suppl.Supplement 3, 110, S278-S280. doi:https://doi.org/10.2105/AJPH.2020.305916

Scholars (including in this issue of AJPH) have debated which interventions limit the spread of health misinformation on social media, including promoting high-quality information, removing misinformation from platforms, and inoculating people against misinformation by bolstering news, information, and health literacy. Unfortunately, these preventative solutions cannot eliminate health misinformation, necessitating strategies that respond to misinformation to limit its pernicious influence on public attitudes and behaviors. Corrections-the presentation of information designed to rebut an inaccurate claim or a misperception -are an important treatment for misinformation. Despite the relative stickiness of misinformation, corrections are typically effective in reducing beliefs in health misinformation, although they are less so as issues become more polarized or beliefs become embedded in an individual's self-concept.

Scherer, L. D., PhD., & Pennycook, G., PhD. (2020). Who is susceptible to online health misinformation? American Journal of Public Health, Suppl.Supplement 3, 110, S276-S277. doi:https://doi.org/10.2105/AJPH.2020.305908

Although everyone has the potential to be misled by false information, online misinformation is not an equal opportunity aggressor. Some of us are more likely to believe misinformation than are others and serve as vectors by sharing it on social media. To effectively combat misinformation on social media, it is crucial to understand the underlying factors that lead certain people to believe and share false and misleading content online. A growing body of research has tackled this issue by investigating who is susceptible to online misinformation and under what circumstances. This literature can help shape future research and interventions to address health misinformation. We provide a brief overview of what we know about who is susceptible and what we still have to learn.

Broniatowski, D. A., PhD., Jamison, Amelia M,M.A.A., M.P.H., Johnson, N. F., PhD., Velasquez, N., PhD., Leahy, R., B.A., Restrepo, N. J., B.Sc, . . . Quinn, S. C., PhD. (2020). Facebook pages, the "disneyland" measles outbreak, and promotion of vaccine refusal as a civil right, 2009–2019. American Journal of Public Health, Suppl.Supplement 3, 110, S312-S318. doi:https://doi.org/10.2105/AJPH.2020.305869

Objectives. To understand changes in how Facebook pages frame vaccine opposition. Methods. We categorized 204 Facebook pages expressing vaccine opposition, extracting public posts through November 20, 2019. We analyzed posts from October 2009 through October 2019 to examine if pages' content was coalescing. Results. Activity in pages promoting vaccine choice as a civil liberty increased in January 2015, April 2016, and January 2019 (t76]= 11.33 P< .001]; t46] = 7.88 P< .001];and t41] = 17.27 P<.001], respectively). The 2019 increase was strongest in pages mentioning US states (t41] = 19.06; P< .001). Discussion about vaccine safety decreased (rs119] = -0.61; P< .001) while discussion about civil liberties increased (rs119] = 0.33; Py< .001]). Page categories increasingly resembled one another (civil liberties: rs119] = -0.50 P<.001]; alternative medicine: rs84] = -0.77 P<.001];conspiracy theories: rs119] = -0.46 P< .001]; morality: rs106] = -0.65 P< .001];safety and efficacy: rs119] = -0.46 P< .001]). Conclusions. The "Disneyland" measles outbreak drew vaccine opposition into the political mainstream, followed by promotional campaigns conducted in pages framing vaccine refusal as a civil right. Political mobilization in state-focused pages followed in 2019. Public Health Implications. Policymakers should expect increasing attempts to alter state legislation associated with vaccine exemptions, potentially accompanied by fiercer lobbying from specific celebrities. (Am J Public Health. 2020;110:S312-S318. https://doi. org/10.2105/AJPH.2020.305869)

Vanderpool, R. C., DrP.H., Gaysynsky, A., M.P.H., & Chou, Wen-Ying Sylvia,PhD., M.P.H. (2020). Using a global pandemic as a teachable moment to promote vaccine literacy and build resilience to misinformation. American Journal of Public Health, Suppl.Supplement 3, 110, S284-S285. doi:https://doi.org/10.2105/AJPH.2020.305906

Vaccination against infectious disease has been recognized as one of the "Ten Greatest Public Health Achievements" of the 20th century, given the substantial impact immunizations have had globally across a range of diseases, including polio, influenza, pneumonia, measles, mumps, rubella, viral hepatitis, pertussis, and oncogenic human papillomarvirus.1 Populationlevel vaccination programs have resulted in significant declines of new cases of disease, decreased morbidity and mortality, lower health care costs, and improved productivity.1 However, despite the proven clinical and cost effectiveness of vaccination, vaccines have not yet achieved their full potential, as rates of immunization among children and adults remain suboptimal, leading to a resurgence ofsome infectious diseases (e.g., measles).

Guidry, J. P. D., PhD., Vraga, E. K., PhD., Laestadius, L. I., PhD., Miller, Carrie A,PhD., M.P.H., Occa, A., PhD., Nan, X., PhD., . . . Carlyle, Kellie E,PhD., M.P.H. (2020). HPV vaccine searches on pinterest: Before and after pinterest's actions to moderate content. American Journal of Public Health, Suppl.Supplement 3, 110, S305-S311. doi:https://doi.org/10.2105/AJPH.2020.305827

Objectives.To compare how human papillomavirus (HPV) vaccination was portrayed on Pinterest before and after the platform acted to moderate vaccine-related search results to understand (1) what the information environment looked like previously and (2) whether Pinterest's policy decisions improved this environment in terms of sources and content. Methods. In this quantitative content analysis, we compared 2 samples of 500 HPV vaccine-focused

Pinterest posts ("pins") collected before and after Pinterest's actions to provide more reliable vaccine-related information. Pins were based on search results and were analyzed using the Health Belief Model. Results. The majority of preaction search results leaned toward vaccine skepticism, specifically focused on perceived vaccine barriers. Few pins were published by public health-related Pinterest accounts. Postaction search results showed a significant shift to HPV vaccination benefits, and the number of pins by government or medical accounts increased. However, the proportion of pins in search results containing HPV content of any type was significantly lower. Conclusions. Pinterest's efforts to moderate vaccination discussions were largely successful. However, the ban also appeared to limit HPV vaccination search results overall, which may contribute to confusion or an information vacuum. (Am J Public Health. 2020;110:S305-S311. https://doi.org/10.2105/AJPH.2020.305827)