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COMMENTARY

Social media and vaccine hesitancy: new updates for the era of COVID-19 and globalized infectious diseases

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ABSTRACT

Despite major advances in vaccination over the past century, resurgence of vaccine-preventable illnesses has led the World Health Organization to identify vaccine hesitancy as a major threat to global health. Vaccine hesitancy may be fueled by health information obtained from a variety of sources, including new media such as the Internet and social media platforms. As access to technology has improved, social media has attained global penetrance. In contrast to traditional media, social media allow individuals to rapidly create and share content globally without editorial oversight. Users may self-select content streams, contributing to ideological isolation. As such, there are considerable public health concerns raised by anti-vaccination messaging on such platforms and the consequent potential for downstream vaccine hesitancy, including the compromise of public confidence in future vaccine development for novel pathogens, such as SARS-CoV-2 for the prevention of COVID-19. In this review, we discuss the current position of social media platforms in propagating vaccine hesitancy and explore next steps in how social media may be used to improve health literacy and foster public trust in vaccination.

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Background

Vaccination is one of the most successful public health interventions and a cornerstone for the prevention of communicable infectious diseases.[1] Notwithstanding vaccine progress, ongoing public acceptance is required to maintain herd immunity, prevent outbreaks of vaccine preventable illnesses, and ensure adoption of novel vaccines.[2]

Unfortunately, uptake of many vaccines continues to be suboptimal. The ongoing resurgence of vaccine-preventable illnesses has led the World Health Organization (WHO) to name vaccine hesitancy as one of the top ten threats to global health in 2019.[3] Vaccine hesitancy, defined as patient-level reluctance to receive vaccines, may be fueled by a spectrum of held views regarding vaccination spanning from cautious acceptors to outright deniers.[2,4,5] Amongst the barriers to universal vaccination, misinformation regarding the benefits, medicinal composition, and adverse effects of vaccination limits patient understanding and overall buy-in.[6]

As patients increasingly consult the Internet and peer networks, such as those generated on social media, for health information, growing interest has emerged in the role of interactive social media in public health promotion.[7-10] However, there is also substantial potential for harmful misinformation to spread across networks which may be propagated via the contemporary anti-vaccination movement, fueling vaccine hesitancy.[11] In response to these concerns, Dr. James Madara, the chief executive officer of the American Medical Association, published a public letter urging leading technology companies to ensure access to accurate information on the safety and efficacy of vaccinations on their platforms.[12]

These worries may be magnified in the face of the current COVID-19 pandemic, as the ongoing development and subsequent deployment of a vaccine is expected to play a critical role in downstream global control efforts.[3,13] Further, intensive global efforts for physical distancing and isolation to curb the spread of SARS-CoV-2 may intensify the use of social media as individuals try to remain connected while apart.[14] Concerningly, misinformation and unsubstantiated rumors regarding COVID-19 and potential vaccination against SARS-CoV-2 have already begun emerging on social media platforms, threatening to erode public confidence well before the release of an effective vaccine.[15,16] We thus sought we sought to review the state of anti-vaccination messaging on social media platforms, examine their role in propagating vaccine hesitancy, and to explore next steps in how social media may be used to improve health literacy and build public trust in vaccination.

Social media

Social media platforms are internet-based applications that enable communities of users to create, interact, and share with others, with multiple platforms for different content-types (Table 1).[17-22] They allow for real-time communication amongst quasi-peer networks, allowing users to actively participate in public discourse.[21,23] In contrast to traditional media, content posted

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Table 1. Social media platforms and their characteristics.

Social Media Platform	Year of Inception[18]	% of U.S. adults who use this platform in 2019[17]	# of monthly active users world-wide in 2018[19]	Unique Characteristics[20]
Facebook	2004	69	2.26 billion	Platform that allows users to upload, share and like various images, videos, live-videos, stories and specific pages
Reddit	2005	11	355.00 million	Platform that allows users to submit and discuss questions, links, and images
Twitter	2006	22	329.5 million	Platform that allows real real-time sharing of Tweets (i.e. short messages) which can be accompanied with images
Instagram	2010	37	1.00 billion	Image-sharing platform that allows users to upload, share and like images and short videos
Pinterest	2010	28	246.50 million	Platform that aims to foster inspiration through allowing users to browse different images organized into categories
Snapchat	2011	24	255.00 million	Platform that allows real-time sharing of short videos or images between contacts
YouTube	2005	73	1.90 billion	Video-sharing platform that allows users to upload, favorite and share videos
LinkedIn	2002	27	294.00 million	Career focused platform where industry specialists can share content, network, and build their personal brand

need not undergo editorial curation nor scientific vetting, and may represent a more complex mixture of evidence and personal opinion.[24,25] Further, users frequently maintain anonymity, allowing individuals to express their views unadulterated.[26] Social media is also characterized by its potential to reach large audiences and propagate information very rapidly.[21,27]

Social media allow users to "follow" or "like" other users or groups to keep updated with their postings and self-select streams of content relevant to their interests, whilst simultaneously rejecting content with which they do not agree.[28,29] As a result, each user develops a unique network of content and interactions within the broader network. Such self-selection may allow individuals to aggregate and cluster within ideologically distinct sub-communities commonly known as "echo-chambers".[30,31]

Vaccine content on social media

Vaccine content is widely present across social media platforms, with several studies characterizing how vaccine content is portrayed on these platforms and, more broadly, the Internet.[32-37]

Basch et al. examined 87 videos from YouTube in 2017 using the keywords "vaccine safety" and "vaccines and children".[38] Amongst these, 65% of them expressed an anti-vaccine sentiment; however, only 5.6% were produced by government professionals and 36.8% provided no scientific evidence.[38] Further, amongst the top YouTube videos identified via search of "COVID-19" and "coronavirus", 27.5% of videos contained non-factual information and had already accrued over 60 million views.[39]

This is possibly self-reinforcing as studies indicate that anti-vaccine content engenders more user engagement; Blankenship et al., for instance, analyzed tweets with the "vaccine" hashtag (#vaccine) between 2010 to 2016, finding that anti-vaccine tweets were 4.13-fold more likely to be re-tweeted than neutral tweets.[27] Similarly, Basch et al. analyzed 150 Instagram posts with the #HPV and found that anti-vaccine posts had a significantly higher average number of likes.[33]

Vaccine discourse on social media has evolved over time, with trends often linked to real-world events.[34] Gunaratne et al. demonstrated that anti-vaccine discourse on Twitter experienced a large surge in 2015, coinciding with the 2014–2015 measles outbreak, publication of the anti-vaccine book *Vaccine Whistleblower* (#cdcwhistleblower), and release of the film *Vaxxed* (#vaxxed).[34] This study further demonstrated that pro- and anti-vaccine content may also naturally segregate into distinct communities, possibly due to self-selection on social media amalgamating like-minded communities.[34] Anti-vaccine content on Twitter largely coalesced into a community centered around #cdcwhistleblower and #vaxxed proponents, while pro-vaccine content primarily centered around the hashtag #vaccineswork.[19,34] Content appears to transfer between users who share similar sentiments regarding vaccination but rarely across those with differing opinions, suggesting the structure of such platforms may give the illusion of debate, but in practice mainly serves to reinforce previously-held opinions rather than the consideration of new ones.[40] Such ideologic isolation may limit public health penetration to promote vaccination on social media.[40]

More recently, the rapid spread of COVID-19 and resultant global pandemic have become a focus of intense social media discourse, with Twitter reporting a COVID-19 related tweet every 45 milliseconds and the hashtag #coronavirus rapidly becoming the 2nd most used in 2020.[41,42] Unfortunately, false and misleading information about COVID-19, potentially dangerous treatments, and eventual vaccination continues to grow on social media platforms.[43,44] Cinelli et al. examined this "infodemic" in the early stages of COVID-19, applying epidemic modeling to the dissemination of information on various social media platforms to calculate basic reproduction numbers for the "transmissibility" of posts on each platform.[42] Irrespective of platform, there were no significant differences between the spreading patterns of information considered questionable compared with that deemed reliable.[42]

Additionally, increasing concern has arisen that vaccine-related discourse may not be limited to genuine human-run accounts. Broniatowski et al. studied the role of such non-human accounts on the Twitter, describing the role of two types of inorganic users; "bots", accounts which generate automated content, and "trolls", accounts which misrepresent their identity and attempt to purposefully instigate conflict.[45]

Content-polluting bots were most likely to amplify anti-vaccination content whereas troll accounts tended to amplify both pro- and anti-vaccine content, thereby creating a false sense of equipoise regarding the safety and benefits of vaccination.[45] The use of bot accounts is also widespread in the dissemination of information regarding COVID-19 on social media, in particular Twitter. Using a combination of machine learning and manual validation, Ferrara analyzed the content and dissemination patterns of over 62 million tweets.[46] They determined that Twitter accounts ranked at high likelihood of being automated bots posted significantly more COVID-19-related tweets than non-bot accounts; content analysis of these tweets showed that they heavily promote political conspiracies and divisive hashtags in conjunction with the posted COVID-19 content.[46] The spread of such conspiracies can have severe consequences, including the dissemination of theories linking 5 G cellular networks to the spread of COVID-19, which has led to vandalism of cellular towers.[47] Overall, these studies have demonstrated that the relative amount of pro- and anti-vaccine content varies by platform, but that anti-vaccine content frequently generates greater user engagement than its pro-vaccine counterparts and that such engagement may be related to the occurrence of relevant current events and the activity of non-human accounts.

Social media and vaccine hesitancy

Extensive anti-vaccine content is frequently shared across social media.[24,48,49] Although preliminary, the existing evidence suggests that exposure to such content may directly influence vaccination opinions and drive downstream vaccine hesitancy. Betsch et al. and Nan et al. have demonstrated that exposure to vaccine-critical websites and blogs negatively impacts intention to vaccinate.[50,51] In comparing users' perceptions of vaccine risks amongst those exposed to control websites versus vaccine-critical websites, Betsch et al. found that even brief exposure – as little as five-to-ten minutes – to vaccine-critical websites increased the overall perception of vaccine risk in comparison to exposure to control websites.[50] Similarly, Ahmed et al. demonstrated that the use of Twitter and Facebook as sources of health information and influenza knowledge has a significant inverse association with influenza vaccine uptake.[52] Bhattacharyya et al. generated a social network simulation model in which the introduction of a perceived small vaccine adverse event had pronounced impact on vaccine uptake.[53] Their simulated epidemic models indicated that social media dissemination of vaccine adverse events results in outbreaks of vaccine-preventable illnesses with a more protracted course, lasting 150% longer.[53]

It is not readily evident why social media is so disproportionately successful in promoting vaccine hesitancy as opposed to uptake. Social media users may represent a skewed population sample with baseline misperceptions regarding the benefits and side effects of vaccination whilst simultaneously lacking familiarity with the consequences of vaccine-preventable disease.[23] Moreover, when evaluating the risks and benefits of vaccination in general, the risks may be overestimated and may seem more immediate and tangible as compared to the more abstract potential benefits of disease prevention.[2,21,54,55]

Furthermore, social media may propagate misinformation by employing vivid narratives and powerful imagery.[56-58] The success of such methods may be explained through the "fuzz-trace theory" whereby individuals integrate information in two methods; through verbatim memories which includes all precise details and through gist memories which contain the bottom-line basic meaning.[21] Decisions are usually made based on gist memories.[21] Social media posts expressing gist are more likely to be shared.[59] In contrast, quantitative information offered by evidence-based medical literature on pro-vaccine platforms may be less evoking than personal anecdotes offered by social media.[50]

Certain users have been demonstrated to be more vulnerable to these narrative emotional appeals of social media, including those with cognitive impairment, older age, lower literacy, and less digital literacy.[2,21] Users' baseline personal values and biases prior to their exposure to social media content, such as ethno-cultural, religious, or political beliefs, may modulate their response to such posts.[23,60,61] Helge et al. conducted an study in which 400 participants with differing opinions regarding the flu vaccination were organized into 3-link experimental diffusion chains.[62] This study assessed how information is conveyed, perceived, and altered between links and found that participants would largely alter messages to align with their baseline attitude.[62] Furthermore, messages were perceived to be more convincing if they aligned with the individual's attitudes.[62]

Moreover, individuals may find it challenging to adjudicate the credibility of the multiple information sources on social media.[54] In a case-control study by Salmon et al., parents of both vaccine-exempt and fully vaccinated children identified an anti-vaccination organization as a reliable source of information.[54] Similarly, when students were exposed to vaccine-related websites, 59% were unable to identify misinformation and over 50% of students reported inaccurate statements regarding vaccinations after such exposure.[63]

Digital health strategies to overcome vaccine misinformation on social media

While still an evolving field, research into evidence-based social media interventions are crucial to ensure uptake of new vaccines and provide accurate information to users. Potential strategies include developing public health campaigns specifically tailored to the platforms and their users, increasing the use of emotive language and imagery common to social media, and advocating for increased moderation and fact-checking on the part of the social media companies themselves to tighten content standards.

Leveraging social media platforms

Healthcare providers are amongst the most trusted information sources, with the caveat that vaccine hesitant parents may harbor anti-physician and anti-establishment sentiments.[54,61,64,65] Nevertheless, direct communication between healthcare providers and patients is known to reduce vaccine concerns and improve overall uptake.[57,61] Healthcare providers should become acquainted with social media

platforms to increase communication between themselves and their patients.[25,48,66] Health agencies and government websites should also improve their overall social media presence, and fostering partnerships with social media platforms may be a tool for accelerated promotion of evidence-based public health strategies.[48,67-69]

Several strategies have been explored to improve the social media presence of health providers and agencies. Ortiz et al. designed a three-month social media health intervention on Facebook which resulted in increased interpersonal discussions between users and their doctors.[70] Shoup et al. found that the most effective interactive social media interventions are those that contain balanced information, acknowledge parental concerns and avoid scientific jargon.[71] Furthermore, interactive components are most effective when they are carefully monitored by topic area experts who respond to questions and comments in a timely fashion.[71]

Although designing a robust intervention can be resource- and time-consuming, individual healthcare providers can easily begin disseminating messages on personal social media platforms such as Twitter.[71] However, in light of the presence of social media echo-chambers, healthcare providers working alone on Twitter may not readily reach isolated anti-vaccine communities.[72]

Structural change to social media networks

In response to heightened concerns surrounding the negative impact of online anti-vaccine messaging, several social media networks have committed to counteract anti-vaccination content as part of broader efforts to curtail misinformation.[15,73,74] It is essential for social media agencies to identify and flag potentially harmful misinformation, and consider active promotion of content from public health agencies.[15] Pinterest, for example, has redirected vaccine-related searches to a small set of handpicked results from public health organizations, including the WHO and CDC.[73] They have further disabled advertisements and comments on these topics to prevent user-driven contribution to vaccine misinformation or the influence of external, nonscientific entities.[73]

Other platforms have also proposed strategies, albeit with lesser extents of moderation. Facebook is attempting to "tackle vaccine misinformation (…) by reducing its distribution and providing people with authoritative information the topic".[75] This will be achieved by algorithmically reducing the ranking of anti-vaccine pages, excluding such pages from search recommendations, and rejecting advertisements with frank anti-vaccine messaging.[75] This will extend to their partner networks, including Instagram, where anti-vaccination content will not be included on hashtag search pages. These networks also report that they will identify mechanisms to provide more accurate information from reputable organizations regarding vaccinations to be including as leading results for vaccine-related searches.[75] In the US, Twitter has partnered with the Department of Health & Human Services to link vaccine-associated keywords to Vaccines.gov, as a pinned Tweet.[76]

Further, in response to COVID-19 misinformation, an array of social media companies have again produced joint statements to combat "misinformation about the virus." Twitter is implementing tools to label tweets as containing misleading information, provide linkage to validated sources of information, and to remove such tweets with a high propensity for harm.[77] In addition to combating misinformation, platforms such as YouTube, are working with high-profile content-producers to widely disseminate videos in support of physical distancing and quarantine measures for COVID-19 control directly to users as advertisements.[78]

Promoting information accuracy

Networks may not only introduce structural changes but may support end-users to share accurate information.[79] This is demonstrated in a social psychology study on the posting habits of 1600 social media users sharing COVID-19-related information.[79] Pennycook et al. found that members of the lay public share misinformation about COVID-19 in part because they failed to reflect sufficiently on whether or not content was accurate when deciding what to share; further, this phenomenon could be countered by a simple accuracy reminder prior to confirmation of the social media post, resulting in a more than doubling of the truth discernment in participants' sharing intentions.[79] In addition, First Draft has produced guidance on how the public and journalists can handle misinformation as it pertains to COVID-19.[80]

Framing messages

Understanding how messages are perceived by healthcare consumers is essential to successfully communicating pro-vaccine messages. Gain-framed messages are those that emphasize the benefits of adopting a recommended behavior.[81] Conversely, loss-framed messages emphasize the losses from not adopting a recommended behavior.[81] While similar, patient perception may be varied based on method of delivery. Lee et al. analyzed 142 college students' perceptions of gain-framed versus loss-framed messages on social media about HPV vaccination and found that the loss-framed messages created a higher level of behavioral intention and a higher perceived severity of the disease.[81] These findings suggest that the method of delivery is crucial to optimizing behavioral change.

Using narratives and leveraging celebrities

Sharing narratives is a popular and effective method to disseminate anti-vaccine content on social media; given its demonstrated efficacy, use of narratives to support vaccine uptake should be also promoted.[56] Popular celebrities and politicians are known to be instrumental in spreading both pro and anti-vaccination news, and often do so via narrative appeals. It is also known that on social media, elite users have the greatest user following.[82]

The cross-sectional questionnaire study by Zhang et al. examined the impact of parental attitudes toward vaccination after viewing pro- and anti-vaccine messaging from prominent medical and political figures.[83] Exposure to vaccine-content from popular figures impacts willingness to vaccinate, albeit

exposure to anti-vaccine content appears to have the most significant impact on downstream vaccine hesitancy amongst susceptible parents.[83]

During the COVID-19 pandemic, world leaders have taken to twitter to disseminate medical information to the public, which is known to incite interest in both social and traditional media spheres.[84,85] While a study of viral tweets produced by G7 country leaders suggest that the majority of tweets are informative, concerns have also been raised regarding the dissemination of false information by world leaders.[84,86] It is thus important for public figures to recognize the importance of disseminating accurate, evidence-based, health information on social media.[83]

Targeting parents and youth

Parents play a significant role in decisions regarding vaccination.[87,88] Kagashe et al., demonstrated that teenagers were more likely to get their influenza vaccine because of the persuasion of their parents.[89] There are well-described social media anti-vaccine campaigns targeting parents and specifically mothers.[90,91]

Further, in addition to promoting vaccine buy-in amongst parents, youth are heavy consumers of social media. Therefore, equipping youth with the skills to discern between evidence-based and reliable and misleading or evidence-poor information is a major priority.[63]

Recruiting research participants

Beyond direct engagement of the public to promote vaccine uptake, social media may serve as unique venue for epidemiological research into vaccine misinformation, vaccine hesitancy, communicable disease incidence and prevalence, and recruitment of participants for studies.

In the former cases, social media platforms can be used to monitor real-time public confidence in vaccination and undertake surveillance via virtual monitoring of vaccine-related discussion trends.[5,22,92] By recognizing public concerns, healthcare providers and health agencies can enlist strategies listed above to combat misinformation early. As an example of the latter, Reiter et al. used paid Facebook advertisements between July 2016 and September 2016 to recruit men who have sex with men to study HPV vaccination. Their advertisement reached over 35,000 users.[93] In another study, Tustin et al., designed a Facebook advertisement linked to a survey about vaccination beliefs aimed to reach Canadian parents.[94] Their advertisement resulted in over 4500 clicks with over 1000 completed survey results.[94] In light of this, Twitter is now being used to help identify participants for clinical trials for COVID-19.[95]

Conclusions

The ongoing resurgence of vaccine-preventable illnesses has led the WHO to identify vaccine hesitancy as a major threat to global health. In the digital era, patients have access to health information from a variety of sources including the Internet and social media platforms. As social media platforms gain increasing popularity globally, there has been growing public health concerns regarding the impact of anti-vaccination content on downstream vaccine denial. This further threatens the uptake of emerging vaccines, such as ongoing efforts to develop an effective vaccine against SARS-CoV-2. Future work in this field should focus on developing and analyzing effective strategies to foster vaccine uptake and promote evidence-based health literacy.

Contributor statement

N.P. and E.A.C designed the review. N.P. and E.A.C. wrote the manuscript. All authors edited the manuscript and reviewed it critically for important intellectual content.

Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

References

1. Andre F, Booy R, Bock H, Clemens J, Datta SK, John TJ, Lee BW, Lolekha S, Peltola H, Ruff TA, et al Vaccination greatly reduces disease, disability, death and inequity worldwide. Bull World Health Organ. 2008;86(2):140–46. doi:10.2471/BLT.07.040089.
2. Callender D. Vaccine hesitancy: more than a movement. Hum Vaccin Immunother. 2016;12(9):2464–68. doi: 10.1080/21645515.2016.1178434.
3. World Health Organization. Top ten threats to global health in 2019. 2019.[accessed 2019 Dec 12]. https://www.who.int/emergencies/ten-threats-to-global-health-in-2019.
4. Carrieri V, Madio L, Principe F. Vaccine hesitancy and (fake) news: quasi-experimental evidence from italy. Health Econ. 2019;28(11):1377–82. doi:10.1002/hec.3937.
5. Wilson K, Atkinson K, Deeks S. Opportunities for utilizing new technologies to increase vaccine confidence. Expert Rev Vaccines. 2014;13(8):969–77. doi:10.1586/14760584.2014.928208.
6. Tustin JL, Crowcroft NS, Gesink D, Johnson I, Keelan J, Lachapelle B. User-driven comments on a Facebook advertisement recruiting Canadian parents in a study on immunization: content analysis. JMIR Public Health Surveillance. 2018;4(3):e10090. doi:10.2196/10090.
7. Coomes EA, Haghbayan H, Finken LR, Quadros KK, Bagai A, Cheema AN. Information on cardiovascular disease in the digital era: results from a cross-sectional patient survey. Can J Cardiol. 2019;35(6):791–94. doi:10.1016/j.cjca.2019.03.015.
8. Warren KE, Wen LS. Measles, social media and surveillance in Baltimore city. J Public Health (Bangkok). 2016;39(3):e73–e78. doi:10.1093/pubmed/fdw076.
9. Daley MF, Narwaney KJ, Shoup JA, Wagner NM, Glanz JM. Addressing parents' vaccine concerns: A randomized trial of a social media intervention. Am J Prev Med. 2018;55(1):44–54. doi:10.1016/j.amepre.2018.04.010.
10. Gunaratne K, Haghbayan H, Coomes EA. Tweeting authors: impact on research publicity and downstream citations. J Gen Intern Med. 2019. doi:10.1007/s11606-019-05454-0.
11. Faasse K PhD, Chatman CJ, BA M LR, PhD. A comparison of language use in pro- and anti-vaccination comments in response to a high profile Facebook post. Vaccine. 2016;34(47):5808–14. doi:10.1016/j.vaccine.2016.09.029.
12. Lou M, Ahmed S. The American medical association is asking tech companies to stop the spread of vaccine misinformation. *CNN Wire Service*. [accessed 2019 Mar 14]. https://search.proquest.com/docview/2191086633
13. Al-Shamsi HO, Alhazzani W, Alhuraiji A, Coomes EA, Chemaly RF, Almuhanna M, Wolff RA, Ibrahim NK, Chua MLK, Hotte SJ, Meyers BM, Elfiki T, Grigliano G, Eng C, Grothey A, Xie C. A practical approach to the management of cancer patients

during the novel coronavirus disease 2019 (COVID-19) pandemic: an international collaborative group. Oncologist. 2020;25(6):e936-e945. doi:10.1634/theoncologist.2020-0213.
14. Limaye RJ, Sauer M, Ali J, Bernstein J, Wahl B, Barnhill A, Labrique A. Building trust while influencing online COVID-19 content in the social media world. Lancet Digital Health. 2020;2(6):e277–e278. doi:10.1016/S2589-7500(20)30084-4.
15. Donovan J. Social-media companies must flatten the curve of misinformation. Nature. 2020. doi:10.1038/d41586-020-01107-z.
16. Covid-19 updates: "Covid hoaxes are using a loophole to stay alive —even after content is deleted. Erkan's Field Diary [BLOG] Web site. https://search.proquest.com/docview/2397362298. 2020.
17. Pew Research Center. Social media fact sheet. 2019.
18. The history of social media: A timeline. https://phrasee.co/the-history-of-social-media-a-timeline/. 2018. accessed 2020 Jan 5.
19. Ortiz-Ospina E The rise of social media. 2019. [accessed 2020 Jan 5]. https://ourworldindata.org/rise-of-social-media.
20. Lua A 21 top social media sites to consider for your brand. 2019. [accessed 2020 Jan 5]. https://buffer.com/library/social-media-sites.
21. Betsch C, Brewer NT, Brocard P, Davies P, Gaissmaier W, Haase N, Leask J, Renkewitz F, Renner B, Reyna VF. Opportunities and challenges of web 2.0 for vaccination decisions. Vaccine. 2012;30(25):3727–33. doi:10.1016/j.vaccine.2012.02.025.
22. Wilson K, Keelan J. Social media and the empowering of opponents of medical technologies: the case of anti-vaccinationism. J Med Internet Res. 2013;15(5):e103. doi:10.2196/jmir.2409.
23. Buller DB, Walkosz BJ, Berteletti J, Pagoto SL, Bibeau J, Baker K, Hillhouse J, Henry KL. Insights on HPV vaccination in the united states from mothers' comments on facebook posts in a randomized trial. Hum Vaccin Immunother. 2019;15(7–8):1479–87. doi:10.1080/21645515.2019.1581555.
24. Meleo-Erwin Z, Basch C, MacLean SA, Scheibner C, Cadorett V. "To each his own": discussions of vaccine decision-making in top parenting blogs. Hum Vaccin Immunother. 2017;13(8):1895–901. doi:10.1080/21645515.2017.1321182.
25. Massey PM, Budenz A, Leader A, Fisher K, Klassen AC, Yom-Tov E. What drives health professionals to tweet about #HPVvaccine? Identifying strategies for effective communication. Prev Chronic Dis. 2018;15:E26. doi:10.5888/pcd15.170320.
26. Charles-Smith LE, Reynolds TL, Cameron MA, Conway M, Lau EHY, Olsen JM, Pavlin JA, Shigematsu M, Streichert LC, Suda KJ. Using social media for actionable disease surveillance and outbreak management: A systematic literature review. PLoS One. 2015;10(10):e0139701. doi:10.1371/journal.pone.0139701.
27. Blankenship EB, Goff ME, Yin J, Tse ZTH, Fu K-W, Liang H, Saroha N, Fung ICH. Sentiment, contents, and retweets: a study of two vaccine-related twitter datasets. Perm J. 2018;22:17–138. doi:10.7812/TPP/17-138.
28. Schmidt AL, Zollo F, Scala A, Betsch C, Quattrociocchi W. Polarization of the vaccination debate on Facebook. Vaccine. 2018;36(25):3606–12. doi:10.1016/j.vaccine.2018.05.040.
29. Salathé M, Khandelwal S, Meyers LA. Assessing vaccination sentiments with online social media: implications for infectious disease dynamics and control. PLoS Comput Biol. 2011;7(10):e1002199. doi:10.1371/journal.pcbi.1002199.
30. Del Vicario M, Bessi A, Zollo F, Petroni F, Scala A, Caldarelli G, Stanley HE, Quattrociocchi W. The spreading of misinformation online. Proc Natl Acad Sci U S A. 2016;113(3):554–59. doi:10.1073/pnas.1517441113
31. Getman R, Helmi M, Roberts H, Yansane A, Cutler D, Seymour B. Vaccine hesitancy and online information: the influence of digital networks. Health Educ Behav. 2018;45(4):599–606. doi:10.1177/1090198117739673.
32. Ekram S, Debiec KE, Pumper MA, Moreno MA. Content and commentary: HPV vaccine and YouTube. J Pediatr Adolesc Gynecol. 2019;32(2):153–57. doi:10.1016/j.jpag.2018.11.001.
33. Basch CH, MacLean SA. A content analysis of HPV related posts on Instagram. Hum Vaccin Immunother. 2019;15(7–8):1476–78. doi:10.1080/21645515.2018.1560774.
34. Gunaratne K, Coomes EA, Haghbayan H. Temporal trends in anti-vaccine discourse on twitter. Vaccine. 2019;37(35):4867–71. doi:10.1016/j.vaccine.2019.06.086.
35. Davies P, Chapman S, Leask J. Antivaccination activists on the world wide web. Arch Dis Child. 2002;87(1):22–25. doi:10.1136/adc.87.1.22.
36. Arif N, Al-Jefri M, Bizzi IH, Perano GB, Goldman M, Haq I, Chua KL, Mengozzi M, Neunez M, Smith H. Fake news or weak science? Visibility and characterization of antivaccine webpages returned by google in different languages and countries. Front Immunol. 2018;9:1215. doi:10.3389/fimmu.2018.01215.
37. Odone A, Ferrari A, Spagnoli F, Visciarelli S, Shefer A, Pasquarella C, Signorelli C. Effectiveness of interventions that apply new media to improve vaccine uptake and vaccine coverage. Hum Vaccin Immunother. 2015;11(1):72. doi:10.4161/hv.34313.
38. Basch CH, Zybert P, Reeves R, Basch CE. What do popular YouTube TM videos say about vaccines? Child Care Health Dev. 2017;43(4):499. doi:10.1111/cch.12401.
39. Li HO, Bailey A, Huynh D, Chan J. YouTube as a source of information on COVID-19: A pandemic of misinformation? BMJ Global Health. 2020;5(5):e002604. doi:10.1136/bmjgh-2020-002604.
40. Yuan X, Schuchard RJ, Crooks AT. Examining emergent communities and social bots within the polarized online vaccination debate in twitter. Social Media + Society. 2019;5(3):205630511986546. doi:10.1177/2056305119865465.
41. Josephson A, Lambe E Brand communications in time of crisis. 2020. https://blog.twitter.com/en_us/topics/company/2020/Brand-communications-in-time-of-crisis.html.
42. Cinelli M, Quattrociocchi W, Galeazzi A, Valensise CM, Brugnoli E, Schmidt AL, Zola P, Zollo F, Scala S. The COVID-19 social media infodemic. 2020. https://arxiv.org/abs/2003.05004.
43. Brennen S, Simon F, Howard P, Nielsen R Types, sources, and claims of COVID-19 misinformation. 2020. https://search.proquest.com/docview/2387269560.
44. Kouzy R, Abi Jaoude J, Kraitem A, El Alam MB, Karam B, Adib E, Zarka J, Traboulsi C, Akl EW, Baddour K. Coronavirus goes viral: quantifying the COVID-19 misinformation epidemic on twitter. Cureus. 2020;12(3):e7255. doi:10.7759/cureus.7255.
45. Broniatowski DA, Jamison AM, Qi S, AlKulaib L, Chen T, Benton A, Quinn SC, Dredze M. Weaponized health communication: twitter bots and russian trolls amplify the vaccine debate. Am J Public Health. 2018;108(10):1378–84. doi:10.2105/AJPH.2018.304567.
46. Ferrara E COVID-19 on twitter: bots, conspiracies, and social media activism. 2020. https://arxiv.org/abs/2004.09531.
47. Ahmed W, Vidal-Alaball J, Downing J, López Seguí F. COVID-19 and the 5G conspiracy theory: social network analysis of twitter data. J Med Internet Res. 2020;22(5):e19458. doi:10.2196/19458.
48. Oehler RL. On measles, vaccination, social media activism and how to win back our role as our patients' best advocates. Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America. 2019. doi:10.1093/cid/ciz656.
49. Ortiz RR, Smith A, Coyne-Beasley T. A systematic literature review to examine the potential for social media to impact HPV vaccine uptake and awareness, knowledge, and attitudes about HPV and HPV vaccination. Hum Vaccin Immunother. 2019;15(7–8):1465–-75. doi:10.1080/21645515.2019.1581543.
50. Betsch C, Renkewitz F, Betsch T, Ulshöfer C. The influence of vaccine-critical websites on perceiving vaccination risks. J Health Psychol. 2010;15(3):446–55. doi:10.1177/1359105309353647.
51. Nan X, Madden K. HPV vaccine information in the blogosphere: how positive and negative blogs influence vaccine-related risk perceptions, attitudes, and behavioral

intentions. Health Commun. 2012;27(8):829–36. doi:10.1080/10410236.2012.661348.
52. Ahmed N, Quinn SC, Hancock GR, Freimuth VS, Jamison A. Social media use and influenza vaccine uptake among white and african american adults. Vaccine. 2018;36(49):7556–61. doi:10.1016/j.vaccine.2018.10.049.
53. Bhattacharyya S, Vutha A, Bauch CT. The impact of rare but severe vaccine adverse events on behaviour-disease dynamics: A network model. Sci Rep. 2019;9(1):7164–13. doi:10.1038/s41598-019-43596-7.
54. Salmon DA, Moulton LH, Omer SB, deHart MP, Stokley S, Halsey NA. Factors associated with refusal of childhood vaccines among parents of school-aged children: A case-control study. Arch Pediatr Adolesc Med. 2005;159(5):470–76. doi:10.1001/archpedi.159.5.470.
55. Dredze M, Broniatowski DA, Smith MC, Hilyard KM. Understanding vaccine refusal: why we need social media now. Am J Prev Med. 2016;50(4):550–52. doi:10.1016/j.amepre.2015.10.002.
56. Shelby A, Ernst K. Story and science. Hum Vaccin Immunother. 2013;9(8):1795–801. doi:10.4161/hv.24828.
57. Robichaud P, Hawken S, Beard L, Morra D, Tomlinson G, Wilson K, Keelan J. Vaccine-critical videos on YouTube and their impact on medical students' attitudes about seasonal influenza immunization: A pre and post study. Vaccine. 2012;30(25):3763–70. doi:10.1016/j.vaccine.2012.03.074.
58. Chen T, Dredze M. Vaccine images on twitter: analysis of what images are shared. J Med Internet Res. 2018;20(4):e130. doi:10.2196/jmir.8221.
59. Broniatowski DA, Hilyard KM, Dredze M. Effective vaccine communication during the disneyland measles outbreak. Vaccine. 2016;34(28):3225–28. doi:10.1016/j.vaccine.2016.04.044.
60. Dubé E, Gagnon D, Clément P, Bettinger JA, Comeau JL, Deeks S, Guay M, MacDonald S, MacDonald NE, Mijovic H. Challenges and opportunities of school-based HPV vaccination in canada. Hum Vaccin Immunother. 2019;15(7–8):1650–55. doi:10.1080/21645515.2018.1564440.
61. Jones AM, Omer SB, Bednarczyk RA, Halsey NA, Moulton LH, Salmon DA. Parents' source of vaccine information and impact on vaccine attitudes, beliefs, and nonmedical exemptions. Adv Prev Med. 2012;2012:932741–48. doi:10.1155/2012/932741.
62. Giese H, Neth H, Moussaïd M, Betsch C, Gaissmaier W. The echo in flu-vaccination echo chambers: selective attention trumps social influence. Vaccine. 2019. doi:10.1016/j.vaccine.2019.11.038.
63. Kortum P, Edwards C, Richards-Kortum R. The impact of inaccurate internet health information in a secondary school learning environment. J Med Internet Res. 2008;10(2):e17. doi:10.2196/jmir.986.
64. Perkins RB, Fisher-Borne M, Brewer NT. Engaging parents around vaccine confidence: proceedings from the national HPV vaccination roundtable meetings. Hum Vaccin Immunother. 2019;15(7–-8):1639–40. doi:10.1080/21645515.2018.1520592
65. Mohanty S, Leader AE, Gibeau E, Johnson C. Using facebook to reach adolescents for human papillomavirus (HPV) vaccination. Vaccine. 2018;36(40):5955–61. doi:10.1016/j.vaccine.2018.08.060.
66. Yammine S. Going viral: how to boost the spread of coronavirus science on social media. Nature. 2020;581(7808):345–46. doi:10.1038/d41586-020-01356-y.
67. Chen Q, Min C, Zhang W, Wang G, Ma X, Evans R. Unpacking the black box: how to promote citizen engagement through government social media during the COVID-19 crisis. Comput Human Behav. 2020;110:106380. doi:10.1016/j.chb.2020.106380.
68. Basch CE, Basch CH, Hillyer GC, Jaime C. The role of YouTube and the entertainment industry in saving lives by educating and mobilizing the public to adopt behaviors for community mitigation of COVID-19: successive sampling design study. JMIR Public Health Surveillance. 2020;6(2):e19145. doi:10.2196/19145.
69. D'Souza RS, D'Souza S, Strand N, Anderson A, Vogt MNP, Olatoye O. YouTube as a source of medical information on the novel coronavirus 2019 disease (COVID-19) pandemic. Glob Public Health. 2020:1–8. doi:10.1080/17441692.2020.1761426.
70. Ortiz RR, Shafer A, Cates J, Coyne-Beasley T. Development and evaluation of a social media health intervention to improve adolescents' knowledge about and vaccination against the human papillomavirus. Global Pediatr Health. 2018;5:2333794X18777918. doi:10.1177/2333794X18777918.
71. Shoup JA, Wagner NM, Kraus CR, Narwaney KJ, Goddard KS, Glanz JM. Development of an interactive social media tool for parents with concerns about vaccines. Health Educ Behav. 2015;42(3):302–12. doi:10.1177/1090198114557129.
72. Chou WS, Oh A, Klein WMP. Addressing health-related misinformation on social media. JAMA. 2018;320(23):2417–18. doi:10.1001/jama.2018.16865.
73. Ozoma I Bringing authoritative vaccine results to Pinterest search. 2019. [accessed2020 Jan 5].
74. WHO director-general statement on the role of social media platforms in health information. 2019. [accessed2019 Dec 10]. https://www.who.int/news-room/detail/28-08-2019-who-director-general-statement-on-the-role-of-social-media-platforms-in-health-information
75. Combatting vaccine misinformation. accessed 2019 Mar 8]. *allAfrica.com* (English).
76. Harvey D Helping you find reliable public health information on twitter. [2019. accessed Dec 12 2019]. https://blog.twitter.com/en_us/topics/company/2019/helping-you-find-reliable-public-health-information-on-twitter.html.
77. Roth Y, Pickles N Updating our approach to misleading information. 2020.
78. At home #WithMe. YouTube Web site. https://www.youtube.com/channel/UCK8qVjkRMI1lRcYp6_W_1qw.
79. Pennycook G, McPhetres J, Zhang Y, Rand D. Fighting COVID-19 misinformation on social media: experimental evidence for a scalable accuracy nudge intervention. MIT Initiative Digital Economy. 2020.
80. Too much information: A public guide. First Draft Web site. Updating our Approach to Misleading Information.
81. Lee MJ, Cho J. Promoting HPV vaccination online: message design and media choice. Health Promot Pract. 2017;18(5):645–53. doi:10.1177/1524839916688229.
82. Massey PM, Leader A, Yom-Tov E, Budenz A, Fisher K, Klassen AC. Applying multiple data collection tools to quantify human papillomavirus vaccine communication on twitter. J Med Internet Res. 2016;18(12):e318. doi:10.2196/jmir.6670.
83. Zhang EJ, Chughtai AA, Heywood A, MacIntyre CR. Influence of political and medical leaders on parental perception of vaccination: A cross-sectional survey in australia. BMJ Open. 2019;9(3):e025866. doi:10.1136/bmjopen-2018-025866.
84. Rufai SR, Bunce C. World leaders' usage of twitter in response to the COVID-19 pandemic: a content analysis. J Public Health (Oxford, England). 2020. doi:10.1093/pubmed/fdaa049.
85. Haghbayan H, Coomes EA, Cheema AN, Shojania KG. Media dissemination of the montreal cognitive assessment after president donald trump's medical evaluation. JAMA Neurol. 2018;75(10):1286–87. doi:10.1001/jamaneurol.2018.1777.
86. Elliott J Trump vs. himself: how he dismissed the coronavirus, in his own words. [accessed 2020 Apr 15.https://globalnews.ca/news/6820223/coronavirus-donald-trump-timeline/.
87. Vrdelja M, Kraigher A, Vercic D, Kropivnik S. The growing vaccine hesitancy: exploring the influence of the internet. Eur J Public Health. 2018;28(5):934–39. doi:10.1093/eurpub/cky114.
88. Greenberg J, Dubé E, Driedger M. Vaccine hesitancy: in search of the risk communication comfort zone. PLoS Curr. 2017:9. doi:10.1371/currents.outbreaks.0561a011117a1d1f9596e24949e8690b.
89. Kagashe I, Yan Z, Suheryani I. Enhancing seasonal influenza surveillance: topic analysis of widely used medicinal drugs using twitter data. J Med Internet Res. 2017;19(9):e315. doi:10.2196/jmir.7393.

90. Kata A. Anti-vaccine activists, web 2.0, and the postmodern paradigm – an overview of tactics and tropes used online by the anti-vaccination movement. Vaccine. 2011;30(25):3778–89. doi:10.1016/j.vaccine.2011.11.112.
91. Dannetun E, Tegnell A, Hermansson G, Giesecke J. Parents' reported reasons for avoiding MMR vaccination. Scand J Prim Health Care. 2005;23(3):149–53. doi:10.1080/02813430510031306.
92. Rosselli R, Martini M, Bragazzi NL. The old and the new: vaccine hesitancy in the era of the web 2.0. challenges and opportunities. J Prev Med Hyg. 2016; 57(1): E47–E50. https://www.ncbi.nlm.nih.gov/pubmed/27346940
93. Reiter PL, Katz ML, Bauermeister JA, Shoben AB, Paskett ED, McRee A. Recruiting young gay and bisexual men for a human papillomavirus vaccination intervention through social media: the effects of advertisement content. JMIR Public Health Surveillance. 2017;3(2):e33. doi:10.2196/publichealth.7545.
94. Tustin JL, Crowcroft NS, Gesink D, Johnson I, Keelan J, Lachapelle B. Facebook recruitment of vaccine-hesitant canadian parents: cross-sectional study. JMIR Public Health Surveillance. 2017;3(3):e47. doi:10.2196/publichealth.6870.
95. UAlberta Medicine. Are you interested in being part of a trial for the prevention of COVID-19? 2020 https://twitter.com/UAlberta_DoM/status/1259902360824025088.