

## **UC Irvine**

### **UC Irvine Previously Published Works**

**Title**

Online misinformation and vaccine hesitancy

**Permalink**

<https://escholarship.org/uc/item/7r5262nf>

**Journal**

Translational Behavioral Medicine, 11(12)

**ISSN**

1869-6716

**Authors**

Garett, Renee  
Young, Sean D

**Publication Date**

2021-12-14

**DOI**

10.1093/tbm/ibab128

Peer reviewed

## Online misinformation and vaccine hesitancy

Renee Garrett,<sup>1</sup> Sean D. Young<sup>2,3</sup>

<sup>1</sup>ElevateU, Irvine, CA, 92617, USA

<sup>2</sup>Department of Emergency Medicine, University of California, Irvine, CA 92697, USA

<sup>3</sup>University of California Institute for Prediction Technology, Department of Informatics, University of California, Irvine, CA 92697, USA

Correspondence to: SD Young, [syoung5@hs.uci.edu](mailto:syoung5@hs.uci.edu)

Cite this as: *TBM* 2021;11:2194–2199 <https://doi.org/10.1093/tbm/ibab128>

© Society of Behavioral Medicine 2021. All rights reserved. For permissions, please e-mail: [journals.permissions@oup.com](mailto:journals.permissions@oup.com).

### Abstract

Although rates of vaccination have increased worldwide, the rise in nonmedical exemptions for vaccination may have caused a resurgence of childhood vaccine-preventable diseases. Vaccine hesitancy plays an important role in the decreasing rates of vaccination and is considered by the World Health Organization as a top ten global threat to public health. Online vaccine misinformation is present in news outlets, websites, and social media, and its rapid and extensive dissemination is aided by artificial intelligence (AI). In combating online misinformation, public health experts, the medical community, and lay vaccination advocates can correct false statements using language that appeal to those who are undecided about vaccination. As the gatekeepers to online information, they can implement and enforce policy that limits or bans vaccine misinformation on their platforms. AI tools might also be used to address misinformation, but more research is needed before implementing this approach more broadly in health policy. This commentary examines the role that different online platforms appear to be playing in the spread of misinformation about vaccines. We also discuss the implications of online misinformation on attitudes about COVID-19 vaccine uptake and provide suggestions for ways to combat online misinformation.

### Keywords

COVID-19, Media, Misinformation, Vaccine, Vaccine hesitancy

### BACKGROUND

Although global vaccination rates continue to trend up [1], the resurgence of vaccine-preventable diseases, such as measles, may be attributable to the decrease in vaccine coverage [2, 3]. Vaccine hesitancy is a rejection, reluctance, or delay in vaccination despite availability of efficacious vaccines [4] and is considered by the World Health Organization (WHO) as a top ten threat to global health [5]. Some of the factors that influence vaccine hesitancy include personal beliefs (i.e., safety concerns, skepticism of vaccine effectiveness) [6], social networks [7], and exposure to misinformation online [8]. In California, prior to legislation that barred personal belief exemptions for vaccination, rates of personal belief exemption for vaccination among kindergartners slowly increased from 2000 to 2015 [9]. Similarly, in states without such exemptions, nonmedical exemptions increased and had an inverse association to coverage of the measles, mumps, and rubella

### Implications

**Practice:** Providers can continue to discuss with their patients the importance, safety, and effectiveness of vaccines. They can also inform their patients that there are massive amounts of vaccine misinformation online and provide them with sources containing factual information with lay language.

**Policy:** Social media platforms that want to decrease the spread of misinformation on their sites should continue to monitor and develop new algorithms that identify vaccine misinformation, as well as implement and enforce bans on the content and advertising on their website that contain misinformation.

**Research:** Future research should be aimed at identifying appropriate messages to deliver for maximum effectiveness to appeal to those who are undecided by vaccination. Additionally, researchers can develop digital tools that can identify, respond to, or eliminate misinformation online.

### Lay summary

Vaccine hesitancy, the rejection or delay to get vaccinated even if there is an effective vaccine available, may be instrumental in the resurgence of vaccine-preventable disease. Studies have shown that the rise in nonmedical exemptions for vaccination increases rates of childhood vaccine-preventable disease. One factor that influences vaccine hesitancy is online misinformation. False or misleading information online regarding vaccines can be found in independent news outlets, websites, and social media. The spread of vaccine misinformation is especially important during the COVID-19 pandemic as false information can decrease pro-vaccine opinions. The recent announcement of an effective COVID-19 vaccine became a hot topic online, with many adults hesitant to take the vaccine. Public health experts, medical professionals, and pro-vaccine individuals can help curb the spread of misinformation by correcting false statements online. Social media companies can also aid in stopping misinformation by implementing and enforcing policy that limits misinformation on their platforms.

vaccine among kindergarteners [10]. Globally, trends in confidence in vaccine safety, importance, and effectiveness have decreased in certain countries while increasing in others between 2015 and 2019, with confidence in vaccines significantly associated with uptake of vaccines [11]. More recently, as news of the COVID-19 vaccine efficacy emerged, over 55% of U.S. adults surveyed expressed hesitation in obtaining the vaccine once available citing effectiveness, side effects, trust, politics, and expediency in production as reasons for waiting or uncertainty. Additionally, those who stated that they would not receive the vaccine cited misinformation, misperception, and mistrust about the vaccine, and not needing a vaccine as reasons for not obtaining the vaccine [12].

A report from The European Centre for Disease Prevention and Control stated that digital social networks (e.g., social media) are primary factors affecting vaccine hesitancy because they allow the fast spread of rumors and myths regarding vaccination [13]. It is therefore important that researchers and health departments become aware of the potential digital social networks and how vaccine-related information is being shared on them.

Susceptibility to vaccine misinformation can be attributed to many factors, including a lack of scientific education and understanding by the consumer [14] and the public's declining trust in figures of authority [15]. Investigators explored the role of information sources on vaccine knowledge and vaccine hesitancy and found that parents who turned to the internet/social media for information had less correct knowledge compared to parents who received information from a healthcare provider and that using the internet/social media as a source was associated with vaccine hesitancy [16]. Another study investigated the role of fake news and online misinformation on immunization rates and found decreased rates after the proliferation of false information online [17]. There are both human and nonhuman components that enable the dissemination of massive amounts of misinformation online. Previous investigators found that social media bots and content polluters ("accounts that disseminate malware and unsolicited content") significantly tweeted anti-vaccination posts at a higher rate than average Twitter users, while Russian trolls amplified the tweets [18].

This viewpoint examines the role that different online platforms appear to be playing in the spread of misinformation about vaccines. We also discuss the implications of online misinformation on attitudes about COVID-19 vaccine uptake and provide suggestions for ways to combat online misinformation. We also discuss potential applications of artificial intelligence (AI) related to vaccines and provide a call for additional research before implementing these approaches more widely in the policy.

## NEWS

The diffusion of vaccine misinformation is a topic that has been covered by news organizations, especially in times when infectious disease outbreaks occur. A study that analyzed online newspaper articles about the Ebola vaccine found that misinformation and corrections surrounding the vaccine development included the vaccine being secret, beliefs that the trials would cause an Ebola outbreak, and impropriety of incentives for participants [19]. In another study, the fallout from a fake mainstream media article regarding the polio vaccine in Pakistan resulted in violent and nonviolent incidents. Consequently, the Taliban halted the vaccination campaign resulting in a rise in polio cases [20]. Table 1 shows sample texts of misinformation from various online sources.

## WEBSITES

Online misinformation on websites can also negatively impact people's willingness to take vaccines. According to the Pew Research Center, 55% of Americans with access to the internet sought health or medical information online with some reporting that the information they obtained influenced their health behaviors. Unfortunately, content on health websites varies in accuracy and quality with approximately 6% of those examined containing incorrect information [21]. Anti-vaccination websites take many forms from activism to natural health sites to general news and blogging sites, with some sites receiving 1.5 million unique visitors per month [22]. This is unsurprising since researchers found that 43% of websites propagated during a web search for "vaccination" and "immunization" comprised of anti-vaccination websites [15]. Once led to websites, readers may be bombarded with information that questions scientific integrity, use emotive appeals for civil liberties, and concern for the health and welfare of children. Anti-vaccination persuasion centers on creating a community affected by vaccines and vaccine-related practices [23]. Main themes used by anti-vaccine champions include safety and effectiveness, alternative medicine, freedom and rights, conspiracy theories, and morality [14].

## SOCIAL MEDIA

One of the most efficient methods of spreading vaccine misinformation online is through social media. A report by the Centre for Countering Digital Hate (CCDH) found that social media accounts by anti-vaccination proponents gained 7.8 million followers since 2019, with 31 million Facebook users following anti-vaccination accounts and 17 million YouTube users subscribing to similar accounts [24]. In examining vaccine chatter on Facebook, researchers found that though anti-vaccination clusters were fewer in numbers than pro-vaccination clusters, they

**Table 1** | Sample text of online misinformation about vaccination

Source	Platform	Engagement	Text <sup>a</sup>
<b>Vaccination</b>			
News	SHTFplan	4 comments	(Headline) <i>The Flu Vaccine Won't Help You This Year, But Big Pharma Wants You To Get It Anyway</i>
Website	Mercola	595,145 views 161 comments	(Title) <i>Squalene: The Swine Flu Vaccine's Dirty Little Secret Exposed</i>
Social Media	Facebook	18 reactions 25 comments 10 shares	<i>Gene mutations are very common after getting vaccinated.</i>
	Twitter	4.7K likes 136 quote tweets 1.3K retweets	<i>If you believe that an unvaccinated person is a threat to someone who is vaccinated, then do you really believe vaccines work?</i>
	Reddit	9 comments	<i>Are unvaccinated children healthier than children who are vaccinated? One study's findings</i>
	YouTube	539,043 views 10, 876 reactions 4,402 comments	<i>I'm in the medical field, and I now know the truth about vaccines.</i>
	Instagram	366 likes 6 comments	<i>Vaccines were founded on dodgy science, and unfortunately, parents and experts have been fooled into thinking it's necessary for the public's health to jab themselves and their kids with poison.</i>
<b>COVID-19</b>			
News	The Liberty Beacon	0 comments 0 shares	(Headline) <i>Top Pfizer Whistleblower Trashes Company's Vaccine "Breakthrough" Spin</i>
Website	Natural News	14K views 6 comments	(Title) <i>Prediction: The insidious COVID-19 vaccine will infect you with a virus that will lead to an outbreak of a new COVID-21 pandemic</i>
Social Media	Facebook	47 reactions 40 comments 102 shares	<i>Think: China recovered from COVID-19 without needing a vaccine. So, what's really going on here that is pushing this mandate to be vaccinated?</i>
	Twitter	4.4K likes 137 quote tweets 1.6K retweets	<i>The young and healthy DO NOT need a Covid-19 vaccine. Over 99% of people recover without treatment and with minor symptoms.</i>
	Reddit	1.4K upvotes 727 comments	<i>A pharmaceutical company makes a claim that their COVID-19 vaccine is effective, but an executive says viral transmission can happen after vaccination. So, what is it effective against, then?</i>

<sup>a</sup>Quotes from individuals have been modified to protect individuals from being identified by or linked to this report.

nevertheless had very high presence and were well entangled with undecided clusters [25]. One study found that public use of social media to organize action was associated with the belief that vaccines were unsafe and that foreign disinformation campaigns on social media were associated with lower vaccination rates and negative discourse/posts on social media [26]. Another study examined coverage of the human papilloma virus (HPV) vaccine in social media and state-level HPV vaccine coverage. Results showed that exposure to information on social media explained a higher proportion of the variance in vaccine coverage compared to socioeconomic factors, and that vaccine coverage was lower in states with higher exposure to misinformation, conspiracy theories, and safety concerns [27].

**COVID-19 VACCINE-RELATED MISINFORMATION**

During the current COVID-19 pandemic, it is especially important to be aware of the prevalence and role that online misinformation is having on

people’s attitudes and behaviors as this affects willingness to get the COVID-19 vaccine. News of the availability and near dissemination of the recently developed and tested vaccines began to circulate in headlines and social media posts. Subsequently, misinformation and conspiracies about the COVID-19 vaccine gained traction [28, 29]. Investigators who examined media consumption and reliance on specific institutions regarding COVID-19 found that reliance on certain news formats and sources was associated with knowledge, misinformation, and prejudice [30]. The amount of misinformation online surrounding the vaccine has been labeled as a second pandemic and has fueled the mistrust surrounding the handling of the pandemic, which can undermine efforts to vaccinate [31]. Surveys of adults about getting the COVID-19 vaccine showed reluctance in doing so. The report by CCDH noted that one in six British would get vaccinated for COVID-19 [24] and an even higher number of Americans, four in ten, stated they definitely or probably would not

get the COVID-19 vaccine [32]. In a randomized control study, participants who were exposed to snippets of social media posts containing COVID-19 misinformation had a decrease in intent to obtain the vaccine compared to controls who were exposed to factual COVID-19 information [33].

#### WAYS TO MITIGATE THE EFFECTS OF ONLINE VACCINE-RELATED MISINFORMATION

Mitigation of the spread of misinformation online necessitates an ongoing process involving health experts, lay advocates, and the cooperation of social media platforms. Although a detailed description of theoretical frameworks for attitude and behavior change is outside the scope of this viewpoint, health researchers and health departments could benefit from leveraging science-based behavioral frameworks to mitigate the spread of online vaccine-related misinformation and its effects. Examples of these behavioral frameworks that might be incorporated include diffusion of innovations theory [34], the health belief model [35], and the Stick With It model of lasting behavior change [36].

Public health and medical professionals may curb the spread of misinformation through engagement in public forums and social media [37]. Health experts can correct misinformation posts using language that would appeal to those who are on the fence about vaccination. Additionally, lay proponents of vaccination can provide factual information and counter anti-vaccine rhetoric. Correction of misinformation on social media is possible, and that the correction should be conducted as soon as possible to obviate further deepening and ingraining of the false opinion [38]. Researchers are utilizing novel approaches to combat misinformation online. One study examined the efficacy of an online game that purports to create fake news and misinformation to show gamers the methods used to create and spread disinformation [39]. Hossain and colleagues developed an annotated dataset aimed at assisting AI models to detect misinformation on social media [40].

#### PUBLIC HEALTH AND THE IMPLEMENTATION OF AI

AI and associated technologies are increasingly being applied in the healthcare sector. The healthcare system is currently under strain, due to an increase in chronic diseases among the general population [41]. Public health providers and organizations have started to discuss incorporating AI, machine learning, and deep learning into their population and community level care policies [42]. With the dawn of neural networks, AI had started to become popular since the 1980s. In recent years, deep learning has been widely used in primary health care (PHC). For example, diabetic retinopathy in PHC centers can be detected by an AI system developed by Abramoff et al. and approved

by the Federal Drug Administration of USA [43]. Machine learning methods were also used in the health sector by [44] to identify children at risk of not being vaccinated against Measles, Mumps, and Rubella in WHO countries. Similarly, machine-learning-based approaches were used by [45] for COVID-19 using LASSO logistic regression on a low number of attributes of the child and his or her family and community.

Social media platforms have the capacity to quell the spread of misinformation through AI and policy. With respect to policy, social media platforms have begun to curtail the flow of misinformation online. As early as 2017, Pinterest addressed misinformation about vaccines in their community guidelines and prohibited ads supporting anti-vaccination advice and misinformation. The platform continued its efforts in combating misinformation by discontinuing showing any results for vaccine searches [46]. Other platforms followed suit. In March 2019, Facebook announced its plan for mitigating vaccine misinformation that spread on the platform [47], however, efforts have not been successful as misinformation continued to flourish and spread [48]. Subsequently, Facebook updated its policy that removed posts containing misinformation about SARSCoV-2 and recently expanded the policy to include removal of posts containing misinformation about the vaccine [49]. Similarly, YouTube began banning any content with misinformation that contradicted information from health authorities in October 2020 [50].

However, prior to implementing these approaches more broadly in policy, there are a number of issues related to AI that require more research. For example, a key technical constraint of these models and approaches is that they need external validation, integration into a medical roadmap, and the boldness of clinicians to support them (Stead, 2018). There are also ethical and implementation concerns in the application of AI including issues with data in the training validation dataset that can lead to biases. Moreover, the dependence on AI changes the patient-clinician relation dynamics. Therefore, an appropriate collective knowledge regarding AI is required to help health care organizations and departments make decisions on how to use AI systems.

#### CONCLUSION

Misinformation about vaccines is complex and an ongoing battle that often uses rhetoric in lieu of science. The maelstrom of false and misleading information online through websites, independent media outlets, and social media is fueled by lack of scientific understanding and mistrust of authority, and aided by AI. Amidst the COVID-19 pandemic, misinformation has reached new heights and further endangers public health. Efforts by public health experts, the medical community, and vaccine advocates should be swift and intentional to correct



misinformation online. In addition to social media engagement, novel digital tools and applications may be useful in this effort. The cooperation of social media platforms is paramount in terminating the spread of misinformation. In essence, they are the gatekeepers to the limitless information available on the internet.

**Acknowledgment** This study was funded by the National Institute of Mental Health (NIMH), grant #MH106415, National Institute of Allergy and Infectious Diseases (NIAID), and National Center for Complementary and Integrative Health (NCCIH).

#### Compliance with Ethical Standards

**Conflicts of Interest:** Sean D. Young is the PI of grants from the National Institutes of Health (NIH) and a board member for the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine (NASEM).

**Human Rights:** This article does not contain any studies with human participants performed by any of the authors.

**Informed Consent:** This study does not involve human participants and informed consent was therefore not required.

**Welfare of Animals:** This article does not contain any studies with animals performed by any of the authors.

#### Transparency Statement

The manuscript has not been submitted to more than one journal for simultaneous consideration.

## REFERENCES

- GAVI. Annual progress report, 2019. The Vaccine Alliance; 2020. Available at <https://www.gavi.org/news-resources>. Accessibility verified July 20, 2021.
- Patel M, Lee AD, Clemmons NS, et al. National update on measles cases and outbreaks—United States, January 1–October 1. *Morb Mortal Wkly Rep*. 2019;68(40):893–896. Centers for Disease Control and Prevention. Available at <https://www.cdc.gov/mmwr/volumes/68/wr/mm6840e2.htm>
- Phadke VK, Bednarczyk RA, Omer SB. Vaccine refusal and measles outbreaks in the US. *JAMA*. 2020;324(13):1344–1345.
- MacDonald NE, SAGE Working Group on Vaccine Hesitancy. Vaccine hesitancy: Definition, scope and determinants. *Vaccine*. 2015;33(34):4161–4164.
- World Health Organization (WHO). Ten health issues WHO will tackle this year. World Health Organization; 2019. Available at <https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019>. Accessibility verified September 7, 2021.
- Majid U, Ahmad M. The factors that promote vaccine hesitancy, rejection, or delay in parents. *Qual Health Res*. 2020;30(11):1762–1776.
- Brunson EK. The impact of social networks on parents' vaccination decisions. *Pediatrics*. 2013;131(5):e1397–e1404.
- Milondzo T, Meyer JC, Dochez C, Burnett RJ. Misinformation drives low human papillomavirus vaccination coverage in South African girls attending private schools. *Front Public Health*. 2021;9:598625.
- Delamater PL, Leslie TF, Yang YT. Change in medical exemptions from immunization in California after elimination of personal belief exemptions. *JAMA*. 2017;318(9):863–864.
- Olive JK, Hotez PJ, Damania A, Nolan MS. Correction: The state of the antivaccine movement in the United States: A focused examination of nonmedical exemptions in states and counties. *PLoS Med*. 2018;15(7):e1002616.
- Figueiredo A de, Simas C, Karafillakis E, Paterson P, Larson HJ. Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: A large-scale retrospective temporal modelling study. *Lancet*. 2020;396(10255):898–908.
- Graham G, Chaguturu S, Brennan T. White paper: understanding and addressing vaccine hesitancy. CVS; 2020. Available at <https://payorsolutions.cvshealth.com/insights/white-paper-understanding-and-addressing-vaccine-hesitancy>. Accessibility verified September 9, 2021.
- European Centre for Disease Prevention and Control (ECDC). *Systematic Scoping Review on Social Media Monitoring Methods and Interventions Relating to Vaccine Hesitancy*. Stockholm, Sweden: European Centre for Disease Prevention and Control; 2020.
- Kata A. A postmodern Pandora's box: Anti-vaccination misinformation on the Internet. *Vaccine*. 2010;28(7):1709–1716.
- Davies P, Chapman S, Leask J. Antivaccination activists on the world wide web. *Arch Dis Child*. 2002;87(1):22–25.
- Ashkenazi S, Livni G, Klein A, Kremer N, Havlin A, Berkowitz O. The relationship between parental source of information and knowledge about measles/measles vaccine and vaccine hesitancy. *Vaccine*. 2020;38(46):7292–7298.
- Carrieri V, Madio L, Principe F. Vaccine hesitancy and (fake) news: Quasi-experimental evidence from Italy. *Health Econ*. 2019;28(11):1377–1382.
- Broniatowski DA, Jamison AM, Qi S, et al. Weaponized health communication: Twitter Bots and Russian trolls amplify the vaccine debate. *Am J Public Health*. 2018;108(10):1378–1384.
- Kummervold PE, Schulz WS, Smout E, Fernandez-Luque L, Larson HJ. Controversial Ebola vaccine trials in Ghana: A thematic analysis of critiques and rebuttals in digital news. *BMC Public Health*. 2017;17(1):642.
- Bahk CY, Cumming M, Pausher L, Madoff LC, Thomson A, Brownstein JS. Publicly available online tool facilitates real-time monitoring of vaccine conversations and sentiments. *Health Aff*. 2016;35(2):341–347.
- Rainie L, Fox S. The online health care revolution. Pew Research Center; 2020. Available at <https://www.pewresearch.org/internet/2000/11/26/the-online-health-care-revolution/>. Accessibility verified September 12, 2021.
- Kata A. Anti-vaccine activists, Web 2.0, and the postmodern paradigm – an overview of tactics and tropes used online by the anti-vaccination movement. *Vaccine*. 2012;30(25):3778–3789.
- Grant L, Hausman BL, Cashion M, Lucchesi N, Patel K, Roberts J. Vaccination persuasion online: A qualitative study of two provocative and two vaccine-skeptical websites. *J Med Internet Res*. 2015;17(5):e133.
- Burki T. The online anti-vaccine movement in the age of COVID-19. *Lancet Digit Health*. 2020;2(10):e504–e505.
- Johnson NF, Velásquez N, Restrepo NJ, et al. The online competition between pro- and anti-vaccination views. *Nature*. 2020;582(7811):230–233.
- Wilson SL, Wiysonge C. Social media and vaccine hesitancy. *BMJ Glob Health*. 2020;5(10).
- Dunn AG, Surian D, Leask J, Dey A, Mandl KD, Coiera E. Mapping information exposure on social media to explain differences in HPV vaccine coverage in the United States. *Vaccine*. 2017;35(23):3033–3040.
- Anti-coronavirus vaccine movement grows, fueled by online misinformation, conspiracies. wbur; 2020. Available at <https://www.wbur.org/hereandnow/2020/12/08/anti-vaccine-misinformation>. Accessibility verified December 8, 2020.
- Researcher Cites Uptick In COVID-19 Vaccine Misinformation. NPR. org. Available at <https://www.npr.org/2020/12/05/943533947/researcher-cites-uptick-in-covid-19-vaccine-misinformation>. Accessibility verified December 5, 2020.
- Dhanani LY, Franz B. The role of news consumption and trust in public health leadership in shaping COVID-19 knowledge and prejudice. *Front Psychol*. 2020;11:560828.
- Kaur H, Thomas N. "Fake news" about a Covid-19 vaccine has become a second pandemic, Red Cross chief says. CNN; 2020. Available at <https://www.cnn.com/2020/12/01/media/red-cross-chief-warns-vaccine-mistrust-trnd/index.html>. Accessibility verified September 7, 2021.
- Funk C, Tyson A. Intent to get a COVID-19 vaccine rises to 60% as confidence in research and development process increases. Pew Research Center; 2020. Available at <https://www.pewresearch.org/science/2020/12/03/intent-to-get-a-covid-19-vaccine-rises-to-60-as-confidence-in-research-and-development-process-increases/>. Accessibility verified September 7, 2021.
- Loomba S, de Figueiredo A, Piatek SJ, de Graaf K, Larson HJ. Measuring the impact of COVID-19 vaccine misinformation on vaccination intent in the UK and USA. *Nat Hum Behav*. 2021;5(3):337–348.
- Rogers EM. *Diffusion of Innovations*, 5th ed. New York, NY: Free Press; 2003.
- Jones CL, Jensen JD, Scherr CL, Brown NR, Christy K, Weaver J. The Health Belief Model as an explanatory framework in communication research: Exploring parallel, serial, and moderated mediation. *Health Commun*. 2015;30(6):566–576.
- Young SD. *Stick with It: A Scientifically Proven Process for Changing Your Life-for Good*. New York, NY: Harper; 2017.
- Young SD. Recommendations for using online social networking technologies to reduce inaccurate online health information. *Online J Health Allied Sci*. 2011;10(2). Available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3196338/>
- Bode L, Vraga EK. In related news, that was wrong: The correction of misinformation through related stories functionality in social media. *J Commun*. 2015;65(4):619–638.

39. Roozenbeek J, van der Linden S. Fake news game confers psychological resistance against online misinformation. *Palgrave Commun.* 2019;5(1):1–10.
40. Hossain T, Logan IV RL, Ugarte A, Matsubara Y, Young S Singh S. COVIDLies: Detecting COVID-19 misinformation on social media. Proceedings of the 1st Workshop on NLP for COVID-19 (Part 2) at EMNLP 2020. EMNLP-NLP-COVID19; 2020, Online. doi: [10.18653/v1/2020.nlpCOVID19-2.11](https://doi.org/10.18653/v1/2020.nlpCOVID19-2.11).
41. Beard JR, Bloom DE. Towards a comprehensive public health response to population ageing. *Lancet.* 2015;385(9968):658–661. doi:[10.1016/S0140-6736\(14\)61461-6](https://doi.org/10.1016/S0140-6736(14)61461-6)
42. Miotto R, Wang F, Wang S, Jiang X, Dudley JT. Deep learning for healthcare: review, opportunities and challenges. *Brief Bioinform.* 2018;19(6):1236–1246. doi:[10.1093/bib/bbx044](https://doi.org/10.1093/bib/bbx044)
43. Abràmoff MD, Lavin PT, Birch M, Shah N, Folk JC. Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices. *NPJ Digit Med.* 2018;1:39.
44. Bell A, Rich A, Teng M, et al. Proactive advising: a machine learning driven approach to vaccine hesitancy. *2019 IEEE International Conference on Healthcare Informatics (ICHI)*. 2019;1–6. doi:[10.1109/ICHI.2019.8904616](https://doi.org/10.1109/ICHI.2019.8904616).
45. Oreskovic T, Tiljak KM. Proactive machine-learning-based approaches to vaccine hesitancy for a potential SARS-Cov-2 vaccine. *Eur J Public Health.* 2020;3(suppl 5):ckaa165.035. doi:[10.1093/eurpub/ckaa165.035](https://doi.org/10.1093/eurpub/ckaa165.035)
46. Ozoma I. Bringing authoritative vaccine results to Pinterest search. Pinterest Newsroom. Available at <https://newsroom.pinterest.com/en/post/bringing-authoritative-vaccine-results-to-pinterest-search>. Accessibility verified August 28, 2019.
47. Bickert M. Combatting vaccine misinformation. About Facebook. Available at <https://about.fb.com/news/2019/03/combating-vaccine-misinformation/>. Accessibility verified March 7, 2019.
48. Avaaz. Facebook's algorithm: a major threat to public health. Avaaz. Available at [https://secure.avaaz.org/campaign/en/facebook\\_threat\\_health/](https://secure.avaaz.org/campaign/en/facebook_threat_health/). Accessibility verified August 19, 2020.
49. Needleman SE. Facebook to remove Covid-19 vaccine misinformation from platforms. Wall Street Journal. Available at <https://www.wsj.com/articles/facebook-to-remove-covid-19-vaccine-misinformation-from-platforms-11607015562>. Accessibility verified December 3, 2020.
50. Culliford E, Dave P. YouTube bans coronavirus vaccine misinformation. Reuters. Available at <https://www.reuters.com/article/health-coronavirus-youtube-int-idUSKBN26Z21R>. Accessibility verified October 14, 2020.