SCIENCE AND HEALTH MISINFORMATION IN THE DIGITAL AGE:

How does it spread? Who is vulnerable? How do we fight it?

ERIC MERKLEY & PETER LOEWEN

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EXECUTIVE SUMMARY

Misinformation on science, technology and public health poses serious challenges to society, a situation magnified by rapid advancement in communications technology and development of online social networks. As enabling as these developments have been for the sharing and dissemination of credible information, the same is true of misinformation — and there is no silver bullet to address it.

Misinformation comes from a variety of sources, exploiting the tendency of many to fail to evaluate the veracity of information they are receiving and to prefer information aligned with their political beliefs. If it were benign, the prevalence of misinformation — and, similarly, fake news — could be dismissed, but exposure to misinformation is a cause of misperceptions among the general public that shape how people act politically.

Nowhere is that truer than in the context of public health. Misinformation has been particularly problematic in science, technology and health policy. It preys on people's predisposition to have strong, intuitive reactions to scientific advances, while having little knowledge base to accurately distinguish facts from falsehoods. Fueled by misinformation, many people endorse science-related beliefs that run counter to established scientific consensus, and they are less likely to heed the advice of scientists and medical experts as a result.

While the proliferation of misinformation and fake news appears low, there is little data that tracks its exposure and consumption. This report looks to answer three questions related to science communication and misinformation — How is misinformation spread? Who is most likely to fall prey to misinformation? How do we combat misinformation and its effects? — in part by highlighting case studies on climate change, vaccines and COVID-19.

Broadly speaking, there are three approaches to this problem: controlling its spread; correcting its effects through debunking (fact-checking) or persuasion; and pre-emptive interventions that allow the public to resist misinformation they encounter. With this in mind, five recommendations are presented:

Track misinformation and debunk when needed;	**Promote accuracy-focused messaging;**
Invest in targeted persuasion focusing on downstream behaviours;	**Build relationships with trusted community leaders;**
Start early to create digital literacy and interest in science.	

When taken in concert, these recommendations have the potential to mitigate the consequences of misinformation in science and public health.

INTRODUCTION

Society has long struggled with the spread of inaccurate or misleading information. However, rapid advancements in communications technology and the development of online networks have rapidly magnified this problem. As enabling as these developments have been for the sharing and dissemination of credible information, the same is true of misinformation.

Exposure to misinformation may increase political cynicism,[1] change voting patterns,[2] distort national debates on important questions[3] and potentially reinforce polarization and political dysfunction in much the same way as hyper-partisan news media.[4] At a minimum, misinformation is a cause of *misperceptions* among the general public — attitudes and beliefs that run counter to established facts.[5] Although scholars debate the degree to which people's misbeliefs about specific facts shape their fundamental attitudes towards politics or their support for political candidates, these misbeliefs can have important consequences in their own right.[6]

Fueled by misinformation, many people endorse science-related beliefs that run counter to established scientific consensus, for instance that climate change is real and human-caused,[7] or that technologies such as nuclear power or genetically modified organisms that add important medical interventions like vaccines and water fluoridation are fundamentally safe.[8]

These beliefs aren't benign. "Misinformation wouldn't be problematic if people didn't act on it. The problem is that misinformation shapes how people act politically," notes Matthew Motta, assistant professor of political science at Oklahoma State University.

And nowhere is that truer than in the context of public health, because "people who are misinformed are less likely to heed the advice of scientists and medical experts. They are less likely to take recommended health actions," explains Motta. Public health misperceptions may heighten people's reluctance to get themselves and their children vaccinated against preventable illnesses or to take other actions to protect the health of themselves and others.

This report synthesizes existing academic research and perspectives shared by academics and practitioners to answer three questions:

1. How is misinformation spread?
2. Who is most likely to fall prey to misinformation?
3. How do we combat misinformation and its effects?

In answering these questions, the report highlights three case studies of science communication and misinformation — climate change, vaccines and COVID-19. It concludes with recommendations for practitioners and government agencies to combat misinformation and its effects in science and health policy.

THE PREVALENCE AND SPREAD OF MISINFORMATION

Misinformation has always been a challenge in democratic politics, but technological changes over the past two decades have dramatically changed the landscape. Information — true and false — can spread far more rapidly, both top down from political elites and news media to the public and between citizens. The past decade has also seen the rise of what has been termed "fake news," where fabricated information is dressed up to look like legitimate news stories.[9]

The content of fake news, and misinformation more broadly, varies considerably, but issues of science and public health appear to be particularly vulnerable[10] — a point we will return to in the case studies.

Social media provides the primary means through which fake news spreads, as well as an avenue for the dissemination of misinformation more broadly.[11] Misinformation and fake news appear to spread comparatively quickly through social media channels due to the content's novelty and capacity to illicit emotional responses.[12] Once a preference for misinformation or fake news is established, recommendation algorithms may direct people to similar content and encourage people to travel down a "rabbit hole" of misinformation and fake news.[13]

Social media is a uniquely problematic vector of misinformation, but it is hardly the only source to be concerned about. Technological changes have fragmented the news media ecosystem, providing more choice to individual news consumers.[14] Mainstream news media increasingly compete with partisan news outlets that cater to people's well-established preference to read news that aligns with their political beliefs (i.e., selective exposure).[15] Partisan media offer more opinion-oriented content with less journalistic quality control, leading to the dissemination of misinformation, or at least exaggerated and misleading content. "A lot of partisan media content is clearly within the realm of misinformation," says Gordon Pennycook, assistant professor of behavioural science at the University of Regina.

So, how far and wide is the reach of misinformation? The good news is that it appears exposure to fake news is relatively low in the United States.[16] The story is likely even more positive in Canada. Although we have yet to have a systematic study of fake news here, the case of the 2019 federal election is instructive: A fake news outlet called the Buffalo Chronicle began to produce false news stories about Liberal party leader Justin Trudeau, sparking concern among observers about the growth of fake news in Canada. But in a sample of 750 people whose online media consumption was tracked over four weeks by the Digital Democracy Project (DDP), only one person ever visited the Buffalo Chronicle website over the period of tracking.[17]

Similarly, consumption of partisan news is lower than we might expect. A vast majority of Americans consume a broadly balanced news media diet, though there is a small and vocal minority who heavily consume news from partisan sources.[18] In Canada, partisan news media have virtually no foothold among the masses. DDP tracking found just one percent of their sample visited Rebel News at any point over four weeks, for example.[19] Canadians also trust and actively prefer news from mainstream rather than partisan sources.[20]

However, there are important limitations to these findings. Online tracking data is not available for representative samples of the public and it monitors only desktop browsers, when mobile devices account for [over 50 percent of total website traffic](). Data only track fake or partisan news links that respondents actively click on, leaving out information they are passively exposed to on social media.[21] Perhaps even more importantly, these studies evaluate people's engagement with fake or partisan news. But misinformation can be disseminated by social media users directly or by political elites, whose messages may be carried unchallenged by mainstream news outlets to maintain "balance."[22]

WHO FALLS PREY TO MISINFORMATION?

Misinformation would only emerge and spread if there was some demand for it. Identifying groups of citizens more inclined to believe and share misinformation is important. Academic research on this topic has advanced considerably over the last five years and a clear picture is beginning to emerge, even if the story is more nuanced than we might expect.

CONGENIAL POLITICAL BELIEFS

One set of factors making people vulnerable to misinformation is their political beliefs and identities.[23] Citizens are more inclined to believe and share misinformation when it aligns with their political commitments than when it does not.

Partisanship and ideology have been a dominant focus of inquiry, in part because of growing concern about political polarization in the United States. And we do see a lot of evidence that people are more likely to believe misinformation that aligns with their political orientation as a Republican or Democrat, liberal or conservative.[24]

Partisanship matters most when the misinformation in question targets salient partisan divides. This is not always the case. For example, although partisan divides on climate change are sizable in the United States and Canada,[25] this is less true in other countries.[26] Nor are there necessarily sharp partisan or ideological divides on other matters of scientific consensus, like the safety of genetically modified foods, water fluoridation or childhood vaccinations.[27] And while there is strong partisan and ideological polarization over all matters

related to COVID-19 in the United States,[28] this is not found to the same extent in other countries, including Canada.[29]

Partisanship is unlikely to motivate the uptake of misinformation when the issue or national context doesn't lend itself to partisan or ideological polarization. This is all to say that other political orientations can come into play when misinformation targets issues that aren't shaped by left-right or partisan politics, like populism,[30] conspiratorial ideation[31] and anti-intellectualism.[32]

The precise reason why we are more likely to believe and share misinformation aligned with our beliefs is still contested. Some scholars argue we are cognitively motivated to seek out and accept information that serves our political goals and identities, and this motivation crowds out our desire for accuracy.[33] We may believe and share misinformation when it serves our political goals.[34] Particularly important in this process is social identity, like partisanship, race or ethnicity, religion, and so on. People derive a lot of value from their membership in social groups, such as self-esteem and feelings of belonging.[35] These identities are often at the centre of political conflict, so citizens will be motivated to defend them.

But there is still sharp disagreement among scholars about whether the tendency to believe and share congenial content is because people's beliefs or identity bias them towards information that supports these beliefs and identities. The degree of alignment between prior beliefs and identities does not appear to make one any better or worse at discerning the veracity of information.[36] Rather, we more readily believe and share any information — regardless of its veracity — when it is aligned with our political commitments.

ANALYTICAL THINKING AND PRIOR KNOWLEDGE

Political beliefs may not make us any more or less accurate in our ability to discern true from false information. This capacity may instead be a product of our reasoning. People may be less able to discern misinformation from truthful information if they are engaging with information in an automatic and intuitive manner rather than being deliberate and analytical.[37]

Research has begun to accumulate on the importance of reasoning in explaining susceptibility to misinformation. It appears people who are more deliberate and reflective when they encounter information are better able to discern false headlines and news stories from what is truthful.[38] In all likelihood, this is because people are more likely to draw on their prior knowledge to determine veracity when being reflective — those with high levels of political knowledge and media literacy tend to do better at discerning true and false information.[39] The takeaway here is positive:

> **It may well be possible to combat misinformation by harnessing people's capacity to reason and the value they place on the truth.**

STRATEGIES FOR COMBATTING MISINFORMATION

Analyses of the causes of misinformation from both supply and demand perspectives has inspired subsequent research on strategies to combat misinformation. Broadly speaking, there are three approaches to this problem: controlling its spread; correcting its effects through debunking or persuasion; and pre-emptive interventions that allow citizens to resist misinformation they encounter. This section focuses on the latter two.

CORRECTIVE STRATEGIES — DEBUNKING OR FACT-CHECKING

Perhaps the most popular means of combatting misinformation is through fact-checking by journalists or dedicated fact-checking organizations such as snopes.com. There is considerable evidence that well-tailored fact-checks can help partially correct mistaken beliefs induced by misinformation.[40] What's more, these interventions are even successful among people who may be politically motivated to resist their implications,[41] and this is true of partisans in Canada as well.[42] Importantly, it also appears these interventions are at least somewhat durable, with effects lasting days or weeks.[43] Initially, it appeared fact-checks were prone to creating a "backfire effect" by increasing misperceptions among people who are politically resistant to the correction,[44] but more recent analysis has shown such reactions are rare and likely confined to those on extremely salient and identity-threatening issues.[45]

That doesn't mean there aren't limitations to fact-checking. "It was always going to be a Band-Aid, but still very important to do," remarks Pennycook. The effects of fact-checks are relatively durable, but they do fade over time, particularly in the face of misinformation from political elites who reinforce the original misperception.[46] Fact-checks also only ever partially correct misperceptions, and the effects of misinformation can persist for some even in the face of immediate and clear corrections — the "continued influence effect"[47] — with little evidence they actually influence downstream opinions on policy or support for politicians.[48] The promise of fact-checks to substantially weaken the intensity of partisan conflict by providing a shared sense of factual reality is minimal.

These reported downsides of fact-checks have been found in experiments by researchers, but there are also practical limits to fact-checks deployed in the real world. First and foremost is self-selection, says Pennycook. "The people who are most interested in (fact-checks) are the least in need of it." Fact-checking often requires people to opt into content. And even though fact-checks mostly work regardless of whether the content is politically helpful, people do seem to prefer to engage with and share fact-checks when they target political opponents (fact-checking selective exposure).[49]

Fact-checks have greater potential to address problems of misinformation if they can be scaled to reach wider audiences more consistently, but this also poses a challenge. It takes a lot of time and effort to research and refute a claim, while it takes very little effort to spread misinformation. "You can keep knocking them down (with fact-checking)," says Pennycook, "but more are just going to sprout up." Even in instances where it may be possible to attach warnings to social media posts flagged by fact-checkers, this practice could generate an implied-truth effect that makes people think content that isn't tagged is factual.[50]

In addition to these practical concerns, there are larger normative questions surrounding the practice of fact-checking. It is often difficult to establish what is true from what is clearly false. There are shades of grey, such as misleading or exaggerated claims, and large sets of other claims that arguably cannot be justifiably fact-checked, like predictions of future events, interpretations of specific facts or claims based on values or emotions.[51] It should then not be surprising that we see substantial variation across fact-checkers in the claims that are checked and their ultimate outcome.[52] A recent analysis of PolitiFact corrections shows a substantial number of fact-checks (33 percent) problematically applied a single truth rating to complex multidimensional claims, and 11 percent fact-checked claims whose truthfulness could not be established.[53] More research is needed on the quality and appropriateness of fact-checking in practice.

CORRECTIVE STRATEGIES — PERSUASION AND MESSAGE/MESSENGER MATCHING

There is another class of corrective approaches that stands out from fact-checking. It sees the problem of misinformation through the lens of politically motivated reasoning, which can be remedied through efforts at targeted persuasion or "message matching." All things being equal, people will be more persuaded by messages that appeal to their values and identities or that use messengers they trust.

"You need to make an effort to try to understand why it is that people reject scientific reality or consensus and use that to formulate persuasive messages," says Motta. Misinformation can be more readily debunked, or downstream attitudes and behaviours can be more easily changed, by breaking (or at least weakening) the link between these misperceptions, beliefs and behaviours on the one hand, and people's political commitments on the other.

Most research in this area has focused on message frames — the emphasis on certain aspects of an issue to change its interpreted connection to people's political beliefs. Conservatives and liberals tend to hold distinct moral foundations, with conservatives valuing moral purity, sanctity, authority and loyalty, while liberals value fairness and caring for others.[54] Messages that tap into these foundations can be persuasive to sympathetic ideologues[55] and potentially could dislodge misinformation.[56]

The persuasiveness of a message is also dependent on the communicator. People are persuaded by those they trust.[57] It is not surprising, then, that we see considerable evidence that people are persuaded by the political leaders they support[58] and are repelled by those they do not.[59] Misinformation can be more easily corrected by trusted political elites[60] and these sources — and others trusted by partisan groups — can also have influence on broader attitudes and downstream behaviours.[61] To date, studies of persuasion via framing or source cues have focused primarily on persuading ideological and partisan groups. More work is needed on targeted approaches for other sub-populations who may be prone to endorsing science and health misinformation.

Targeted persuasion appears to be effective in lab-based settings, but there are important limitations. "Scaling (message matching) up is really, really hard, because of the nature of what it is," says Motta. "It is something that is focused on a particular group of people who believe a particular thing," and "there are so many different reasons that people might not accept scientific reality, so you have to have lots and lots of different messages for lots and lots of different audiences." There is also the risk of producing backlash effects among non-targeted sub-populations with widely disseminated messages.

Message matching is also of limited utility in rebutting and challenging fast-changing science and health misinformation, though it could be effective in influencing the downstream behaviours and attitudes that matter most.

"We don't necessarily need to correct misinformation if we can change the behaviour. We might be able to get stronger bang for our buck if we say we think being misinformed leads to X, Y and Z behaviour," says Motta. "Let's put aside the challenge of getting people to accept the facts and instead say irrespective of how you feel about whether climate change is human-caused, can we get you to recycle? … We might be able to get more purchase there."

PRE-EMPTIVE STRATEGIES

Limits to correcting the effects of misinformation after the fact has spawned growing interest in finding ways to inoculate people against misinformation before it is even encountered. One avenue is to "pre-bunk" misinformation by correcting false claims in advance or highlighting tactics and strategies influencers use to spread these claims.[62] These interventions appear to be highly effective.[63] Researchers have gotten creative with inoculation, such as by creating an online fake news game via a smartphone app that gets people to act as a fake news creator.[64] However, challenges of scale and targeting remain. Their opt-in nature ensures these efforts will not readily reach sub-populations most in need of inoculation in practice.

There may be other types of less intensive interventions that can scale more easily to reach less engaged citizens. One promising avenue is to improve digital literacy and empower citizens to identify false information. One such intervention, conducted in India and the U.S. using a list of tips and tricks to identify false content, markedly improved people's ability to discern false from correct information.[65]

Also promising in the short term are interventions that get individuals to stop and consider the veracity of the story they are about to read or share. "We want to try to get ahead of things and change the way people make choices in the first place… because when people make choices about what to share on social media, they often don't even consider whether it is accurate," explains Pennycook.

 Experiments have shown that asking people to reflect on the news they are receiving[66] or to rate the accuracy of a headline can allow people to more accurately discern between true and false content.[67]

This strategy has been successfully deployed in a large field experiment on Twitter, so it has the potential to be implemented by social media companies.[68] Perhaps most importantly, these prompts can significantly improve the quality of information that is shared online as well, since sharing patterns under normal conditions — unlike beliefs — aren't driven principally by accuracy considerations.[69]

That being said, accuracy prompts have their limits. Getting people to consider the veracity of information only works insofar as "they would be able to identify that it is false or truth when they thought about it," says Pennycook. This might not be the case for less obvious forms of misinformation or for false claims disseminated by trusted communicators. "In cases where elite sources that are trusted make a claim, (accuracy nudges) may increase sharing… The nudge would not help mitigate the spread of (former U.S. president) Donald Trump's tweets, for example."

CASE STUDIES

Misinformation has been particularly problematic in science, technology and health policy. It exploits people's tendency to have strong, intuitive reactions to scientific advances, while having little knowledge base to accurately distinguish facts from falsehoods. Here we note challenges of misinformation in the context of climate change and vaccination. We then turn to a discussion of the challenges public health experts have faced over the COVID-19 pandemic.

CLIMATE CHANGE

One of the foremost challenges faced by society in the long term is climate change. It is also an issue that features one of the clearest examples of scientific consensus — that climate change is happening, is human-caused through the emission of greenhouse gases and is a serious threat to society and the environment in the medium and long term.[70] At the same time as this scientific consensus emerged, misinformation campaigns organized by conservative and fossil fuel interests, particularly in the United States, began to gather steam.[71] Claims around climate misinformation are numerous, but they typically question the trend (whether climate change is happening), blame (human-caused vs. natural) and the seriousness of the impact.[72]

The climate misinformation campaign occurred well before the advent of fake news and social media. Conservative political elites, fossil fuel interests, and contrarian scientists were able to disseminate their message through traditional news media, exploiting a tendency of journalists to provide balanced coverage.[73] It appears mainstream news media no longer partakes in such coverage,[74] but the rise of partisan media and social media has provided additional avenues for climate denialists to reach the public. Fox News, specifically, has consistently spread climate misinformation[75] and this may have accelerated in the last 10 years.[76] Messages from politicians and parties may have played an important role in facilitating polarization as partisan voters "followed the leader."[77] Misinformation from political elite sources (e.g., Republican political leaders) may have been comparatively more important in the climate change context compared to other areas of science communication.

Climate misinformation is a cause of misperceptions among the general public — that climate scientists disagree about the science of climate change or that climate change either isn't happening or isn't caused by the buildup of human-produced greenhouse gases. Experimental research has found that presenting contrarian scientific voices in an effort to "balance" those of mainstream climate scientists does indeed confuse people as to the state of the scientific consensus.[78] Another study found presenting people with a climate denialist video increased misinformation endorsement and even decreased reported willingness to engage in a number of pro-environmental behaviours, like willingness to sign a petition on climate change, by 10 percentage points,[79] though some other studies have found more limited effects.[80]

Complicating matters for policymakers is that the tendency to believe and disseminate climate misinformation is heavily shaped by political beliefs. There is a strong degree of political polarization in the climate context.[81] This is most apparent in the United States, where anywhere from 40 to 60 percent of Republican voters dispute the scientific consensus on climate change (depending on how it is measured).[82]

 But some degree of polarization is also evident in Canada, with 25 percent of Conservative partisans embracing climate denialism, compared to four percent of partisans of the Liberal party and NDP, as found in our Media Ecosystem Observatory polling.

Climate denialism is also stronger among those with anti-intellectual predispositions,[83] those who embrace hierarchical and individualist value orientations,[84] and those with lower levels of science literacy and analytical thinking (at least among those on the political left).[85]

Partisan polarization presents a serious obstacle in reaching cross-party consensus on the rather dramatic policy actions that need to be taken to sufficiently reduce greenhouse gas emissions. Consequently, a considerable amount of research has been undertaken on strategies to undo the effects of climate misinformation and polarization. These efforts have taken two forms. The first is informational corrections. Fact-checking appears to be effective at correcting specific pieces of misinformation. One study, for instance, found corrections of a false Trump claim that the polar ice caps are growing rather than melting to be effective, improving accuracy by approximately 10 percent across two studies. Accuracy improved even among Republican voters, although it was less effective among this group than among non-Republicans. However, this study also found the correction failed to influence overall beliefs about climate change,[86] consistent with broader research on the efficacy of fact-checking. Correcting the effects of specific pieces of climate misinformation may have only a limited effect on downstream attitudes and beliefs.

Even more promising are inoculation-based strategies that either explain the strategy behind climate denialism or highlight the scientific consensus on climate change to allow people to resist misinformation when they encounter it. These interventions appear to mitigate the effects of climate misinformation exposure, even among political conservatives.[87] For instance, one study found providing misinformation regarding the state of the scientific consensus on climate change reduced people's beliefs in its existence by nine percentage points. Providing contradictory information illustrating the consensus undid these effects, while providing this information with an inoculating message explaining the political tactics of climate denialists increased perceptions by 13 points above the initial baseline.

Relatedly, communicating messages about the scientific consensus of climate change appears to heighten support for the scientific consensus across partisan lines.[88] One experiment found providing consensus information heightened acceptance of the climate consensus by 10 percent and perceptions that scientists

have such a consensus by 31 percent,[89] though there remains some debate as to whether these cues backfire among Republicans[90] or other sub-groups in the public, like anti-intellectuals.[91]

"The question isn't whether or not (consensus messaging) can work. The question is for whom it works. If you don't trust scientists and medical experts, for example… you can tell people that experts agree until you are blue in the face, but if that's not a group you find credible, you're not going to accept that," argues Motta. More research is needed on the conditions under which scientific consensus can be persuasive or produce backlash effects.

The second dominant approach to correcting climate misinformation focuses on persuasive messages targeted at political conservatives. Some studies have found framing climate change in ways to make it or its policy solutions compatible with conservative values can enhance the persuasive appeal of pro-climate messages.[92] Others have found utilizing messengers who are trusted among conservatives — like Republican politicians,[93] evangelical scientists[94] or members of the military — can do the same.

 For instance, communicating climate change with a messenger in the military and as a national security concern, more than doubled the share of strong conservatives believing in the climate consensus, to 38 percent from 16 percent.[95]

These efforts have not been focused on countering specific pieces of misinformation, per se, rather they aim to heighten acceptance for climate change consensus and support for related policies.

A combination of debunking, inoculation and message matching approaches holds considerable promise in combating climate misinformation, but it remains difficult to scale these efforts to sufficiently combat the polarizing effects of political discourse on climate change found in the American and Canadian national contexts. Policymakers hoping to build consensus for climate mitigation policies should depoliticize the debate as much as possible, communicate the existence of scientific consensus alongside scientists, build relationships with trusted communicators in hesitant communities and frame messages in ways that are aligned with the values held by members of these communities.
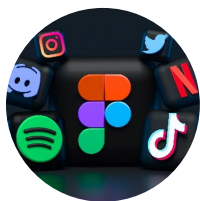
VACCINES

Another area of scientific and medical consensus that has been a frequent source of misinformation is vaccines, perhaps one of the greatest public health triumphs in history.[96] Successful vaccination campaigns, to a large degree, depend on people voluntarily consenting to vaccination for themselves or their children. Vaccine hesitancy, or a reluctance to get oneself or one's children vaccinated, poses grave public health risks by facilitating the spread of preventable illnesses.

Vaccine hesitancy and related streams of misinformation have a long history stretching back to the 1800s, when opposition in the form of anti-vaccination leagues emerged in response to smallpox vaccination campaigns.[97] Although, it does appear new life has been breathed into the anti-vaccination movement in recent decades, particularly after the release of Andrew Wakefield's fraudulent study alleging a link between the measles, mumps and rubella (MMR) vaccine and autism.[98]

Much like climate change misinformation, anti-vaccine content typically makes heavy use of pseudoscientific claims to cast doubt on the safety of vaccines, such as by alleging links of vaccines to autism, multiple sclerosis and diabetes or the presence of toxic contaminants like mercury.[99] These claims tend to be wrapped in anti-intellectual and conspiratorial themes.[100] Scholars have also shown experimentally that vaccine misinformation can heighten misperceptions about vaccines along with vaccine hesitancy.[101] One study found exposing people to an anti-vaccine conspiracy theory increased endorsement of the belief by 21 percent and reduced vaccination intention by 13 percent.[102] Misinformation on the safety and efficacy of vaccines may fuel hesitancy and put lives at unnecessary risk.

The good news for policymakers is that the issue of vaccines, unlike climate change, has not been nearly as politically fraught, leaving room for cross-partisan consensus. There is a relative absence of strong partisan or ideological polarization on these questions among the masses.[103] According to public opinion tracking by the Media Ecosystem Observatory, there is no difference between Conservative partisans and Liberal, NDP or Green partisans in their disagreement with the notion that vaccines cause autism. However, polarization may be emerging in the United States with some evidence of growing anti-vaccine sentiment on the political right.[104] Further, an overwhelming majority of mainstream news content also accurately reflects scientific consensus on vaccination, even if journalists do not clearly articulate the nature of that consensus as often as we might like.[105] The ground is not fertile for the mainstreaming of anti-vaccine sentiment and misinformation.

The relative absence of vaccine misinformation carried by political elites or mainstream news sources has magnified the importance of the internet and social media in facilitating its spread.

Facebook, Twitter and YouTube all facilitate access to vaccine misinformation,[106] as do internet search browsers like Google that elevate anti-vaccine content when people use even innocuous search terms.[107] However, overall exposure to vaccine misinformation online is still relatively limited, representing only eight percent of vaccine-related page views and reaching only 18 percent of people annually. As with other forms of misinformation, its consumption is highly concentrated among people who are already sympathetic to the misinformation — those who are skeptical of vaccines.[108]

Research on correcting vaccine misperceptions and reducing vaccine hesitancy is not as rich as with climate change. There is some evidence that informational corrections, like fact-checks, work as intended in correcting

misperceptions about vaccines.[109] In one experiment, the share of people strongly agreeing that vaccines cause autism drops to five percent from nine percent for those who receive a fact-check.[110] However, it also found these corrections actually reduce willingness to vaccinate among those who are skeptical of vaccines,[111] though others find no such effect.[112] At best, correcting vaccine misinformation doesn't appear to dampen hesitancy, which is key given its public health consequences.

Clearly communicating the scientific consensus on vaccines also appears to heighten support for vaccines in much the same way it does for climate change. Providing consensus information reduced endorsement of the vaccine-autism link by 45 percent and heightened support for vaccines by 12 percent, though this study did not examine the effects on vaccine intention.[113] Greater communication of the scientific consensus on the safety and efficacy of vaccines offers a potential way to combat vaccine misinformation, especially since this information is not as robustly communicated as it is with climate change.[114]

There is also new evidence that persuasive messages targeted at vaccine-hesitant groups, such as those who value moral purity (i.e., conservatives) and those who have needle sensitivity, can reduce misinformation endorsement.[115] "Rather than trying to tell people, 'Hey you're wrong about vaccines, they are effective and here's why,'… we instead say, 'Look, we totally get it. Vaccines are a violation of bodily purity on some level. You know what else is a violation of bodily purity? Measles, mumps and rubella.' And when we tell people that, we find they are more likely to reject the misinformation," explains Motta. However, analysis has not been done on whether these interventions can have downstream effects on reducing vaccine hesitancy. The effectiveness of targeted messages or messengers at vaccine-hesitant sub-populations deserves further analysis.

COVID-19

The COVID-19 pandemic has also brought problems of misinformation to the forefront, but with a host of added complications. Unlike with climate change and well-established vaccines, the science of COVID-19 is continuously evolving. "People think that science is set in stone; it is finite and clear and it has been established over time," explains an assistant deputy minister responsible for pandemic response in a provincial government. "People's frustration with the pandemic is that everything keeps changing. It's exhausting… It's happening in real time, but people want to know the answers, and the answers aren't already there."

Not only does the public demand immediate answers to difficult questions, but so do journalists. "You have to come up with something to say because you are going to get asked about it all the time. You can't say, just hold off and we'll come back to you in two weeks with an answer, so it forces you to come out with these hypotheses," says the ADM. "You are at the beginning of your research, and you don't have the luxury of waiting until it's set in stone." The result is confusion amidst a public that wants answers.

The uncertainty and anxiety fostered by the pandemic is a breeding ground for misinformation and conspiracy theories, such as COVID-19 was manufactured in a lab as a weapon by China or the U.S., or that it is being transmitted with 5G technology. There are other conspiracy theories related to COVID-19 vaccines, such as the presence of microchips to facilitate tracking by Microsoft co-founder Bill Gates, or that there was always a vaccine for COVID-19 hidden by pharmaceutical companies and government. Perhaps most prominent is the conspiracy theory that the threat posed by the pandemic is greatly exaggerated.[116] Other forms of misinformation can be more accurately characterized as rumours or medical folk wisdom, like the potential for high temperatures, homeopathic remedies or Vitamin C to cure COVID-19.[117]

Exposure to this misinformation increases misperceptions about COVID-19. This would not be concerning on its own were it not for the reality that these mistaken beliefs are strongly linked to self-reported failure to comply with important public health guidelines such as social distancing, mask wearing and vaccination.

A study by the Media Ecosystem Observatory found people who endorsed eight COVID-19 misbeliefs scored 45 percent lower on their social-distancing compliance than those who endorsed none of them.[118] COVID-19 misinformation puts people's lives at risk.

Misinformation is particularly prevalent on social media channels such as Twitter. Social media "creates certain pockets of people who are anti-maskers, who are anti-vaxxers…[their perspectives] start to compete with the single source of truth," explains the ADM. The Media Ecosystem Observatory study indeed found that discussion positively comparing the effects of COVID-19 to the seasonal flu, for example, was more than four times higher on Twitter than in mainstream news.[119] Consequently, it appears that frequent social media users in Canada are twice as likely to endorse misinformation related to COVID-19 than those who do not use social media at all, and they self-report social-distancing compliance 15 percent lower than non-users.[120] This has also been found in the United Kingdom.[121]

A particular Canadian vulnerability to misinformation about COVID-19 may be our cultural and physical proximity to the United States. COVID-19 misinformation has been trafficked by political elites and partisan media in the United States (but not by Canadian politicians)[122] and reinforced by partisan media.[123] Social media provides a gateway through which Canadians can be influenced by American political dynamics.[124]

More than half of misinformation-focused retweets are of U.S. accounts, compared to 39 percent from other Canadians. Canadians who follow more American accounts also tend to tweet more misinformation-related content, and those who are more exposed to U.S. news content are more likely to harbour COVID-19 misperceptions, especially those who intensely use social media.[125] Social media can combine with elite-sponsored misinformation to mislead the general public.

These processes don't stop at national borders; science communicators face a daunting challenge of competing with the noise coming from south of the border.

COVID-19 misinformation endorsement has polarized across partisan and ideological lines, but the extent to which this is true varies cross-nationally. Political conservatives are typically more inclined to endorse COVID-19 misperceptions in the United States.[126] They are also far less inclined to express concern about COVID-19 and follow public health recommendations.[127] The same appears to be true of those harbouring populist predispositions.[128] The link between ideology and COVID-19 misinformation endorsement is less true in Canada, where anti-intellectualism — or distrust in experts — appears to be more central in shaping COVID-19 misinformation endorsement, risk perceptions and compliance with public health guidelines.[129]

Analytical thinking and prior knowledge also seem to be important factors in shaping COVID-19 misinformation endorsement. People who are more prone to reasoning in a more deliberate and rational manner and those who have higher levels of science literacy or numeracy are less likely to endorse COVID-19 misinformation.[130] These individuals are also more likely to be able to resist misinformation found on social media. The linkage between Facebook usage and misinformation endorsement does not exist among individuals who are likely to carefully and deliberately evaluate new information.[131]

Research on combatting the effects of COVID-19 misinformation is less developed than on climate change and vaccines owing to the novelty of the issue, but some of the same mechanisms of correcting and countering misinformation have shown promise. Fact-checks appear to reduce demand for misinformation and its promotion.[132]

Brief prompts that encourage people to consider the accuracy of non-COVID-related headlines have been shown to triple people's ability to discern false from true headlines.[133] However, other work has shown that asking people to think carefully about the logic of conspiracy theories actually increases their acceptance.[134] More research is needed on how the conditions under which people deliberate and reflect increase or reduce COVID-19 misinformation endorsement.

Researchers at the University of Cambridge have also created a fake news game called GoViral! geared towards allowing people to identify and discount COVID-19 misinformation. It is modelled after a similar game for political misinformation that has been found to reduce the perceived reliability of fake news by 21 percent with effects lasting at least three months.[135] The results of the COVID-19 version of the inoculation game have not yet been released. Ultimately, more research is needed on the effectiveness of fact-checking, accuracy primes, inoculation and message matching in reducing misinformation endorsement in the COVID-19 context.

RECOMMENDATIONS

Misinformation on science, technology and public health poses serious challenges moving forward. The above discussion has made clear there is no silver bullet to addressing misinformation. It comes from a variety of different sources, exploiting the tendency of many to not carefully evaluate the veracity of the information they are receiving and to prefer information aligned with their political beliefs. With this in mind, we provide five recommendations that, when taken in concert, have the potential to mitigate the consequences of misinformation in science and public health.

1. Track misinformation and debunk when needed

Public health organizations need to partner with social scientists or build in-house capacity to monitor misinformation on social media and web pages. "Debunking every rumour, every conspiracy theory and all political punditry exhausts critical resources… (Instead), 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."[136] The aim should be to identify claims that are becoming viral so as not to elevate those with low levels of public exposure. Efforts should be made to extend debunking in the mainstream press in partnership with journalists and in online advertising to reach larger numbers of citizens.

2. Accuracy-focused messaging

Health misinformation is a moving target. It is impossible to debunk every false claim found online. "The one benefit of the accuracy prime is that it is easy to slip it into your messaging: a focus on the truth," explains Pennycook. "We can take advantage of the fact that people do care about the truth." People might just not be sufficiently motivated towards accuracy while browsing online. Public health organizations should provoke citizens to think about the accuracy of the information they are receiving online and offline in their messaging and advertising. This can allow citizens to resist misinformation whenever they find it.

3. Targeted persuasion focusing on downstream behaviours

Public health agencies should invest resources — either in-house or in partnership with social scientists — in understanding why exactly people believe health misinformation or resist certain recommended health behaviours. "The first thing to do is to conduct public opinion research that is focused on understanding why people are misinformed… Why are people telling us they hold positions that are inconsistent with scientific consensus," says Motta. "Then the second step is to create messages that attempt to recognize those concerns and leverage them into a communication approach that encourages people to vaccinate and to take protective health actions, not even necessarily by correcting misinformation." The aim here should be to break the link between certain political predispositions and misinformation, or rejection of public health recommendations, by finding message frames and messengers who appeal to people in these sub-

populations. It may make the most sense to focus on targeting persuasion to change downstream behaviour (e.g., vaccination) rather than on countering specific pieces of misinformation (e.g., there is no microchip in the COVID-19 vaccines), since corrective approaches appear to have only limited effects on downstream attitudes and behaviours.

4. Build relationships with trusted community leaders

Sub-populations resistant to public health messages and who embrace related misinformation often have lower levels of trust in science and expertise. Scientific facts and appeals to the authority of scientists and doctors are unlikely to be effective for these individuals. Public health organizations should build relationships with trusted community leaders, potentially exposing them to inoculating information so that they persuade others in their social network. "It has to be done at a local community level," argues an assistant deputy minister responsible for pandemic response in a provincial government. "You have to get those influencers. You have to understand who is influencing those beliefs. Is it a faith leader? Is it a community leader? Who has influence over this group or individual that could counter the misinformation that they are getting on social media?" Not all learning about science and politics occurs from the top down. Bottom-up approaches can be effective as well by harnessing the power of trusted messengers.

5. Start early

The previous recommendations are all focused on countering health misinformation at the present, but public health organizations and governments need to have an eye to the future as well. "If part of the problem is that people don't tend to… embrace analytical cognitive styles, it implies you need to encourage people to embrace that type of thinking during impressionable years when they are formulating their cognitive styles," argues Motta. Digital literacy and interest in (and curiosity about) science appears to build resistance to misinformation. Efforts need to be made in childhood education to prepare future democratic citizens for a digital world and the misinformation and disinformation that inevitably comes with it.

ENDNOTES

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