

INVITED ARTICLE

Trustworthy maps

Amy L. Griffin

School of Science, RMIT University, Australia

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Abstract: Maps get used for decision making about the world’s most pressing problems (e.g., climate change, refugee crises, biodiversity loss, rising inequality, pandemic disease). Although maps have historically been a trusted source of information, changes in society (e.g., lower levels of trust in decision makers) and in mapmaking technologies and practices (e.g., anyone can now make their own maps) mean that we need to spend some time thinking about how, when, and why people trust maps and mapmaking processes. This is critically important if we want stakeholders to engage constructively with the information we present in maps, because they are unlikely to do so if they do not trust what they see. Here I outline three questions about trust and maps that I think need research attention. First, how can we focus map readers’ attention on the trustworthiness of mapped data, especially if trustworthiness changes as in the case of real-time data sources? Second, does presenting uncertainty information on maps affect the level of trust map readers have in the map, and if so, does trust vary depending on how the uncertainty information is presented? Finally, how does virality affect trust? Are viral maps less trusted? The time and resources required to develop a better understanding of how trust in maps might be changing will be repaid. The world needs good information to guide policy- and decision-making. Well designed maps can help stakeholders to work together to solve problems, but only if they are trusted.

Keywords: trust, maps, mapping, visualization, COVID-19

1 Introduction

As the decade turned to the 2020s it has sometimes seemed that the number of the world’s critical and pressing problems is increasing. Climate change, refugee crises, biodiversity loss, rising inequality, and pandemic disease all come immediately to mind. None of these problems is solely local (though their impacts vary locally), and addressing them requires an understanding of processes and interactions across multiple scales involving actions by many different stakeholders who often have different agendas. There is a sense that these

problems, some of which are longstanding, are more intractable than ever. They are made more challenging by developments in the political sphere that have left citizens trusting their governments less than they used to [7, 26, 34], and many individuals feel incapable of contributing to change, leading to disengagement [36]. After being asked to write this vision piece, I have been thinking about how spatial information science research, and in particular, research on cartography and visualization, can contribute to solving these important problems and building a healthier, more equitable planet.

Maps get used for supporting public and private discussions about problems. They have historically been a trusted source of information despite the fact that no single map ever tells the whole truth [21, 22]. Maps are perhaps undeservedly trusted given that they are usually made to serve their maker's interests, as has been convincingly argued by Denis Wood and other critical cartographers [5, 45, 46]. But changes in mapmaking technologies and in the availability of spatial data have widened who is able to make maps, and anyone with access to the Internet and a basic computer can now make maps to serve their own interests, whatever they may be. Fast forward ten years into the future and we may find that many maps are not even made by humans, but by bots. These trends, combined with the "post-truth" politics practiced in a growing number of countries may mean that people will trust maps less than they have historically.

Which maps should we trust when we use them to explore problems and enact change in the world? The answer to this question is more unclear than ever, other than perhaps to say that the map you can trust the most is the one you made yourself, assuming you have some awareness of your own potential blind spots and are an informed consumer of spatial information who can evaluate the quality of the data you are using to make your map. Therefore, a theme that I think needs much more research attention and focus in the coming years is trust, specifically understanding how, when, and why people trust maps and mapping processes. If we want stakeholders to engage constructively with the information we present in maps, they first need to trust what they see.

One place that we probably need to start is by considering what the concept of trust means in the context of maps and mapping. Do we trust information because we know it is true? Because it is reliable? Because it fits our world view? Must it be all of these things to be trustworthy? Space precludes a full exploration of how we might conceptualize trust in the context of maps here in this piece, but it is a question that also requires some research thinking and attention. In the remainder of this piece, I highlight a number of specific aspects of maps and trust that I believe need further research and I illustrate how they are exemplified in maps of a current global challenge, the COVID-19 pandemic.

2 Trust: which information?

A fundamental decision when creating any map is the choice of which source of information to use. Pre-Internet, spatial information was (relatively) hard to come by.¹ It was often held closely in government departments or had to be painstakingly compiled by hand. Some of the authority map readers ascribe to maps probably derives from this historical information asymmetry. Developments in communication and computing technology have, of course, greatly reduced the friction of compiling and distributing many sources of spa-

¹I acknowledge that in some locations or for some topics, information is still difficult to obtain. Nevertheless, there has been a marked increase in the availability of mappable data in the last two decades.

tial data. This has simultaneously put pressure on governments to open up their data to citizens—witness the growth of open data initiatives [18]—and made it easier for groups of citizens to coordinate and compile their own data when authorities either did not hold it or were unwilling to release it at an affordable price, if at all (e.g., [25]). Journalists, likewise, have been impacted by these developments because their trusted role as the suppliers of the authoritative version of an event can also now be more easily challenged by individuals who have their own data [40]. Crowd-sourcing capabilities and the capacity for those who have not traditionally been considered to be information gatekeepers to compile their own spatial information that may challenge the perspectives of those in positions of power is perhaps even more important than it otherwise might have been given the commonplace practice today of establishing a “single source of truth” about a particular phenomenon within many government agencies and corporate organizations.

As a map reader, being capable of critically interrogating a map to understand the extent to which its information can be trusted is more important than ever. There are now multiple sources of spatial information about many phenomena, usually generated using different methodologies, with impacts on the datasets’ quality and trustability [10]. Although crowdsourcing efforts have increased the availability of data, they also bring new challenges to selecting trustable data, such as differing levels of skill among data compilers [14, 27, 51] and problems such as digital vandalism [1]. Lush et al. [19] present one approach to communicating the trustworthiness of spatial data through a GEO label approach that borrows from eCommerce trust triggers. Their evaluation of the labels was limited to spatial data experts rather than non-expert users. However, other research suggests that this approach could perhaps be successful for non-experts. In a study of non-expert web GIS users, Skarlatidou et al. [32] found that participants focused on interface design elements rather than metadata when judging whether data in a web GIS were trustable, reconfirming that when relevant elements are not perceptually salient, visualisation users can make incorrect inferences about information [8]. Lush et al.’s GEO label approach might make the metadata-derived information salient enough that non-expert users pay attention to it.

Many datasets are now being generated by automated sensors or machines, presenting additional challenges for understanding their trustworthiness. For example, Crampton et al. [6] identified observations generated by bot activity within their geosocial dataset, and it is likely that we will see increasing levels of non-human actants generating data that describe human activities. Even when they measure accurately, sensors are not always trustworthy sources of information, as a recent performance art project highlighted when a Berlin artist was able to alter the traffic congestion levels displayed in Google Maps (and the consequent routing of vehicles through that part of the city) when he dragged a wagon filled with 99 smartphones running the Google Maps app through the city’s streets [42]. With growing use of real-time data on maps, trustworthiness will be a dynamic property of data, making it even more challenging to evaluate as a data consumer.

We will need to find ways of communicating about the trustworthiness of datasets that work for both mapmakers and map readers and that account for dynamic trustworthiness when we use real-time data.

3 Trust: communicating uncertainty?

Trustworthiness is not only a property of the whole dataset, but can vary spatially across a dataset. Moreover, even with a generally trustworthy dataset, there are limits to the level of trust a map reader should place in the map because of uncertainty in the information. Knowledge of uncertainty associated with particular pieces of information helps the map reader to answer the question of how much trust to put in that information.

Many researchers believe that communicating uncertainty information to map readers will help them to make more effective and accurate use of the information and increase their trust in science and/or the data producer [30]. Significant amounts of research effort have been directed to developing and testing methods for visually representing uncertainty in maps and in other types of information graphics (see [16] for a recent review of this work). There have also been numerous studies that focused on decision making with uncertain spatial information (see [15] for a recent review).

However, there has been little empirical study directed to how judgements of trust derived from uncertainty representations propagate further into the map reader's decision-making process. Much of the research that has been conducted on uncertainty and decision making with maps relies on indirect measurements such as decision confidence [15]. Only a few studies have examined trust directly. This trust-focused work has aimed to understand the extent to which analysts trust visual analytics applications and considered how uncertainty propagates through visual analytics workflows during an analysis [29]. The authors suggested that building trust in an outcome (i.e., the mapped results of an analysis) might first require building trust in the analysis system that produced the outcome.

An audience of visual analytics application users can be expected to have a reasonable amount of knowledge about different types of uncertainty and how uncertainty might influence the quality of inferences in analytical reasoning processes. Less is known about whether representing uncertainty is helpful and whether it increases or decreases trust in the information among audiences who have less technical knowledge about uncertainty, such as members of the general public. An intriguing finding from a recent study suggests that, at least in some cases, showing uncertainty to non-experts might decrease their trust in information that is critical to making a good decision [17]. This study found that participants were more likely to choose to buy a house in a zone at high risk of a natural hazard when uncertainty information was depicted, perhaps because they reasoned that the zone might be less at risk because the risk information was uncertain. In other decision-making contexts, at least some evidence from other fields indicates that knowledge of uncertainty can be paralyzing and can lead to inaction [20]. Therefore we must ask whether presenting uncertainty information is even beneficial in all contexts.

An urgent question therefore that needs answering is whether and how presenting uncertainty information affects the level of trust map readers have in the mapped information.

4 Trust: viral maps

Fake news, deep fakes, and social media posts generated by troll farms have become prominent topics of conversation in the news media and academic circles, if not in everyday life. Few studies have been carried out to examine the extent to which maps have been participants in modern misinformation attempts. Given their long history of use as propaganda

tools [33] and the fact that they are often attention grabbing, we should suspect that maps also are being used for misinformation in these new media and platforms. Robinson [28] demonstrated one approach that might help to unearth the provenance of maps that go viral. He suggests, for example, that image matching using machine learning platforms such as Google Cloud Vision together with URL tracing could be used to identify bot-promoted maps that have been disseminated while attempting to conceal their origins or promoters. Journalism desks are experimenting with artificial-intelligence-generated news stories [39], and it's likely that we will also see maps made by bots in the not too distant future. While even recent efforts (e.g., [12]) have limitations or are targeted primarily to improving upstream map design processes like updating map data (e.g., [4]), the technology will inevitably continue to improve.² How much should we trust a machine-generated map? This is an open question that is yet to be answered.

A study of persuasive online maps found that a large proportion of maps in the study sample adopted the authoritative rhetorical style, which tended to promote trust in the map [24]. Shannon and Walker [31] argued but did not empirically demonstrate that the cultural authority ascribed to maps through their presumed scientific objectivity can help viral maps to be perceived as being more legitimate than other viral content. However, their interactions with readers of their own viral maps also demonstrated skepticism and mistrust among map readers when what they saw in the map did not match their own lived experiences, whether that mismatch was due on the one hand to the mapmaker's use of messy data to create a map very quickly, or on the other hand, to the map reader's misinterpretation of what the dot locations represent on a dot density map. An important research need is empirical work to understand the extent to which viral maps remain trustworthy among readers as well as how design decisions might modify these perceptions of trustworthiness [28].

Muehlenhaus [24] argued that the easy sharing of maps through social media makes it more important than ever before to educate map readers to be critical consumers of visual media. Sharing maps can take them out of their original context, causing misinterpretation, as in the recent example of readers inferring that the entire continent of Australia was simultaneously on fire, not realizing that they were looking at a screenshot from a temporal composite of fire hotspots [9]. Cartographers can help prevent misinterpretation by considering how to more transparently communicate how the map was constructed [13]. Harley first urged cartographers to do this back in 1991, but it may be that threat posed by deep fakes and other forms of misinformation to the perception that maps are trustworthy will be what finally motivates practicing professional cartographers to engage with his call for an ethically informed cartography when the more benign, common problem of a map being viewed outside of its original context has not. Even if such an effort is successful, there remains the challenge that Web 2.0 environments enable those without formal cartographic training to make maps, also raising the question of how to build community norms about ethical practice among mapmakers who may not realise the ethical implications of their maps [35].

²There have been periodic waves of scientific effort directed to developing systems that can replace human cartographers. Despite a rash of work in the 1980s and early 1990s, no expert system has yet caught on widely. Contemporary artificial intelligence techniques show more promise.

5 A brief illustration using maps of COVID-19

A current global challenge the world is grappling with is the pandemic sparked by the novel coronavirus. Contagious infectious diseases are inherently geographical phenomena because the movement of people greatly influences how they spread. For that reason, maps are being used extensively for purposes ranging from planning where to deploy medical resources to communicating with citizens about the risks of the situation to understanding where the disease might spread next at a given point in time. In this section, I examine a selection of recent coronavirus maps to illustrate how a better understanding of the three dimensions of trust I outlined above could help us to make better maps.

There are many maps of coronavirus case or death counts and/or rates. If one does a Google search on “coronavirus map”, the first result is a map from Wikipedia (Figure 1). The dataset underpinning this map also comes from Wikipedia, and is a mashup of sources of highly varied levels of authority and reliability. Wikipedia, moreover, can be edited by anyone, so the data quality can vary depending on who has contributed the edit, their knowledge of reliable sources, and (sometimes) on their politics or other motivations. In fact, when inspecting the edit history for the Wikipedia page whose information is fed into this map, it was not hard to find one such instance (Figure 2). Although any errors or edits made with political or mischievous motivations may be corrected quickly by other editors, anyone inspecting the map at a particular point in time may be looking at unreliable information, meaning that the trustworthiness of the information as well as the information itself varies dynamically.

If one accepts that Wikipedia’s data may not be sufficiently trustworthy, where can one find more authoritative, if slightly less timely, data? Figure 3 is a map published by the World Health Organization (WHO). Although it may also suffer from data quality issues such as different data reporting practices in different countries, it only includes cases that meet the WHO case definition, a data quality standard set by the WHO [48].



Coronavirus (COVID-19) map

Updated less than 30 minutes ago

Worldwide ▾

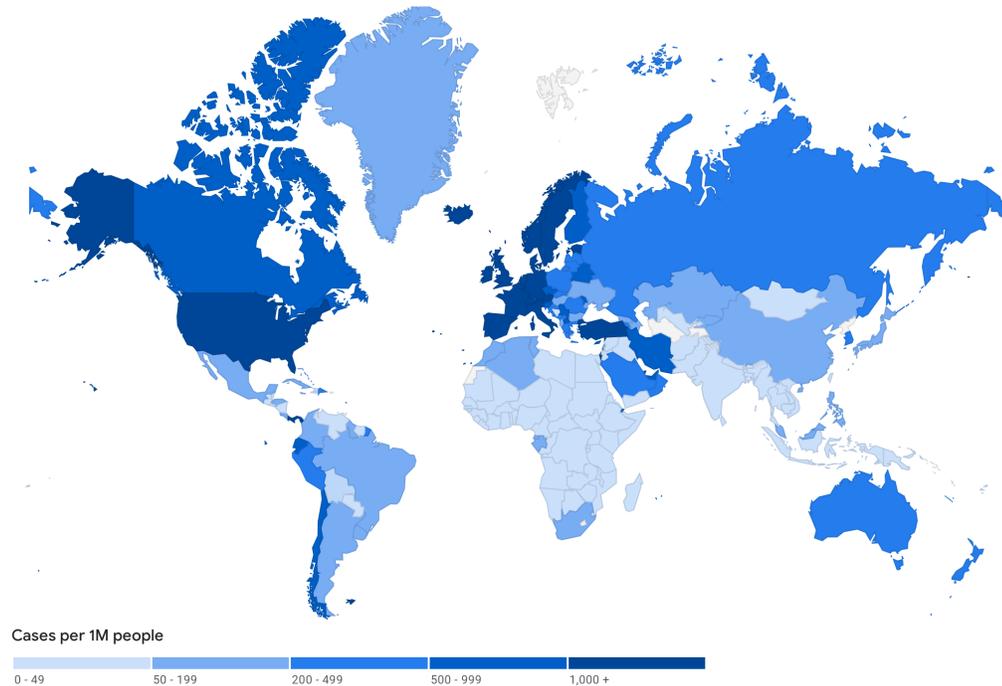


Figure 1: Wikipedia's COVID-19 map on 20 April 2020 [43].

Template:2019–20 coronavirus outbreak data [edit]

This edit is clearly politically motivated. I understand that you don't want Taiwan to be grouped with China, but that is not a valid reason for you change it. BNO news is the core source for all countries on the template except China, because there are two (sometimes only one) main sources just for China. The reason why Taiwan is group with China right now is because BNO News hasn't updated yet to include the latest numbers in Taiwan (39 cases, 9 recoveries). The Chinese source stays on the page permanently, so if it has the latest numbers for Taiwan (which it does), we'll use it as the source for Taiwan as well, instead of having a separate source. This is the case with Hong Kong and Macau, too. So it's not because "Chinese news agencies do not have faster information updates on Taiwan compared to Taiwan CDC", it's just for convenience, saving space and reducing unnecessary clutter. *Hayman30* (talk) 04:23, 1 March 2020 (UTC)

@Hayman30: Your complaint here was overturned later it seems. For future reference, I would say that you ought not group territories with hostile military forces in a list together like that. *Geographyinitiative* (talk) 12:12, 4 April 2020 (UTC)

Figure 2: Edit history documenting discussion about two politically motivated edits to COVID-19 figures (one edit, later overturned) [44].



Figure 3: World Health Organization's Map of COVID-19 cases on 20 April 2020 [47].

In the early stages of a pandemic, particularly when the organism causing the pandemic is novel (i.e., not known to human immune systems), many things are unknown and uncertain. For example, although we can count the number of people displaying clinical signs and symptoms, we do not currently know what proportion of all infected persons are asymptomatic carriers of the virus and therefore do not present themselves to the healthcare system. Thus widespread testing is critical for answering questions like “what is the infection rate” or “what is the case fatality rate?” Without knowing the total number of infected persons, any estimate of these rates will be uncertain. Moreover, testing rates vary geographically, meaning the uncertainty associated with the rates also varies geographically. Good knowledge of both these rates is important for monitoring the success of intervention strategies.

To provide a truthful picture of the level of certainty associated with infection rates—they are more certain when more tests are being done on a per capita basis—maps of cases

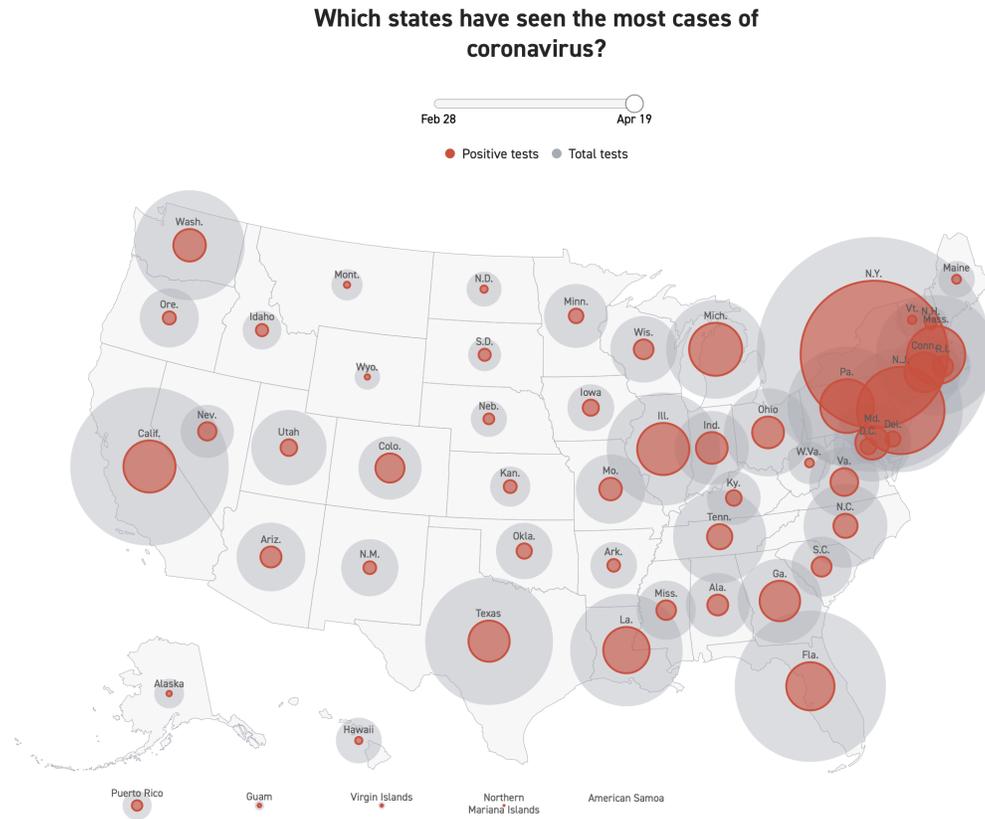


Figure 4: Screenshot of an interactive map comparing numbers of cases and tests in the U.S. on 20 April 2020, published on Politico Magazine’s website [11].

should also include information about testing rates.³ Yet despite the information being available [49], few mapmakers are making maps that represent or otherwise account for testing levels. Figure 4 is an example of a map that does. This map provides an implicit representation of uncertainty, which must be inferred from a comparison of the two counts plus knowledge of the state’s population, which is not represented on the map. I was unable to find any examples of COVID-19-related maps that explicitly represented uncertainty. Although the benefit of helping public health decision makers understand the limitations of mapped data is clear, perhaps some mapmakers believe that the public will not understand data uncertainty if it is shown on the map or that they may trust the map less if uncertainty is acknowledged. There has not been much direct study of whether the

³There is the additional issue of the quality of information being reported by different state or national public health authorities, which varies. For some discussion of this point related to data from the United States, see the Covid Tracking Project’s website [37]. The website also provides advice on visualizing the project’s data and includes clear directives: “include the denominator” and “don’t ignore data uncertainty” [38].

public will trust maps less if uncertainty is represented in them, but a recent study that included verbal and numeric descriptions of uncertainty associated with data demonstrated that there was only a very small decrease in trust when uncertainty information was provided, and that numeric descriptions decreased levels of trust less than verbal descriptions did [41].

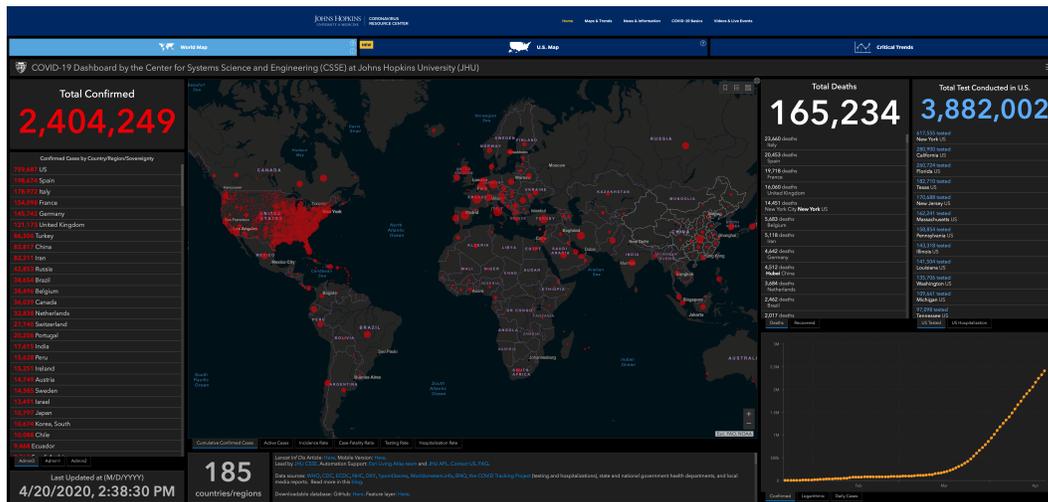


Figure 5: Screenshot from Johns Hopkins University’s COVID-19 Dashboard, a map of the pandemic that went viral [3].

Maps of COVID-19 are everywhere. They appear in blogs, are published by mapping companies and academics, and appear in newspapers and other periodicals. Some of these maps could be described as having gone viral. It’s not clear whether the Johns Hopkins COVID-19 Dashboard (Figure 5) circulated so widely simply because it was one of the first maps of COVID-19 to be published (it was first published on 22 January 2020) or because, at least to Western eyes, its color choices connote danger and urgency: a black background and saturated red symbols.⁴ Nevertheless, its design is emotionally arousing, especially in comparison with the rather staid, neutral appearance of the WHO map (Figure 3), which perhaps epitomizes the authoritative style that Muehlenhaus [23] described in his study of rhetorical styles and persuasive geocommunication. It’s possible the COVID-19 dashboard appears authoritative because it is a dashboard, and despite its use of strong colors rather than the more neutral palette that is typical in the authoritative rhetorical style. Another map that went viral first appeared in a tweet from a UK research team that modeled the movement of travellers from Wuhan. The tweeted map was misinterpreted by many news outlets, beginning with an Australian television broadcast, from which it was shared more than seven million times [2]. The news report described the map as showing locations to which residents of Wuhan had fled. In fact the map was a map of all of the airline flight routes across the world, and was an input into the researchers’ model in a 2012 paper.

⁴This map was so popular that it was targeted by cybercriminals who developed a fake version of the dashboard that concealed malware, hoping readers would stumble upon the fake version and unwittingly infect their computers [50].

Minimizing the damage caused by the COVID-19 pandemic is a monumental challenge for the world. Maps can and are playing an important role in these efforts. But for them to make the best contribution they can make to the decisions that individual citizens and government decision makers take, we need trustworthy maps. Here I provided a few examples of how not knowing whether a given map can or should be trusted (and why it should or should not be trusted) makes maps work less well than they might if they were trustworthy.

6 Conclusion

No mapmaker wants to make a map that is dismissed by its readers. The cultural authority conferred on maps has enabled cartographers to be a bit lazy—to avoid thinking as much as we perhaps should about the relationship between maps and trust. Changes in the world and in mapmaking practices might force us to divert more of our attention in that direction. The world needs good information to guide policy- and decision-making, given the number of critical global problems that threaten the health of our population and planet. Well designed maps can play a role in helping stakeholders to work together to solve these problems, but only if they are trusted.

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