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Strengthening scientific credibility against misinformation and disinformation: Where do we stand now?

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A B S T R A C T

Health behaviors related to COVID-19 prevention measures, especially vaccination, are used to exemplify mechanisms whereby misinformation and disinformation can spark an "infodemic": a situation in which false information can spread more rapidly and widely than its truthful, science-based counterpart. We define key terminologies and identify potential sources that led to the pandemic infodemic, and highlight the harmful implications of such events. Issues related to scientific communication, how the public perceives information, and factors influencing individuals' decision-making are also discussed. This is the first in a series of two perspective articles on this topic.

1. The crisis: vaccine hesitancy

Vaccine hesitancy, defined as "*the reluctance or refusal to vaccinate despite the availability of vaccines*", was listed as one of the top 10 threats to global health by the World Health Organization (WHO) in 2019 [1]. As of August 2022, only 64% of people worldwide were fully vaccinated against the SARS-CoV-2 virus, and only 30% had received a booster dose [2]. Vaccine hesitancy appears across different socioeconomic, religious, and ethnic groups, irrespective of geography or income level [3]. A critically important means of reducing vaccine hesitancy is timely communication about key scientific findings: notably, regarding vaccines' target diseases, their efficacy and safety, and immunization policy. However, given the dynamic nature of pandemics and vaccine development, spreading scientific evidence promptly in the face of misinformation and disinformation has become very challenging.

2. Misinformation, disinformation, and infodemics

People now process an unprecedented amount of information daily, and are highly likely to receive conflicting information from different sources. Verifying which information is authentic and credible and which constitutes "information pollution" (sometimes known as "information disorder") [4] can be very difficult. According to a report from the Council of Europe, information disorder can be divided into three major categories based on differences in its degree of *falseness* and *harmfulness* [4]. They are:

Misinformation: Information that is false, but not necessarily harmful or intended to be harmful. An example is that receiving COVID-19 vaccines will make people magnetic [5].

Mal-information: Information that is true, but causes harm, such as leaking an individual's private information to the public.

Disinformation: Disinformation is false and intended to (or inevitably does) cause some harm. For example, one common myth about COVID-19 vaccines is that they will change human DNA [5].

The WHO defined an infodemic as "too much information, including false or misleading information, in digital and physical environments during a disease outbreak" [6]. In the following sections, we will discuss why the dissemination of scientific information was problematic in the first two years of the COVID-19 pandemic, using potential treatments and vaccination as examples. We then discuss some potential causes of distrust in scientific information and why scientific communication is inherently challenging, especially in the early stages of a major disease outbreak. Potential solutions to these key problems will be provided in the next perspective in this series.

3. The way of scientific communication

Contrary to what many people might think, scientists themselves

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typically have difficulty clarifying scientific information, and are thus not ideal candidates to solve the misinformation problems described above. Effective communication requires not only evidence-based content, but also an audience-friendly style that engages readers/viewers [7]. Scientists and other researchers are trained to build arguments on solid evidence and carefully examine all possibilities, and due to such training, they face two key obstacles when disseminating accurate and objective scientific evidence to the public.

First, a general audience often expects a firm decision (e.g., whether a mask should be worn during a pandemic), whereas scientific training requires the investigation and explanation of risks and uncertainties [7]. Additionally, scientists generally do not have the journalistic acumen required to provide compelling, yet understandable arguments to a public with limited scientific training.

Second, the public may not comprehend and interpret genuine scientific information that is disseminated beyond its scientific context. British statistician David Spiegelhalter used smoking and the risk of depression to exemplify why the medical-research term "odds ratio" should not be used outside scientific contexts such as journal articles. In Spiegelhalter's example, the risk of depression is 15% in smokers and 5% in non-smokers, so the absolute risk difference is 10%, but the odds ratio is 3.3, which could be spun as a huge "spike" in depression rates when reported in the media [8].

In practical terms, moreover, due to the sometimes overwhelming demands of their own research and project management, most scientists cannot afford to serve on the front line in the war against misinformation [9]. They tend to focus their energies on forums in which genuine, peer-reviewed data is disseminated, and devote limited time, or no time at all, to websites and chatrooms where scientifically incorrect information may be spreading. Correcting misinformation requires people to have skills (often, including visualization) that allow them to transform scientific evidence into plain language that can be easily understood and remembered by the public. Unfortunately, scientists are not trained to do so. In 2020, netizens in Taiwan circulated a message that eating garlic could prevent COVID-19. To debunk this misinformation, a non-governmental organization called the Taiwan FactCheck Center created a card with simple text and vivid graphics (Fig. 1), which could be easily disseminated via social media and instant-messaging applications.

4. The clash between the nature of scientific research and its consumption

Ironically, scientists' dedication to research and eagerness to disseminate new findings may be one of the drivers of misinformation. It is not uncommon for a recent discovery to contradict earlier evidence, particularly when dealing with a rapidly mutating virus and the associated urgent need to develop effective new vaccines. Whereas scientists

Fig. 1. Simple text and vivid graphics used to debunk misinformation by a Taiwanese non-governmental organization [10].

have the resources to update their knowledge of a disease and the evolution of the pathogen causing it as a pandemic unfolds, the general public is likely to be left out of the loop on such knowledge and continue acting based on the outmoded information [11]. For instance, the potential use of vitamin D_3 to prevent and treat COVID-19 was investigated early in the COVID-19 pandemic, but no clear evidence of its effectiveness for these purposes was found. Nevertheless, public interest in it as a COVID-19 countermeasure faded away only slowly as more effective ones were developed [12,13]. In other words, something that scientists had told the public about the virus and the pandemic evolved into misinformation without anyone intending it to.

Frustration and even outrage may arise due to misinformation [14], leading to a mental shutting-down that limits the intake of information updates, and thus, complacency about dangerous situations [15]. Some people may take contradictory findings covered in the mass media to mean that scientists and public-health officials are incompetent, and in such cases, tend to regard the newer findings as less reliable than the old ones [16–18]. Lack of trust in and understanding of scientific research also prompts the general public to seek information and recommendations from their peers and family members, and/or from celebrities and others whom they perceive as key opinion leaders. Thus, anyone perceived as trustworthy can become a hub for disinformation and misinformation [19].

5. Uncertainty around an emerging disease and new technology

Lack of evidence adds another layer of complexity to communication. Little was known about SARS-CoV-2 when it first appeared in late 2019, but by early 2020, the virus had spread to more than two dozen countries [20]. It was not until the number of cases became high that sufficient research resources (including time) were applied to the problem, and the scientific community obtained a sufficient grasp of the disease's transmission, progression, and severity to enable the formulation of informed public-health strategies. But even so, since late 2020, there have been five SARS-CoV-2 variants – alpha, beta, gamma, delta, and omicron – rapidly circulating around the world and posing continuous challenges for disease prevention and vaccine development [21].

Several distinct techniques have been used to develop COVID-19 vaccines. As of 2020, there were at least three types of such vaccines: whole-microbe vaccines (inactivated whole virus, viral-vectored, live-attenuated), protein-subunit vaccines, and genetic vaccines (messenger RNA [mRNA], plasmid DNA) [22]. Two of these approaches have a lengthy history in the development of effective childhood vaccines. Vaccines against measles, mumps, and rubella are live-attenuated vaccines, while those against diphtheria, tetanus, and pertussis are protein-subunit vaccines. The high effectiveness and safety of these types of vaccines are well understood, in part because of our clear understanding of their target pathogens and the diseases they cause. In contrast, much less was known about the SARS-CoV-2 virus and the COVID-19 disease it produced. For these reasons, the first vaccines against COVID-19 used mRNA, for the first time in human medicine. Because of the urgent need for pandemic control, mRNA vaccines were authorized under emergency authorizations, based on limited evidence; and uncertainty about this new technology increased people's concern about this vaccination approach [23].

Public and scientific uncertainty about both COVID-19 disease and the new technology being used to combat it made decision-making and public communication difficult. Vaccine efficacy and safety were in doubt at the beginning of the pandemic; and then, as shortages of mRNA-based vaccines occurred and other types of vaccines were developed, questions about vaccine-mixing arose, causing further confusion. In addition, the rapid mutation rate of SARS-CoV-2 made it challenging to evaluate the protective effects of the vaccines against its variants, especially in special populations such as children and pregnant women. Finally, the duration of booster benefit, and the optimal timing for booster shots, remain subjects of ongoing uncertainty, and the potential risks and benefits of mixing and matching COVID-19 vaccine boosters are still an active area of investigation [24].

The issues described above create challenges not only for researchers, but also for anyone tasked with public communication about the pandemic or pandemic countermeasures. Messages delivered to the public must change as new evidence is obtained, and frequent adjustments to public-health messages regarding disease control and prevention were indeed made at different phases of the outbreak. Better communication about where uncertainties lay, and avoidance of conflicting and complex messages delivered to the public in a non-scientific voice, might have helped reduce public misconceptions the SARS-CoV-2 virus, the COVID-19 disease it can cause, and the mRNA-based vaccine approach that was initially selected.

6. How people interpret evidence and their health behaviors

Timely dissemination of easy-to-read health information is the first step toward equipping the public with awareness of the latest and most accurate scientific basis for their self-care during a pandemic. Behavior represents a complex interplay of affective and cognitive processes that guide decision-making in the short- and long-term [25]. Knowledge is inarguably a crucial factor in behavioral change, but the converse is not always the case. That is, change in behavior does not always follow knowledge acquisition. A variety of individual factors influence how individuals perceive and interpret health information and make health-related decisions based upon it. One of the salient factors is *health literacy*: an individual's ability to acquire, process, and understand basic information that can inform appropriate health-related decisions [26]. Previous studies have shown that behavioral changes are also affected by individual socio-demographics, social support, psychosocial factors (e.g., illness perceptions, concerns about medication use), and patient-provider communication [27,28]. Health-promotion efforts that address these individual-level factors tend to be more effective than those that do not when it comes to changing individuals' behaviors and empowering them to make appropriate decisions for better health outcomes [29,30].

One study of medication adherence showed how personal experiences impacted the ways patients interpreted and responded to the medication instructions they were given by healthcare professionals. Specifically, it found that patients who felt specific medications were linked to negative experiences undergone by themselves or their friends were less likely to adhere to such instructions [31]. Another study indicated that Americans' attitudes and life experiences both affected their COVID-19 vaccine-uptake intentions. Its participants who were overoptimistic regarding disease-course severity or hesitant about vaccine safety reported lower levels of intention to receive a COVID-19 vaccine. On the other hand, those who had been exposed to SARS-CoV-2 reported higher levels of such intention [32]. A study conducted in Taiwan indicated that parental norms were closely linked to vaccine hesitancy, and that this phenomenon generally deterred parents from vaccinating their children [33]. Another U.S. study mapped perceptual differences to understand beliefs about SARS-CoV-2 infection and COVID-19 symptom severity in people with vaccine hesitancy. It found that trust in healthcare providers and personal beliefs impacted individuals' perceptions of both disease severity and vaccine effectiveness [34]. Collectively, such studies highlight the need for communicators tasked with reducing vaccine hesitancy and increasing vaccine uptake to focus on relevant psychosocial factors and message framings, rather than scientific knowledge alone.

From this perspective, the challenges to scientific communication during the COVID-19 outbreak are somewhat easier to understand. The way that scientists are trained to communicate with one another, which focuses on uncertainties and explanations of risk, differs fundamentally from how scientific information should be disseminated to the public: a general audience often expects a single, clear answer. However, other factors, such as uncertainty around disease and new medical technologies, also affect public perceptions of scientific information. We recommend that, to provide the public with up-to-date and transparent information that will facilitate proper health decision-making, scientists and healthcare professionals should strive to improve their ability to translate scientific evidence into plain language. As well as being an end in itself vis-à-vis message clarity, such an approach can be expected to help combat misinformation. In addition, information campaigns should be tailored to their target audiences' unique backgrounds and psychosocial factors; regularly refined; and frequently monitored to ensure early detection of misinformation and disinformation [35].

In the next installment of this two-part perspective article, we will look more deeply into feasible strategies for prompting effective communication between healthcare experts and the public.

Data availability

No data was used for the research described in the article.

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