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Informing the Misinformed

In 1854, there was a mysterious cholera outbreak in the Soho area in central London that killed over 600 people. The famous English physician John Snow (1813–1858) was intrigued by the calamity and was determined to find the cause of the outbreak. He used a form of Voronoi diagrams, which are common nowadays in the implementation of nearest-neighbor rules in machine learning, to conclude that most of the individuals infected by the cholera disease lived closer to the Broad Street public water pump than any other water pump in the Soho area. His investigation led to the conclusion that the cholera outbreak was caused by contaminated water due to the lack of sanitation infrastructure in the neighborhood. For his work, Snow is regarded as the father of modern epidemiology.

Snow's work is one interesting instance of science in the service of humanity. The effort provides an example from the 1800s where a data-based approach was applied to the resolution of a public health problem. His discovery helped inform the "uninformed" about the cause of the cholera outbreak through a systematic use of "reliable" data.

Today information is in abundance, including "misinformation." We face the bigger challenge of having to inform the "misinformed" about the consequences of their actions. For instance, one would expect that at the dawn of the third millennium, the human race would have progressed enough to curb the spread of contagious diseases through its wondrous web of science and technology. Unfortunately, this expectation could not be further from the truth. We continue to face insurmountable challenges, some of which are caused by our reliance on "misinformation" rather than on soundproof science. The recent outbreak of the measles disease on a global scale is a testament to this state of affairs.

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Prior to the measles outbreak, there were several other disease outbreaks. Examples include the 2002–2003 SARS outbreak leading to over 700 deaths in Asia, the 2012 MERS outbreak leading to over 400 deaths worldwide, the 2014 swine flu outbreak leading to 2,000 deaths in India, and the 2014 Ebola outbreak leading to over 11,000 deaths in West Africa [1]. Such outbreaks lead to the tragic loss of life and to serious disruption in otherwise normal activities. In 2003, the IEEE Signal Processing Society had to cancel its flagship conference, which today attracts close to 3,000 attendees, from being held in Hong Kong due to the SARS epidemic.

Fast-forward to the present, and we are again witnessing another serious outbreak involving measles on a scale unseen in recent decades, including in high-income regions of the world, such as the United States and Western Europe. The global reach of the problem is reflective of the interconnected world we live in. In contrast to Snow's situation from the 1850s, the main cause for the measles outbreak today is not a lack of scientific knowledge, medical expertise, or health and sanitary infrastructure. After all, we pride ourselves on living in an expansive modern world. The current outbreak is instead largely driven by the spread of misinformation, especially over social media.

Measles is a highly contagious disease that spreads easily through the air when a person sneezes or coughs. In some cases, it can cause serious complications including seizures, blindness, brain inflammation, and even death. What is worrisome is that measles can spread even before the infected person shows any symptoms of the disease, and one person can easily infect a dozen other individuals. If you have not had the measles vaccine, there is a 90% chance that you will get the disease if you are exposed to the virus. In stark contrast, there is only a 3% chance that you will get the disease if you have had the measles vaccine and are exposed to the virus.

To get an idea of the scale of the current outbreak, the World Health Organization (WHO) estimates that the number of measles cases in the world has quadrupled in 2019 relative

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to the same time period in 2018 [2]. In the United States alone, there have been over 760 cases reported between January and May of this year, while the number was at 372 for the entire year of 2018 [3]. This is troublesome given that the United States declared the virus eliminated from its territory in 2000. An alarming number of 83,000 cases and 74 deaths have been reported by the WHO in the European region during the first three months of 2019, with the majority in Ukraine [4]. Last April, over 200 students and staff members were quarantined in two California universities after a couple of buildings were exposed to the virus from infected students [5]. The consequences can be serious, and more so in poorer countries where fewer people tend to be vaccinated due to lack of resources, lack of communication, or lack of adequate transportation. For example, close to 1,000 children have died in Madagascar since October 2018.

Measles is a preventable disease. Despite continuous assurances from the medical community about the safety of the measles vaccine and the need to acquire immunity, some parents continue to resist vaccinating their children. Driving the antivaccination debate is the antivax movement, which discourages parents from vaccinating their children. Their argument propagates a piece of false information that appeared originally in a now discredited scientific publication in the medical journal *The Lancet*. In an article published over two decades ago in 1998, the author, Andrew Wakefield, falsely claimed that there is a link between the measles vaccine and autism in children. The article was retracted by the journal in 2010 after a long delay of 12 years, despite earlier objections and counterarguments by scientists who refuted the results. Unfortunately, by then, the damage had already been done. The false claims in the article have been picked up by the antivaccination movement and regularly propagated over social media, especially in Western Europe and the United States.

Being a scientific Society ourselves, with our own inventory of scientific publications, we see here one example where an extended delay by the editors to act may cause some irreparable harm to a debate of great societal value.

Misinformation is becoming a hallmark of our times due to the ease with which our technology enables its spread. Many may not realize that misinformation, whether intentional and coordinated or not, can have deadly consequences. In the measles outbreak, we have a situation where misinformation at a small scale, believed by only a handful of individuals, can wreak havoc at a grander scale. While Snow's cholera work was able to inform the "uninformed," we now face a new reality where we need to inform the "misinformed." This is a more challenging problem to address. It is also an area where our signal processing discipline can and should contribute more.

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We need to develop methods and theories to untangle information from misinformation in real time, track them, and separate what is correct from what is incorrect. After all, we are the discipline that knows how to separate meaningful "signals" from "noise." We are not tamed by the impossible. We can even develop sophisticated computational imaging techniques that are capable of peering into supposedly invisible black holes in space, as was witnessed in the first black hole image published this last April [6]. We are also the discipline that is at the forefront of research in studying how signals flow and interact over networks. This domain of research is ripe and full of opportunities, calling out loudly for the ingenuity of our scientists. The automated detection and filtering of misinformation should not be left solely in the hands of social media companies because their current business models are largely based on the concept of sharing the very information that they need to control.

No one questions that there are important ethical dilemmas to consider when striking a balance between ensuring the public's health and respecting the rights of individuals, including the right to refuse vaccinations based on religious grounds. At the same time, and as the news has shown time and again in recent months, the ramifications can be deadly for society at large. One infected student on a college campus or in a crowded train can cause serious disruption to the lives of hundreds of individuals, including some catastrophic consequences. For these reasons, some cities and countries have gone as far as to impose fines on parents who refuse to vaccinate their children. A recent fine of US$1,000 has been introduced in New York City, and Germany is considering a heftier fine of US$2,800. There is also a nontrivial financial dimension. Just imagine the cost in millions of dollars of public funds that are being spent on fighting an outbreak that is preventable in the first place. Add to this the human toll, measured in terms of loss of work, loss of days in school, or the tragic deaths of the most vulnerable patients.

One notable historical incident that sheds light on the human dimension of any personal tragedy is the event surrounding the death of Benjamin Franklin's four-year-old son from smallpox in 1736. Benjamin Franklin (1706–1790) was a prolific inventor and one of the Founding Fathers of the United States. He did not inoculate his son against the disease. This is how he describes his personal loss in his autobiography [7]: "In 1736 I lost one of my sons, a fine boy of four years old, by the smallpox, taken in the common way. I long regretted bitterly, and still regret that I had not given it to him by inoculation. This I mention for the sake of parents who omit that operation, on the supposition that they should never forgive themselves if a child died under it; my example showing that the regret may be the same either way, and that, therefore, the safer should be chosen."

The challenge we face today is to separate information from misinformation. From a signal processing perspective, if we treat information as the good signal and misinformation as the bad signal or noise, then we face a new paradigm where the noise component is now "smart" or "intelligent" or "has malicious intent" and adapts to the scenario at hand. Nevertheless, our scientific discipline should be able to develop equally smart signal processing techniques that stay ahead of the curve and reduce the spread of misinformation over networks. We can also play a role in advancing the state of the art in monitoring the spread of contagious diseases in real time. Using tools such as bio sensing devices, imaging technologies, data analytics, and graph signal analysis, we should be able to develop algorithms that assist public health officials in their fight against the spread of diseases.

Many of the global challenges we are facing today require our collective effort.

The measles outbreak has brought to the forefront the important question of social responsibility, and how individual behavior can trample on the common good. I love the wit in the African proverb that says: "If you want to go fast, go alone. If you want to go far, go together." Many of the global challenges we are facing today require our collective effort. Each individual is part of the puzzle and our behavior influences the dynamics around us in nontrivial ways. If you think your actions as an individual are not consequential or important on the grand scale, then think again and consider this beautiful quote attributed to the Dalai Lama: "If you think you are too small to make a difference, try sleeping with a mosquito."

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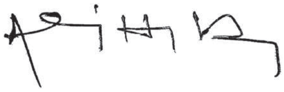

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