Bulletin of the Atomic Scientists

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rbul20

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To cite this article: Walter Scheirer (2020) A pandemic of bad science, Bulletin of the Atomic Scientists, 76:4, 175-184, DOI: 10.1080/00963402.2020.1778361

To link to this article: https://doi.org/10.1080/00963402.2020.1778361

Published online: 20 Jul 2020.

BULLETIN OF THE ATOMIC SCIENTISTS
2020, VOL. 76, NO. 4, 175–184
https://doi.org/10.1080/00963402.2020.1778361

Routledge
Taylor & Francis Group

A pandemic of bad science

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ABSTRACT

What can epidemiological models tell us about our potential exposure to COVID-19? What progress is being made with regard to coronavirus vaccine development? These days, the general public is asking these questions and more as the COVID-19 pandemic rages on. That there is an extraordinary level of interest in coronavirus news should come as no surprise, but this elevated interest society now has in pandemic-related science has unintended consequences that shouldn't be ignored. Studies are being rushed to publication even in well-regarded journals. Unvetted articles on so-called preprint servers have received enormous attention. Predatory journals are giving anyone with the ability to pay the opportunity to publish pseudoscience that can be amplified by mainstream news sources. Marketers are exploiting the public's desperation for protection against COVID-19 and adding a scientific sheen to dubious products. And perhaps well-meaning experts in data science are producing a raft of arguably meaningless research, creating a distraction at best and wasting valuable resources at worst.

KEYWORDS

Pseudoscience; disinformation; predatory journals; preprint servers; coronavirus; photo editing

Never before in history has humankind been so prepared to face a deadly pandemic. Our meticulous understanding of infectious agents, life-saving technologies, and sophisticated epidemiological models all mean the COVID-19 pandemic shouldn't be as deadly as it might have been in a previous era. Scientific research will no doubt lead to an effective preventative treatment for COVID-19 in due time.

Countries and institutions around the world are investing heavily in vaccines, treatments, and research into the epidemiology of COVID-19, and to quench the public's thirst for information, the news media is reporting on each development at a feverish pace. Prominent sections of news sites such as *The New York Times*, or *The Washington* Post have essentially been transformed into running scrolls of up-to-the-minute coronavirus news.

The public's level of interest in science is high and many people of varying expertise have become eager to weigh in on COVID-19 in the media or on social platforms. Scientists in some fields such as epidemiology have even taken to Twitter to police who is and who isn't a legitimate expert in certain subfields. But there are some unintended effects of the elevated importance society is placing on scientific endeavors surrounding the pandemic that shouldn't be ignored.

Studies are being rushed to publication even in well-regarded journals. Unvetted articles on so-called pre-press servers have received enormous attention. Predatory journals are giving anyone with the ability to pay the opportunity to publish pseudoscience that has been amplified in mainstream news sources. Marketers are exploiting the public's desperation for protection against COVID-19 and adding a scientific sheen to dubious products. And perhaps well-meaning experts in data science are producing a raft of arguably meaningless research, creating a distraction at best and wasting valuable resources at worst.

Compared to public health crises of the recent past, there has been a distinct change in how science is communicated to the public. Experts no longer control the narrative through trusted outlets, and, accurate or not, social media allows anyone to craft their own narrative about science and publish it to an audience of millions.

Much like other contemporary cases of disinformation, this is happening because of the open nature of the internet (Woolley and Howard 2019; Yankoski, Weninger, and Scheirer 2020). Furthermore, the "shelter in place" orders many people have been living under mean that a substantial part of the global population has been spending considerably more time staring at their phones and computers, sifting through pandemic-related information. A larger than usual audience is taking in pseudoscientific conspiracy theories, medical scams, and even well intentioned, but half-cocked scientific work. Good science can be twisted in this environment. Perhaps no better example can illustrate how the coronavirus era has been shaped by this phenomenon than the story of bat soup.

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An illegitimate coronavirus origin story and its legitimate origins

Shortly after reporting began on the outbreak of the novel coronavirus (later dubbed SARS-CoV-2) in Wuhan, China, in January, the general public was already well aware of the alleged origin of the virus: bats. Chinese doctors initially suspected that what they were seeing in Wuhan was a resurgence of SARS, a disease caused by the coronavirus SARS-CoV-1 which caused a deadly but limited outbreak from 2002–2004 (Green 2020). They were quick to draw on existing biological research pointing to bats as likely natural hosts of the virus.

While SARS-CoV-2 has proved to be distinct from the earlier pandemic coronavirus (Bar-On et al. 2020), the two still share significant genetic similarity (the viruses share 80 percent of their nucleotides), and published studies linking SARS-CoV-1 to coronaviruses harbored in bats (Lau et al. 2005; Li et al. 2005) were a natural starting point for scientists hunting for the origin of the novel coronavirus.

In 2020, genome sequencing is fast and accurate, and a genetic match was immediately established (Andersen et al. 2020): the nucleotide identity of a coronavirus found in bats had a 96 percent genetic similarity to SARS-CoV-2 (Bar-On et al. 2020). But if bats are the true origin of SARS-CoV-2, how did people come in contact with them in the first place?

This is where the narrative begins to veer away from evidence-based science and into the realm of fantastic speculation. The outbreak in Wuhan was reported to have started on December 12, 2019, with a group of employees at the Huanan Seafood Wholesale Market, a so-called wet market where live and freshly killed animals are available for purchase (Zhou et al. 2020). In spite of a persistent Western stereotype that Asians prefer unusual cuisine, the practice of selling exotic animals is not widespread in such markets (Palmer 2020). Here genetic evidence, a seafood market, racial stereotypes, and an already heated East-West political divide all collided to form an imaginary cross-species jump for SARS-CoV-2: bat soup.

In January 2020, a repurposed digital video surfaced of Chinese travel vlogger Wang Mengyun dining on bat soup in the Pacific island nation of Palau (Figure 1 Left), where fruit bats are served to tourists as a novelty (Lubba 2015). Inspired by Wang's video, Internet trolls and tabloid news outlets sought out more tourist footage from Palau, claiming that all of it was from China, where wild-seeming dishes were common (with ingredients readily available at the local wet market) (Thomson 2020; RT 2020). In fact, bat soup does not belong to any regional cuisine within China, and all

Figure 1. Left: Chinese travel vlogger Wang Mengyun samples bat soup while vacationing in the Pacific island nation of Palau. Right: Wang issued an apology after her video became the source of an internet rumor that bats are commonly consumed in Wuhan.

Figure 2. Three photos used by the Daily Mail and the Fox News Channel to imply that bat soup is consumed in China (Thomson 2020; Fox News Channel 2020). All were posted on Twitter by anti-Communist Party of China accounts, and are repurposed tourist photos that were taken in Palau.

extant photographic claims lead back to Palau (Mas 2020). Wang received death threats and even apologized for the video, which she stressed had been filmed in Palau (The New York Times 2020), but the Chinese bat soup story stuck, and continued to spread.

Fox News Channel host Tucker Carlson ran a segment based on an article and photos (Figure 2) from the *Daily Mail* (Thomson 2020) criticizing Chinese wet markets, where "consumers buy the meat of wild animals to eat, including bats" (Fox News Channel 2020). Both outlets acknowledged the photos originally came from two Twitter accounts: @HONGKONG3333333 is an Anti-Communist Party of China account that regularly tweets out misleading memes and other propaganda and @CHENQIUSHI404 is an account supporting the activist lawyer Chen Qiushi, who gained prominence within Chinese dissident circles for his coverage of the 2019–2020 Hong Kong protests and the novel coronavirus outbreak. (Qiushi has been missing since February 2020, and is presumed to be held by Chinese authorities (Reuters 2020).)

Using Google's reverse image search tool, it's easy to see that all of the photos used by *Fox* and the *Daily Mail* match other, similar looking photos in posts associated with tourism in Palau that predate the pandemic. The provenance of the photo posted by the @CHENQIUSHI404 account has also been verified by a group of French journalists, who link it all the way back to a specific restaurant in Palau by examining the markings on the dishes (The France 24 Observers 2020).

A further blow to the Chinese bat soup narrative is the distinct possibility that the seafood market in Wuhan is a red herring. Early known cases of COVID-19 have been established with no connection to the market (Margolin and Meek 2020; C-SPAN 2020; Huang et al. 2020). But the public discourse surrounding investigations into the origin of SARS-CoV-2 has largely ignored this finding. The market will continue to be a convenient excuse to spread racist ideas, rooted in bad assumptions about how food is purchased and prepared in China (St. Cavish 2020). It has already spawned an entire genre of internet memes (Matt 2020), in this case, widely circulating visual jokes with a discriminatory message (Figure 3). There is a danger of this reinforcing growing anti-Asian sentiment in the West (Jeung, Gowing, and Takasaki 2020).

Unfortunately, science does not grant us a sense of clairvoyance–we may never know the true origin of COVID-19. This unease leads to speculation, and some people find themselves turning to popular yet false narratives, which ironically have some basis in science. Memes thrive under these circumstances. Chinese bat soup is nothing more than a rumor, but it will likely become an enduring stereotype that won't easily be dislodged.

Trouble in the scientific literature

In a traditional sense, if a scientific finding is published in a reputable venue by acknowledged experts, follows established protocols and procedures, backs its claims with evidence, and can be replicated, we generally trust it. However, checking these criteria requires a careful reading of each paper by other experts, presumably as part of a thorough peer review process. Or, at least, this is how the process used to work.

Now research papers can be posted by anybody on open access preprint servers, where only a light screening takes place before a paper is added to a repository. The underlying motivation for this is good: scholars can make their work publicly available for free, sometimes well in advance of the proper publication date in a professional journal, to encourage related research. But the process is not designed to discourage releasing findings before they are properly vetted. Since the discovery of the novel coronavirus in December 2020, an

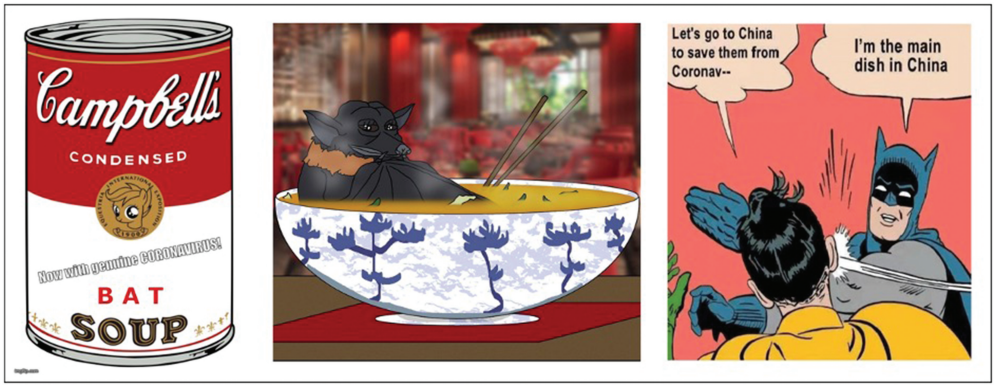

Figure 3. Examples of popular internet memes promoting the false "bat soup" origin of SARS-CoV-2.

unusually large number of research papers related to COVID-19 have appeared in a very short period (Kelland 2020). At the time of this writing in April, 1,822 preprints on COVID-19 are available on the preprint server for health sciences medRxiv, and 496 on bioRxiv, a similar preprint server for biology. Both are operated by Cold Spring Harbor Laboratory, one of America's top laboratories for the biological sciences. Problems in COVID-19 papers that were initially seen as promising have already surfaced, which could have been avoided if proper peer review had been conducted.

For instance, a high-profile paper (Philippe. et al. 2020) on the controversial COVID-19 treatment combination of hydroxychloroquine and azithromycin that was posted to medRxiv in March 2020 was criticized by experts for having mislabeled data, incorrect statistical significance tests, and a questionable accounting of patients within its study (Sciama 2020).

In another case, Elisabeth Bik, author of the blog Science Integrity Digest, found identical images that were portrayed to be different data in a paper posted to medRxiv in March 2020 (Xiang et al. 2020) on biomarkers that are useful in identifying severe cases of COVID-19. The duplication was likely a mistake, but it leads to a misrepresentation of the results between severe and mild cases of COVID-19 for one of the biomarkers studied. As of this writing, the paper has not been corrected. The medRxiv homepage now carries the following disclaimer which should be heeded carefully: "Caution: Preprints are preliminary reports of work that have not been certified by peer review. They should not be relied on to guide clinical practice or health-related behavior and should not be reported in news media as established information."

Even ignoring the preprint question, many published journal papers on COVID-19 have not gone through the usual peer review process. Papers in journals owned by John Wiley & Sons, Elsevier, MDPI, and Springer Nature, among other publishers, have gone from an initial submission to an officially published paper that is available for download in a matter of days (Figure 4). The medRxiv paper by Gautret et al. on using hydroxychloroquine and azithromycin as a COVID-19 treatment passed through peer review in a mere 24 hours before being published in the *International Journal of Microbial Agents*.

One could argue that speeding publication up, given the dire circumstances, is a necessary change in procedure to make potentially life-saving information available to the public. But one could also argue that the risk for not properly vetting scientific research is unacceptably high.

In January 2020, the *Journal of Medical Virology* published an article on the cross-species transmission of SARS-CoV-2 (Ji et al. 2020). It passed through peer review in five days. This paper is remarkable in that it claims SARS-CoV-2 originated in snakes, not bats. If true, this finding would upend a concerted global effort to study bats as the most likely source of the virus. However, a closer examination of the paper's own data undermines its conclusion. Instead of making a genetic comparison to other coronaviruses harbored in animals, as established studies have made (Andersen et al. 2020; Bar-On et al. 2020), the authors compared SARS-CoV-2 to animal DNA, under the assumption that viruses evolve part of their genetic material to match their host. Using this less precise methodology, the published analysis still shows bats as a highly plausible genetic match, in spite of the paper's main argument–not to mention that there is no evidence that SARS-CoV-2 can infect snakes. Post-publication review of the paper by experts has pointed this out, thus dispensing with the misleading claim (De Jesus 2020; Callaway and Cyranoski 2020).

Even more dangerous are forums where literally anything can be published as scientific fact. An ecosystem of so-called predatory journals has developed, pay-for-play routes to publication where authors simply pay a fee to have their paper placed in an online journal without any quality control (Grudniewicz et al. 2019). They exist to make money on academics who are either naive or opportunistic, and primarily target those in the developing world where ethical standards in the academy are looser. In a disinformation context, these journals are

Figure 4. Unusually brief peer review periods for COVID-19 papers published in journals owned by John Wiley & Sons, Elsevier, MDPI, and Springer Nature.

dangerous because the lay person does not often know how to judge journal quality or the merit of scientific work. To some, the mere fact that a paper is published lends it an air of credibility.

For instance, the journal *Acta Scientific Microbiology* recently published a surprising article about a new therapy for COVID-19. The publisher of the journal, Acta Scientific, appears on an updated version of Beall's List, a collection of potentially predatory journals that academic libraries, including those at Yale University and Caltech, use as resource for academics interested in publishing (Yale 2020; Caltech 2020; Beall's List 2019). *Acta Scientific Microbiology*'s article introduces an oral spray that is reportedly a successful treatment for coronavirus infections, as well as HIV, hepatitis and herpes (Saharan 2020). To justify this rather astonishing claim, the paper presents its methodology in a series of composite images that have been cobbled together from disparate uncredited sources on the internet. The provenance of this source material can be easily traced using Google's reverse image search tool (Figure 5).

While trained scientists can easily dismiss the bogus work found in predatory journals, it is not as easy for non-experts to separate real discoveries from fabricated findings. The pandemic has introduced a tremendous amount of uncertainty into society, and understandably, the media and public are grasping for a medical breakthrough and better insight into what is going on. With a receptive audience, fake information can easily seep into the conversation. And this remark is not merely speculative. Major news outlets such as *US News & World Report* (Fetters 2019) and *The Times of India* (Rupera 2020) have cited material from Acta Scientific journals in the past.

Dubious marketers are exploiting new technologies to cash in on pseudoscience

The phenomenon of exploiting an emergency for profit is nothing new. However, the strategies for doing so have evolved to make use of professional graphic design software to create ads, as well as social media platforms to distribute them on. In what has become a recurring theme on the internet, a host of fraudulent businesses piggyback on major events, where any related content has the potential to draw many clicks. This is particularly troubling when it comes to unproven treatments and diagnostics for COVID-19.

Much has been reported on the potentially fatal drug combination of hydroxychloroquine and azithromycin (Sciama 2020; US Food & Drug Administration 2020d), but it can only be administered by prescription. More disquieting are the health-related products available for sale on the internet that may appear legitimate to the layperson, but are not. A flood of fake products targeting a public worried about COVID-19 has prompted stern warnings from federal agencies within the United States (US Food & Drug Administration 2020a). Some of these products are promoted by familiar media personalities. Conspiracy theorist Alex Jones and televangelist Jim

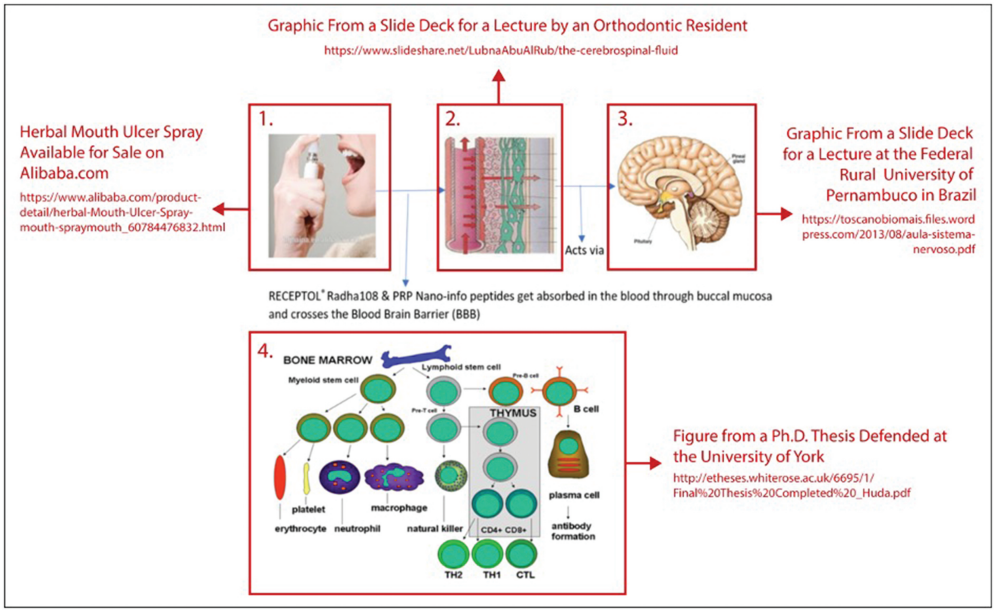

Figure 5. Predatory journals routinely publish papers with inappropriately assembled figures. This composite figure is from a paper that discusses a fake orally administered coronavirus treatment (Saharan 2020). Each panel (1–4) in the original has been highlighted, with the original source of the imagery, as identified by Google reverse image search, noted.

Bakker surfaced during the pandemic to promote colloidal silver gels as coronavirus cures (Marantz 2020). Colloidal silver has no known therapeutic value, and the US Food & Drug Administration has issued warning letters related to the sale of these products (US Food & Drug Administration 2020b; U.S. Food & Drug Administration 2020c).

Fake products sold under mundane circumstances are more insidious, however, because they aren't being scrutinized as carefully as those promoted by celebrities. In this regard, *Science Integrity Digest*'s Elisabeth Bik noted a suspicious Covid-19 self test being sold on the Dutch cosmetics website Beautytec.nl. Promotional material associated with this test raised a number of red flags, including specimen collection instructions inconsistent with home use, apparently plagiarized text and seemingly doctored images in the product description, and reported performance characteristics that appeared too good to be true. The product has been removed for sale, but a PDF product sheet still exists on the internet as of this writing in April 2020. Let's take a close look at one of the accompanying graphics in that product sheet to gain a sense of how existing legitimate content is manipulated in the creation of fake products.

The graphic in the upper-right hand side of the first page of the product sheet is an altered version of a diagram for a typhoid test sold by a legitimate laboratory supply company (Figure 6, Panel 1). Google's reverse image search tool confirms the provenance of this image. An analysis making use of digital image

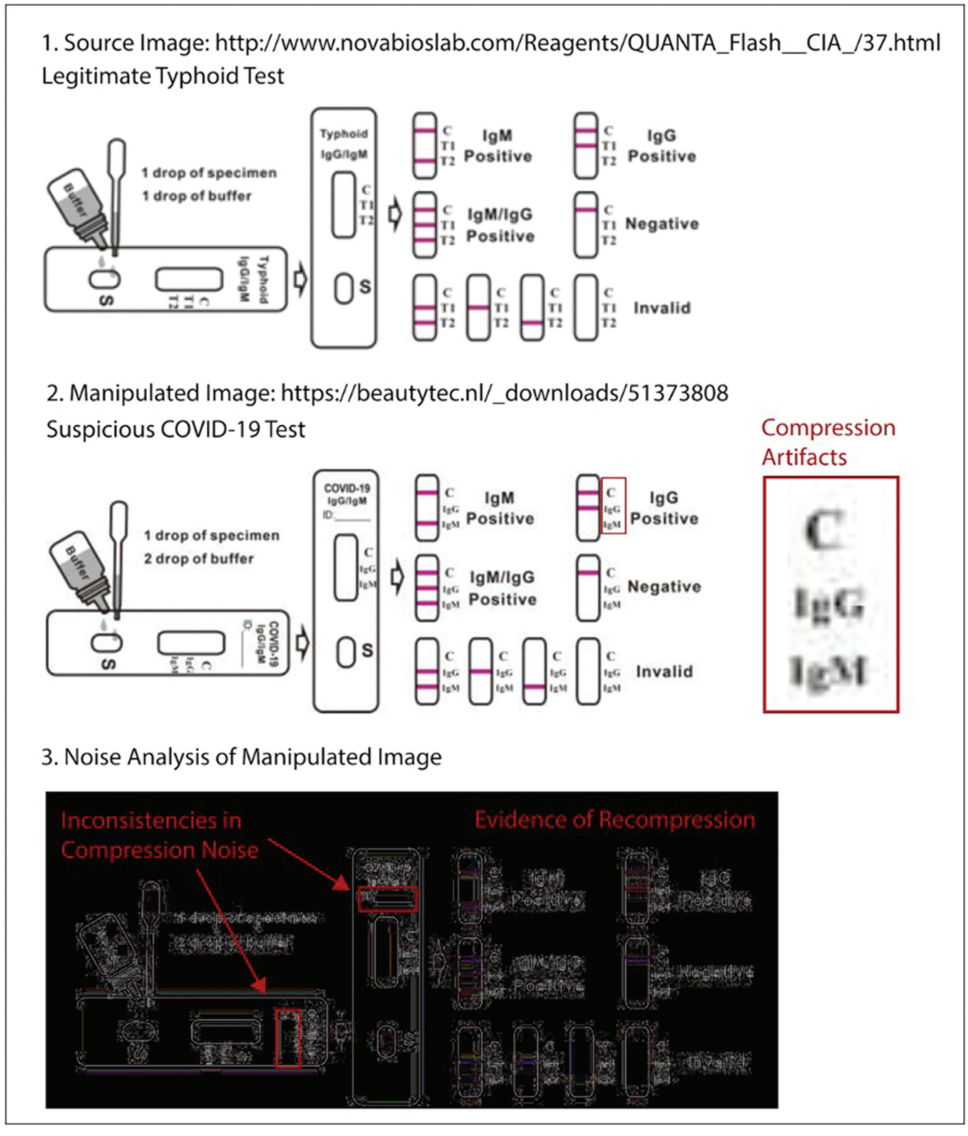

Figure 6. Using a source image from a legitimate typhoid test as a basis (Panel 1), the website Beautytec.nl created a graphic for a suspicious COVID-19 testing product by editing the original image to replace labels and add ID lines (Panel 2). A noise analysis of the manipulated version of the image shows signs of tampering (Panel 3).

forensics techniques reveals the telltale signs of tampering in the version showing a COVID-19 test diagram. A simple manual inspection of the image at high magnification shows the presence of compression artifacts, hinting that the original image had been recompressed (i.e. saved in an image editing tool that attempted to make an already small file even smaller, creating visible problems in the resulting image) at some point in time (Figure 6, Panel 2). Using another analysis tool, it is possible to look for inconsistencies in the image, where editing may have occurred. Two such inconsistencies are visible after this analysis, confirming that the image was edited after it had been recompressed (Figure 6, Panel 3). A clear sign of this is that there is less noise in the "ID" sections of the diagram. Comparing the edited image to the original shows that that the "ID" lines were added to the two large rectangles. This example isn't a particularly sophisticated manipulation, but it was likely enough to convince some consumers that the product was real.

Good intentions, questionable outcomes

Helping others during a cataclysmic event demonstrates the best side of humanity. But doing so should be coordinated in some fashion to address real needs–especially when it comes to scientists whose role in the crisis may not be immediately apparent. On the one hand, we have witnessed this in the selfless actions of biologists who are keeping their laboratories open during shelter-in-place orders to work toward a viable vaccine for COVID-19. On the other hand, we have also witnessed scientists from other fields begin work on COVID-19 research without any relevant training, knowledge, or partnerships. These latter cases may prove to be distractions at best, and more threatening than the coronavirus itself at worst.

Since the declaration of the COVID-19 pandemic, a number of related problems have surfaced, from data visualization specialists misinterpreting disease progression (David 2020) to experts in artificial intelligence promoting dubious surveillance technologies to assess risk of contracting the disease (Bengio 2020). Community-driven efforts to combat COVID-19 have emphasized the past decade's trend of data science, a field that seeks out patterns in unstructured data, which has a low barrier to entry (no expensive wet lab required). While naiveté is certainly a stumbling block, a more fundamental problem facing data scientists is that they lack relevant questions to answer.

The Allen Institute for AI has released a COVID-19 open research database of academic papers (including many preprints from bioRxiv and medRxiv), which forms the basis of an open prize challenge offered by the website Kaggle (Kaggle 2020). The objective of this prize challenge is to apply machine learning techniques to summarize the database in order to answer questions such as what's known about COVID-19 risk factors or what's known about non-pharmaceutical interventions. All of these questions could be answered by simply reading the relevant papers identified via traditional search mechanisms. Nonetheless, significant time and money is being invested in natural language processing capabilities to automatically mine this database (Collins 2020). Moreover, given concerns about the veracity of work appearing on open access preprint servers, which form the bulk of the papers included in the Allen Institute's database, any automatically generated analysis would have to be validated through intense human scrutiny anyway. Is this the best use of potentially valuable resources for conducting research?

The Kaggle challenge hints at another motivation beyond altruism for the sudden uptick in non-expert participation in COVID-19 research: funding. Early entrants seek to gain as new funding mechanisms appear from government and industry sources. Indeed, the Kaggle challenge itself is backed by several grant-making bodies, and the US Department of Health and Human Services (US Health and Human Services Department 2020) and the National Science Foundation (Crim 2020) have already announced new funding for COVID-19 research programs. A similar phenomenon was observed after the 9/11 attacks, when non-experts entered the arena of terrorism research, following an unprecedented swell in funding (Mehta 2018). It is entirely unclear whether any of that work led to useful outcomes for the war on terror, which is now entering its 19th year with no end in sight. Worries over the appropriate distribution of funding are not unfounded in this new pandemic scenario, and the current priorities of data scientists are not aligned with the needs of improved diagnostic testing, vaccine development, and drug discovery.

What can be done to mitigate the unanticipated consequences of COVID-19 science?

A policy response need not be overly complicated. In general, there are five basic components to this response, and distinct communities of actors that must take action for each:

(1) Social media content should be more heavily filtered. Recall the earlier era of the internet, when mailing lists and message boards were moderated, a largely uncontroversial and effective mechanism for reducing noise and keeping discussions on-topic. Moderation

procedures need to be updated for the social media age and integrated into each platform. Similarly, the open nature of commenting and sharing content needs to be rethought. More stringent fact checking needs to take place before news outlets use sources from social media. Media forensics tools can be deployed to help with this.

(2) Preprint servers should have more quality control. Basic checks for plagiarism and repurposed content (including text and images) should be deployed on preprint servers. Automatic tools for this purpose already exist (e.g. the Institute of Electrical and Electronics Engineers deploys the iThenticate service on submitted papers before they are published in its conferences and journals). New capabilities to check multimedia content should be integrated as digital publications evolve beyond the standard print format.

(3) Scientists need to be patient. Traditional peer review is not perfect, but the slow process helps catch problems in research and allows authors to make corrections, thus leading to publications that can be trusted after they are published. Preprint servers are fine for making work available as open access content, but they should not be used as a way to rush research out prematurely. Further, scientists must be skeptical when they approach a new piece of research, and a key benchmark for experimental work should be its reproducibility. Confirming that a study can be reliably replicated may be slow, but is a necessary step to establishing that a finding is real. And the scientific community should continue its crackdown on predatory journals. An authoritative list of active predatory journals should be compiled and consulted during employment-related performance reviews, with harsher consequences for researchers that are paying money to avoid peer review.

(4) Let the actual experts lead. Too many unqualified scientists jumping on the COVID-19 bandwagon is problematic, especially when valuable resources are diverted to them. In order to get money into the hands of those that have a more direct need, qualified experts should handle the distribution of funding at a strategic level, based on what they believe the most effective allocation is. This should take place as a partnership between funding sources and topic area experts who can prioritize needs and make reasonable predictions about outcomes based on their relevant prior experience.

(5) Reestablish public trust in credible experts. For too long, science has done a poor job communicating its achievements to the public. This has not been helped by the increasing politicization of various scientific fields and specific findings. Scientists should take an apolitical stance when discussing their work, point to evidence-based findings, and strive to make their work as accessible as possible. The head of the National Institute of Allergy and Infectious Diseases, Anthony Fauci, is a good example of a scientist who has received popular acclaim for promoting sound science. Scientists from around the globe should follow his example, and consciously avoid pitfalls that have been discussed in this article.

The COVID-19 pandemic has understandably led to heightened public interest in science. Epidemiological models, vaccine development processes, and other public health and scientific endeavors are frequently discussed in the media and online. At the same time, this scientific moment isn't without drawbacks. We have incredible tools to wield against this disease, but in order to use them, researchers and others should endeavor to make sure that high-quality science can cut through the disinformation.

Acknowledgments

Thanks is extended to Maria Ma, Bingyu Shen, Ernesto Verdeja, and Michael Yankoski, who provided feedback and corrections on an earlier version of this article.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

No funding of interest was reported by the author.

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