Title

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Journal

Minerva, 55(1)

ISSN

0026-4695

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Publication Date

2017-03-01

DOI

10.1007/s11024-016-9311-z

Peer reviewed

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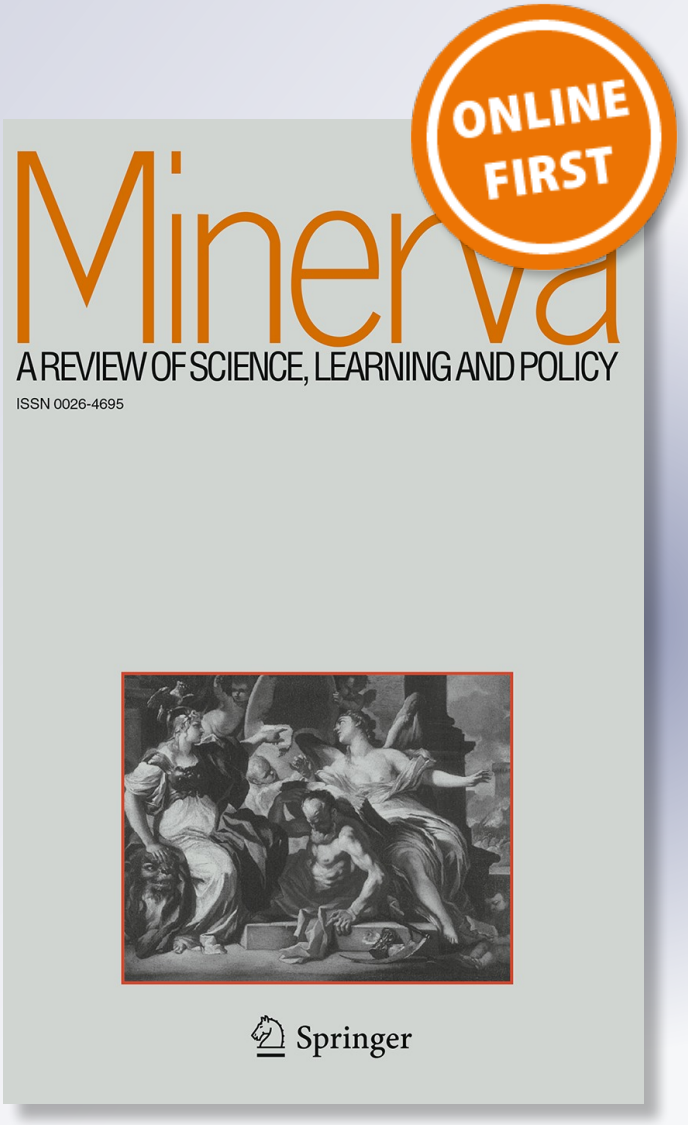
Minerva
A Review of Science, Learning and Policy

ISSN 0026-4695

Minerva
DOI 10.1007/s11024-016-9311-z



Springer

Minerva
DOI 10.1007/s11024-016-9311-z

Conceptualizing Fraudulent Studies as Viruses: New Models for Handling Retractions

Kathleen Montgomery[1] · **Amalya L. Oliver**[2]

Abstract This paper addresses the growing problem of retractions in the scientific literature of publications that contain bad data (i.e., fabricated, falsified, or containing error), also called "false science." While the problem is particularly acute in the biomedical literature because of the life-threatening implications when treatment recommendations and decisions are based on false science, it is relevant for any knowledge domain, including the social sciences, law, and education. Yet current practices for handling retractions are seen as inadequate. We use the metaphor of a virus to illustrate how such studies can spread and contaminate the knowledge system, when they continue to be treated as valid. We suggest drawing from public health models designed to prevent the spread of biological viruses and compare the strengths and weaknesses of the current governance model of professional self-regulation with a proposed public health governance model. The paper concludes by considering the value of adding a triple-helix model that brings industry into the university-state governance mechanisms and incorporates bibliometric capabilities needed for a holistic treatment of the retraction process.

Keywords Knowledge management · Governance · False science · Bad data · Infection · Contact reporting · Retraction · Triple helix

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Published online: 08 November 2016

Background

Misconduct in scientific research is nothing new. For decades, scholars — and occasionally the general public — have been aware of reports and investigations of authorship misconduct (e.g., ghost authors, guest authors, and plagiarism), improper use of human subjects (e.g., failures of disclosure and informed consent), and data mishandling or "bad data" (e.g., improper coding, careless or erroneous analytical procedures, fabrication, and falsification) (http://ori.hhs.gov/historical-background). Although each of these acts of scientific misconduct does a disservice to the cumulative scientific body of knowledge and scientific progress (Azoulay et al. 2015), those that involve bad data also have the potential to create serious harm when policies and practices are based on invalid findings. This is particularly dangerous for research in the health and human services fields, where medical care decisions based on bad data can have life-threatening effects. For example, in 1998 the British medical journal *Lancet* published a paper in which the authors claimed to have identified a link between autism and the mumps, measles, and rubella (MMR) vaccine. The paper was fully retracted in 2010 for data fabrication and other misconduct (Harris 2010), but it is thought to have contributed to a dramatic — and ongoing — drop in vaccination rates, leading to several serious measles epidemics, a deadly disease, including a recent outbreak in the United States (CDC 2016; Deer 2011; Godlee 2011). In fact, the persistent fallacy linking autism and vaccines surfaced again in a recent US Presidential debate (Tavernise and Louis 2015). (For additional background on this case, see Decoteau and Underman 2015).

In 1986, the United States Department of Health and Human Services established the Office of Scientific Integrity (reconstituted in 1992 as the Office of Research Integrity) to investigate allegations of misconduct in federally funded research studies and to promote research integrity through training and oversight. Universities imposed requirements on their academic personnel for additional training in ethical scientific conduct, and professional societies presented workshops for their members to explore ethical challenges likely to be faced when engaging in research.

Despite these ambitious public and private educational and training efforts to thwart research misconduct in the earliest stages of research, it is unrealistic to expect that all future studies will be conducted with appropriate rigor and integrity such that bad data will become a thing of the past. Thus, a challenging problem remains: what to do about studies with bad data that have made their way into the scientific body of knowledge and that continue to have an impact on an unsuspecting audience of scientists, policymakers, and practitioners, who mistakenly further cite and rely on these studies.

In what follows, we provide an overview of the current situation involving retractions of studies with bad data, and we discuss inadequacies of current practices. We then explore the feasibility of alternative frameworks for dealing with retractions to minimize the persistence of papers with bad data in the literature and the impact on policy and practice.

The Current Situation of Retractions

When a study is found to contain bad data, the standard approach has been for journals to issue a retraction, defined as "the removal from the literature of a paper determined to be sufficiently fraudulent, falsified, mistaken, or not reproducible that the authors or editors act to acknowledge its invalidity in the pubic record" (Furman et al. 2012: 278). Yet, as described below, retraction guidelines and practices are inconsistent, with the result that fraudulent papers can remain in the knowledge base for years.

The Incidence of Retractions for Bad Data

Retractions occur for a variety of reasons, collectively referred to as "false science" by Azoulay et al. (2015), all of which can contaminate the scientific database. Some retractions are related to authorship fraud (e.g., plagiarism or duplicate publishing). Others are related to the quality of the data, resulting from outright data fabrication and fraud or honest error on the part of the scientists in data collection or analysis. In a comprehensive search of the PubMed database from the 1940s until 2012, Fang et al. (2012) identified 2,047 retracted articles. They note that retraction in the biomedical literature is a relatively recent phenomenon, with the earliest retracted article having been published in 1973 and retracted in 1977. Recent reports suggest that the rate of retractions has spiked in the last 15 years. For example, Furman et al. (2012) report that the rate of retractions has increased from 3.6 per year in the 1970s (2 retractions per 100,000 PubMed publications) to 36 per year in the 2000s (8 retractions per 100,000) (2012: 279). Similarly, Van Noorden (2011), reporting in *Nature,* cited a ten-fold increase in the number of retraction notices by 2010, compared to the number at the beginning of 2000, with an estimated 400 retraction notices posted on the Web of Science in 2011, compared to 30 retraction notices in the early 2000s — even though the total number of papers published during that time has risen only 44%.

Although bad data is not the only cause of retractions, Van Noorden (2011) estimates that over two-thirds of retracted articles may contain bad data, based on the following calculations: fabrication or falsification (11%), honest error (28%), irreproducible results (11%) or some other unspecified reason (17%). Steen (2011) examined 742 English language research papers retracted from the PubMed database between 2000 and 2010, finding that 31.5% of retracted papers were because of scientific mistake, 26.6% were retracted for fraud, and another 18.1% were retracted for ambiguous reasons. An estimate of retracted papers with unreliable or invalid data could be well over 50%.

Using the same database of retracted papers in the biomedical literature between 2000 and 2010, Samp et al. (2012) divided the sample into papers reporting on drug studies (n=102) and categorized the reasons for retractions. Within this subsample, the authors reported that over 60% were retracted for bad data (33% for data fabrication and 28% for error). The authors also reported finding a greater

proportion of drug therapy articles being retracted for reasons of fraud and misconduct compared with other biomedical studies.

Time Lag Between Publication and Retraction, and Continued Citation

The time lag between publication of a paper with bad data and the retraction can be years, such as the 12-year lag in the MMR vaccine-autism case, noted above. A recent examination of time-to-retraction shows a mean time lag of over four years for papers published in or before 2002, and a mean time lag of about two years in the decade since (Steen et al. 2013).

Moreover, even when an article is formally retracted, citations to the study may continue. A review of retracted articles showed that continued citation of retracted articles between 1997 and 2009 remains substantial, with 94% of citing articles making no mention of the retraction of the original paper (Budd et al. 2011). Furman et al. (2012) found that nearly 50% of post-retraction citations built unknowingly on false knowledge.

The problem is magnified when policymakers and practitioners also draw on the scientific knowledge base for decision-making. One of many examples is a study conducted by Japanese scientists published by the *Lancet* in 2003 reporting a promising new approach for the treatment of high blood pressure by using a two-drug combination. The original paper led to rapid adoption by physicians in the US and elsewhere, who prescribed the therapy to over 100,000 patients; it also inspired additional clinical trials in the US and the UK, enrolling up to 36,000 patients, before it was retracted by *Lancet* in 2009 for fraudulent data collection (Naik 2011).

Current Approaches to Handling Retractions

Typically, a retraction occurs through editorial dictate (e.g., an investigation, often prompted by a whistle-blower, has uncovered falsified data in one of the journal's publications), followed by a retraction notice issued by the journal. Yet, retraction notices vary widely in the amount of information they convey about the reason for the retraction, with some notices offering little to no rationale, and others providing substantial elaboration of the rationale behind the retraction (Azoulay et al. 2015; McNutt 2015). Such an information void makes it difficult for researchers to ascertain whether a retraction occurred because of bad data or for a less ominous reason (e.g., authorship dispute or duplicate publication), which might not corrupt future studies.

Two consortia of journal editors in the biomedical field have issued recommendations for handling retractions: The first is the Committee on Publication Ethics (COPE), established in 1997 in the UK by a small group of medical journal editors, with over 9,000 members today, including editors and others interested in publication ethics. In 2009, COPE issued Retraction Guidelines (COPE 2009), but these recommendations are voluntary, with little teeth beyond normative expectations. The second is the International Committee of Medical Journal Editors (ICMJE), a consortium of 14 medical journal editors established in 1978 to systematize publication norms and procedures in biomedical journals. In 2014,

ICMJE issued revised *Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals* (ICMJE 2014), recommending that editors should label a retracted article as such online and that the article should remain in the public domain clearly labeled as retracted.

While useful guidelines for journals and authors, a lingering problem is that many papers are retrieved from the database not long after publication — before they are discovered to contain bad data and before they may be retracted — and users are unlikely to return to the database to check on their validity (Davis 2012).

In practice, the procedures and standards associated with article retraction remain idiosyncratic (Furman et al. 2012; Pfeifer and Snodgrass 1990). An ambitious effort to track retraction stories is the recent blog Retraction Watch (Oransky and Marcus 2010), but these authors acknowledge that the system for catching fraudulent studies, for withdrawing such studies from the knowledge base, and for assuring that stakeholders do not continue to rely on invalid studies remains worrisomely porous (Marcus and Oransky 2014, 2015).

Analyzing the Bad Data Issue: A Virus Metaphor

We propose an alternative approach to addressing the phenomenon of studies with bad data in the scientific literature that draws on the metaphor of viruses. Metaphors have long been recognized as a fruitful means of reconceptualizing organizational phenomena and generating new ways of seeing (Morgan 1986; Cornelissen and Kafouros 2008; Jermier and Forbes 2011). Our thinking about this perspective has been enriched by Rovik's (2011) theorizing, in particular, about viruses as a metaphor for handling management ideas.

We begin by characterizing the issue of retractions as a virus and extend the metaphor by drawing on the public health domain to discuss possible strategies for dealing with viruses.

Elaborating the Metaphor

Virus

We can think of publications with bad data as similar to an *infectious agent* – a virus – that has a harmful effect on the scientific *body* of knowledge, either through direct or indirect contact between the infected agent (i.e., a study with bad data) and the uninfected host (i.e., future work that has not yet been influenced by the false study and that has not yet cited the false study). As Rovik explains (2011), an important prerequisite for viral infections is an active host, which actively absorbs the virus. In other words, the virus does not "attack" a passive host, and future work is not infected unless a scientist is conducting research in a related area and incorporates reference to the faulty study, as if it were valid, in subsequent studies. Not only can scholarly work serve as an active host for potential infection when false studies are cited as valid, but policy papers and practice guidelines can also function as active

hosts for viral infection when their conclusions and recommendations are based on studies with bad data.

Modes of Transmission: Direct Contact

The *pathways* through which the infectious agent can travel from one entity to another include various dissemination avenues through which scientists share their work. Similar to a biological virus that is spread through direct contact, the modes of transmission for this kind of infectious agent begin with direct contact with the study. These may include informal discussions among collaborators, students, and colleagues, as well as working papers, personal websites, and workshops. More formal modes of transmission include presentations of the study at professional conferences, research seminars, and proposals for funding. Ultimately, the virus becomes implanted in the body of knowledge through publication.

Contagion and Spread: Indirect Contact

Studies with bad data can remain dormant in the body of knowledge until they are activated by some form of contagion. This requires an active host, as a subsequent citer and/or user of the invalid study, who serves as the conduit that enables the virus to spread. In most cases, active hosts are unlikely to know that they are carriers of a virus unless symptoms arise. In terms of studies with bad data, such symptoms would be discoveries that the initial study contained bad data.

The principal action that enables the *spread* of the virus is through citing studies that have entered the informal or formal body of knowledge via one or more of the dissemination venues listed above. The body of scientific work is tapped by a variety of (unwitting) stakeholders, including the scientists and scientists-in-training who rely on papers with bad data to inform their own research and future studies; funding bodies who support additional studies extending fraudulent work; policymakers, practitioners, and organizational leaders who base strategic decisions and formulate practice guidelines on invalid studies; and members of the general public who are the recipients of such ill-founded decisions.

Epidemic

The problem can reach epidemic levels when there is a widespread occurrence of an infectious agent. If left unchecked, the virus and its effects can rapidly escalate in a domino fashion, affecting not only the stakeholders who draw on the original study, but also tainting the work and decisions of subsequent users, who may have learned of the original study only third- or fourth-hand through citations of citations. The case of the MMR vaccine and its invalid relationship to autism demonstrates how a single study with bad data can continue to reverberate through the body of knowledge, adversely affecting decisions of many stakeholders for years who never encountered the original study.

Immunity and Isolation

Immunity refers to various defense mechanisms that prevent the virus from infecting other agents. The primary formal immune mechanisms under the current system are (a) the peer review process that is intended to stop bad studies from being published in the first place, (b) journal procedures for retracting published papers that have subsequently been found to be false, and (c) isolating (i.e., removing or retaining and labeling as invalid) the offending studies from the extant body of scientific knowledge. Another informal immune mechanism would be avoidance: the reluctance of scientists to associate with colleagues and their research, as well as continuously checking and rechecking the sources they use to assure that these sources have not subsequently been labeled as retracted.

A Public Health-Based Strategy

Recognizing that retraction notices apparently do not reach the community of users as quickly or thoroughly as needed, one approach followed in the public health sector is to switch from a *reactive* to a *proactive* attitude to thwart spread of the virus. This approach involves several steps: awareness, prevention, screening, containment, reporting, and notification.

Awareness and Prevention

The first step is a coordinated effort to persuade the relevant stakeholders to engage in behaviors that will stop and prevent the future spread of infectious agents. This would require acknowledging the growing phenomenon of retractions and determining that it requires a coordinated response at the individual, organizational, and professional community levels. *Awareness* can be heightened through workshops, conferences, open discussions, and publications in the scientific literature, as well as proactive interest on the part of key stakeholders, including funding agencies, scientists, peer reviewers, and universities.

Along with awareness, public health strategies typically target *prevention* activities. In this context, prevention takes the form of enhanced ethics training for doctoral and postdoctoral students, as well as senior scholars, aimed at highlighting responsible and competent conduct of research at the outset, as well as higher levels of research monitoring and reporting requirements. Yet, we know that prevention efforts do not eliminate all instances of faulty research. Hence, it is also essential to put in place a more targeted strategy to deal with the faulty studies that remain, as described next.

Screening

Public health outreach efforts typically call for screening of potentially infected individuals. In the case of the AIDS virus, for example, this involved recommendations that individuals known to have engaged in at-risk behaviors for HIV

infection be tested for markers of the virus. The purpose of screening is to alert those who are infected that they are carriers and can pass on the virus to others. In this context, the initial screening stage occurs during peer review. Although all scholarly papers undergo a level of peer review prior to acceptance for publication, it is well known that peer review does not catch all studies with bad data before they appear in print, as it is extremely hard to detect intentional data fabrication or falsification as well as honest errors. A second level of screening occurs post-publication through replication studies, which can reveal problems or errors in the initial study.

Containment: Reporting and Notification

The current reporting mechanisms are imperfect, because of a lack of clarity about how and to whom to report suspected fraud, as well as a lack of follow-up to assure that the retraction notices reach those who are most affected. Therefore, an essential prerequisite for a successful containment strategy is identification of a *centralized body* to serve as the repository of reporting so that the information about studies with bad data can be compiled in order to reach all relevant stakeholders.

Borrowing from the model used by the U.S. Centers for Disease Control and Prevention (CDC) to restrain the AIDS epidemic in the 1980s, and not unlike the model used during the recent Ebola virus outbreak, a vigorous reporting system can be established that focuses on *contact networks*, with the *network node* being the study with bad data, also referred to as "root articles" (Furman et al. 2012: 279). In this sense, the study is the "carrier" of the virus, capable of infecting all who come into contact with the study. Thus, it is critical that modes of transmission be clarified, as suggested above, and that the members of the contact network be quickly identified and then notified of the suspected fraud. Ideally, this also would require that anyone with knowledge of the false science cooperate by informing the reporting agency of known network contacts, such as collaborators and trainees, much in the same way that individuals found to be infected with the AIDS virus were expected to report the names of sexual partners so the partners could be alerted to their possible infection.

Comparing Models for Knowledge Management

In the foregoing, we have described two substantively different models for dealing with retractions, what Furman et al. would label "governing knowledge in the scientific community" (2012: 276): the current model based on professional self-regulation and the proposed model based on public health outreach and containment. Institutional theory offers a promising way to assess the relative strengths and weaknesses of different models of governance, because of the theory's emphasis on the influence of beliefs and rules about appropriate behavior within a relevant environment (the organizational field), including sanctions when violated.

The concept of the organizational field (DiMaggio and Powell 1983) is important because it places boundaries around the phenomena in order to examine governance models within a field. That is, beliefs and rules appropriate to one environment would not necessarily be applicable to actors in a different environment. For our purposes, the organizational field is broadly defined as the field of "scholarly research" and thus includes all the participants who act as suppliers (e.g., the scientific professions, research teams, and individual scientists), resources (e.g., universities and public and private funding agencies), consumers (e.g., other scientists, policymakers, organizational leaders, commercial firms, and the general public), and other actors (e.g., journal editors, professional associations, and ethicists) (Montgomery and Oliver 2009).

The second key concept is the institutional logic — the cultural beliefs and rules that shape the cognitions and behaviors of actors within the field (Friedland and Alford 1991). A central assumption is that the interests, identities, and values of individuals and organizations are embedded in logics and provide the context for decisions and outcomes (Thornton and Ocasio 2008).

We draw from these concepts of institutional theory to contrast the two models of governance of the scientific body of knowledge presented above — professional self-regulation and public health outreach and contact reporting.

Governance Model A: Professional Self-Regulation

The first — the model of long standing that remains in use today — rests on the informal network of trusted peers (Furman et al. 2012) within the scientific community who engage in a form of self-regulation through peer review at the pre- and post-publication stages. As such, the emphasis of this model is on individual responsibility. If and when a study is found to have bad data (i.e., through an author's acknowledgement of error or through an investigation following charges of fraud), the normative expectation is that a retraction will be issued by the journal that published the study and that scientists will no longer treat the study as valid.

Borrowing from the typology developed by Montgomery and Oliver (2009), this model and its prevailing institutional logic would be characterized as "following normal practice of science," based on traditional behavioral norms articulated by Merton (1973). The primary governance mechanism is professional self-regulation, motivated by the desire to preserve scientists' autonomy. Pressures for conformity arise from normative expectations and are codified through professional codes of ethics, including publishing codes of ethics.

However, as shown in the discussion and examples provided above, the system of governance by self-regulation is porous, allowing studies with bad data to remain in the scientific literature and to be cited as valid, long after having been discredited, with potentially life-threatening ramifications.

Governance Model B: Public Health Outreach and Contact Reporting

In response to these shortcomings, we have proposed reframing the governance problem along the lines that have met with success in the face of public health

crises. That is, we can consider studies with bad data as akin to a biological virus that can be spread to others who come into contact with the false science through various modes of transmission. As such, this model emphasizes responsibility at the community level.

In order to prevent the virus from becoming highly contagious and leading to an epidemic of studies based on bad data, we have envisioned a centralized governance system that relies on reporting to an administrative body to serve as a repository for retraction notices. It would also be the agency proactively engaged in alerting the network of scientists and practitioners most likely to have come into contact with the false study.

Referring again to the typology developed by Montgomery and Oliver (2009), this model and its prevailing institutional logic would be characterized as "thwarting the spread of false science." The primary governance mechanism is proactive administrative coordination and involvement, motivated by the desire to assure not only that the virus of studies with bad data is removed from the system, but also that potential subsequent users of studies with bad data are identified and notified of the need to purge their own work of any reference to the discredited studies. Thus, this model contains a high degree of collective accountability, facilitated by administrative coordination and monitoring.

Points of Conflict Between Governance Models A and B

The main features of the two models of governance are presented in Table 1.

The potential conflicts between them are readily apparent, as they represent two different sets of beliefs and rules (institutional logics) that are shared by actors within the organizational field of scholarly research about how to treat false science. The two models also emphasize responsibility and intervention at two different levels: the individual level and the community level. In essence, these can be considered ideal types of two governance logics, which reflect a clash of authority structures between professional self-regulation and external oversight and reporting.

We recognize that worries about intrusion into professional self-regulation and encroachments on professional autonomy remain a high concern for scientists. Nevertheless, as Leahey and Montgomery (2011) have pointed out, professional self-regulation has long been constrained by various forms of administrative oversight, which scientists have acceded to, often in order to secure funding for their work. These constraints include requirements to obtain approval from Institutional Review Boards (IRBs) before initiating any project involving human subjects, as well as substantial review by funding bodies before providing support for a study. Such oversight activities have remained palatable because they are conducted by scientists themselves, who serve, for example, on their institution's IRB committees and on scientific review panels on behalf of funding bodies. Through such service, the norm of professional accountability and responsibility is reinforced as a counterpart to unfettered professional autonomy.

Indeed, the success of a public health campaign to contain a biological virus rests on an assumption of a high level of awareness and a norm of collective accountability and responsibility to assist in preventing further contagion to

Table 1 Components of Governance Models A and B

Governance Model	Model A: Professional self-regulation and peer review	Model B: Public health outreach and contact reporting
Institutional Logic	Following normal practice of science	Thwarting the spread of false science
Motivation	Maintain integrity of scientific body of knowledge through preserving *status quo*	Maintain integrity of scientific body of knowledge, while containing spread and use of studies with bad data
Locus and sector of activities	De-centralized, professional-peer driven; intervention at individual level	Centralized, administratively driven; intervention at community level
Normative pressures for conformity	Norm of appropriate professional behavior, as defined by peers	Norm of deferring to interests of protecting community under exceptional circumstances
Activities	Idiosyncratic and reactive	Proactive outreach to prevent and contain virus
Predominant actors	Scientists, journal editors and peer reviewers, professional societies, journal consortia	Scientists, centralizing coordinating body, journal editors and peer reviewers
Primary Processes	Retractions issued by journals after discovery of studies with bad data	Retractions reported to centralized coordinating agency, which maintains database of all retracted papers; agency initiates identification of contact networks of scientists associated with discredited study; contacts are notified and advised against relying on discredited study
Weaknesses	Porous system: inconsistent practices regarding how and when to issue retraction notices; wide variation in rationale given for issuing retraction; discredited papers remain in the literature and remain cited; heavy burden on scientists to make sure papers they cite have not been retracted; no centralized database to consult	Intrusive system: concerns that professional privacy is overrun by requests for contact reporting; costs to maintain and monitor centralized database and to engage in outreach to contact networks

vulnerable and uninformed members of the community. These activities include voluntary reporting and notifying of contact networks, even though this may be viewed as an intrusion into personal privacy. A public health perspective enables people to understand and accept that collective interests take precedence during such crises and that, in return, people trust those coordinating the contact reporting process to conduct it in a confidential manner, such as in the case of identifying and notifying partners of AIDS-infected individuals. Thus, the shared norm of collective accountability carries with it a norm of mutual trustworthiness among all stakeholders. And, as we have seen in the recent experience of Ebola cases in the US and elsewhere, a well-managed campaign of contact reporting and monitoring can be highly effective in thwarting the spread of a deadly virus.

The challenge in this context is to reframe the activities of contact reporting from being seen as a negative encroachment on professional autonomy to being seen as a positive collective professional responsibility designed to preserve the integrity of the literature. It is noteworthy that the professional stakeholders who strongly support the public health model to thwart biological viruses like AIDS and Ebola are likely to be many of the same stakeholders asked to embrace a new model for thwarting the spread of a virus of bad data. Norms of shared responsibility and mutual trustworthiness already exist in the biomedical context, where it is understood that collective interests of the community prevail when warranted by exceptional circumstances. Scary biological viruses are uncommon, and retractions of studies with bad data are also uncommon. Hence, public health campaigns are carefully targeted so as not to upset the norm of respect for personal privacy and individual agency under ordinary circumstances. Similarly, a campaign to cleanse the literature of studies with bad data should be balanced so as to complement, rather than unnecessarily intrude on, professional self-regulation.

Governance Model C: A System-Level Integration

We have discussed the limitations of the *status quo* Model A and have considered the promise of a community-based Model B for minimizing the fallout from retractions. One potential weakness in Model B is the difficulty in tracking all cases of research studies with bad data and their related citations. To address this challenge, we propose that a public health approach can form the foundation of an integrated governance model that incorporates a system-level intervention, shifting the level of intervention from individual and community to a system-wide focus. This is similar to the triple-helix approach, introduced by Leydesdorff and Etzkowitz (1996) and Etzkowitz and Leydesdorff (2000) for understanding patterns of triadic relations (university-government-industry relations) in the knowledge society. The value of the triple-helix model is that it allows us to view the three principal institutional actors as having equal interest in and contribution to the task of thwarting the spread of studies with bad data, although each is positioned differently with respect to the joint infrastructure they collectively produce.

In this context, a system-level integrated model can be of value since it encompasses the involvement of academia (universities and research centers) as the main contributors to the body of research, the government (mainly research funding agencies) and now, the industry (bibliometric-based organizations). All these participants have stakes and capabilities as well as compatibilities to join forces in the effort to provide an effective model of dealing with retraction of studies with bad data.

In recent years, bibliometric systems, such as the Institute for Scientific Information's Web of Science, have provided robust mapping mechanisms that enable not only measures of popularity and impact of articles and authors, but also the diffusion patterns through examination of citations. For example, bibliometric methods can be used to provide co-citation-based mapping, with fraudulent papers as the "seeds" for the analysis, which can then track how the virus may have already spread through the scientific literature via citations, including a time

Table 2 Components of Governance Model C

Governance Model	Model C: Triple-helix of academia-government-industry
Institutional Logic	Promoting a healthy body of scientific literature
Motivation	Maintain integrity of scientific body of knowledge, while collaborating to accommodate the shared interests of key stakeholders
Locus and sector of activities	Hybrid coordinating body, aligning interests of academia, government, industry; intervention at system level
Normative pressures for conformity	Balance between norms of academic and public interests; norm of efficiency in contact tracing
Activities	Proactive coordinated engagement with multiple actors to advance shared interests
Predominant actors	Scientists, coordinating agency, journal editor boards and sponsors, bibliometric firms, Retraction Watch blog
Primary Processes	Retractions reported to a centralized coordinating body (established by, agreed upon, and funded by all parties); contact reporting initiated by central body and facilitated by bibliometric firms with software capable of identifying network nodes and tracking citation patterns
Weaknesses	Complex hybrid system with many working parts: concerns about leadership, coordination, and funding; challenge to preserve paramount goal of integrity of scientific knowledge base, and withstand competing interests from some participants

dimension to track the spread. A second level of analysis, known as bibliographic-coupling mapping, can help to identify those papers (and the scientists who wrote them) that share references with the fraudulent paper. (See van Raan (2015) for an application of bibliometric mapping and the detection possibilities from using large-scale mapping technologies.)

These sophisticated techniques serve as warning systems that can facilitate the identification and notification necessary to contain the virus, assuring that all relevant stakeholders — scientists, universities, journal editors, funders, and monitoring agencies — are made aware of the invalidity of the fraudulent paper.[1]

Adding industry as the third helix would foster a combined effort of stakeholders from multiple domains, who are brought together for the shared goal of keeping studies with bad data from infecting the body of scientific knowledge. With commitment of the need to preserve the integrity of the body of knowledge (a primary goal of the scientific professional communities), a powerful and central monitoring, detection, informing and alerting system (a primary goal of the public health model), and a transparent representation of diffusion processes (a primary goal of bibliometric analyses), the immunization process can achieve system-level maximum protection. The main features of this third model of governance are presented in Table 2.

[1] We thank one of our reviewers for suggesting these bibliometric mapping illustrations.

Conclusion

We have presented an ambitious new model for dealing with retractions of studies with bad data, which deviates substantially from the long-established model of professional self-regulation. Although the public health approach has been successful in the health care communities, it has not yet been used in the context of scientific literature. We also recognize that any shift away from the *status quo* would necessitate buy-in from powerful professional stakeholders, ready to seek alternative ways to preserve the integrity of the scientific body of knowledge, even at the risk of losing some autonomy.

Thus, as noted earlier, an awareness of both the problem and the inadequacies of the current governance approach is an essential first step, best underwritten by leaders in the scientific professions. This appears to be occurring through the blog Retraction Watch, written by Adam Marcus, a science writer and journal editor, and Ivan Oransky, a physician and medical journalist on the faculty of New York University. An important sign of the growing visibility of the blog is funding from the John D. and Catherine T. MacArthur Foundation and the Laura and John Arnold Foundation, and accolades from a former editor of the *British Medical Journal* who called Retraction Watch "one of the best innovations in science in recent years" (Oransky 2014).

In this sense, we can consider Marcus and Oransky to be institutional entrepreneurs (Garud et al. 2007), who are already bridging the domains of academia and industry through their relationships with universities, journals, and funding sources. Thus, these writers are well positioned to move beyond merely publicizing retraction stories, but also to facilitate a change in governance of the scientific body of knowledge by creating a new system of meaning that "ties the functioning of disparate sets of institutions together" (Garud et al. 2007: 957). Recognizing stakeholders' shared goal of preserving the integrity of the body of knowledge may serve as the mechanism for such a change.

To this end, a commitment from the key stakeholders to take active measures to address the problem is essential. The integrated triple-helix governance model is promising because of the joint interests it embraces across stakeholder groups: First, it is in the interest of universities to preserve their scholarly reputation by being transparent in exposing fraudulent research conducted by their scientists. Despite the embarrassment and shame that may accrue when false studies are revealed, far more damaging are stories about cover-ups, which are becoming harder to sustain in the face of blogs like Retraction Watch.

Second, it is in the interest of governments and private funding sources to assure that funding is given to studies that do not perpetuate false science, in order to justify responsible use of taxpayer funds or shareholder resources, as well as to avoid harm to the general public by supporting studies that are not valid. And third, it is in the interest of industry, including bibliometric firms, to demonstrate their central role in fostering the preservation of a credible body of knowledge. This is accomplished by providing a tagging and flagging system of retracted research and conducting a network-based examination of mistaken citations conducted by

members of the scientific community. We propose that this shared goal has strong potential to rise above any arguments against changing the governance processes in the scientific body of knowledge.

Although this paper offers a general model of dealing with retracted papers, most examples are taken from the medical sciences, mainly due to their potential life-threatening effect of relying on studies with bad data for policy and practice decisions. Yet, this analytical framework is also highly relevant to any scientific community because studies with bad data shake the foundations on which knowledge advancements are made through the scientific research process and on which trust in the knowledge base is built and sustained. Furthermore, when organizational leaders, in any domain, base strategic and policy decisions on results and recommendations from discredited studies, all stakeholders who are exposed to the outcomes of such decisions may suffer.

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