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Retractions in *Science*

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Abstract:

Retractions are rare in science, but there is growing concern about the impact retracted papers have. We present data on the retracted paper in the journal *Science*, between 1983 and 2017. Each year, approximately 2.6 papers are retracted; that is about 0.34% of the papers published in the journal. 30 % of the retracted papers are retracted within one year of publication. Some papers are retracted almost 12 years after publication. 51 % of the retracted papers are retracted due to honest mistakes. Smaller research teams of 2 to 4 scientists are responsible for a disproportionately larger share of the retracted papers especially when it comes to retractions due to honest mistakes. In 60 % of cases all authors sign the retraction notice.

Retractions in *Science*

Publication plays a pivotal role in the growth and dissemination of scientific knowledge. But the growth of knowledge is neither strictly linear nor unidirectional. Mistakes are made. Retraction is one means by which the scientific record is corrected. In this paper, we examine the retraction practices and prevalence in the journal *Science*. We focus on 35 years of published retractions, from 1983 to 2017. We are not only concerned with determining the scope of the problem, but also the patterns in the data. From a policy perspective, knowledge of any patterns in retractions may be useful in developing targeted responses to deal with the root causes.

Background

Retractions are complex, and they can be seen from two very different perspectives, one negative, and one positive. On the one hand, retractions seem to indicate that there is something significantly wrong somewhere in the publication process in science. A retraction may signal a problem with the peer review process, for example, indicating a failure to weed out improperly conducted research. Alternatively, it could indicate a problem in the contexts where research is being conducted, in the laboratories or other sites of research. Perhaps the problem arises even earlier, in the context where the norms of research are being taught.[1] Regardless what the cause of the problem is, in the United States both the popular press and politicians have appealed to retractions as a way to undermine confidence in scientific claims.[2]

On the other hand, a number of scholars have noted how rare retractions are. By one count, there were ““some 300 retractions among 1.4 million papers published annually’.”[2]

Thus, it appears that less than one in 4,500 published papers are retracted. Given that so few papers are retracted, there may be no problem at all. In fact, the low levels of retractions might speak to the good health of the peer review system, the laboratory cultures, and the training of young scientists.[3]

Perhaps more noteworthy than how infrequently retractions are issued, is the increase in frequency of retractions over time.[4][5] And there are concerns that the present culture of scientific publication is apt to make matters worse with respect to retractions. Again, though, an increase in the frequency of retractions need not necessarily signal that a particular type of problem is becoming more prevalent. It may merely signal a shift in editorial policies, as journal editors try to improve an already well-functioning system, or respond to public perceptions of a problem in science.[6]

But some have raised the concern that retractions are an ineffective means to correct the scientific record, as retracted papers continue to be cited for some time afterwards.[7][8] Others suggest that the problems created by retractions and papers in need of retraction are quite small compared to the problems related to the crisis surrounding reproducibility.[8] Our study aims to enrich our understanding of retraction in science. We suspect that a study focussed narrowly on one of the two key general science journals may shed some new light on the issue.

Data and Methods

We report on data on:

the **numbers of retractions**;

the **time between publication and retraction**;

the **cause of the retractions**: (i) error, (ii) misconduct, and (iii) ambiguous cases;

the **number of scientists who authored the retracted articles**;

how often (i) **all authors**, (ii) **only some authors**, and (iii) the editors of *Science*

retracted the article; and

whether the articles continued to be cited after they were retracted.

Our aim is to identify patterns in the retractions, thus revealing a structure to this aspect of the growth of scientific knowledge. This study will aid us in understanding the publication process, and the role that corrections play in the growth of science. Retraction is just one form of correction in the scientific literature, but a deeper and systematic understanding of it will provide a fuller picture of the role of publication in advancing scientific knowledge.

We used the search engine of *Science* at science.com to find the partial and full retractions of papers. We searched for occurrences of the words: retraction, retractions, retract, retracts, retracted. We looked through all of the hits to ensure that we had found all notices retracting a part of a paper or a paper in full. In two cases, 'retraction' does not appear in the title. Before presenting our findings, it is worth noting that **retracted articles** published in *Science* outnumber **retraction notices** published in *Science*. This is because a single retraction notice will sometimes announce the retraction of more than one published article. In fact, in our survey of retractions in *Science*, there were four notices retracting two articles, two notices retracting three articles, and one retraction notice retracting eight articles. When we report the data on retractions we are ultimately counting the retracted articles, not the retraction notices. But we

date the retraction to the date of the retraction notice.[9] We refer to a retraction notice by the date of its publication. [2016 12 16], for example, refers to the retraction notice published in *Science* on December 16, 2016.

Findings

A. The numbers of retractions. We collected data on 35 years of publications in the journal *Science*, from 1983 to 2017.[10] In that 35 year period 92 articles were retracted. So on average about 2.6 articles were retracted each year. In some years there were no retractions, whereas in other years there were a significant number. The five years in which no retractions were made are 1984, 1987, 1988, 1993, and 1996. Since 1996, there has not been a year in which no retractions were made. There is a measurable increase in the number of retractions as we approach the present, from 3 retractions in the period of 1983-1987, to 17 retractions in the period of 2013-2017, though the final period was not the period in which the most retractions occurred. See

Figure 1.

It is worth noting that the great increase in the number of retractions from the five year period 1993-1997 to the five year period 1998-2002 is due, to a large extent, to eight retractions in 2002 involving a single scientist, Jan Hendrik Schön. Schön did not publish alone, but this is a case in which he alone was singled out as responsible for misconduct in all eight of the retractions.[11] Schön, incidentally, was also responsible for two additional retractions in the next five year period, 2003-2007.

It is worth adding some context to the numbers of retractions. *Science* publishes 51 issues a year. We counted how many Research Articles and Reports were published in 2010,

assuming that 2010 was a typical year. There were a total of 762 Research Articles and Reports published in that year. So, given that on average 2.6 articles are retracted each year, approximately 0.34 % of the articles published in *Science* are retracted (or, about 1 in 300).[12] This figure is higher than the figure reported above in [2]. It may reflect the fact that scientists who publish in *Science* are under greater pressure to publish in the most prestigious venues, and as a consequence may be more inclined to compromise their research. Alternatively, it may suggest that other journals are under less scrutiny than *Science*, and articles that should be retracted, and would be retracted if they were published in *Science*, are going undetected. But our finding is in keeping with a previous study which found that there was a correlation between the impact factor of a journal and the rate of retracted articles. That is, journals with higher impact factors have higher rates of retractions.[13][14] But, as Daniele Fanelli notes, “journals with a high impact factor are more likely to have clear policies for scientific misconduct.”[6]

Caption: The number of retractions in *Science*, grouped in five year periods, beginning from 1983.

We date a retraction to the date of the published retraction notice.

B. The time between publication and retraction. It is interesting to note the time between the publication of the article and the retraction. The time between publication and retraction will provide some indication of the efficiency of the scientific publication system in responding to problems. We measured the time between publication and retraction in terms of months. In our data, the time between publication and retraction ranged from two months to 141 months, that is, from 2 months to almost 12 years. The median time between the publication of the original article and the publication of the retraction was 24 months, that is, two years. The mean time between publication and retraction is 34 months (3113/92; about 2 years and 10 months). Almost 30 % of the retracted papers were retracted within a year of publication (27/92; 29 %). And 76 % of the retracted papers were retracted within four years of publication (70/92). The remaining 24 % were retracted between 4 years and 12 years of their publication (22/92). See **Figure 2**. The best fit curve is described by a power law, where $y = 3.0338x^{-0.228}$ and $R^2 = 0.1854$. Our figures on the time between publication and retraction are similar to those reported in an earlier study.[15]

The fact that many retractions occur within 12 months of publication speaks to the efficiency of the scientific publication system, at least as it operates in the journal *Science*. A retraction cannot occur until a publication has been scrutinized, and a significant error or concern found with the publication. Then the retraction has to be written, sent to the journal, and vetted by editors or referees. Perhaps it also speaks to the integrity of the system that even papers that were published five years ago (that is, 60 months ago) are retracted. It suggests that scientists do not take the scientific record as settled after something has been published, not even five years after something is published.

Caption: The time between the publication of the (retracted) article and the publication of the retraction of the article, in months.

C. The cause of the retractions. To address policy issues, it is worth considering the cause of the retractions. We distinguish between retractions due to unintentional **Error**, retractions due to **Misconduct**, and **Ambiguous** cases where it is unclear whether the errors are intentional. Errors account for 51 % of the retractions (47/92). Misconduct accounts for 35 % of the retractions (32/92). The remaining 14 % of the retractions are ambiguous cases (13/92).

In the Error category we have included the retractions we presume to be due to error because the retraction notice gives us no reason to suspect misconduct.

In the Misconduct category we have included the retractions where there is a clearly stated admission or judgment of misconduct expressed either in the retraction notice or elsewhere in *Science*. Data alteration or fabrication are examples of misconduct. It is worth noting that in the cases that fall into this category the misconduct has been committed by an individual member of the collaborative team.

In the Ambiguous category we have included the retractions where the retraction notice gives us some reason to **suspect** misconduct but there is no definitive statement of retraction. Retraction notice [1989 1 6] provides one example of this. The retracted article has two authors and the first author did not sign the retraction notice. The notice merely states: “I have decided to retract the paper ‘Virusspecific splicing inhibitor in extracts from cells infected with HIV-1’ by D. Gutman and myself published in the 16 September 1988 issue of Science (volume 241, p. 1492). The data in that paper should no longer be considered reliable.” Retraction notice [2004 3 26] provides a different kind of example. The retraction notice, signed by all the authors, is more explicit about the authors’ lack of knowledge as to what went wrong. After mentioning a couple of exceptions, the retraction notice states that “all data published in the Report were produced by C.C.Q. when he was in G.D.’s laboratory. We cannot presently explain the lack of reproducibility of the data.”

Our categorization rests on the assumption that the collaborative teams generally do not disguise misconduct as honest mistakes. This seems clear in the cases where an individual team member has committed misconduct. If an individual member of a research team commits misconduct on her own she is betraying the team and not acting as a member of the team given that the aim of the team is to conduct good scientific work.[16] The team is already in a position where it has to make the retraction and it would seem to be in the interest of the team to place the blame on the individual in question instead of accepting full responsibility itself, if the team could. Furthermore, the retraction notices show that research teams are generally capable of and willing to expose individual team members when they commit misconduct. But it may be in the interest of a research team to disguise misconduct as an honest mistake if most or all team members together committed the misconduct. But for the team members to commit misconduct

together each of them would have to be willing to act immorally and they would have to know each other very well. They would have to know each other well enough to trust that each of them keeps quiet. Presumably this very rarely happens.

A number of scholars have developed several different taxonomies of reasons for retraction in an effort to understand the phenomena.[7][17][18] But none of the existing taxonomies separate error from misconduct. These taxonomies include categories such as “Could not replicate results.” Such a would group together cases that may be due to oversight with cases that may be due to misconduct. Separating error from misconduct is clearly useful for policy purposes since preventing honest errors requires different tools and strategies than preventing misconduct. Aiming to ensure that scientists exhibit greater care when conducting research is very different from aiming to ensure that scientists refrain from cheating. Our data suggest that error is a common cause of retraction and, as we show in the next subsection, they also suggest that small collaborative teams of scientists are much more likely to commit an error that leads to retraction than large teams. If this is the case, then in an effort to reduce substantial errors in science, policy makers may want to give special attention to the challenges that smaller research teams face.

D. The number of scientists who authored the retracted articles. It is also worth noting how many authors were responsible for the retracted papers, that is, how many scientists authored the original papers that needed to be retracted. There was not one single-authored paper retracted in *Science* during the 35-year period we studied. This may seem to suggest that retractions are a consequence of co-authorship and collaboration. But such an inference is unwarranted for the following reason. Given our count of the articles published in *Science* in 2010, we know that very

few Research Articles and Reports in *Science* are published by a single author these days. In fact, only 8 of the 762 Research Articles and Reports published in 2010 were single authored (that is about 1 %).

A little over half of the retracted papers were authored by collaborative teams of two to four scientists (47 out of 92 papers; 51 %). The remaining 49 % of the retracted articles were authored by teams ranging from 5 scientists to 26 scientists. See **Figure 3**. The best fit curve is described by a power law, where $y = 55.45x^{-1.319}$ and $R^2 = 0.761$. This distribution is not surprising, given that earlier research by Derek de Solla Price suggests that there are more publications by smaller research teams than larger research teams in science.[19]

Caption: The number of scientists who authored the retracted articles published in *Science*.

Interestingly, although collaborative teams of two to four scientists are responsible for 51 % of the retracted articles (47/92), such groups authored only about 29 % of the articles published in *Science*, assuming 2010 is a typical year. See **Figures 4a and 4b**. Thus, these smaller

groups are more prone than larger research teams to publish articles that are ultimately retracted. Collaborative teams of five to seven scientists are responsible for roughly their share of the retracted articles. They were responsible for 30 % of the publications, and 27 % of the retracted articles (25/92). Larger research teams, teams of eight or more scientists, were responsible for less than their share of the retractions. Though they were responsible for 40 % of the publications in *Science*, they were only responsible for 22 % of the retracted articles (20/92).[20]

It is worth noting that the overrepresentation of teams of two to four scientists among the teams responsible for the retracted articles is in part due to the ten retractions resulting from the misconduct of Jan Hendrik Schön. Nine of the ten retracted articles that Schön was implicated in were authored by teams of two to four scientists. If we disregard the ten retractions involving Schön, collaborative teams of two to four scientists are responsible for 46 % of the retracted articles (38/82). Collaborative teams of five to seven scientists are responsible for 29 % of the retracted articles (24/82). And collaborative teams of eight or more scientists are responsible for 24 % of the retracted articles (20/82). So smaller research teams, teams of two to four scientists, are still responsible for significantly more than their share of the retractions even if we disregard the ten retractions involving Schön.

Figure 4a: Percentage of Publications, by Size of Authorship Team

Figure 4b: Percentage of Retractions, by Size of Authorship Team

Caption: 4a shows the proportion of articles published in *Science* by the size of the author team (single author, 2 to 4 authors, 5 to 7 authors, and 8 or more authors), in 2010. 4b shows the proportion of retracted articles published in *Science* by the size of the author team.

It is particularly interesting to consider the retractions that are due to an honest mistake. Although collaborative teams of two to four scientists authored only about 29 % of the articles published in *Science*, such groups are responsible for 51 % of the retractions due to an honest mistake (24/47). Again, collaborative teams of five to seven scientists are responsible for roughly their share of the retracted articles. They were responsible for 30 % of the publications, and 32 % of the retractions due to an honest mistake (15/47). Larger research teams, teams of eight or more scientists, were responsible for much less than their share of the retractions due to honest mistakes. They were responsible for 40 % of the publications in *Science*, and only for 17 % of the retractions due to an honest mistake (8/47). Hence the data suggest that smaller teams of two to four scientists are four times as likely as larger teams of more than eight scientists of committing honest errors that lead to retraction (24/29 divided by 8/40 is approximately four). The reason for this could be that larger teams are more likely to have devised means for critically reviewing their own research before publication.[21] Note that the numbers are so small that we should be cautious about attributing great significance to this result.

Future research should explore whether in fact larger teams are more careful than research teams of two to four scientists, or whether some other factors explain this pattern in the data.

E. The number of authors who signed the retraction. It is also worth noting how many of the authors of the retracted articles sign the retraction. In 15 % of the cases (14/92) none of the authors of the retracted article signed the retraction. These are called “editorial retractions,” as it is the editorial team of the journal that issues the retraction.[22] Most often the articles that are

retracted by an editorial retraction involve misconduct. Some of the editorial retractions involve honest mistakes but not all of the authors agree to the retraction. It is worth noting that an earlier study of retraction in biomedicine found that 29 % of retractions were issued by editors, and an additional 7 % were issued by a combination of authors, editors, and publishers.[17]

Perhaps a more important figure to note is that in 60 % of the retractions all of the authors of the retracted paper signed the published retraction (55/92). In many respects this is a comforting figure. These findings are similar to those reported in an earlier study.[5]

It is worth noting that in 2002 *Science* had “a standing policy that ***all authors of a paper must agree to its retraction***”.[11] But policies change. In 2009, the editors of *Science* informed a scientist involved in a case where a retraction seemed appropriate “that the journal’s editorial practice requires that they ***get signatures directly from all authors wishing to retract a paper***”.[23] This is a subtle change, so it is worth highlighting it. The earlier policy was that ALL authors of the retracted paper agree to its retraction. The more recent policy is that ALL AUTHORS WISHING TO RETRACT the paper sign the retraction. Thus, it is important to remember that the publication system in science is dynamic, responding to challenges in different ways at different times, as lessons are learned from past experiences.

In some cases people other than the authors of the paper sign the retraction notice together with all or some authors of the paper. Sometimes these other people assisted in re-evaluating the original data or attempting to replicate the study. These cases deserve further study.[24]

F. The post-retraction citations. We found that almost all of the papers continued to be cited after they were retracted in part or in full, if we disregard the papers that were retracted in 2016

or 2017. These latter papers have had little time to be cited since being retracted. Another paper, from 2010, received no citations at all, neither before nor after it was retracted. This paper was retracted 16 months after it had been published.

The remaining retracted papers got between 1 and 936 post-retraction citations. An earlier study, conducted before journals became widely available on-line, also found that retracted articles were cited for their reported findings even after they were retracted. There is no evidence that on-line publishing is affecting a change here.[7]

Whether these finding about post-retraction citations are a disconcerting sign depends on the nature of the post-retraction citations. Provided they explicitly acknowledge the problems with the original paper, then there is no problem. Whether the post-retraction citations are a disconcerting sign *also* depends on the nature of the retractions. When a paper is retracted in part or in full, parts of the paper may remain valid. Further study is required to determine the nature of the post-retraction citations.[25] Only then would we be in a position to determine how disconcerting post-retraction citations are. In a subsequent study we hope to analyze the nature of post-retraction citations.

Discussion

We have only reported on the most straightforward descriptive statistics here in our study of retraction in *Science*. We have a wealth of additional data that will support additional studies in the near future. For example, we would like to examine the implications that our retraction data have for understanding the notion of collective authorship in science. We would also like to

conduct a detailed qualitative study of the causes of retraction. A few qualitative remarks are in order.

We believe that the notion of retraction can give the false impression that this is a categorical concept. The varieties of retractions may be better conceived of as laying on a continuum. A full retraction signed by all the authors of the original paper, for example, is quite different from a retraction of some claims in a paper, which is in turn different from a retraction of a particular analysis or interpretation. Second, at the one end of the retraction continuum, a retraction can differ little from a correction. Clearly, there is a significant difference between a full retraction and a correction. But we want to insist on the importance of recognizing more distinctions.

It is perhaps natural to think of retractions as a sign of the toxic effects of the pressure to publish. But there are other considerations that need to be acknowledged. Some retractions are made after a research team has conducted further research. Again, one's initial impulse may be that these retractions could and should have been avoided by not rushing to publish in the first place. We believe that the situation may be more complex than this explanation suggests. It is likely that some important research that is published in articles that never need to be retracted may never have been conducted in the first place if some research that was published in a retracted paper was not published first. Not all mistakes in science can be anticipated or identified in the short term, before they are made. This is a normal part of learning from our mistakes.

References and Notes

- [1] One high profile case from the USA suggests that the propensity to cheat in scientific research may originate quite early in one's training. In the case of John R. Darsee, a research fellow at Harvard who was caught fabricating data, an inquiry traced his irresponsible behavior back to his undergraduate days at Notre Dame. See B. J. Culliton, Coping with fraud: The Darsee case, *Science*, 220: 4592 (April 1, 1983), 31-35.
- [2] J. Hilgard, K. H. Jamieson, "Science as 'broken' versus science as 'self-correcting': How retractions and peer-review problems are exploited to attack science," in K. H. Jamieson, D. Kahan, D. A. Scheufele, (eds.), *The Oxford handbook of the science of science communication* (Oxford University Press, 2017), pp. 85-92.
- [3] David Hull argues that, compared to politicians, scientists seem to be far less inclined to act dishonestly. Hull attributes this to the fact that the interests of individual scientists line up with the interests of science, the institution. D. L. Hull, "Why scientists behave scientifically," in *Science and selection: Essays on biological evolution and the philosophy of science* (Cambridge University Press, 2001), pp. 135-138.
- [4] R. Van Noorden, The trouble with retractions, *Nature*, 478 (6 October 2011) 26-28.
- [5] E. Wager, P. Williams, Why and how do journals retract articles?: An analysis of Medline retractions 1988-2008, *Journal of Medical Ethics*, 37: 567-570 (2011).
- [6] D. Fanelli, Why growing retractions are (mostly) a good sign, *PLOS Medicine*, 10: 12, 1-6 (2013). (e1001563)
- [7] J. M. Budd, M. Sievert, T. R. Schultz, Phenomena of retraction: Reasons for retraction and citations to the publications, *Journal of the American Medical Association*, 280: 3, 296-297 (1998).

- [8] A. Marcus, I. Oransky, “Is there a retraction problem? And, if so, what can we do about it?,” in K. H. Jamieson, D. Kahan, D. A. Scheufele, (eds.), *The Oxford Handbook of the Science of Science Communication* (Oxford University Press, 2017), pp. 119-126.
- [9] In one case, a single article was retracted in two notices. In this particular case, two months after the initial retraction a more elaborate retraction was issued. In the data we report below, we only count this retracted paper once, and we focus on the initial retraction.
- [10] The most recent retraction notice published in *Science* prior to 1983 was published in 1968.
- [11] D. Kennedy, Next steps in the Schön affair, *Science*, 298 (18 October 2002), 495.
- [12] We have included one retracted piece in our study that is neither a Research Article nor a Report, but rather a Review Article.
- [13] F. C. Fang, A. Casadevall, Editorial: Retracted science and the retraction index, *Infection and Immunity*, 27: 10, 3855-3859 (2011).
- [14] M. Cokol, I. Iossifor, R. Rodriguez-Esteban, A. Rzhetsky, How many scientific papers should be retracted?, *EMBO Reports*, 8: 5, 422-423 (2007).
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- [16] K. Mathiesen, The epistemic features of group beliefs, *Episteme*, 2: 3, 161-175 (2006).
- [17] J. M. Budd, Z. C. Coble, K. M. Anderson, Retracted publications in biomedicine: Cause for concern, *Association of College and Research Libraries National Conference Proceedings*, 390-395 (2011).
- [18] M. L. Grieneisen, M. Zhang, A comprehensive survey of retracted articles from the scholarly literature, *PLOS One*, 7: 10, 1–15 (2012).

[19] D. de Solla Price, *Little science, big science* (Columbia University Press, New York, 1963).

[20] Our findings deviate somewhat from findings reported in an earlier study of articles in PubMed. In that study, 9 % of the retracted articles were single authored, and 46 % were authored by teams of two to four scientists. The remaining 45 % were authored by teams of five or more scientists (see [5], 568-569). It is noteworthy that PubMed is an archive of the scholarly literature in biomedicine and the life sciences only.

[21] K. Brad Wray describes how some very large research teams have internal peer review processes in place. K. B. Wray, "The impact of collaboration of the epistemic cultures of science," in T. Boyer-Kassem, C. Mayo-Wilson, and M. Weisberg, (eds.), *Scientific Collaboration and Collective Knowledge: New Essays* (Oxford University Press, 2018), pp. 117-134.

[22] Five of the 14 editorial retractions were not titled as such in *Science*, though it was the editors of *Science* who issued the retractions. Perhaps a lower level of warning is the "Editorial expression of concern." An example is J. Berg, Editorial expression of concern, *Science*, 357: 6357 (22 September 2017), 1248.

[23] R. F. Service, A dark tale behind two retractions, *Science*, 326 (18 December 2009), 1610-1611.

[24] Sometimes when a retraction notice retracts more than one article, the various retracted articles will not have all the same authors. For example, a notice may announce the retraction of two articles, one authored by authors A, B and C, and the other authored by A, B, D, and E. The retraction may then be authored by A, B, C, D and E. C, D, and E are then retracting a paper that they did not co-author together with a paper they did co-author.

[25] Judith Bar-Ilan and Gali Halevi have studied the citations of 15 articles after they were retracted. They take into account the nature of both the retractions and the citations and still find

a large majority of the post-retraction citations to be problematic. J. Bar-Ilan, G. Halevi, Post retraction citations in context: A case study, *Scientometrics*, 113, 547-565 (2017).