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When a journal article is found to contain significant errors or the experiment cannot be reproduced, it is typically retracted by the journal. Because a retraction statement appears in a subsequent issue of the journal, there is little linkage between the retraction and the retracted article. Being unaware of the retraction, researchers go on to reference retracted articles in their publications, further perpetuating this erroneous work. This study examines citations to retracted papers in the scientific literature and the context of these citations. Citations to 211 articles, published between 1996 and 2000, were analyzed; about 30% of the citations occurred after the articles had been retracted. An in-depth analysis of the context of four selected articles was conducted. Most of the citations were affirmative; only five of the 137 citations were negative. It is concluded that, with electronic publication and in electronic databases, retractions should be more closely linked with the article retracted.

Headings:

Scientific and technical literature

Citation analysis

AN ANALYSIS OF CITATIONS TO RETRACTED ARTICLES IN THE SCIENTIFIC LITERATURE

by
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Introduction

The process of scientific publication, through peer-review, is largely one of trust. There is no reason to assume a scientist came to his conclusions through fraudulent means and it is assumed by many that the peer-review process will bring to light any inaccuracies. However, it is not unusual to unearth tales of fraud and misconduct in the scientific literature. These can include anything from fabrication of data to plagiarism to distortion of actual data. Evidence of misconduct will lead to an investigation of that scientist's work and ultimately, if proven invalid, the publication is retracted.

A retraction is simply a statement, usually, but not necessarily, issued in the original journal of publication but not necessarily, informing the readers that a previously published paper has been proven invalid. It is typically issued by the original authors but in special cases, can also be retracted by the authors' institution or the journal editor. Since the retraction is printed in a subsequent issue, there is no indication in the original print journal that this article has been retracted, so there is nothing to stop the reader of the article from using it as a reference in his own manuscript as if it were valid. In the electronic environment it is easier to link retraction statements to original articles so there is less chance that a reader will assume a retracted article is a valid piece of scientific research.

Scientific error can be intentional, including fabrication of data or plagiarism, but it can also be unintentional. Not all article retractions are the result of misconduct;

sometimes it is simply a mistake too large to be rectified by printing a correction. Even with this admission of an honest mistake, the reputations of both the scientist and the journal are called into question. Even if the article is known to be fraudulent, “the business of declaring a biomedical paper flawed and retracting it from the body of literature is an inexact undertaking, fraught with legal, ethical, and scientific complications” (Snodgrass and Pfiefer 332).

It is important to know the way information is disseminated in scientific research to understand how fraudulent research is perpetuated in the literature as if it were valid. There are several ways researchers find information on their topic of choice. One is by doing a literature search through a database like MEDLINE or Web of Science. Another way is by culling through the reference lists of articles they have found useful. Researchers can also find articles by word of mouth from colleagues or reviewers, recommendations from librarians and by browsing the current literature in their field. These are just a few methods for finding information in the sciences, but not all of these methods of research would inform the researcher if he were using a source which had been retracted.

The National Library of Medicine has been tagging retracted publications in their MEDLINE database with the heading “Retracted Publication” since 1984 and they also link the retraction statement to the original article, as they would do for a comment or erratum. Other scientific databases, such as the Institute for Scientific Information’s (ISI) Web of Science, do not link retractions to their original article, so a researcher would not know if an article had been retracted when using these databases to find research on their topic. Some publishers also create a link between the retraction and the original article in

their electronic versions of the journal, but not all do and there is inconsistency among the publishers as to how this is accomplished. If a researcher were to cull references of other articles or browse the print journals to find relevant research, he or she would not necessarily be alerted to a retraction.

There is a very good chance a researcher would stumble upon a retracted article without ever knowing it had been proven invalid and use it as if it were a valid source. Then the researcher could unknowingly use this retracted paper to support his or her research or validate an idea, unaware that this article is of questionable validity. Citing a retracted paper not only has negative implications for the citing author's work, but also further muddies the scientific record. Theoretically, once an article has been retracted, there should not be any more citations to this work unless it is cited negatively or its retraction is acknowledged in the text. But, is there any way to get a sense of how often invalid research is being cited after it has been retracted?

Literature Review

In trying to understand a topic, authors look at what has previously been written. When they write on that subject, they create links to those resources in the form of a citation. Small explains a citation as, “when we attempt to express ourselves on a topic, and in our train of thought, come to an idea which is in our mind associated with a specific source” (339). Citations are used to attribute ideas to the source from which they came. Several people have studied the field of citation behavior to better understand the reasons authors cite certain works.

Shadish et al. studied author judgments of works they had chosen as references and found several motivations behind using a specific resource for citation. They surveyed 192 authors in the field of psychology to try to assess the most important reason, out of 28 reasons, those authors chose to cite one specific article in their reference list. They found that 18% chose “this reference supports an assertion in the sentence in which it occurred,” 16% said “this reference documents the source of a method or design feature used in [the] study,” and 9% said “it was a classic reference in the field” (481). The study also found that 45% of the citing authors had either spoken directly or by phone with the referenced author (483). This study helps explain the basis on which authors chose works to cite in their writing.

In another article about citation behavior, Michael and Barbara MacRoberts explain why negative references are infrequently seen in the literature. The authors

present several reasons which could explain this hesitancy to criticize a colleague in print; the colleague in question could be a friend or superior, “editors routinely send manuscripts to the very person or persons being criticized,” or criticism is not necessarily well received by editors who sometimes want it toned down before publication (92). The MacRoberts’ conclude that it would be “almost impossible to detect all negational references without author cooperation” (93).

Studies of citations and citation behavior can be carried out using a citation index. According to Eugene Garfield, founder of the Institute for Scientific Information, the oldest citation index still in existence is *Shepard’s Citations*, which was first published in 1873 to aid the legal profession in searching the case literature (*Citation Indexing* 7). The first annual edition of ISI’s *Science Citation Index* was published in 1963 and Garfield credits *Shepard’s Citations* as being his inspiration (*Citation Indexing* 18).

Citation indexes use the citations of works to provide access to the literature. When an author cites a work, it is assumed that the two articles have something in common, and citation indexes rely on this linkage rather than the subject or keyword indexing used by MEDLINE and other databases. Citations can be used as “measures of scientific accomplishments of an individual, a group, an institution, or a country, as well as for following the temporal evolution of science in general, or a certain field of science in particular” (Moravcsik 86).

Several studies have investigated the context in which works are cited in papers. Moravcsik and Murugesan created a classification scheme of references to better understand the context in which papers were being cited. Citations were labeled conceptual or operational, organic or perfunctory, evolutionary or juxtapositional, and

confirmative or negational (88). This classification was developed to study articles in theoretical high energy physics, but has also been applied in contextual analyses of publications in other fields.

Inspired by the Moravcsik-Murugesan study, Chubin and Moitra focus on classifying citation context as affirmative or negational. Affirmative citations can be either essential or supplementary and negational citations are either partial or total (426-427). The authors found that 95% of their citations fell into the affirmative categories and only 5% were negational (429).

There are few studies that explore the citation history of retracted articles. Three papers investigated citations to articles written by three specific authors whom were proven to have committed scientific fraud and misconduct. All three authors wrote many articles and their cases of fraud were well publicized in the literature. Garfield and Welljams-Dorof used ISI's *Science Citation Index* to identify citations made to 23 articles authored by Stephen Breuning. They excluded instances where Breuning cited himself and analyzed the remaining citations to determine if Breuning's work was mentioned positively, negatively or neutrally. They found that 57.4% of the citations were neutral, only mentioning some aspect of his work, 32.3% were negative and 9.9% were positive (1426).

The second case, studied by Kochan and Budd, used the *Science Citation Index* to determine post-retraction citations to the literature of John Darsee, who was found to have falsified much of his data. His work was proven invalid in 1981 (489). Similar to the Garfield and Welljams-Dorof study of the Breuning case, the authors studied citations to Darsee in the period from 1982-1990 and performed citation context analysis to see if

they were positive, negative, or mention fraud. The authors found that 85.9% of the citations were positive, 8.4% negative, and 5.7% made mention of the fraud (491). The authors acknowledged different findings from the earlier study and said “it is obvious that Garfield and Welljams-Dorof’s finding cannot be extrapolated to all cases of fraud” (491). Although citations began to taper off after several years, the authors found that there were still positive citations to Darsee’s work up to ten years after the discovery of the fraud.

The third case studied was the Robert Slutsky case, investigated by Whitley, Rennie and Hafner. The authors chose 86 of Slutsky’s articles published in five journals and looked at the citations to these articles in an 11 year period, from 1979 to 1990. Slutsky resigned from his position as a cardiologist in 1985 so the authors were analyzing citations to Slutsky before and after his work was proven to be invalid to see if there was any tapering off of citations to his work post-retraction. The authors compared the citation performance of each of Slutsky’s articles to two articles from a control group, appearing in the same issue as the Slutsky article, to try to understand any impact retraction had on the citation life of his papers. The authors found that the citations to Slutsky articles were reduced after they were exposed as invalid (173).

In her dissertation, Wright studied 53 retracted articles to see if citations to those papers went down after the retraction, by comparing the number of citations two years before and after retraction and comparing that to the normal rate of decline for citations due to obsolescence. She found that there was a statistically significant difference between the number of pre- and post-retraction citations (223). Secondly, Wright performed citation context analysis on over 300 articles which cited the retracted papers

to see if they were being cited positively or negatively. The author found that only about 10% of the citations to these retracted papers were negative (234).

A study by Pfiefer and Snodgrass chose 82 retracted articles and analyzed citations to these articles. The authors identified 733 citations to these 82 articles and looked at the impact factor of the citing journal, the geographic distribution of citing author, and the number of cumulative citations versus how many years had elapsed since the retraction. Also, interestingly, the authors found that only 56% of their 82 articles were tagged with the "Retracted Publication" heading in the MEDLINE database (1422). Snodgrass and Pfiefer also looked at the standardization of retraction notices in the scientific literature. The authors concluded that, despite guidelines in place to establish some unity among retraction notices, out of 35 retraction notices, only one adhered to all of the guidelines (331). They found that "too many retractions, roughly half, continue to be published as letters to the editor," and "significant format problems remain" (331).

Further information about MEDLINE retraction policies can be found in Atlas and in the National Library of Medicine's fact sheet, "Errata, Retraction, Duplicated Publication, and Comment Policy." Their policy on retractions is that a retraction will only be indexed as such if "it clearly states that the article in question is being retracted or withdrawn, and is signed by an author of the retracted paper or the author's legal counsel; by the head of the department, dean or director of the laboratory where the paper was produced; or by the journal editor" (4). In addition, it "must be labeled and published in citable form; that is, the retraction must appear on a numbered page in an issue of the journal that published the retracted article" (4). The National Library of Medicine (NLM) is requiring publishers to print retractions in a very specific way, so it is not surprising

that Pfeifer and Snodgrass found that 44% of their retracted articles were not labeled as such in the MEDLINE database. In response to NLM issuing these guidelines, the International Committee of Medical Journal Editors (ICMJE) met to establish their own set of rules to comply with NLM so retractions can be indexed in the proper way and be effectively communicated. They decided “the retraction, so labeled, should appear in a prominent section of the journal, be listed in the table of contents page, and include in its heading the title of the original article” (304). Publishers are not required to follow these guidelines and it seems, even today, there is little consistency among scientific, medical and technical (STM) publishers.

Methodology

This study of retracted papers has two aims: 1) to see if retracted articles in the scientific, technical and medical literature are still being cited, and 2) to look at the citations to four retracted papers to get a sense of whether the context of the references is positive or negative.

A study of the medical literature was chosen because the MEDLINE database can be used to easily locate retracted publications because retracted articles are tagged with a MeSH heading specific to retraction. To identify the retracted publications used for this study, the MEDLINE database available through PubMed was used, and all of the citations for the years 1994 to 2000 with the MeSH heading "Retracted Publication" as a publication type were imported into the reference management software EndNote. Because citations to these papers were being studied, it was decided not to choose any retracted articles more current than the year 2000 to ensure there was enough time for significant citations to accrue. In addition to using PubMed to find retracted papers, the *Office of Research Integrity (ORI) Newsletter* and the NIH Guide for Grants and Contracts website (http://grants.nih.gov/grants/guide/index.html) were searched for those years to ensure there were none missed by PubMed. Only one additional paper was identified this way.

Once the pool of 211 retracted articles was established, PubMed was used to identify the date of retraction and the citation of the retraction statement. Then, ISI's

Science Citation Index was used to ascertain the total number of citations and the number of citations post-retraction for each retracted article. Based on the method used by Pfiefer and Snodgrass, the citations post-retraction were counted starting the next calendar year after the retraction was published (1420).

Four retracted articles were then chosen as case studies to perform citation context analysis on the references to those four cases. The cases were chosen because of oddities or a high number of citations to the article after retraction. From *Science Citation Index,* the bibliographic information of the citations to each article was downloaded, separately for each of the four articles, into an EndNote file. All articles not in English were eliminated before context analysis. The 137 referent articles were analyzed according to Chubin and Moitra's study design. The citation was found in each article and the context was determined as affirmative or negational. The authors categorize a citation as affirmative if it is "declared central to the reported research, a reference on which its findings depend" or "provide[s] additional information" (427). A negational reference is if "a citer suggests that the paper is erroneous in part" or when the "citer refers to the paper as being completely wrong" (427). These definitions were used in categorizing the context of references to the retracted articles.

Results

Large set of retracted papers

There were 211 retracted articles identified for the first part of this study. They were originally published in the years 1996 to 2000 and all retracted by 2004. These articles had a total of 7,937 citations with 2,393 of the citations published after retraction. On average the articles were cited 11.3 times after retraction and 37.6 times in total, which shows that about 30% of the articles' citations were after retraction. Also, eight of the 211 articles were never cited and 28 articles, about 13.3%, were not ever cited after retraction.

Case studies

Four retracted articles were chosen for case studies. Two were chosen because of the oddity of their retractions, one because of its high proportion of citations after retraction, and the last because it was highly publicized. The post-retraction citations to these four retracted articles were examined to determine the context of the references. The following are the four articles chosen as case studies:

Buchdunger, E., et al. "Selective Inhibition of the Platelet-Derived Growth Factor Signal Transduction Pathway by a Protein-Tyrosine Kinase Inhibitor of the 2-Phenylaminopyrimidine Class." Proc Natl Acad Sci U S A 92.7 (1995): 2558-62.

Schon, J. H., et al. "A Light-Emitting Field-Effect Transistor." Science 290.5493 (2000): 963-6.

Sparks, L. E., et al. "Volatile Organic Compound Emissions from Latex Paint--Part 1. Chamber Experiments and Source Model Development." Indoor Air 9.1 (1999a): 10-7.

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Case Study 1: Two papers by Sparks et al.

The first two articles were both retracted papers by the same authors and were published in the same issue of the journal *Indoor Air*. These two articles were chosen because of the nature of their retraction. In examining the June 2000 retraction statement, it was found that these two articles were retracted simply because of an issue of trademark. As explained by editor-in-chief of the journal *Indoor Air*, David Grimsrud, the journal published four papers "that used TEXANOL® and TXIB® as generic names for the chemicals 2,2,4-trimethyl-1,3-pentanediol monisobutyrate and 2,2,4-trimethyl 1,3-pentanediol diisobutyrate. TEXANOL® and TXIB® are registered trademarks of the Eastman Chemical Company" (136). Two of the four papers retracted from this issue of *Indoor Air* were by Sparks et al.

The reason this retraction is so unusual is because there is no error or flaw in the paper itself, just in the choice of a few words. It seems like the kind of problem that could easily be made right with a correction, but for some reason, possibly legal, the journal decided to completely retract the four articles. In this case, there is nothing to indicate the research published in these two studies is invalid but because of the retraction of the articles, they should be stricken from the literature and cited accordingly.

The lists of papers referencing these two articles are in Appendix A, citing the article beginning on page 10, and Appendix B, citing the article beginning on page 18. The result of the context analysis performed on the references is summarized in Table 1.

One article was removed because it was not in English and the context of the citation could not be determined. For the first article, 15% of the citations, or two references out of ten, were found to be negational citations. Neither negative reference mentioned the retraction. For the second article, none of the five references were negational.

Table 1: Analysis of post-retraction citations to Sparks et al. (1999a, 1999b)

	Sparks et al. (1999a)		Sparks et al. (1999b)	
Type of citation	**Frequency**	**Percent**	**Frequency**	**Percent**
Affirmative	10	77%	5	100%
Negational	2	15%	0	0%
Eliminated	1	8%	0	0%
Total	13	100%	5	100%

When examining the citations to the first article, two were published in the same journal as the retracted article (Fjallstrom, et al.; Yang and Chen). The editors of this journal must not have noticed that articles accepted for publication in their journal were citing an article that they had just retracted a few years earlier.

Case study 2: Buchdunger et al., 1995

The next case study was chosen because a high proportion of the citations came after the retraction. The article has been cited 148 times since publication, with 100 of those citations coming post-retraction (see Appendix C for post-retraction citations). In their retraction, the authors state, “In the interest of scientific accuracy and our mutual desire with the editors that only high quality and reliable data are published, we regret to say that the *in vivo* data for the articles above are not considered reliable” (12069). This is a more typical retraction than the retraction of the first two articles; it states that an aspect

of the experiment could not be reproduced or verified so the authors are retracting the article.

It was found in this case that most of the citations to the article were affirmative, as seen in Table 2. Six articles were eliminated because they were in a foreign language or because a copy could not be located. The remaining 94 citations were analyzed and 93 were affirmative while only one was negational. Although location of the reference in the article was not specifically studied, in many of the articles, the reference was made to support some part of the author's methodology.

It was also interesting to see that the author of the retracted article, Buchdunger, cited this retracted work in six of her subsequent publications. As she was the first author listed on the retraction, it is hard to imagine that she would not know she was citing a retracted article in her subsequent articles.

Table 2: Analysis of post-retraction citations to Buchdunger et al., 1995

Type of citation	Frequency	Percent
Affirmative	93	93%
Negational	1	1%
Eliminated	6	6%
Total	100	100%

Case study 3: Schon et al., 2000

The last case was chosen because it was a very high-profile case, with proven misconduct and several of the author's articles being retracted. The first author, Hendrik Schon, was a physicist at Bell Labs, owned by Lucent Technologies. An article in *Wired* says he has published more than 80 articles before the age of 32, many in high-impact journals like *Science* and *Nature* (1). The final report issued by Bell Labs in the investigation into Schon's work listed his work in three categories of misconduct:

substitution of data, unrealistic precision of data, and results that contradict known physics (2). The committee found misconduct in 16 of Schon's articles and recommended their retraction and also cleared all coauthors of any responsibility (3-4). This was a very well-publicized case of misconduct, with much coverage in the scientific news and on the Internet. It is important to perform citation context analysis on references to a Schon article to see if a retracted paper with so much publicity is still receiving citations.

The article chosen was cited 19 times after retraction and 60 times in total since publication; for a bibliography of post-retraction citations see Appendix D. A further examination of these citations revealed that 17 of the citations were affirmative and only two negational, which means 11% of the citations are negative (see Table 3). Both of the negative citations mention the retraction.

Table 3: Analysis of post-retraction citations to Schon et al., 2000

Type of citation	Frequency	Percent
Affirmative	17	89%
Negational	2	11%
Eliminated	0	0%
Total	19	100%

It was surprising to see an article (Meng, et al.) with two of the listed authors from Lucent Technologies, where Schon worked at the time the scandal erupted. The reference to Schon's work in this article was positive. One would expect that those authors would have known of the scandal or any internal review process would have caught the inappropriate reference.

The referring articles in this case study were also analyzed for location of the authors because it was thought that maybe authors outside of the United States would not receive the same exposure to the news of the Schon scandal. It was found that 16 of the

19 articles, about 84%, had author addresses outside of the United States, which could easily contribute to the authors' lack of knowledge about the retraction.

Another interesting finding in this case was that two of the articles (Xie et al.; Kim et al.) cited several of Schon's works in their papers. In fact, in both articles, 6 of the 10 references were to Schon articles. If their work is so based on work that has been proven invalid, one has to wonder about the validity of their two studies. It is easy in these cases to see how much citations to fraudulent research can taint the results of subsequent papers.

Discussion

The study of a large group of retracted articles showed that retracted papers are still being cited with some regularity. A further examination of these citations, with respect to context, found that the majority of these citations were positive, indicating that the fact that the article was retracted was either not known or not understood by the citing authors.

The case studies illustrated that, even in the case of references to retracted articles, there are very few negative citations. There was variance in the percentage of negational references in the four cases, ranging from 1% negative references to Buchdunger et al. to 15% citing Sparks et al. (1999a). The two Sparks articles and the Schon article had significantly fewer citations to study, so one negative reference would affect the ratio of positive to negative citations more than the Buchdunger article with 100 citations.

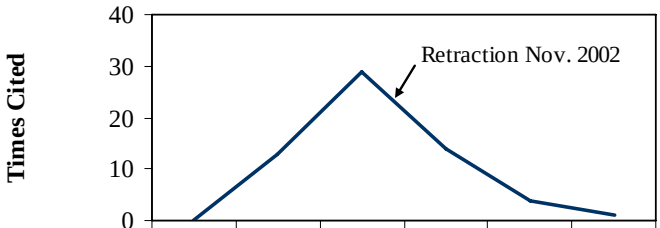
While there were few negative citations found in the case studies, there were also few mentions of retraction in works citing these retracted articles. Of the 137 citing articles analyzed for context in the case studies, only five were negative citations, and of those five, only two mention the retraction. None of the affirmative citations mention the retraction. The two negative citations to Sparks et al. (1999a) questioned the complexity of the authors' method (Guo; Yang et al.). The two negational citations to Schon et al.

referred to his study but also stated that the findings could not be reproduced and that the work was subsequently retracted (Chen et al; Hepp et al.).

Comparing the number of negative citations in this study to similar studies it is seen that the results are fairly consistent. The Kochan and Budd study found 8.4% of citations to their retracted articles were negative, Wright found about 10% of citations to retracted papers to be negational, and Garfield and Welljams-Dorof found 32.3% were negative citations. In the present study, the range of negational citations to the retracted case studies was between 0% and 15% for the four articles chosen to study.

It would be interesting to compare the post-retraction citations with a control group to get a better understanding of whether or not any decline in citations is because of the retraction or if it is a normal drop off of citations due to aging or obsolescence. The Schon article's post-retraction citations seemed to drop off steeply, as seen in Chart 1, but presumably that is because of the story's coverage in the scientific news.

Chart 1: Citations to Schon et al. by year



	2000	2001	2002	2003	2004	2005
Times Cited	0	13	29	14	4	1

Year

A limitation of this study is the author's lack of subject specialty for the context analysis. Many articles have obvious clues in terms of referencing, but subject specialty would unearth the subtleties of language used and a better understanding of the true

context of the reference. As noted by MacRoberts and MacRoberts, not only is it difficult to assess the citation's context, but even negative references are sometimes veiled to appear positive.

Another important aspect of the study's methods was that there was not one specific scientific subject chosen for this study. Since all retracted articles were taken from MEDLINE, they come from a broad range of scientific topics. In a future study, it may be fruitful to choose a specialty, like genetics or oncology, to study so that only one specialist would be needed to perform the citation context analysis.

Another limitation of this study is the availability of only one citation index, *Science Citation Index* (SCI), to find the articles that refer to the retracted papers. Although SCI indexes a wide variety of scientific, technical and medical journals, they do not include all journals in their database and do not index books' or conference proceedings' citations, so it is likely that references could be missed, especially from journals published outside of the United States and Western Europe. *Science Citation Index* also suffers from misspellings in author references, so it is not easy to locate all of the references to a certain article.

Conclusion

It has been shown that positive citations to retracted articles continue in the scientific, technical and medical literature. As previously discussed, this could be a problem with the way the news of a retraction is disseminated. Because retractions are announced in a subsequent issue of the journal, there is no indication of the retraction in the original print copy of the article. It is not surprising that researchers do not know their sources have been retracted. It was interesting to study the citations to a highly-publicized case, citations to the Schon article, because it showed that even an abundance of news coverage did not keep people from still citing his work positively.

The emergence of the Internet and the availability of electronic journals and online databases for searching present an opportunity for more linkage of retraction statements to the article being retracted. The MEDLINE database has been a leader on this front and hopefully more databases and publishers will follow suit. Electronic counterparts of print journals could very easily link the article with its retraction but still many do not.

It is equally important that authors and editors check the reference lists in articles before publication. Not only do they need to check for misspellings and errors, but one of the references could be to a work proven to be invalid. A good place to start would be to check references in the MEDLINE database. Another good resource is the Retractions Database (http://www.scc.rutgers.edu/retractions/index.cfm) available from the Scholarly

Communications Center at Rutgers University. It is a database of retracted articles that can be searched by fields like author and title. It does not seem, at this time, that there is an adequate amount of reference checking done before publication.

Hopefully this problem will get better in the future, with the opportunities for more communication of retractions presented by the increased use of online environments for scholarly communication. Citations to retracted articles affect the scientific record in a harmful way so it is important that these retractions be more effectively communicated.

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