Systematic Examination of Pre- and Post-Retraction Citations

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ABSTRACT

Scientific retractions occur for a multitude of reasons. A growing body of research has studied the phenomenon of retraction through systematic analyses of the characteristics of retracted articles and their associated citations. In our study, we focus on the characteristics of articles that cite retracted articles, and the changes in citation dynamics pre- and post-retraction. We leverage descriptive statistics and ego-network methods to examine 4,871 retracted articles and their citations before and after retraction. Our retracted articles data was obtained from PubMed, Scopus, and Retraction Watch and their citing articles from Scopus. Our findings indicate a stark decrease in post-retraction citations and that most of these citations came from countries different from the retracted article's country of publication. Citation context analyses of a subset of retracted articles also reveal that post-retraction citations came from articles with disciplinary and geographical boundaries different from that of the retracted article.

KEYWORDS

Retraction; Post-retraction citation; Citation networks

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Bibliometrics; Citation Analysis; Network Analysis; Scholarly Publishing

INTRODUCTION

Scientific retractions occur for a multitude of reasons, including minor problems such as publisher versioning mistakes, or major concerns such as plagiarism or fabrication of data. Scientific misconduct was found to be the most prominent reason for retraction [Fang et al., 2012], accounting for 94 of the 288 retracted articles identified. Thus, it is necessary that retracted articles are promptly retracted and publicly recognized to "minimize the number of researchers who cite the erroneous work, act on its findings or draw incorrect conclusions" [COPE, 2009].

The problem arises when retracted articles continue to be cited [Redman et al., 2008], at times even at a higher rate than before retraction (see [Fukuhara et al., 2005]). As an example, a study of 315 retracted articles found that articles published in higher-impact journals remained highly cited even after they were found to have committed research misconduct [Redman et al., 2008]. The reasons for these problematic citations are two-fold: (1) citing articles did not show awareness of the retraction statuses of the articles they cited [Da Silva and Bornemann-Cimenti, 2017]; (2) retraction information is not consistently presented across platforms where citing authors obtain bibliographic records [COPE, 2009]. Nevertheless, the continued circulation of retracted articles poses significant risks to the integrity of scientific research as honest and reliable works. [Bar-Ilan and Halevi, 2017; Da Silva and Bornemann-Cimenti, 2017].

To examine the citation dynamics of retracted articles in more detail, we analyze the citations of 4,871 biomedical articles from PubMed, leveraging both descriptive statistics and ego-network analysis methods. Our contributions are as follows: (1) we examine the characteristics of articles that cite retracted articles, and (2) we explore pre- and post-retraction citation ego-networks of 250 retracted articles using both citation context analysis and quantitative measures such as cited half-lives and time-lag. Ultimately, we hope to shed light on the potential reasons retracted articles continue to be cited and whether these citations can be considered as problematic.

RELATED WORK

There is a significant body of research about retraction of scientific publications. These articles analyze the characteristics of retracted articles such as retraction counts by disciplines and/or countries, reasons for retraction, cited half-lives, and self-citing dynamics [Bar-Ilan and Halevi, 2017; Redman et al., 2008; Bornemann-Cimenti et al., 2016]. While these studies examined characteristics of retracted articles at great lengths, more attention could be given to the characteristics of citing articles. [Budd et al., 1998] and [Bar-Ilan and Halevi, 2017] have begun to look into citing articles and their reasons for citing retracted articles. Additional characteristics of citing articles, such as their scholarly discipline, country of affiliation, and publication type, are needed to fully understand the citation dynamics of retracted articles pre- and post-retraction.

Along with bibliometric statistics, network analysis is frequently adopted to examine the underlying citation structures of retracted articles [Madlock-Brown and Eichmann, 2015; Lu et al., 2013]. Specifically, ego-network analysis [Wasserman and Faust, 1994] where the retracted paper is the ego, is useful to reveal the dynamics between

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citing articles (alters) connected to a common ego. Analysis of ego-network data focuses on the composition of the alters, and posits that characteristics of both the ego (retracted article) and the alters (citing articles) will have an impact on the ego-network structure [Borgatti and Ofem, 2010]. Therefore, we sought to explore characteristics of both retracted articles and their citing articles to understand how and why some retracted articles continue to be cited.

RESEARCH QUESTIONS

We examine citation dynamics of retracted articles by understanding the relationships between characteristics of retracted articles (*AR*) and citing articles (*AC*). Inspired by prior works, we operationalize characteristics in terms of citation counts, year of publication, and year of retraction. Hence, we address the following research questions:

RQ1: What are the characteristics of citing articles (*AC*) that cite retracted articles, pre- and post-retraction?

RQ2: What are the citation dynamics of retracted articles (*AR*) pre- and post-retraction?

DATA COLLECTION

Our list of *AR* comes from the intersection of three sources, PubMed, Scopus, and Retraction Watch. We collected a subset of biomedical *AR* verified to be retracted by PubMed (i.e. articles with publication type="Retracted Publication") that were also available in Scopus. We then collected *AC* that cited *AR*, all of which were published in or before 2018. Using Scopus and Retraction Watch, we collected several characteristics of articles. For *AR*, we collected country and retraction date information from the Retraction Watch Database; citation and publication date information were collected from Scopus. For *AC*, we collected country, publication date, and *AC*'s citation counts from Scopus.

RESULTS AND DISCUSSION

Characteristics of Retracted Articles (*AR*)

Our dataset contains 4,871 *AR* published from 1959 until 2018. The distribution of citation counts of *AR* are shown in Table 1. The average citation count is 35 (Min=0, Max=1416, SD=71.9). Average time from publication to retraction is about 3.9 years (46.8 months) (Min=0, Max=33 years, SD=4.12). Our reported mean time is twice as long as the mean time of 25.8 months (Min=2 months, Max=197 months) found in [Budd et al., 1998], whose data consist of MEDLINE articles from 1966 to 1997.

The distribution of citation counts exhibits a power-law distribution (α=2.933, R^2=0.831), consistent with many prior studies of citation networks that found most articles are cited a several times, and very few articles are cited many times [Redner, 1998]. Articles were by authors from 95 different countries of affiliations, with 16% of the articles being multi-country collaborations.

Citation Count	*AR* Count	*AC* Count
0	307 (6.3%)	15,745 (10.5%)
1	237 (4.9%)	8,362 (5.6%)
2-10	1,566 (31.9%)	39,321 (26.3%)
11-20	889 (18.2%)	23,267 (16.2%)
21-100	1,514 (31.0%)	48,339 (32.3%)
101-1000	370 (7.6%)	13,108 (8.8%)
>1000	4 (0.1%)	326 (0.2%)

Table 1. Citation Counts of A_R and A_C in our dataset

Characteristics of Citing Articles (*AC*)

We found 149,471 articles that cite one or more AR in our dataset. 1,086 of these *AC* are retracted as well. Author affiliations of *AC* were from 158 countries; country information was available in Scopus for all but 6,400 *AC* (4%). The top citing country of affiliation, the United States, accounts for 29% (n=43,402) of these *AC*. China is second with 13% (n=18,775) of the *AC*. 4% (n=5,402) of the *AC* resulted from collaborations of 2 to 5 different countries.

Most of the citations (66%, n=98,818) to *AR* came from journal articles. 22% of *AC* are review articles. This can be problematic as review articles sum up prior research and are usually highly cited. We found a notable decline in *AC* pre-retraction in 2010, yet there is an increasing trend in *AC* post-retraction that same year onwards. This trend is potentially problematic, and warrants further investigation.

Relationships between *AC* and *AR*

We partition the citations into pre-retraction and post-retraction. We define post-retraction citations as citations at least two years after the retraction date. Thus, if an article was retracted in 2013, we still consider a *AC* published in 2014 as pre-retraction. Articles published 2015 onwards are considered post-retraction. This two-year rule takes into account the delayed nature of journal publication and retraction process. We found 129,727 pre-retraction citations by 112,614 *AC* to 4,360 *AR*. 1,347 *AR* were not cited pre-retraction. The total number of post-retraction citations is substantially smaller, with 40,050 post-retraction citations by 38,134 *AC* to 3,223 *AR*. 210 *AR* were not cited post-retraction. We found that *AC*, on average, cite *AR*, post-retraction, that have been retracted about 5 years ago (Mean=5.02, SD=4.05). In addition, we conducted a one-tailed *Wilcoxon signed-rank test* for non-normally distributed data to determine difference between pre-retraction and post-retraction citation counts. We found that post-retraction citation counts were significantly lower than pre-retraction counts ($Z=-12.1$, $p<0.001$). This finding is consistent with prior studies that report a decrease of citations rates after retraction [Chen et al., 2013].

Ego-network Analysis

We also used ego-network analysis to examine the structural changes in each *AR*'s network pre- and post-retraction. We extracted a subset of 250 articles from the entire *AR* dataset with identical pre-retraction and post-retraction citation time-lag, i.e. identical time elapsed considering the pre-retraction timeframe for citation as publication to retraction + 2 years, and the post-retraction timeframe for citation as retraction + 2 years to 2018.

Out of these 250 *AR*, 8 articles had no change in pre- vs. post- citation counts, 240 experienced a decrease in citation counts, and 2 articles had increased (though minimal) citation counts after retraction. We also found that on average, articles experience a citation loss of 86.5% (Min=0%, Max=100%) after retraction. Our reported finding is much larger than what was found in [Pfeifer and Snodgrass, 1990], who found that articles lost about 35% of citations after retraction (their data consists of 82 articles retracted between 1977 and 1988, with 6-month washout period). One possible reason could be that retraction has received more attention and higher scrutiny [Steen, 2012].

To take into account natural citation decay, we compared each *AR* to its similar articles, which we defined as articles published in the same journal and on the same year. We compared the year when the *AR* reached half of its current citations (*YR*) to the average year similar articles received half of its citations (*YJ*). In 127 of the 250 retracted articles, *YR* is before *YJ*, indicating that the retracted articles receive fewer citations over time compared to their similar articles. In 91 retracted articles, *YR* = *YJ*, while in 22 retracted articles, *YR* is after *YJ*. 8 retracted articles either did not have citations or had an irretrievable set of similar articles.

We also compared the percentage of citations received after the year of retraction for both the *AR* and its set of similar articles. In 221 of out the 250 retracted articles, the percentage of citations received by *AR* after retraction (i.e. post-retraction citations) is smaller than the average percentage received by its similar articles. For instance, one article published in 2007 and retracted in 2013 received 4% of its citations post-retraction, while on average, its similar articles received 58% of citations after 2014. This analysis shows that the decrease in citations may be attributed to a retraction effect, rather than just a natural citation decay. We aim to extend this analysis to all retracted papers in our dataset to determine whether the retraction effect persists.

To capture structural changes of the ego-networks after retraction, we partitioned the networks into 3 equal sets (*low-medium-high*) based on their citation counts, and conducted ego-network analysis for each set. The *low* set, contains *AR* with citation counts of 0-7, *medium* set of 8-26, and *high* set of 27-1426. We picked an exemplar case from each set to do an in-depth ego-network and citation context analysis of the changes pre- and post-retractions.

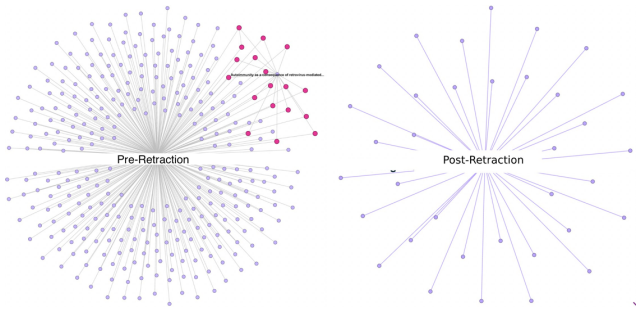

Figure 1: Ego-networks of *high* set example (PMID: 10514006) pre-retraction (left), post-retraction (right)

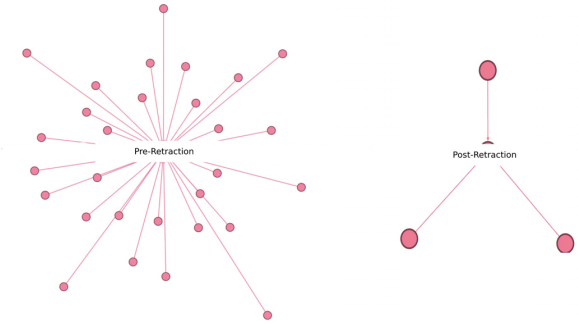

Figure 2: Ego-networks of *medium* set example (PMID: 19716552), pre-retraction (left), post-retraction (right)

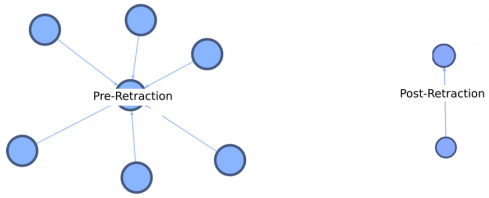

Figure 3: Ego-networks of *low* citation example (PMID: 21633303), pre-retraction (left), post-retraction (right)

Figure 1 shows the ego-networks extracted from an *AR* in the *high* set of citation counts (n=382). The time-lag of this *AR* is 10 years, and was retracted due to duplication of an image. The citation counts dropped from 347 to 35, reducing the size of the post-retraction ego-network by 90%. The cited half-life (i.e. years from publication until 50% of citations is reached) is about 5 years, and was reached 4 years before this paper was retracted. Interestingly, the pre-retraction network illustrates an *AR* citing another *AR*, and both were from the same group of authors. This is consistent with [Rubbo et al., 2018]'s finding that self-citations often occurred pre-retraction.

Figure 2's ego-networks are from an *AR* from the *medium* set (n=33). This article has a time-lag of 5 years, and was retracted due to its manipulation of data. Its cited half-life is 4 years, and was reached 1 year before retraction. Post-retraction, the citation counts dropped from 29 to 3. These post-retraction citations were from Austria, Argentina, and Turkey, none of which were from the *AR*'s country of publication (United States). All 3 articles were published in

areas only broadly related to *AR*'s field of neuroscience (e.g. genetics), and recognized the findings from the *AR* as legitimate. Citation context analysis reveals that these articles treated the experimental results in *AR* as reliable, indicating that they "have shown that calcineurin blockage increases depressive-like symptoms" [Turkish article], "induced depressive-like behavior" [Argentinan article] and "shown to cause neurotoxicity" [Austrian article].

Figure 3 shows the change in an ego-network of an *AR* in the low set of citation counts (n=6). The article has a time-lag of 4 years, reached its cited half-life at 3 years, and was retracted due to manipulation of images. Pre-retraction, the article was cited 5 times by different articles broadly related to oncology, with 4 articles from China and 1 from the Czech Republic, none of which were from Japan (*AR*'s country of affiliation). After retraction, only 1 article from China cited *AR*, and the citation context was positive as it was used to affirm the authors' findings.

CONCLUSION AND FUTURE WORK

Our research sought to examine the characteristics of (1) citing articles (*AC*) that cite retracted articles, and (2) retracted articles' (*AR*) pre- and post-retraction citations, using descriptive statistics and ego-network analysis. Some of our statistical results differ from studies done about 20 years ago in terms of the citation loss rate post-retraction (our 86.5 % vs 35%) and the time-lag between pre- and post-retractions (our 46.8 months vs 25.8 months). These differences in findings suggest that the process of retraction, and the dynamics of citing *AR* have evolved.

Ego-network analysis shows decreasing trends in citations post-retraction [Bornemann-Cimenti et al., 2016], but also that these citations still recognized *AR* "positively" [Bar-Ilan and Halevi, 2017] as legitimate work. We also found that citations post-retraction came from articles affiliated with a different country than the *AR*. Although *AC* and *AR* are broadly related, they are not from the same specialized research areas (e.g. *AR*: neuroscience; *AC*: genetics). Consistent with [Pfeifer and Snodgrass, 1990] and [Bornemann-Cimenti et al., 2016], we suspect that the awareness of retractions may be lower as the *AR* disseminate across geographical and disciplinary boundaries.

Our study has several limitations. Our data only consists of retracted biomedical articles available in the intersection of PubMed, Scopus, and the Retraction Watch Database. Secondly, we only examined a subset of ego-networks and compared their pre- and post-retraction structures by their network degree counts.

In future work we plan to expand this dataset to research disciplines beyond biomedicine, in order to check for differences in citation dynamics across disciplines. We also aim to collect citation networks that extends beyond relations between retracted and citing articles, but also relations among citing articles.

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