Institute for Scientific Information

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Global Research Report
Research Integrity: Understanding our shared responsibility for a sustainable scholarly ecosystem

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About the Institute for Scientific Information

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Executive summary

This report encourages everyone involved in research to broaden their view of what it means to conduct research with integrity and to consider how certain research evaluation instruments and incentive mechanisms are leading to a rise in deviant publication behavior.

Research integrity is a crucial topic for all those involved in the creation, delivery and assessment of academic literature. Without a trusted record of research, it is impossible to reliably build on previous ideas, replicate results, or effectively utilize the outcomes of research. The traditional focus on fabrication, falsification and plagiarism is no longer enough – new forms of manipulation are emerging as some stakeholders seek an unfair advantage.

Our report is intended as a guide – first, to expose the range of tactics used; second, to describe our varied and collaborative responsibilities; and third, to highlight current and future technological enhancements that will help us all uphold the principles of research integrity. Many of the tactics we describe are subtle, often manifesting as small infringements, but when accumulated over large quantities, their effects can be substantial and rewarding.

The future will be challenging as the digital transformation of research continues to accelerate our progress. Collaboration is essential since no single party can be expected to police and enforce research integrity – it is a shared responsibility that will require us to come together to develop new guidelines on what is considered unethical and decide on the appropriate actions to take when community norms are breached.

Introduction

Scholarly publishing has a longstanding, crucial role in the communication of academic research, providing the essential substrate on which ideas can be exchanged, criticized, and improved.

Thanks to developments in digital technologies, this process is now more rapid and far-reaching than ever before, providing extra momentum to the global scientific endeavor. This shared enterprise has widespread, socio-economic benefits, and it plays an important role in building an equitable and sustainable future.

Much of the value of research is attributed to a shared ideology of integrity – the notion that honest, ethical behavior coupled with sound methodology and rigorous peer review leads to results that can be trusted, replicated, and built on. Whether the research is performed in the lab, in the field, in silicon, or intellectually, it is typically embodied in the form of a scholarly publication that is used to communicate findings and form a shared record of knowledge. As such, a publication reflects the level of integrity that was followed, not only in terms of the underlying research, but also the process that created it – the drafting of the manuscript, the peer-review process, and the editorial input.

Following publication, the quality of research is judged through evaluation, using various forms of assessment implemented by many different stakeholders. This last step is critical as it fuels underlying incentive mechanisms and supplies pressure necessary for continual improvement. However, when enacted inappropriately, it can become an incentive for perversion of research integrity, leading some actors to seek short-cuts to gain an unfair advantage.

This report seeks to survey the scholarly landscape from the perspective of research integrity, documenting the various stages when the system can be undermined, revealing the growing number of mechanisms used to game the system, and identifying different stakeholder motivations. Through this mapping out of responsibilities, it is apparent that a collective effort is needed to combat those seeking to subvert research integrity. We therefore provide recommendations of how technology, data, and analytics can be used to identify and mitigate dishonest and improper practices.

What is research integrity and why is it important?

***"If I have seen further it is by standing on the shoulders of Giants"* – Newton, 1676**

Through the age of enlightenment and the formulation of a scientific method, the 17th century gave rise to normative behavior among scientists, providing a formal basis for scrutiny and the beginnings of scientific record – a shared history of discovery that could be critically examined and used as a basis for the formulation of new ideas and the recognition of contribution (Ayala 1994). This is a fundamental point of interest for this report since the veracity of the publication record is crucial when we consider the long-term sustainability of research. With each successive year, more and more papers are added to the shared human knowledgebase, each referencing prior work to build on previous ideas, challenge existing beliefs, and position the contribution of specific research in a wider context. Clearly, any actor that pollutes this record risks sabotaging future research, undermines aspects of open science, and frustrates those who seek to utilize it in a practical setting.

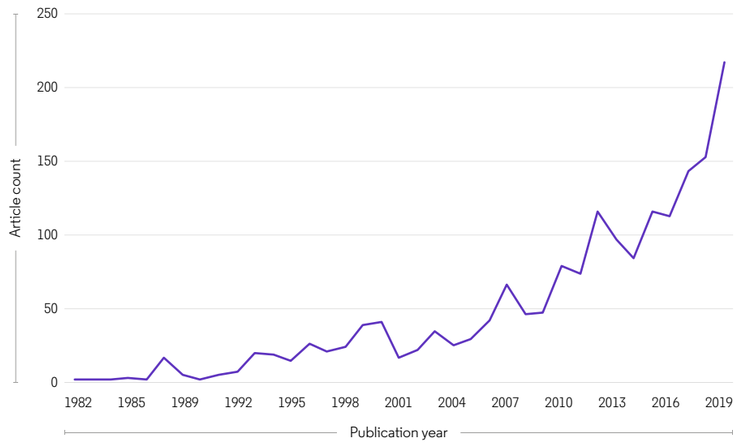
It was not until the 1970s that misconduct became a significant topic of public interest. High-profile cases emerged, notably that of immunologist William Summerlin, who in 1974 used a permanent marker to darken a patch of skin transplanted between mice. These events led to the first hearing on the topic in 1981 by the Investigations and Oversight Subcommittee of the House Science and Technology Committee in the US. Since the 1980s, various institutions have been established to tackle the issues relating to research integrity, including The Office of Research Integrity in the US and the UK Research Integrity Office. Most agencies that fund research have established their own code of conduct, professional bodies and societies provide members with their guidance, and a range of intergovernmental organizations contribute recommendations (see Appendix).

Publishers play a pivotal role in upholding the integrity of the publication record, since they manage the review of submitted manuscripts and determine which are suitable for publication. In recent years, this activity of publishers has become a new ethical battleground as many researchers have realized opportunities to exploit the process to their own advantage. As a result, publishers, their editorial teams, and peer reviewers are all under increasing scrutiny to ensure that proper standards are met. But it also happens that some members of these groups seek to undermine the system; in these cases the battle lines are blurred since it is researchers themselves who are also peer reviewers and members of editorial boards. To this end, organizations such as the Committee for Publication Ethics (COPE) provide extensive and practical advice to publishers on how to identify and take action in cases of misconduct as the need for guidance and advice has escalated.

Research integrity isn't necessarily about getting it right the first time. Researchers, either as authors or peer reviewers, make mistakes and the system of correction and retraction plays an important role in upholding the quality of published works. Pulverer writes *"In fact, the retractions, which often relate to papers that have long been published, ought to be seen as evidence that the much-touted self-corrective nature of the scientific literature is at work more effectively these days."* Even so, the notion of a perfect record is not something that has ever existed, nor is it easily obtainable. The lack of publication of negative results, for example, leaves gaps in our knowledge and remains a problem to overcome (Matosin 2014).

The growing interest in the topic of research integrity is itself evident in the academic literature. As shown in Figure 1, the annual number of articles dealing with research integrity indexed in the Web of Science™ between 1982 and 2019 has risen sharply.

Figure 1. Articles on research integrity indexed in the Web of Science



Why is research integrity undermined?

***"It is almost certain that misconduct has always been a feature of scientific research"* – Lock, 1994**

It is important to note that misconduct is not binary – there is a spectrum of behaviors that could be construed as inappropriate, ranging from minor incursions (such as a researcher adding an superfluous reference to their earlier work), through to catastrophic malpractice (such as fabrication of clinical trial results). In minor cases, individuals may not believe the tactics they use are questionable, perhaps due to ignorance or because they are deemed to be common practice within their community (if everyone else does it, why shouldn't we?). The social and professional construct itself often dictates what is considered acceptable, typically when the advantage gained is small or imperceptible and the ethical threshold is weakly defined. It is only when the scale of misconduct increases that the line becomes clearer and the power to call-out offenders is more readily wielded.

Irrespective of the personal or collective motivation (be it fame, fortune, or influence), it is important to consider the wider context. Within the research system, the pressure to perform is a key influencing factor making assessment a critical component of the machinery that influences individual behavior. Various forms of measurement are taken, such as funding won, journals published in or citations received, and these figures are used to inform a variety of decision makers. Students look at rankings to decide where to study. Researchers are assessed by their employers, funders, and national agencies to judge their suitability and competency to perform research functions. Journals are assessed by researchers when deciding on a publication venue and by their governing boards in terms of financial viability. Of course, everyone is measuring themselves against their peers and developing a strategy on how best to succeed.

Many of the intrinsic problems with this evaluation setup are currently under scrutiny and have led to various efforts to establish consensus and improve research assessment, notably the San Francisco Declaration on Research Assessment (DORA) and Leiden Manifesto (Hicks et al 2015). Reform is evident, as exemplified in the recent policy shift in China away from single point metrics to a more comprehensive evaluation system (Zhang & Siversten 2020). And, of course, there are also wider societal issues that influence the way in which research and researchers are evaluated (e.g. proscriptions against discrimination or bullying, efforts to increase diversity, etc.) that are out of scope for this report.

Below, we summarize the major stakeholders who play a role in upholding research integrity and broadly describe relevant motivating factors. It is useful to bear these in mind as the report continues to dissect the various ways in which misconduct is aligned with them:

- **Researchers** want to improve their standing through the publication of many research articles in high-quality journals that receive a high number of citations. This improves their chances of receiving funding, enables them to take on better positions (institutional, editorial, advisory) and generally ensures longevity of their career.
- **Journals** want to attract and publish the very best research articles in their field or increase their publication volumes to ensure their profitability, long-term sustainability and growth in readership.
- **Publishers** want to build a portfolio of successful journals, possibly specialized by field, access model, threshold for acceptance or otherwise.
- **Institutions** want to attract, develop, promote, and retain academics that produce world-leading research with wide socio-economic benefits. In turn, a better research profile improves their standing in rankings which bolsters student applications, increases alumni support, and enables recruitment of first-rate faculty.
- **Funders** want to invest money in the teams and projects that will deliver high-impact outcomes.
- **Governments** want to build and invest in productive research systems with high quality governance that deliver political, economic, and cultural advantage.
- **Database and Analytics providers** seek to provide useful search and discovery features that help researchers work quickly and more efficiently, and to provide analytical tools (including metrics and indicators) that support research evaluation use-cases.

What are the different types of behavior that undermine research integrity?

The process of proposing, conducting, and publishing research is complex, frequently involves many individuals performing varied tasks, and depends on trust that each actor adheres to community norms.

Of the four norms of science that sociologist of science Robert K. Merton long ago described (Merton 1942), it is disinterestedness that has traditionally served to control self-aggrandizement. Remarking then on "the virtual absence of fraud in the annals of science," Merton connected disinterestedness with "the ultimate accountability of scientists to their compeers." Plainly, as the history of science in the last half century has recorded, there has been an increase in instances of research misconduct with the growth of the scientific and scholarly enterprise in the post-World War II era, and perhaps more so in the last few decades (Fanelli et al 2015, Fang et al 2012). It is, however, notoriously difficult to estimate the extent of misconduct or trends in such behavior (Fanelli 2009, Gross 2016, Zuckerman 2020).

First there is the question of definitions, of what constitutes research misconduct. Most official bodies use fabrication, falsification, and plagiarism (FFP) to describe the phenomenon. Second, there is the issue of reporting and detection. Third, there are changes in the research system itself that render one period incomparable to another.

In the current regime of accountability and measurement of research performance, stiff competition for research funding, and the digital revolution in publication, new behaviors have emerged that are more epiphenomena around research activity and publication than phenomena of the type traditionally monitored, such as FFP (Edwards & Roy 2017). The literature on research misconduct includes discussions of questionable research practices (QRPs), such as self-plagiarism (Martin 2013). But these new behaviors extend beyond and outside of QRPs. Especially in the last several years, both researchers and journalists have called out manipulation of the publication and citation record that is intended to generate "credits" for individuals or journals that, in many cases, can be exchanged for personal and commercial advantage (Biagioli et al 2019, 2020a, 2020b, Chapman et al 2019). Whereas Merton focused on priority in discovery as the main reward for researchers (Merton 1957), scientific achievement may now have lesser value as a "means of exchange" than an exceptional publication and especially citation profile. To that end, all manner of interventions and manipulations are nowadays directed to the goal of attaining scores and a patina of prestige, for individual or journal, although it may be a thin coat hiding a base metal.

Figure 2. Critical stages to ensure integrity in research and publication: More dangers than fabrication, falsification, and plagiarism

Figure 2 illustrates key points along the research and publication cycle when different individuals – typically a researcher, a peer reviewer or a journal editor – can threaten or violate research integrity to advance their own interests. The following description of these stages in the cycle (A through H) include FFPs, QRPs, and the newer forms of self-dealing and misrepresentation.

A

Research problem, literature review, hypothesis and plan.

The research cycle begins with a problem and should include a thorough literature review to avoid research duplication and redundant publication (Smart 2017), to increase efficiency in investigation, and to ensure that appropriate credit is paid to predecessors. It may be mentioned that one of the arguments ISI founder Eugene Garfield made for citation indexes for the scientific literature was avoidance of redundant research and publication (Garfield 1955). Of course, a review of the literature may well alter an initial hypothesis.

B

Research, experiment, and data collection.

Documenting a hypothesis and experimental plan, especially registering trials, prevents fishing for publishable results later. A complete record of experimental methodology and results obtained supports replication, which is today a major concern in many fields (Franca & Monserrat 2019). Shoddy or sloppy record-keeping has been a consistent (and likely intentional) pattern in many instances of research misconduct.

C

Data analysis, hypothesis testing, data preservation.

Fabrication, falsification, "cooking and trimming" of data exemplify misconduct; but other "expedients" include p-hacking, cherry picking data, and hypothesizing after the results are known, also referred to as HARKing (Head et al 2015, Murphy & Aguinis 2019, Raj et al 2018, Kerr 1998). The desire for positive and more-likely publishable results may drive this form of misconduct, which can often arise without conscious intent from confirmation bias and self-delusion.

D

Manuscript preparation, including data, exhibits, and cited references, as well as authorships, affiliations, and funding, acknowledgement, and conflict of interest statements.

There are many opportunities to undermine research integrity in preparing a manuscript that reports research results. Publication of research should represent a complete and accurate description of methods, data, and results, without image fabrication or manipulation (Bik et al 2016, Bucci 2018, Cromey 2010, Koppers et al 2017); the text should be original, not borrowed (no plagiarism, including self-plagiarism without comment), and not purchased from paper mills (Hvistendahl 2013); cited references included should serve only as documentation of related research, ideas, methods, and not to boost the status of authors, other individuals, journals, institutions, etc. (Gasparyan 2015); the authors listed should be valid (Fong & Wilhite 2017, Teixeira da Silva & Dobranszki 2016) according to international standards (no honorary/gift, guest, ghost, fake, or purchased authorships); affiliations of authors should also be accurate, not invented or embroidered (no flimsy, fake, or sponsored associations); finally, the publication should provide complete and accurate acknowledgements of support and forthright conflict of interest statements, if needed.

E

Choice of publication venue and submission.

The manuscript should not be submitted to multiple publication venues simultaneously. Instead, the paper should be directed to the most appropriate outlet, chosen to reach the community relevant to research published. Inappropriate venues include unfocused, predatory channels for the sake of publication alone (Butler 2013, Frandsen 2017). In addition, researchers should avoid "salami science" publishing (Huth 1986, Smart 2017), dividing research into least publishable units (LPUs).

F

Editorial and peer review process, including revisions.

In recent years, new and troubling behaviors have emerged at this juncture in the research and publication cycle. Unscrupulous authors, if asked to recommend reviewers, have suggested accomplices or have redirected a review to themselves using alias email addresses (Ferguson et al 2014, Haug 2015, Kulkarni 2016, Rivera 2019). Such fake, self-directed peer reviews highlight weaknesses in many publishers' peer review systems. Once reviewers' comments are received, authors should provide timely and focused revisions, without substantial

changes designed to benefit self or others (such as adding self-citations or citations to reward others, including peer reviewers or journals at the request of editors; moreover there should be no addition of authors, especially through the sale of authorship). Peer reviewers are expected to provide an unbiased critique of a manuscript and should not insist that authors cite papers by the reviewer (Thombs et al 2015). The reviewers should not attempt to suppress competitors, steal ideas or results in order to claim priority in discovery. In the current environment, journal editors should increase their vigilance in verifying authors, affiliations, and suggested reviewers, as well as in maintaining the identity and security of their own publication (Bohannon 2015). In some cases, editors themselves have become the problem through insistence that authors cite the editor's journal or other journals, especially in attempts to improve their Journal Impact Factor™ (JIF) (Chorus & Waltman 2016, Fong & Wilhite 2017, Herteliu et al 2017, Hickman et al 2019, Ioannidis 2015, Martin 2016, Wilhite & Fong 2012) or engage in journal "stacking" citation schemes (Davis 2012, Fister et al 2016, Heneberg 2016). Creation or use of fake Journal Impact Factors is also malfeasance (Dadkhah et al 2017, Gutierrez et al 2015, Jalalian 2015, Xia & Smith 2018). Editorial decisions of all kinds should be based on research quality and significance and not swayed one way or the other by personal considerations.

G

Publication.

In the end, the publication should conform to community norms, meeting an expectation of honesty, openness, and accountability (Franca & Monserrat 2019). Publication constitutes a contribution to fellow researchers and the advancement of knowledge and should not be designed or deployed as a vehicle for personal gain.

H

Use of the publication record to represent research and researcher.

Research assessment for allocation of resources (involving appointments, promotions, funding decisions) often depends on publication and citation data, in addition to other quantitative data and, most importantly, expert and qualitative judgments. If a publication and citation record has been manipulated and deformed, it cannot serve as a reliable record of individual (or journal or institutional) activity and achievement. Individuals and journal editors engaging in citation manipulation misrepresent their identities and status and undermine community trust. Research misconduct is thus not limited to fraud and plagiarism but includes gaming epiphenomena designed to obtain personal and commercial advantages and real benefits.

Shared responsibility

There are many stakeholders responsible for upholding research integrity and there is no single group that can fix failures in research integrity.

Hence, it is a shared responsibility that requires each actor to seek out information on how to identify and tackle problems of misconduct, many of which will be varied depending on their role. In the table on the next page, we provide a high-level listing of the types of responsibilities that support research integrity within the scholarly publication system. For each, a summary of pertinent aspects is given, and the relevant stakeholders are identified.

Many of these are aspirational and the degree to which they can be fully realized varies. As discussed below, additional data, analytics, and technological solutions can help combat these issues more effectively. In some cases, there are extraneous factors that will affect the ability for individuals to meet these responsibilities, such as being subject to bullying and discrimination, so much of the responsibility is also on those that manage the research environment.

Responsibility	Researchers (authors, coauthors and reviewers)	Publishers (including editorial boards)	Institutions	Funders	Database providers
Perform literature reviews • Check for duplication of work and plagiarism • Ensure appropriate credit is given to predecessors	•	•			
Confirm references are legitimate • Check whether cited works have been corrected or retracted • Ensure referenced material is relevant and avoid superfluous cited references • Maintain a level of self-citation that is appropriate to the field or discipline	•	•			
Ensure the provenance of any experimental data • While many cases of misconduct are deliberate, careless management of source data can lead to accidental use of dubious material • Check for signs of image manipulation and falsification of data	•	•			
Uphold statistical validity • Check that all variables are accounted for and that the expected statistical tests are in place • When possible, verify published data against third-party sources such as clinical trial result databases	•	•			
Verify author identities & affiliations • Make sure the names appearing on papers are for real individuals, the affiliations given are correct, and the named organizations are not fabricated	•	•			
Perform plagiarism detection • Use software tools to enhance plagiarism detection capabilities		•			
Screen images • Provide clear policies on what constitutes image manipulation • Use experts to screen images prior to publication		•			
Validate contributions • Ensure that listed authors did contribute to the research • Provide guidance on what constitutes an author, especially for highly collaborative works • Consider group authorships	•	•			
Perform proper peer-review • Ensure peer-review is not fake or self-directed • Check suitability of suggested peer-reviewers • Verify conflicts of interest • Identify and suppress coercive behavior, e.g. when suggesting additional references	•	•			
Check journal identities and validity • Be aware that those soliciting submissions may not be from the journal advertised either because of blatant hijacking or subtle refactoring of journal names • Avoid submitting to, reviewing for, or serving on editorial boards of journals that do not uphold basic scholarly standards • Proactively identify and exclude low quality and fake sources when selecting content and indexing data	•	•			•
Produce and use bibliometric indicators responsibly • Produce responsible metrics and withhold scores when anomalous behavior is identified • Use metrics to support decision making, not supplant it • Seek out multidimensional quantitative and qualitative indicators • Consider incentives created by evaluative frameworks carefully and the effects they will have on researchers		•	•	•	•
Researcher training & enforcement • Train researchers on fundamental skills including literature review, manuscript preparation, and peer-review • Create clear policies regarding expected behavior, monitor researcher activity, and take punitive action where appropriate • Be accountable to funders and governments			•	•	

How technology, data & analytics can help

Although the task may seem daunting, much progress has already been made to monitor the integrity of the research system.

Further enhancements are also possible as the availability of data increases, new analytical techniques are developed, and novel machine learning algorithms are applied. In the following subsections, we outline six major areas for improvement.

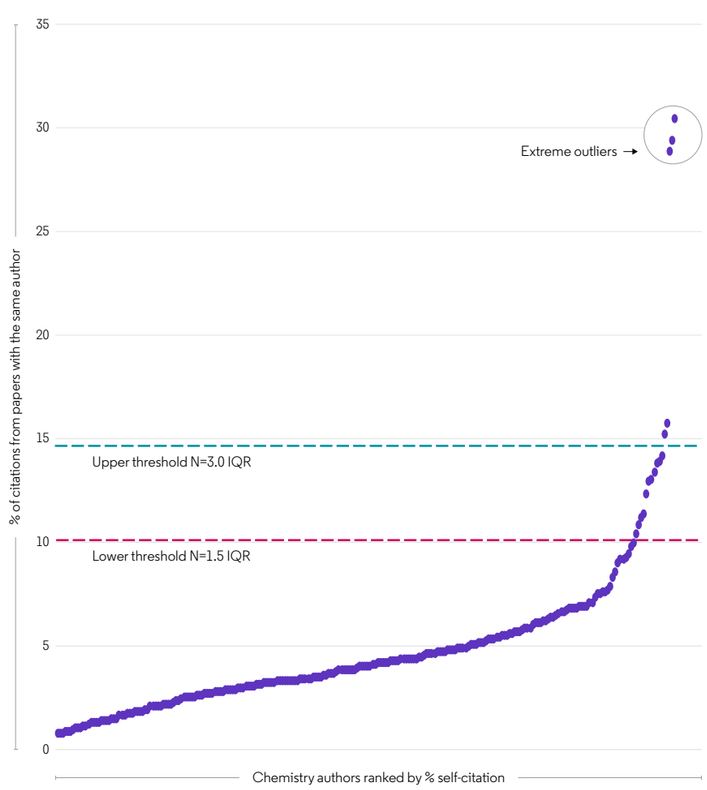
1. Self-citation analysis

Citation indicators are a method to measure the academic influence of a particular research paper based on the number of times it is cited by future works. When aggregated into a portfolio, such as a journal, institutions, or region, the cumulative academic impact of research can be measured and benchmarked against peers to reveal relative differences and changing trends in performance. The rate at which any individual or group (i.e., journal institution, region) references itself is a topic that has received continuous interest since the 1960s (Kaplan 1965), and the debate over what is considered acceptable considers many legitimate and illegitimate factors.

In recent work (Szomszor et al 2020), we conducted an analysis of the cohort of Highly Cited Researchers™ published in 2019 to understand better what can be considered an excessive rate of personal self-citation. In this study, the self-citation rates of individuals were critically reviewed using graphical techniques to understand the relative distribution of self-citation by field, and to highlight those with unusually high rates. An extract for the original work is shown in Figure 3 illustrating the distribution of self-citations (i.e., the percentage of citations received from papers with the same author) for around 250 authors in Chemistry. The chart shows a steady increase for the majority of the population, but a sharp rise towards the end that points to three individuals with unusually high relative rates of self-citation. The two horizontal lines are positioned at standard outlier detection thresholds (1.5 & 3 times the interquartile range from the third quartile).

This technique, in contrast to other work (e.g., Ioannidis et al 2019) that suggests use of percentiles to identify possible gaming, highlights the need for contextualization within field or discipline and human judgement. We can foresee application of this technique in manuscript reviewing scenarios when author self-citation rates for submitted papers could be reviewed in the context of the wider field enabling reviewers to make informed judgements and provide constructive feedback. The same techniques are equally effective when considering journals and could be used by editorial boards to track the self-citation rate of their journal and compare it to others to avoid potential problems (e.g., suppression of a title's Journal Impact Factor).

Figure 3. Distribution of self-citation rates for Highly Cited Authors in Chemistry.



2. Spotting coordinated journal citation manipulation

Since its first release in 1975, Journal Citation Reports (JCR) have provided transparent data on how self-citation and targeted inter-journal citation affects key metrics (Garfield, 1975). Beginning in 2004, analysis of journal-to-journal citation frequency data and the effect on JIF rank in category has been used to detect journals with a highly distorted Journal Impact Factor. These journals are subsequently removed (or suppressed) from the official JCR listing. More sophisticated analysis techniques were incorporated in 2011 to spot excessive citation exchange between multiple donor journals, a practice commonly referred to as citation stacking (Heneberg, 2016).

The concept of a citation cartel (Davis 2012) was discussed in 1999 in an essay by Franck (Franck 1999). He identified editors and journals working together using the mutual exchange of citations to provide a boost to their journals' Journal Impact Factors. It is difficult to uncover algorithmically (both in terms of computational complexity, and availability of high quality author disambiguation), but recent work inspired by network science (Fister et al 2016) has provided some hope that it may be possible to detect this anomalous behavior programmatically, but with the caveat *"We can only indicate that there is a high probability of citation cartel existence, but this fact needs to be confirmed using a detailed analysis."* Deeper analysis (Chakraborty et al 2020) describes the complexity of the issues, as these cases may be hard to distinguish from other gaming strategies, such as excessive self-citation, coercion, citation stacking and the online queue strategy (Martin 2016). Nevertheless, collaboration between database providers (who have the necessary data) and publishers (who may be made aware of these types of behavior) could lead to more sophisticated and readily deployed analysis.

3. Plagiarism detection

Software for the detection of plagiarism was described in 1989 (Parker 1989) and like many later analyses, was originally deployed in educational scenarios to detect when students copy each other's work. Once access to the web became a commonplace, the potential pool of copyable material exploded and more computationally intensive algorithms were developed to compare against huge corpuses of text. However, it is not just a simple task of finding exact replication between text – there are complex issues in terms of the difference between literal and intellectual plagiarism (Alzahrani et al 2012), the subtlety between paraphrasing and plagiarism (Barrón-Cedeño et al 2013), and the obstacle of detecting cross-language plagiarism (Potthast et al 2010). Citation-based approaches have been proposed to overcome these, as Gipp writes *"… citation patterns within documents…form a language-independent 'semantic fingerprint' for similarity assessment."* (2014 Gipp).

Evidently, plagiarism detection software should be a standard component of any editorial pipeline to facilitate rapid detection of dubious submissions, and as solutions become more sophisticated, it will become possible to identify more cases of this kind of misconduct.

4. Image Manipulation

Since the prevalence of papers with problematic images has increased significantly in the past ten years (Bik et al 2016), many editorial processes have been updated to include image screening programmes, and publishers are now expected to provide a clear policy on what constitutes image manipulation. The detective work is typically carried out by experts who look for tell-tale signs of dubious editing, such as cropping, brightness and contrast adjustment, selective enhancement, colour adjustment, cloning, and fabrication to name a few. The need to clean up images for publication is under scrutiny and may signal a shift towards publication of 'dirty' but more accurate renditions of the experimental results. Machine learning and other enhancements (Bayar & Stamm 2018, Bucci 2018, Cicconet et al 2020, Koppers et al 2017) will likely provide more sophisticated tools to aid in these programmes and expand their use outside the biomedical domain which is the current area of focus.

5. Anomalous reviewer activity

Another area in which software can assist editorial teams is flagging unusual reviewer activity such as uncovering when individuals have setup fake accounts and seek to review their own articles or articles from collaborators. This relies on collecting and analyzing many data points during submission and peer review to flag activity that should be further reviewed by the peer review and editorial teams. This could include authors and reviewers that arelocated on the same network or within close geographic proximity, reviewer turnaround times that are short, or the use of author recommended reviewers with non-institutional email addresses. ScholarOne™ includes features that give publishers and editorial teams access to these kinds of insights through their Unusual Activity Detection tool. More detailed analysis of the editorial and reviewer teams has been conducted (Sikdar et al 2016) and explores more specific indicators relating to reviewing frequency, self-assignment by editors, the diversity of materials reviewed, and more.

These provide exciting possibilities for more enhanced reviewing analytics that could strengthen publishers' defenses against reviewing misconduct.

Issues relating to the verification of peer reviewer identity (i.e. to prevent fake reviewing) can be addressed through open peer-review platforms, such as Publons™. These provide a place to record reviewing activity and provide some indication to editorial teams regarding the legitimacy of researchers. If combined with publication profiles, for example through integration with Web of Science ResearcherID or ORCID, it serves as a potential data source for automatic conflict of interest checking, and suitability for reviewing based on similarity of research fields.

6. Authoring tools

When researchers are writing their manuscripts, a great deal of information can be immediately presented to assist them in choosing appropriate references. Reference management tools, such as EndNote™ and Zotero, can make use of indexing services to determine the retraction status of articles, and provide useful information on journal quality, such as the type of peer-review or its transparency index (Nosek et al 2015).

In terms of self-citation, either individual or at the journal-level, it would be possible to use an indexing service to check cited references and flag referenced articles that exhibit unusual self-citation rates, or even to check that the manuscript being prepared has self-citation rates that are within a range typical for the discipline.

What's in store for the future?

This report has highlighted the epiphonema that has emerged around research activity and publication, how it directly relates to the issue of research integrity, and the need to establish new monitoring standards beyond the traditional frame of fabrication, falsification, and plagiarism.

From the mapping out of various stakeholder activities and respective responsibilities, it is clear that collective, proactive effort is required to address multifarious opportunities for misconduct.

There are several trends in research that will influence our journey forward. Open research mandates more transparency that will in turn influence the expectation of repeatability in terms of methodological rigor and data visibility. This will strengthen our ability to identify malpractice at the experimental, analytical, and publication stages of research. The increase in open access publication – an expected outcome as funders push various policies that require their work to be made publicly accessible – will alter how budgets for publication are allocated; how revenue flows between funders, institutions, and publishers; and how decisions are made on where to publish. Perhaps, on the issue of venue, it will become more pertinent for those holding the budgets (namely funders and institutions) to be more proactive in their approach.

Some organizations have already taken the initiative on this front, such as the Australian Research Council, which only considers articles from a defined journal list in their national assessment exercise – Excellence in Research for Australia (ERA). This list is created through consultation with peak bodies and disciplinary experts. Database providers can support this effort by ensuring transparent evaluation criteria are in place (such as that employed for the Web of Science Core Collection)[1] and work alongside community projects, such as the Platform for Responsible Editorial Polices (Horbach et al 2020), to guide researchers and research evaluators towards journals that uphold the principals of research integrity.

A core feature in many of the subversive behaviors identified in this report is misrepresenting identity. While public profiles of a researcher's publication and review activity provide useful data points in terms of corroboration, a further advancement towards verifiability could come from Blockchain technologies. Blockchain (Sherman et al 2019) uses cryptographic techniques to create a public leger that can be used to verify identity and trace transactions. Hence, it could be used to provide proof of identify and publication and establish trust between parties, such as in the peer-review process (Mackey et al 2019).

Finally, as new research evaluation frameworks are defined and revisions are made to existing ones, use of bibliometric indicators should be carefully considered. Any situation in which these are deployed has the potential to alter behaviors (goal displacement) and could lead to even new incentives to undermine research integrity.

[1]www.clarivate.com/webofsciencegroup/journal-evaluation-process-and-selection-criteria/

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Appendix

Statements and guidelines about research integrity, research misconduct, and the ethics of publishing scholarly and scientific research. Most recent listed first.

"Scientific Integrity Principles and Best Practices: Recommendations from a Scientific Integrity Consortium" (2020) Kretser, A. et al., *Science and Engineering Ethics*, 25, 327-355. https://link.springer.com/article/10.1007/s11948-019-00094-3

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Platform for Responsible Editorial Policies (PREP) https://www.responsiblejournals.org/

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