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Quotation errors in general science journals

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Due to the incremental nature of scientific discovery, scientific writing requires extensive referencing to the writings of others. The accuracy of this referencing is vital, yet errors do occur. These errors are called 'quotation errors'. This paper presents the first assessment of quotation errors in high-impact general science journals. A total of 250 random citations were examined. The propositions being cited were compared with the referenced materials to verify whether the propositions could be substantiated by those materials. The study found a total error rate of 25%. This result tracks well with error rates found in similar studies in other academic fields. Additionally, several suggestions are offered that may help to decrease these errors and make similar studies more feasible in the future.

1. Introduction

All scientists must build on the work of others. It should come as no surprise that scientific literature often contains an enormous number of citations and references to this work. These references are necessary to help substantiate one's claims and properly place one's work in a greater context. The reliability of this referencing is often taken for granted. It is generally assumed that a cited proposition can be substantiated by the reference given. When the reference given fails to substantiate the claim for which it is cited, a 'quotation error' has occurred. Quotation errors are a danger because they can result in the propagation of unverified or incorrect information.

Quotation errors are distinct from 'citation errors'. Citation errors include typographical violations of citation styles, excessive or redundant citations, missing citations, etc. Although citation errors are problematic, they can be detected with relative ease. Quotation errors

are far more difficult and time-consuming to discover. They require reviewers to compare the information cited with the source that it came from to verify if the information is contained within that source.

In several disciplines that require copious referencing, a significant amount of research has been done to verify quotation accuracy. In medical journals, for example, research has been done to quantify quotation errors [1]. Other research has been done in the fields of ecology [2], marine biology [3], physical geography [4] and various social sciences [5,6]. Unfortunately, there is significant variance in the criteria used for this reference verification [2–5,7–23]. In addition, the number of citations examined can vary wildly [2–5,7–23]. This makes direct comparisons of quotation error studies difficult. Regardless, in all previous studies surveyed by the authors of this paper, quotation errors were found in significant numbers [1–23]. Despite this, to our knowledge quotation errors in general science literature have never been examined. We present a pioneering study analysing quotation errors in high-impact multidisciplinary science journals.

This study examines 250 citations divided evenly from among five highly influential science journals. Some of the terminology used to discuss referencing has multiple meanings. In this paper, the terms are more specifically defined as follows: 'article' refers to the primary article in which the citations occur, 'reference' refers to the book, article, etc. that is being cited, and 'citation' refers to an individual instance of citing a reference. Throughout scientific articles, citations exist to substantiate specific propositions. The cited propositions were compared with the text of the references being cited. Each citation was then evaluated and categorized to determine its quotation accuracy. This paper provides a breakdown of the findings as well as suggestions to help decrease the number of errors in future papers.

2. Methods

The five general science journals with the highest impact factors in 2017 were used. All references listed in the 100 most cited articles of each journal during 2017 were downloaded from Web of Science and added to a spreadsheet. From these, 50 random references from each journal were selected [24]. One selected reference was found to be non-English, so it was replaced with another random reference from the same journal. Considering the need for a realistic workload for two reviewers and a median sample size of 200 among similar studies [2–5,7–23], this total sample size of 250 references seems reasonable. The references were then divided evenly among the reviewers. The first citation of the reference in the article was located. The first mention of the citation was always used, regardless of whether it was a single citation or part of a string citation (in which multiple references are cited in one citation). The cited proposition was then compared with the referenced article to determine the level of substantiation.

A total of four categories were used. Three of these categories were discussed and decided on by the reviewers before the research began.

Fully Substantiated was used for citations whose propositions are entirely substantiated by the reference cited. If a citation was part of a string citation, *Fully Substantiated* was granted as long as the reference being checked substantiated at least part of the proposition, and other references cited in the string were checked, if necessary, to make sure that the proposition is substantiated in its totality.

Partially Substantiated was used for citations whose propositions contained a minor error. The key division between this category and the following category was 'Does the error invalidate the purpose of the citation?' For example, if an article discusses an upward trend found in a reference but erroneously cites it as being a 25% increase instead of a 20% increase, the proposition would be considered *Partially Substantiated*. As long as the general sense of the proposition is correct, *Partially Substantiated* was used.

Unsubstantiated was used for citations to references that do not substantiate any part of the proposition. This could be because the information contained in the proposition is contradictory to, unrelated to, or simply missing from the reference.

A fourth category, *Impossible to Substantiate*, was added shortly after the study began. While this could in some ways be considered a subset of the *Unsubstantiated* category, the prevalence of *Impossible to Substantiate* citations warranted the category's inclusion. It was used for citations that could not possibly be substantiated by an outside reference. This impossibility occurred for two reasons. The first was simply the lack of a proposition to substantiate. The second was a proposition that is logically impossible to substantiate using a reference. This usually occurs due to the article citing a reference for actions undertaken as part of the study. Obviously, an outside reference—written before a study was published—cannot substantiate actions undertaken as part of that study.

The reviewers were not experts in any of the scientific fields being discussed, but both had significant knowledge and experience working with academic and scientific writings. As they were merely examining the substantiation of individual propositions, issues of misunderstandings due to a lack of expert knowledge were minimized. However, two of the propositions (both dealing with quantum mechanics) were deemed overly technical and beyond the reviewers' ability to evaluate. These citations were removed from the study, making the total number of categorized citations 248.

In cases when categorization was difficult or unclear, the reviewers consulted with one another to determine the proper category. In addition, early in the review process (after each reviewer had categorized approximately 25 citations), 20 randomly selected citations were checked by both reviewers, and there were no discrepancies in categorization.

3. Results

Quotation errors undermine the accumulative basis of scientific knowledge, so it is essential for scientists to be aware of their existence and try to avoid them. Our review of citations in the target journals suggests that problems with quotation errors are substantial (table 1). Although the raw data appear to suggest that error rates differ between journals, we conducted a Fisher's exact test to measure the effect of the journal and found no significant differences in the error rate for total errors ($p = 0.22$) or types of errors: *Partially Substantiated* ($p = 0.86$), *Unsubstantiated* ($p = 0.79$) and *Impossible to Substantiate* ($p = 0.12$).

Throughout all the journals, 75% of the citations were *Fully Substantiated*. The remaining 25% of the citations contained errors. The least common type of error was *Partial Substantiation*, making up 14.5% of all errors. Citations that were completely *Unsubstantiated* made up a more substantial 33.9% of the total errors. However, most of the errors fell into the *Impossible to Substantiate* category.

Although our methods of categorization are not identical to previous studies, a comparison of the overall error rate should still be relevant. In a sampling of 21 similar studies across many fields, total quotation error rates varied from 7.8% to 38.2% (with a mean of 22.4%) [2–5,7–23]. Furthermore, a meta-analysis of 28 quotation error studies in medical literature found an overall quotation error rate of 25.4% [1]. Therefore, the 25% overall quotation error rate of this study is consistent with the other studies.

We also considered differences in error rate due to whether a proposition had a single citation to support it or a string of multiple citations to support it. Table 2 shows the results organized by single and string citations. String citations are common [25]. In this study, they accounted for 63% of all citations. However, they accounted for only 34% of errors. A chi-square analysis of the distribution of references verified that references in string citations are significantly ($p < 0.01$) more likely to be *Fully Substantiated*.

4. Discussion

This study is the first review of quotation errors in high-impact general science journals. Errors were found to exist in considerable numbers. This demonstrates a weakness in the current use of references in scientific writing. There may be several reasons for these errors. Stochastic modelling suggests that 70–90% of references are copied second-hand from other articles' reference lists [26].

Table 1. Categorization of 248 citations by journal.

	Science	Science Advances	Proceedings of the NAS	Nature Communications	Nature	total
fully substantiated	39	39	39	32	37	186 (75%)
partially substantiated	3	2	1	2	1	9 (3.6%)
unsubstantiated	5	5	4	5	2	21 (8.5%)
impossible to substantiate	3	4	6	11	8	32 (12.9%)
total	50	50	50	50	48	

Table 2. Categorization of citations by type.

	single citation	string citation
fully substantiated	52	134
partially substantiated	7	2
unsubstantiated	13	8
impossible to substantiate	21	11

In addition, it has been argued through analysis of misprints that only about 20% of authors citing a paper have actually read the original [27]. As suggested by other quotation error researchers, authors could avoid errors through greater diligence [1,4–5,9]. There is also a lack of agreement regarding the correct reasons to include citations in scientific papers [28]. This could contribute to the citing of inappropriate references. Finally, quotation errors may occur though deliberate malpractice with the goal of increasing the citation metrics for the cited references [4].

Regardless of the cause, the most pragmatic approach to improving this problem is to improve the review and verification of references [1,20]. In the current state of academic literature, this is a very time-consuming task. In this study, it took two reviewers months of work to examine only 250 citations. The 500 articles from which we randomly selected our sample had a total of 26 344 references (many of which were cited multiple times). This suggests that it is unfeasible for editors or reviewers to thoroughly check all citations for substantiation. Therefore, we present two suggestions that would make systematic checking of references far more feasible.

First, most importantly, journals should change their citation styles to require page numbers. None of the high-impact journals reviewed require or even allow the inclusion of page numbers with in-text citations. In the verification process, a huge amount of time is spent searching through references to find the information being cited. Some books and reports are hundreds or thousands of pages long. Furthermore, even relatively short journal articles of 8–10 pages can be very dense and take a long time to thoroughly examine. Requiring page numbers (or paragraph numbers, etc.) places a slightly higher burden on the authors in exchange for significantly lightening the workload of potential reviewers. Lengthy references are often used to cite one specific piece of information, and it is not reasonable to expect reviewers to search through them to find that information. Page numbers should be required. One possible exception to this rule could be when referring to a study as a whole. However, even in those cases, propositions can nearly always be substantiated by referring to the page number of the introduction or abstract of a paper. This makes quotation errors easier to check for, increasing the likelihood of detection both before and after publication.

Requiring page numbers with in-text citations would constitute a significant change for academic publishers. The five journals in our study all use numbered endnotes, with a single endnote used for each reference regardless of how many times it is cited. To require page numbers

in the text, these journals would have to either require page numbers to be included in each in-text citation (along with an endnote reference number), require separate endnotes containing page numbers for each citation of the reference, or abandon endnote citation altogether for some style of parenthetical citation. However, the continued prevalence of quotation errors is a significant problem that more than justifies the one-time cost of journals adopting new in-text citation policies.

We are not necessarily suggesting that systematic review of all quotations should be done by reviewers/editorial staff. However, systematic review of quotations would have benefits. There is a reason that the academic review process exists: to verify and improve the quality of scientific literature. Minimizing quotation errors is certainly one way to do that, and reference verification by journal staff has been significantly correlated with fewer quotation errors [10]. However, even in the absence of such a system of editorial review, including page numbers would give readers and reviewers in studies such as ours a better chance at successfully detecting quotation errors when they happen. Furthermore, the simple act of requiring authors to specifically locate and cite a specific page would necessitate them taking more care with their use of citations.

Our second suggestion refers specifically to the *Impossible to Substantiate* category. We are not aware of any previous studies that include an *Impossible to Substantiate* category, so further explanation and justification for its inclusion is in order. Essentially, this category refers to statements being cited that either lack a clear proposition or contain a proposition that cannot be substantiated through an outside reference. For example, an article might merely mention a novel material and cite a reference discussing that material. There is no specific proposition being made. The reference is simply giving additional background information. Therefore, substantiation is impossible. In other cases, statements cannot possibly be substantiated with a reference. For example, it was not uncommon in the articles surveyed for the methods section to be replaced (in whole or in part) with a citation. Here, there is a claim: 'The methods from this reference were used'. However, it is not possible to substantiate this claim, because the article does not include the details of the methods used for comparison.

Some may consider this approach to be overly fastidious. However, there is no good reason to allow this type of inexact and non-verifiable referencing to pervade scientific literature. The most likely reason for this type of citing is to shorten articles to save printing space. This is a weak justification in the digital age. If background information is so unimportant that it does not merit a few words in the text ('discussed in reference 15' or 'see reference 15 for the history of material *X*' for example), then instead of using a propositionless citation, the information should be edited out of the paper proper and included as a supplement. The citing of methods sections and other unsubstantiatable claims could be dealt with in the same manner.

Of the previous quotation error studies reviewed, 71% did not mention string citations at all, and 14% specifically excluded string citations from their research [2–5,7–23]. Only one study specifically noted a difference in error rate between single and string citations. Surprisingly, that study came to a directly opposite conclusion regarding string citations, finding major errors more common in string citations [9]. The reason behind this discrepancy is unclear, although it may be related to the study's enormous sample size (more than six times larger than the other studies reviewed) or its very limited topic focus (peer-reviewed orthopedic literature related to the scaphoid). It is also not methodologically clear if the study required each reference in a string citation to substantiate the entire proposition being made. Our study did not require this. It required only that all the references in the string—as a whole—substantiate the entire proposition and for the reference being checked to contribute to that substantiation. References mentioned in string citations tend to make overlapping points and are often redundant [29]. Therefore, using our methodology, it seems reasonable to expect string citations to be more likely to be *Fully Substantiated*, not less. Still, the connection between string citations and substantiation needs further investigation.

Previous research has found quotation errors in the physical, life and social sciences [1–23]. This study extends that research to a cross section of high-impact general science journals, finding a similar rate of errors. However, further research is needed to more fully understand

the problem. This paper reviewed only a total of 250 citations, which is less than 1% of the citations included in the five target journals over the course of a year. Although this sample is in keeping with the sample size of similar studies [2–5,7–8,10–23], a larger sample could produce more meaningful results. The main barrier to using a larger sample is the time cost involved. By improving citation and referencing standards for journal articles, reviewers should be able to check references more quickly. Furthermore, in this study the reviewers were not experts in the scientific disciplines to which the references belonged. Even though only two references (0.08%) were deemed too difficult to understand, some classifications required extensive research on the part of the reviewers. Expert reviewers should be able to work at a significantly faster pace, allowing for larger sample sizes. Further review of references can better show the extent of quotation errors in scientific literature. A better understanding of these errors can help decrease them, leading to better, more rigorously supported science.

Data accessibility. The databases generated and analysed during the current study are available in the AHU Digital Repository, https://repository.ahu.edu/handle/20.500.12521/8.

Authors' contributions. Neal Smith participated in the design of the study, participated in data collection, analysed the data and critically revised the manuscript. Aaron Cumberledge participated in the design of the study, participated in data collection and drafted the manuscript. Both authors gave final approval for publication and agree to be held accountable for the work performed therein.

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