THE VALUE OF MENDELEY READERSHIP COUNTS AS A SOURCE OF ACADEMIC EVIDENCE AND IMPACT ON DIFFERENT SUBFIELDS OF PHYSICS: AN ALTIMETRIC ANALYSIS

BY

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Abstract
Counts of citations to academic articles are widely used as indicators of their scholarly impact. In addition, alternative indicators derived from social websites have been proposed to cover some of the shortcomings of citation counts. The most promising such indicator is counts of readers of an article in the social reference sharing site Mendeley. Although Mendeley reader counts tend to correlate strongly and positively with citation counts within scientific fields, an understanding of causes of citation-reader anomalies is needed before Mendeley reader counts can be used with confidence as indicators. In response, this Paper will assess the value of Mendeley readership counts as a source of academic evidence about the scholarly impact of different subfields of physics. To measure this, Mendeley readers and citations will be collected and analyze, in twelve different subfield of Physics [Physics of electronics and semi-conductor device, Waves mechanics, Digital physics, Medical physics, Fluid mechanics, Solid state physics, Radio communication, Atomic and nuclear physics, Bio physics, Thermodynamics (air condition and refrigerator), Electrical electronic physics, Satellite communications].This paper also proposes a list of reasons for anomalies based upon an analysis of articles that are highly cited but have few Mendeley readers, or vice versa. The results show that there are both technical and legitimate reasons for differences, with the latter including communities that use research but do not cite it in Scopus-indexed publications or do not use Mendeley. The results also suggest that the lower of the two values (citation counts, reader counts) tends to underestimate of the impact of an article and so taking the maximum is a reasonable strategy for a combined impact indicator.

Keywords*: Mendeley; Altimetric; Citation Analysis*

Introduction

Although citation counts are widely used informal and formal research evaluations as indicators of scholarly impact, they have many limitations. In particular, citations take time to accrue whilst follow-up research is conducted and published, and citations from the academic literature may not reflect an article's non-academic impact. In response to the latter point, a range of alternative indicators have been proposed to supplement citation counts. These include patent citations as indicators of commercial value (Meyer, 2000; Trajtenberg, 1990), web citations or tweets as evidence of wider or public interest (Eysenbach, 2011) and syllabus mentions as evidence of educational impact (Kousha & Thelwall, 2008). An important limitation of most indicators derived from the web is the ease with which they can be manipulated, making them unsafe for most formal evaluations (Wouters & Costas, 2012). Although many early alternative indicators are difficult to calculate in practice for large sets of articles, those generated from social websites, such as Twitter, can often be calculated automatically on a large-scale using Applications Programming Interfaces (APIs) that allow automated retrieval (Priem, Taraborelli, Groth, & Neylon, 2011). Many of these new indicators correlate positively and significantly with academic citations to articles, but typically with low correlation coefficients (Costas, Zahedi, & Wouters, in press; Thelwall Haustein Larivière Sugimoto 2013). Other analytical strategies are also needed to more fully evaluate these indicators, however (Sud & Thelwall, 2014).

One particularly promising new indicator is Mendeley reader counts (Gunn, 2013; Haustein & Siebenlist, 2011). Although counts of readers of articles in the social reference sharing site Mendeley (Henning & Reichelt, 2008) seem to predominantly reflect scholarly impact, and hence largely duplicate rather than supplement citation counts, they appear earlier than citations (Maflahi & Thelwall, in press) because they are not affected by publication delays and so have value as early impact indicators. This characteristic is particularly important for decisions relating to emerging research areas or recent research. Many studies have shown that counts of Mendeley readers correlate with citation counts for individual journal articles within a field, whichever field is analysed (Bar-Ilan, 2012; Haustein, Larivière, Thelwall, Amyot, & Peters, 2014; Li & Thelwall, 2012; Li, Thelwall, & Giustini, 2012; Thelwall, & Wilson, in press; Zahedi, Costas, & Wouters, 2014). Mendeley users tend to be younger than average and include a small proportion of master's and bachelor's degree students

(less than 20% - perhaps much less due to ambiguity in Mendeley's user category names) that presumably do not publish, as well as professional users such as medical doctors and librarians (Mohammadi, Thelwall, Haustein, & Larivière, in press). Reflecting this, eminent senior researchers seem to rarely use Mendeley (MasBleda, Thelwall, Kousha, & Aguillo, 2014). Those that do use Mendeley may register articles in it and are likely to read them in the future or to have read them before registering them (Mohammadi, Thelwall, & Kousha, in press). It is therefore reasonable to consider Mendeley as a source of predominantly academic readership information with a bias towards younger academics and educational uses. For convenience, the term *reader* is used in the remainder of this article to refer to people that register an article in Mendeley even though not all registered articles are read by the person that registered them.

In order to have confidence about the value of Mendeley as a scholarly impact indicator it is important to understand the contexts in which it does not work. Thus, the current article reports a study of individual articles for which their Mendeley reader count does not correspond to their Scopus citation count (i.e., the number of citations found by Scopus within Scopus-indexed publications). The objective is to produce a list of reasons why articles may be extensively read in Mendeley but rarely cited in Scopus-indexed publications and vice versa. This information can help users of Mendeley reader counts to look for individual problematic cases and to understand the limitations of Mendeley reader counts as a scholarly impact indicator. Scopus was chosen in preference to the Web of Science for its greater coverage of the academic literature (Moed & Visser, 2008; TorresSalinas, Lopez-Cózar, & Jiménez-Contreras, 2009) – for example, 97% of Web of Science publications from 2005 are also in Scopus (Moed & Visser, 2008). Google Scholar probably has wider coverage in general (Bar-Ilan, 2008; Harzing, 2014) but it is not possible to use it in large scale bibliometric studies due to the lack of facilities for providing citation counts for extensive sets of articles as well as the lack of a field classification scheme. The following specific research questions drive the study.

- Why are articles cited in Scopus-indexed publications more often than they are registered by Mendeley users?
- Why are articles registered by Mendeley users more often than they are cited in Scopus-indexed publications?

The goal is not to provide a comprehensive list of reasons in answer to the above research questions, nor to estimate the prevalence of the reasons found in any particular research area or within academia as a whole, but only to identify a set of reasons for discrepancies between reader counts and citation counts and to give evidence for each reason.

Methodology

The general research design was to recognize a collection of articles that had excessively numerous or few Mendeley readers in correlation to citation counts from Scopus for all the different subfield of Physics and afterward to inspect these articles and produce a list of reasons behind the differences found. Since explanations behind the disparities may shift by field. Scopus classifications will be utilized as the essential source of field delimitation. Despite the fact that it would have been conceivable to pick other categorization frameworks, for example, those from WoS or the National Science Foundation (NSF), or to get classes from article content or citations (Braam, Moed, and van Raan, 1991), the utilization of Scopus classifications has the benefits of being straightforward and reproducible.

The following Scopus types were chosen: Physics of electronics and semi-conductor device, Waves mechanics, Digital physics, Medical physics, Fluid mechanics, Solid state physics, Radio communication, Atomic and nuclear physics, Bio physics, Thermodynamics (air condition and refrigerator), Electrical electronic physics, Satellite communications. This is a nearly arbitrary decision, on the other hand. These subjects speak to a wide variety of different types of research. Every subject area was based upon an individual Scopus classification. In spite of the fact that Scopus classifications have constraints, they appear to be adequately intelligent to be examined independently.

For every article downloaded from Scopus in every classification, the Mendeley Applications Programming Interface (API) version 1 will be utilized by means of the free programming Webometric Analyst to download the quantity of readers for the articles. Each Scopus article will be coordinated with comparing articles in Mendeley utilizing a DOI search, when a DOI was enlisted in Scopus, and with a joined title, first author and year search in Mendeley (for all articles, independent of whether a

DOI was available or not). The accompanying query demonstrates the arrangement to be used.

Title: The Prevalence of Micro albuminuria and Proteinuria in Cats with Diabetes Mellitus AND author: Al-Ghazlat AND year: 2011

Two-month period will be utilized to get citations and Mendeley readers as a confinement in light of the fact that data accumulated later may have higher reader and citation counts, so little contrasts ought to be disregarded in correlations between distinctive data sets, particularly for articles from the subfield.

For every subfield, the normal number of citations per scholastic articles and the normal number of Mendeley readers per articles will be ascertained keeping in mind the end goal to uncover the differences. The geometric mean will likewise be used for the average since citation counts and Mendeley readers both take after profoundly skewed distributions. The geometric mean will be altered by adding 1 to all the raw data before the averaging, and after that subtracting 1 from the last average. This is a standard variation of the geometric mean that permits important averages to be figured despite the fact that the data will contain numerous zeros. The outcome is a kind of average that is not significantly changed by individual huge values. Spearman correlations will be computed between the citation counts and reader counts for each subfield to evaluate the degree to which the two concur.

Results

Table 1 summarizes key information about each field analyzed to give context to the main results. It confirms that the fields analyzed are very different, with substantial differences in the mean number of citations per article (from 2.25 to 11.95), the mean number of readers per article (from 3.61 to 16.64) and the ratio of readers to citations (from 0.68 to 2.73 readers per citation). Reader counts correlate strongly (0.567 to 0.691) with citation counts in all subject categories except for medical physics (0.200). Spearman correlations were used to estimate the degree of dependence between reader counts and citation counts because the data was too skewed to use Pearson correlations. The reason for the low medical physics correlation might be a journal with few readers but many citations (Journal of Information Hiding and Multimedia Signal Processing) and several IEEE journals and conference proceedings with a high

ratio of reader counts to citation counts (e.g., IEEE Transactions on Pattern Analysis and Machine Intelligence). These are perhaps peripheral to the subject area and hence may have a different citation/reader profile. More importantly, however, the Annual International Conference of the IEEE Engineering in Medicine and Biology – Proceedings has an ISSN (0589-1019) is classified as a journal in Scopus, hence its presence in the data set. It contributes 2066 (37%) of the Computer Vision articles, many of which are uncited. These articles have 30914 readers and 1907 citations, a ratio of 16.2 to 1. This extremely high ratio seems to be due to the articles occurring twice in Scopus, once as a journal article and once as a conference paper, with the conference paper version tending to be credited with the citations.

Table 1. Spearman correlations between Mendeley reader counts and citation counts for articles in Scopus from 2011 in the fifteen subjects analyzed.

Scopus subject category	**Articles**	**Citation mean (median)**	**Reader mean (median)**	**Spearman correlation**
Physics of electronics and semi-conductor device	3214	11.95(8)	16.14(11)	0.679
Waves mechanics	5620	6.07(2)	13.00(10)	0.200
Digital physics	9020	5.09(3)	8.75(6)	0.664
Medical physics	9861	8.88(5)	7.86(5)	0.568
Fluid mechanics	4539	4.63(3)	4.90(3)	0.604
Solid state physics	10000	11.19(7)	10.32(6)	0.570
Radio communication	1364	1.51(0)	3.89(1)	0.618
Atomic and nuclear physics	7330	7.81(2)	5.61(2)	0.691
Bio physics	6814	7.17(5)	12.54(8)	0.671

Thermodynamics (air condition and refrigerator)	10000	9.10(6)	6.22(4)	0.605
Electrical electronic physics	727	2.25(1)	3.61(1)	0.648
Satellite communications	1195	3.50(2)	8.84(6)	0.638

The outliers identified by the two different methods tend to be similar but the logarithmic method tends to produce fewer outliers with high values on both indicators (figures 1 and 2 - random jitter has been added to the reader counts and citation counts to avoid identical points overlapping).

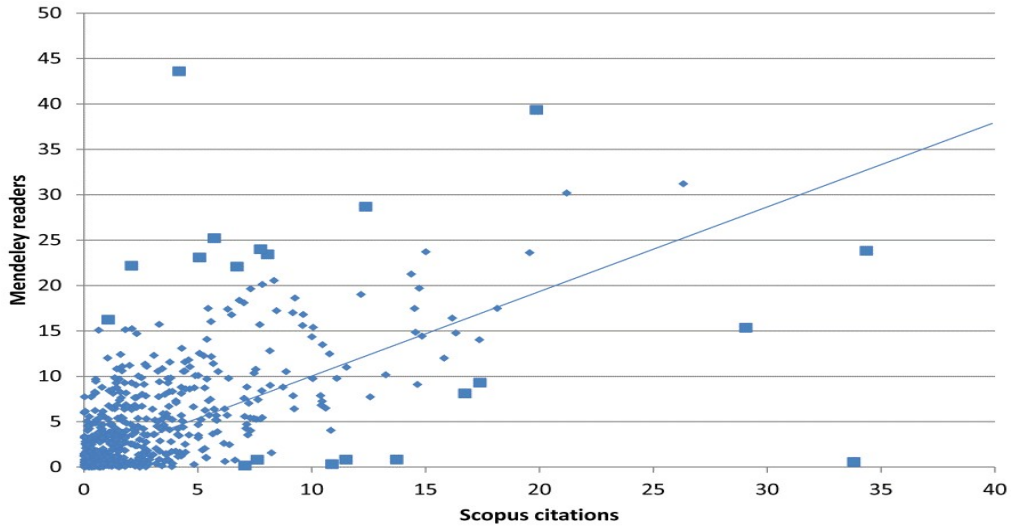

Figure 1. Reader counts compared to citation counts for Electrical electronics physics articles. The top ten Student used residuals according to a standard regression are marked with a square shape.

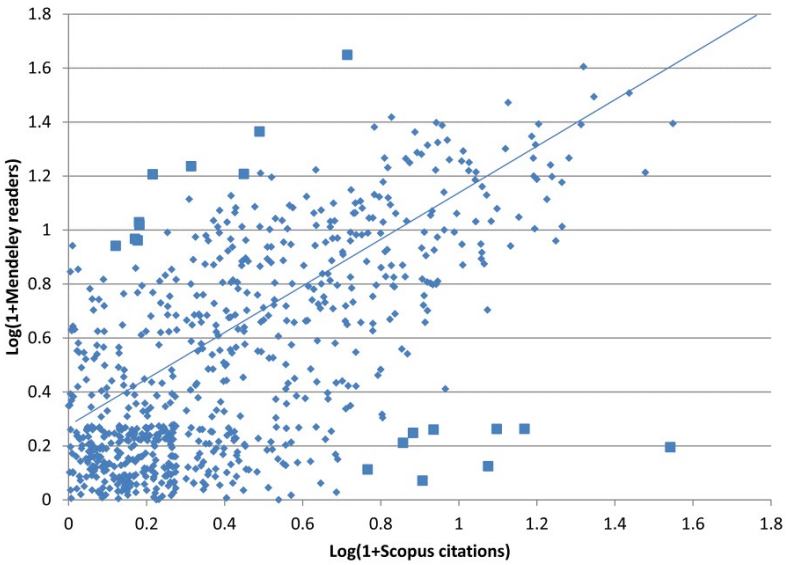

Figure 2. Reader counts compared to citation counts for Electrical electronics physics articles after applying a log(1+x) transformation to both. The top ten Studentized residuals based on this data are marked with a square shape.

The following reasons were found for an article having many Mendeley readers compared to its number of Scopus-indexed citations.

- Articles may attract disproportionately many students compared to academics, with students not producing work that is indexed in Scopus. In Fluid Mechanics, Bachelor's degree and Master's degree students formed 21% of readers overall (a high proportion in comparison to other areas) compared to a Digital physics average of 6%. In Medical physics, it attracted 40% student readers compared to a subject average of 23%. In Waves mechanics, it attracted 47% Master's student readers compared to a subject average of 18%.
- Articles may attract disproportionately many professional readers that may not author articles. Other Professional readers compared to Digital physics average of 6%. "Improving studies of resource selection by understanding resource use" attracted 13% Other Professional readers compared to a Medical physics attracted average of 4%.
- Articles may be multidisciplinary and attract many readers from an area that has a field norm of more readers per citation, despite being legitimately

labelled with another category. In Radio communications, four of the articles with relatively many readers and none of the articles with relatively many citations were from the journal *Psychology of Radio Communications*. In Medical Physics, six of the disproportionately read articles were from *IEEE Transactions on Pattern Analysis and Machine Intelligence*, and only one of the disproportionately cited articles. In Atomic and Nuclear Physics, *Applied Energy* had 9 of the most read articles.

- Magazine-style journals may attract high numbers of article readers, perhaps reflecting a more casual typical reader. The top ten articles for relatively high readership in Solid State Physics were all from *Nature Biotechnology.*
- Review articles may attract disproportionately many readers because some authors cite the reviewed articles rather than the review.
- Academic articles may attract general interest readers from the academic community that do not use the article directly in their work. "Is free will an illusion?" within Physics of Electronics and Semi-conductor device, attracted 233 readers but no citations.
- Articles may support the research process without being citable.
- Article readers may be predominantly from countries with researchers that rarely publish in Scopus journals.

The following reasons were found for articles having many Scopus citations compared to their Mendeley readers.

- Articles may interest an academic community that does not use Mendeley due to limited internet access.
- Articles may be mainly of interest to a publishing author community, such as hospital doctors, that does not use Mendeley due to working practices.
- Articles may be multidisciplinary and attract many citations from one side of their focus, which has a field norm of few readers per citer, despite being legitimately labelled with another category. In Atomic and Nuclear Physics had 8 of the least read articles.
- Mendeley users may register as readers of an update of an article rather than the original version, whilst authors may cite the original. This occurred in

Solid State Physics. It also occurred for, '"Thermodynamics (air-condition and refrigerators), because Mendeley linked to the article.

The following reasons for outliers were found that are technical limitations of the process used.

- An irrelevant journal had been included in the Scopus category, and articles in this journal may have been from a field with a different normal ratio of reader counts to citation counts. This applied to *Academic Digital Physics* and within Radio communications.
- An article may lack a DOI and may have a title that is not searchable in Mendeley. The article "Applications of objective image quality assessment methods [Applications Corner]" is in Mendeley but is not returned by a search for it, with or without the square brackets. These were cited an average of 177.5 times and read an average of 0.8 times each, compared to subject averages of 8.9 and 15.7 respectively. These articles had titles that, in their Scopus format, were difficult to search for in Mendeley due to the inclusion of double hyphens.
- An article may have an incorrect DOI in Scopus. This applied to "Bio physics, which had a DOI of 10.3354/meps010257, which was highly read, but the correct DOI is 10.4319/lo.2011.56.5.1866.
- An article may have an incorrect DOI in Mendeley. This applied to "Bio physics.
- An article may have an incorrect title in Mendeley. Digital physics had a different part number (1) in Mendeley.
- An article may have an incorrect year in Mendeley. Within Electrical Electronics Physics is registered as published in 2013 instead of 2011 in Mendeley.
- An article may have multiple valid DOIs, with different versions in Mendeley and Scopus. This applied to "Preliminary estimation of release amounts of 131 and 137 Cs accidentally discharged from the Atomic and Nuclear Physics into the atmosphere". A new library for nuclear science and engineering within Atomic and Nuclear Physics.

- An article may appear more than once in Scopus, reducing the Scopus-indexed citation count of both versions. This occurred for physics of electronics and semi-conductor device.

Limitations

An important limitation of the method used here is that it is reliant on human judgement and important patterns may have been missed. In addition, some important reasons may not be evident from the data. For example, it seems likely that articles in some cases had many Mendeley readers compared to Scopus citations because the articles were cited in documents not covered by Scopus, such as many non-English journals (particularly for Fluid mechanics), as well as many conference papers (particularly for Waves Mechanics) or books (particularly for Radio Communications). Another limitation is that the anomalies have been extracted from large collections of up to 10,000 articles and in any collection of such a size it is statistically likely for substantial outliers to appear due to random variations even in the absence of external causes. This particularly applies to the cases above where the evidence is based exclusively on the share of one category of user (e.g., Master's students).

Conclusions

Although Mendeley reader counts correlate strongly and positively with Scopus-indexed citation counts in most subject areas, some articles receive disproportionately many or few Mendeley readers in comparison to Scopus-indexed citations. There are many different reasons why this can happen. Although some of the reasons are technical, such as mistakes in DOIs or article titles, others are more fundamental. These fundamental reasons probably do not just cause a few outliers but also affect many other articles to a lesser extent. Perhaps the most important reason is that the ratio of reader counts to citation counts varies substantially by field and that interdisciplinary research articles may attract a ratio mainly from one of their constituent fields whilst legitimately being classified in another field. Related to this, an article may be used by a community (e.g., students, professionals) that do not cite it because they do not publish research or create publications that are not indexed by Scopus. Similarly, an article may be cited by a community that tends not use Mendeley.

With the exception of the technical issues, the reasons for the differences between the Mendeley and Scopus data all suggest that the lower figure may underestimate the wider impact of an article. A logical conclusion from the results is that combining Mendeley readership data with Scopus-indexed citations in a way that uses the maximum rather than the minimum or average would give the most reasonable indicator for article impact. This maximum should take into account the differing average number of readers and citations. This suggestion does not seem to have been made before in published research but is worth considering in applications where it would be important to avoid even small numbers of anomalies, such as when evaluating individual academics. The results also confirm the importance of resolving technical issues with data collection and ensuring that the subject categories used are as homogeneous as possible.

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