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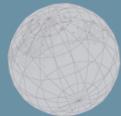
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## Location filtered citation counting: How much of a difference does it make in research evaluation?

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### Introduction

Citation analysis is used in research evaluation exercises around the globe, directly affecting the work and lives of millions of researchers and the expenditure of billions of dollars. It is therefore crucial to address any problems or limitations that plague it. Central amongst critiques of practices of citation analysis has long been that it treats all citations equally, be they crucial to the citing paper or perfunctory. This problem is especially troublesome when tracing or assessing research impact. Weighting citations by how they are used in the citing paper has therefore long been proposed as a solution to this problem (Herlach, 1978; Narin, 1976; Voos & Dagaev, 1976) and has attracted increasing research interest in recent years. By weighing citations, it is hoped that essential citations could be assigned greater weight than perfunctory ones so that citation analysis can focus on more profound influences and organic relationships.

Studies have consistently found that in-text frequency of a cited reference indicates its importance (Bonzi, 1982; Chubin & Moitra, 1975; Herlach, 1978; Tang and Safer, 2008; Voos and Dagaev, 1976; Zhao, Cappello, & Johnston, 2017; Zhu, et al., 2015). Although some studies (e.g. Hanney et al., 2005) found no significant difference in terms of citation location for citation importance, many studies found that citations located in methodology, results, discussion, or conclusion sections may play a more significant or meaningful role than those located in introductory sections (Bertram, 1972; Bonzi, 1982; Cano, 1989; Tang & Safer, 2008; Voos & Dagaev, 1976).

Back in 1989, McCain and Turner (1989) already experimented with weighting citations by their in-text frequency, location, and self-citation in an attempt to construct a “utility index” for citations. Zhao and Strotmann (2016) tested a few schemes for weighting citations by in-text frequency.

However, Zhao, Cappello, and Johnston (2017) found that a large percentage of multi-citations play purely a nonessential role in the citing paper, and would be over-weighted by frequency-weighted citation counting. This finding underscores the importance of filtering out nonessential citations before assigning weight in order to improve the accuracy and effectiveness of frequency-weighted citation analysis. Future studies were invited to explore

effective ways to filter out nonessential citations, and to evaluate the differences that filtering out nonessential citations before assigning weight can make in weighted citation analysis, which promises to improve citation analysis for research evaluation, knowledge network analysis, knowledge representation, and information retrieval (Zhao, Cappello, & Johnston, 2017; Zhao & Strotmann, 2015). The present study is such a study. It explores how much of a difference it makes in research evaluation to filter citations by their in-text location.

## Methodology

Our dataset for this study comprises the full text of all articles on bibliometric studies, especially citation analysis studies, available as fulltext in PubMed Central (PMC). We chose a research area that we are knowledgeable about so that we are in a good position to make sense of the results. PMC was chosen for its quality indexing and full text availability.

We conducted a search in PMC in March 2018 for “citation analysis” OR bibliometric, and there were 6011 hits. We downloaded the full XML records of all articles that have fulltext available in XML format as our dataset. This dataset had 3211 citing articles, which contained a total of 141,324 reference list entries, and a total of 211,228 in-text citation occurrences for these entries.

For each full text in this dataset, we counted the in-text citations to the first author of each cited reference in the following ways. The total citation count for an author (i.e., surname plus initials of first author listed in the PMC XML file for a reference) is then calculated as the sum over all distinct reference list entries with this author in all full-text articles in the dataset.

- (1) W1 – this is traditional citation counting, which adds 1 to an author’s citation count whenever a paper with this author listed as first author is cited regardless of how many times this paper is cited in the text;
- (2) Wn – this method adds N to an author’s citation count when a paper with this author listed as first author is cited N times in a citing text;
- (3) EssW1 – Remove introductory and background sections (i.e., introduction, literature review, related studies, background) and then count W1
- (4) EssWn – Remove introductory and background sections (i.e., introduction, literature review, related studies, background) and then count Wn

The Introduction section has been found to be somewhat different from the literature review, related studies, and backgrounds sections in that the percentage of nonessential citations was in the eighties instead of nineties. Ideally, only uni-citations in the introduction section and all citations in the literature review, related studies, and backgrounds sections should be removed as this was found to provide a good balance between filtration and error rates (Zhao, Cappello, & Johnston, 2017). We removed all citations from the Introduction section in this first attempt to test the differences that removing nonessential citations by location makes in research evaluation, with the assumption that removing all citations instead of just uni-citations in the Introduction section would allow us to study one effect at a time – namely, in the present paper, that of filtering citations by the section type they occur in.

Author names were ranked by each of these counts in the usual way, using the average rank to number tied authors, i.e., all names with the same citation count are assigned the average of their ranks. In total, we computed four different rankings of roughly 66,183 first-author names that are cited in our dataset.

To examine how the various author rankings are different from each other, we first calculated the Spearman correlations of author rankings by these four methods for the 500 most highly cited authors (by the average normalized count over the four counting methods). We then examined rank changes of individual authors and the topics of their highly cited papers.

We did not perform author name disambiguation in any of the four counting methods we compared, and we only counted the first author of each cited reference. Performing disambiguation and counting all authors might well change specific ranks of individual authors, but we cannot think of any reason why the rank difference of the same author between two rankings would be able to change drastically. In particular, the very large or very small rank differences that we relied on in our analysis would remain large, or small, respectively, in practically all cases were disambiguation and all author counts used to determine the same four rankings instead.

## Results and discussions

### *Correlation*

Table 1 presents the Spearman correlations of rankings of top 500 cited author names.

Table 1. Spearman correlations between rankings of top 500 authors.

	<b>W1</b>	<b>EssW1</b>	<b>Wn</b>
<b>EssW1</b>	0.85		
<b>Wn</b>	0.75	0.59	
<b>EssWn</b>	0.30	0.50	0.57

It is interesting and somewhat surprising to see that the ranking by EssW1 is so highly correlated with the ranking by W1 (0.85), the traditional counting method, considering that about 60% of all citations and 80% of all nonessential citations were discarded (Zhao, Cappello, & Johnston, 2017) when counting EssW1.

The ranking by EssW1 has a higher correlation than the one by Wn with the traditional ranking (0.85 vs. 0.75). It appears that simply removing article sections that contain mostly nonessential citations (EssW1) makes even less of a difference in weighted citation counting than direct frequency-weighting (Wn) which has been found to be insufficient to predict important citations compared to squared frequency-weighting (Zhu, et al., 2015).

However, the combination of the two, which filters out a large source of nonessential citations first and then weighs citations by their in-text frequency, makes a huge difference in author ranking compared to traditional citation counting, as shown by the low correlation (0.30) between W1 and EssWn. This indicator may thus deserve further investigation on whether it improves citation analysis results.

This result, i.e., filtering out likely nonessential in-text citations and then weighing the remaining ones by in-text frequency having a large difference (i.e., low Spearman's rank correlation to) from traditional counting, is similar to the one in Zhao & Strotmann (2015; 2016) that proposed and tested filtering uni-citations. However, the present paper's method

for identifying likely candidates for nonessential citations for filtering likely has much higher accuracy rates than the one based on pure in-text frequency used in the earlier papers.

It should be noted that there is only a medium correlation between rankings by EssW1 and Wn (0.59), suggesting that filtering out article sections that contain mostly nonessential citations, on the one hand, and unfiltered frequency-weighting, on the other, might emphasize different aspects of citing behaviors. Both may overweigh some citations, and it is hoped that the combination of the two (EssWn) will reduce the scope of overweighting and result in a more balanced measure of citation impact. This combined measure is clearly very different from each one of its two components, as shown by the medium correlation between EssWn and EssW1 (0.50) or between EssWn and Wn (0.57). Finding out the nature of these differences by examining the rank changes of individual authors between these rankings should be an interesting future study. Below in this paper, we focus on the rank changes between rankings by W1 and EssWn to see what a difference EssWn makes in ranking authors compared to traditional citation counting.

#### *Author rank variability*

Table 2 lists all author names that are ranked higher than 100, and provides their ranks assigned by all four counting methods and the difference in ranks between traditional citation counting (W1) and weighted counting of citations (EssW1, EssWn, Wn). However, as just mentioned, we will focus on comparing EssWn with W1, leaving the comparison of other methods to a future study.

The variability of author ranks by these different counting methods is clearly visible. A general pattern seen from Table 2 for EssWn compared to W1 is that (a) ranks for highly cited authors (top 15) are relatively stable, (b) large drops occurred mostly in the middle (60 and above), and (c) large gains mostly in the lower half especially towards the bottom.

- Authors with stable ranks

The most highly cited authors with stable ranks include both bibliometrists (e.g., Garfield, Bornmann, Leydesdorff, Glanzel, Waltman, Egghe, Van Eck, Falagas) and biomedical researchers (e.g., Moher, Sweileh, Zyoud, Huh), as well as authors with signal work that influenced bibliometrics highly (i.e., Hirsch, Newman). Their rank differences between these two counting methods are small (single digit) except for Moed whose rank dropped 21 places.

A common feature of these bibliometrists is that they introduced, tested, and promoted methods/indicators/tools for studying research evaluations and collaboration – Hirsch's h-index, Newman's network analysis as applied to co-authorship networks, Van Eck's VOSviewer – a visualization tool for studying co-authorship networks, word co-occurrence networks and citation networks, Leydesdorff's work on the Triple Helix of university–industry–government relations, Glanzel's work on co-authorship analysis, Waltman's work on the Leiden ranking methods including the crown indicator, and Falagas' comparison of major citation databases. This feature is not all that surprising, considering that methodology sections are one of the sections that were not removed in calculating EssWn.

The biomedical researchers with stable ranks (i.e., Sweileh, Zyoud, Huh) were cited for their actual bibliometric studies of biomedical fields as compared to those discussed below on problems in the scholarly communication system in general and in bibliometric indicators for

research evaluation in particular. Moher was cited for the PRISMA statement (Preferred reporting items for systematic reviews and meta-analyses) and other guidelines of this sort. Moher ranking high consistently indicates that a large part of our dataset is systematic reviews / meta-analyses, and that bibliometric methods have been used in these types of studies. The large drop in Small's rank from W1 to EssWn discussed below indicates that co-citation analysis has not been used there, which is unfortunate because co-citation networks and other citation-based network analysis methods (e.g., bibliographic coupling analysis) are very informative of intellectual structures of research fields (e.g., White & McCain, 1998; Zhao & Strotmann, 2008a; 2008b; 2011; 2014).

Table 2. Rank differences of top 100 authors.

name	W1	EssW1	Wn	EssWn	EssW1-W1	Wn-W1	EssWn-W1
Garfield,E	1	2	1	4	1	0	3
Bornmann,L	2	4	2	3	2	0	1
Moher,D	3	1	4	2	-2	1	-1
Hirsch,JE	4	5	3	5	1	-1	1
Zyoud,SH	5	3	5	1	-2	0	-4
Leydesdorff,L	6	9	6	11	3	0	5
Falagas,ME	7	6	7	6	-1	0	-1
Sweileh,WM	8	8	9	7	0	1	-1
Moed,HF	9	19	12	30	10	3	21
Newman,MEJ	10	14	10	16	4	0	6
GlÄnzel,W	11	13	11	14	2	0	3
Waltman,L	12	11	13	13	-1	1	1
Seglen,PO	13	15	14	21	2	1	8
Ioannidis,JP	14	16	15	18	2	1	4
Huh,S	15	7	16	8	-8	1	-7
Egghe,L	16	18	17	25	2	1	9
Van Eck,NJ	17	10	22	10	-7	5	-7
Groneberg-Kloft,B	18	12	18	12	-6	0	-6
Masic,I	19	70	8	80	51	-11	61
Boyack,KW	20	20	20	32	0	0	12
Van Raan,AFJ	21	21	23	31	0	2	10
Merton,RK	22	23	27	40	1	5	18
Lewison,G	23	27	28	36	4	5	13
Smith,R	24	71	31	90	47	7	66
Larivière,V	25	30	25	33	5	0	8
Eysenbach,G	26	39	21	35	13	-5	9
Radicchi,F	27	37	35	58	10	8	31
Small,H	28	65	60	95	37	32	67
Ophof,T	29	66	36	81	37	7	52
Altman,DG	30	25	33	29	-5	3	-1
Thelwall,M	31	44	34	67	13	3	36
Greenhalgh,T	32	26	24	15	-6	-8	-17
Ioannidis,PA	33	32	45	68	-1	12	35
Van Noorden,R	34	88	57	98	54	23	64
Katz,JS	35	75	32	73	40	-3	38
Schulz,KF	36	28	41	34	-8	5	-2
Kulkarni,AV	37	22	53	28	-15	16	-9
Hopewell,S	38	24	29	20	-14	-9	-18
Chan,AW	39	33	40	59	-6	1	20
Wang,Y	40	53	37	52	13	-3	12
Porter,AL	41	58	43	79	17	2	38
Chen,C	42	45	65	65	3	23	23
Wang,J	43	49	55	74	6	12	31
Fanelli,D	44	72	38	78	28	-6	34
Cramer,H	45	76	39	85	31	-6	40
Bollen,J	46	89	58	94	43	12	48
Adams,J	47	31	42	41	-16	-5	-6
Buxton,M	48	41	19	19	-7	-29	-29
Abramo,G	49	54	67	86	5	18	37
Chen,YC	50	17	94	43	-33	44	-7
Vinkler,P	51	46	80	69	-5	29	18
Costas,R	52	59	46	53	7	-6	1
Rafols,I	53	73	51	97	20	-2	44
Chalmers,I	54	80	83	96	26	29	42
BÄrner,K	55	84	79	100	29	24	45

Higgins,JPT	56	29	47	23	-27	-9	-33	1
Hicks,D	57	90	62	91	33	5	34	1
Hanney,S	58	40	26	22	-18	-32	-36	1
BarabÁsi,AL	59	47	54	64	-12	-5	5	1
Haustein,S	60	60	48	63	0	-12	3	1
Dickersin,K	61	35	88	70	-26	27	9	1
Wagner,CS	62	67	76	83	5	14	21	1
Schubert,A	63	85	81	92	22	18	29	1
Uthman,OA	64	50	63	45	-14	-1	-19	1
BjÄrk,BC	65	55	70	89	-10	5	24	1
Watts,DJ	66	42	66	44	-24	0	-22	1
Newman,ME	67	51	75	50	-16	8	-17	1
Hanney,SR	68	74	56	39	6	-12	-29	1
Liberati,A	69	34	100	66	-35	31	-3	1
Cohen,J	70	43	84	72	-27	14	2	1
Piwowar,HA	71	61	71	61	-10	0	-10	1
Grant,J	72	86	85	88	14	13	16	1
Bhandari,M	73	48	86	56	-25	13	-17	1
Tadmouri,GO	74	52	95	71	-22	21	-3	1
Clauset,A	75	56	59	60	-19	-16	-15	1
Lavis,JN	76	81	73	82	5	-3	6	1
Callaham,M	77	38	87	57	-39	10	-20	1
Von Elm,E	78	57	98	84	-21	20	6	1
Milat,AJ	79	82	44	38	3	-35	-41	1
Wooding,S	80	83	78	54	3	-2	-26	1
Gastner,MT	81	36	93	49	-45	12	-32	1
Feixas,G	82	62	69	75	-20	-13	-7	1
Ramos,JM	83	63	82	55	-20	-1	-28	1
Michie,S	84	64	74	26	-20	-10	-58	1
Graffigna,G	85	68	61	46	-17	-24	-39	1
Li,Z	86	69	89	62	-17	3	-24	1
Benamer,HT	87	77	90	47	-10	3	-40	1
Graham,JD	88	92	72	87	4	-16	-1	1
Banzi,R	89	78	64	48	-11	-25	-41	1
Grimshaw,JM	90	87	96	76	-3	6	-14	1
Simonton,DK	91	91	50	93	0	-41	2	1
Wager,E	92	94	77	77	2	-15	-15	1
Kuruvilla,S	93	93	52	24	0	-41	-69	1
Arksey,H	94	79	91	51	-15	-3	-43	1
Innes,KE	95	95	68	99	0	-27	4	1
Ward,V	96	97	97	37	1	1	-59	1
Bruix,J	97	96	99	42	-1	2	-55	1
Carnahan,RM	98	98	30	9	0	-68	-89	1
Han,L	99	99	92	27	0	-7	-72	1
Boustani,M	100	100	49	17	0	-51	-83	1

- Authors whose ranks dropped by EssWn

Middle-ranked authors comprise mostly bibliometrists and researchers in the medical fields who were interested in problems in research evaluation and science communication in biomedical fields. The largest drops are represented by Masic, Smith, Ophof, and Van Noorden who are all biomedical researchers (except Van Noorden who is a senior news editor for Nature). Masic and Van Noorden were highly cited for their work / ideas on problems in scholarly communication and publishing in biomedical fields, while Smith and Ophof appeared to have been mostly cited for their work on problems with journal impact factor published in medical fields, such as epidemiology and cardiology. Their drop in rank indicates that their works were mostly cited as background information.

Most bibliometrists only had small to medium drops after introductory and background sections are removed and medical related contents are kept, except Small whose rank dropped 67 places and Thelwall whose rank dropped 36 places. Thelwall is a highly cited webometrists and Small is known for his work on co-citation analysis and the mapping of research fields. Their work was not considered directly related to what was mostly done in the biomedical fields, i.e., evaluative (as opposed to relational) studies based on journal articles (as opposed to websites).

- Authors who ranked higher by EssWn

Authors in the bottom half of the table who rank much higher by EssWn are mostly biomedical researchers, whose work stands out much more after the background information about citation analysis supposedly contained mostly in the introductory and background sections was removed. It appears that the less related to bibliometrics an author is, the larger a gain in rank happens. For example, Carnahan and Boustani whose ranks gained 89 and 83 places respectively were not cited for bibliometrics or science communication, but for their medical research; Kuruvilla (69) was cited for a single article on health research impact in general, of which bibliometrics related measure is just a small part; Milat (41) was cited for both medical and bibliometric studies.

All three types of rank changes described above show that authors whose cited articles had a biomedicine focus rank higher after introductory and background sections were removed, whereas those whose cited articles emphasized bibliometrics or scholarly communication rank lower, except those who introduced, tested, and promoted methods/indicators/tools for studying research evaluations and collaboration. Considering that bibliometric studies in the biomedicine fields are mostly concerned with biomedicine, this general pattern makes good sense and indicates that EssWn weighs citations appropriately, i.e., assigning greater weight to essential citations than to perfunctory ones, and that citation analysis based on this indicator may indeed be able to focus on more profound influences and organic relationships.

## Conclusions

It has been found that in-text frequency of a cited reference indicates its importance but a significant percentage of multi-citations are nonessential citations, and would be over-weighted by frequency-weighted citation counting. It is therefore important to filter out nonessential in-text citations before assigning weight in order to improve the accuracy and effectiveness of frequency-weighted citation analysis.

Previous studies proposed and tested filtering nonessential citations by their in-text frequency, assuming that uni-citations are mostly nonessential (Zhao & Strotmann, 2015; 2016), but found that its error rate might be too high (Zhao, Cappello, & Johnston, 2017). The present study explores an alternative filtering method to see what a difference it makes in ranking authors by citations. Informed by findings from previous studies that citations located in methodology, results, discussion, or conclusion sections may play a more significant or meaningful role than those located in introductory and background sections, we removed introductory and background sections as a way to filter out nonessential citations, which was found to have a lower error rate and a higher filtration rate compared to removing uni-citations (Zhao, Cappello, & Johnston, 2017). We examined the correlations and rank changes of individual authors between rankings by traditional citation counting and those by in-text frequency-weighted citation counting before and after the filtration.

We found that removing introductory and background sections alone doesn't make much of a difference in author rankings, but it makes a huge difference when combined with frequency-weighted counting. This combination appears to make essential citations stand out, as shown by it ranking biomedicine-focused authors higher and bibliometrics-focused ones lower, except those who represent methods/tools/indicators/guidelines that were directly useful for studies of biomedical fields that apply bibliometrics. Interestingly, the present study also finds

that the filtering and the weighing appear to have different effects as indicated by medium correlations between rankings by each separately. This difference warrants future detailed studies to identify the separate factors involved.

The observation that authors who represent guidelines for reporting meta-analysis results are ranked high by all the counting methods tested indicates that many articles retrieved from PMC on bibliometrics in general and on citation analysis in particular belong to meta-analysis type of studies that employ bibliometric methods/tools. This use, however, didn't appear to have included citation-based knowledge network methods such as co-citation analysis or bibliographic coupling analysis. These methods have been shown to effectively reveal intellectual structures of research fields, and should be very useful for systematic reviews and other meta-analyses. It should be an interesting future study to find out why they have not been applied as much in bibliometric studies of biomedical fields.

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