

Do original tweets and retweets differ in indicating research impact across various subject areas in multidisciplinary papers published in PLoS?

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Twitter.com (recently known as X) is a popular platform to discuss and share scientific articles. Earlier altmetrics studies have often focused on investigating whether the number of tweets mentioning scientific articles could be used as an indicator of scientific impact or attention, with results showing weak to moderate correlations with citation counts and some disciplinary differences. But all tweets may not be equal, as original tweets and retweets may reflect different levels of engagement and, with that, impact. This research analyzed whether the correlation between citations and original tweets differs from that between citations and retweets and whether there is any disciplinary difference between the two. For this purpose, the relationship between original tweets and retweets and Scopus citations was analyzed for a total of 330,022 PLoS publications and compared over time and across subject fields. The findings showed that the correlations were strongest between citations and original tweets, and the relationship was stronger in Social Science and Humanities subject fields than in Natural Science, Engineering and Medicine. The results showed that tweets and retweets are very different, and thus they should be considered two different metrics and analyzed separately.

1. Introduction

Twitter.com (recently known as X) is a popular social media platform where users (often called tweeters) can publish and share content to their network of followers. Through retweeting tweeters can easily disseminate content that someone else has originally published. While creating an original tweet can take a bit of effort, retweeting can easily be done just by clicking or tapping on a button, thus it seems fair to say that retweeting doesn't require as much effort as tweeting does. Because of that we can also argue that retweeting signals less engagement than creating and publishing an original tweet does. In altmetrics, i.e., the measuring of engagement or attention that scientific outputs have received online, Twitter is one of the main data sources, as there is significant activity around scientific articles on the platform (Costas et al., 2015; Haustein et al., 2015). Often in altmetrics research tweets and retweets are counted as one measure, without making any distinction between them. We argue that because the two acts are fundamentally different, indicating different levels of engagement and possibly attention or impact, combining them in statistical analyses can potentially yield different outcomes than each separately. The goal of this research is to investigate whether this is true, and whether original tweets and retweets should be analyzed separately in altmetric research.

2. Background

Much of early altmetrics research focused on examining whether altmetrics could be an alternative to traditional citation-based measures of impact. The research focused on testing for correlations between tweets and citation counts, providing some mixed results with large scale studies (e.g., Barthel et al., 2015; Costas et al., 2014, 2015) showing lower correlations between tweets and citations than studies with more focused, journal or discipline specific samples (e.g., Eysenbach, 2011; Shuai et al., 2012). Earlier research has also discovered disciplinary differences in how scientific articles get tweeted, as scientific articles from social sciences and biomedical and health sciences tend to attract more attention on Twitter than articles from

mathematics and computer science, and natural sciences and engineering (Costas et al., 2015; Haustein et al., 2015). Other characteristics too, such as the length of the article (Haustein et al., 2015), OA status (Holmberg et al., 2020), and research funding (Didegah et al., 2018), may be connected to the attention scientific articles receive on Twitter. A more recent study investigated how different types of user engagement behaviors on Twitter, i.e., liking, retweeting, quoting, and replying, were used in connection to scholarly content (Fang, Costas, & Wouters, 2022). The results showed that while likes (44%) and retweets (36%) were frequently used, quotes (9%) and replies (7%) were less frequent. While earlier research has already shown disciplinary differences in the uptake of scientific articles on Twitter (e.g., Haustein, Costas, & Larivière, 2015), and how researchers use Twitter (Holmberg & Thelwall, 2014), the results by Fang, Costas, and Wouters (2022) showed that there are disciplinary differences also in the ways with which users engage with scientific content on Twitter. But do the disciplinary differences extend to both tweeting and retweeting? Or are the possible differences evened out if tweets and retweets are treated as same? This research investigates possible disciplinary differences between tweeting and retweeting, as well as if there are any differences in how citation counts correlate with the number of tweets and retweets.

3. Method

3.1. Data

A total of 330,022 PLoS publications published between 2003-2023 were extracted from Scopus in April 2023. The extracted publications were published in nine PLoS journals and eight proceedings, with majority of the papers (94%) being journal articles. Altmetric.com was used to extract separate datasets of 1) all tweets and 2) original tweets, which were then used to count the number of retweets for each paper.

3.2. Subject fields

As all PLoS papers are only classified as multidisciplinary in Scopus, we used the classification made by Dimensions and used by altmetric.com (Australian and New Zealand Standard Research Classification 2020 (ANZSRC)¹) to assign subject fields to each article. For the analysis we used the first subject field assigned to each paper.

Table 1 shows the number of publications when counting only with the first subject field assigned. The first 11 fields in Table 1 are from Natural Science, Engineering and Medical and Health Sciences (STEM) and the second 11 fields are from Social Science and Humanities (SS&H). Of all the publications about 19% have not been assigned to a field; these mostly were Erratum and non-tweeted.

Table 1. Number of PLoS papers according to first subject field assigned to publications.

Broad field	Fields of Research (FoR)	First field
STEM	Mathematical Sciences	7,787
	Physical Sciences	1,506
	Chemical Sciences	2,855
	Earth Sciences	2,142
	Environmental Sciences	8,631
	Biological Sciences	92,008
	Agricultural and Veterinary Sciences	1,637
	Information and Computing Sciences	6,984
	Engineering	2,555

¹ <https://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/1297.0>

Broad field	Fields of Research (FoR)	First field
SS&H	Technology	851
	Medical and Health Sciences	123,711
	Built Environment and Design	27
	Education	818
	Economics	1,984
	Commerce, Management, Tourism and Services	498
	Studies in Human Society	1,854
	Psychology and Cognitive Sciences	10,496
	Law and Legal Studies	123
	Studies in Creative Arts and Writing	84
	Language, Communication and Culture	529
	History and Archaeology	792
	Philosophy and Religious Studies	100
No subject assigned		62,050
Total		330,022

3.3. Analysis

To analyze the possible relationship between citations and all tweets, original tweets and retweets, comparisons across fields and over time were conducted. For this purpose, proportion non-zero and Geometric mean of citations, tweets and retweets were calculated and normalized for comparisons between subject fields and with the world average (here, all PLoS publications). The data was first prepared (Thelwall, 2017) and then the calculations were conducted with Webometric Analyst (lexiurl.wlv.ac.uk).

- Normalized Proportion non-zero* was used as an estimate for publications with non-zero Scopus citations, tweets and retweets, with a 95% confidence interval.
- World normalised proportion non-zero of metrics (EMNPC)* were used for comparisons. EMNCP values for fields are compared for any variation from the world average (=1).
- Geometric mean* was calculated based on the logarithm of raw metric counts + 1 or $\ln(1+\text{raw data})$, as proposed by Thelwall (2017) and all calculation were in 95% confidence interval.
- World normalised mean metrics (MNLCS)* were calculated on log-transformed data of $\ln(1+\text{raw data})$ and calculated in 95% confidence interval. *MNLCS* values also need to be compared with value one which represents the world average.

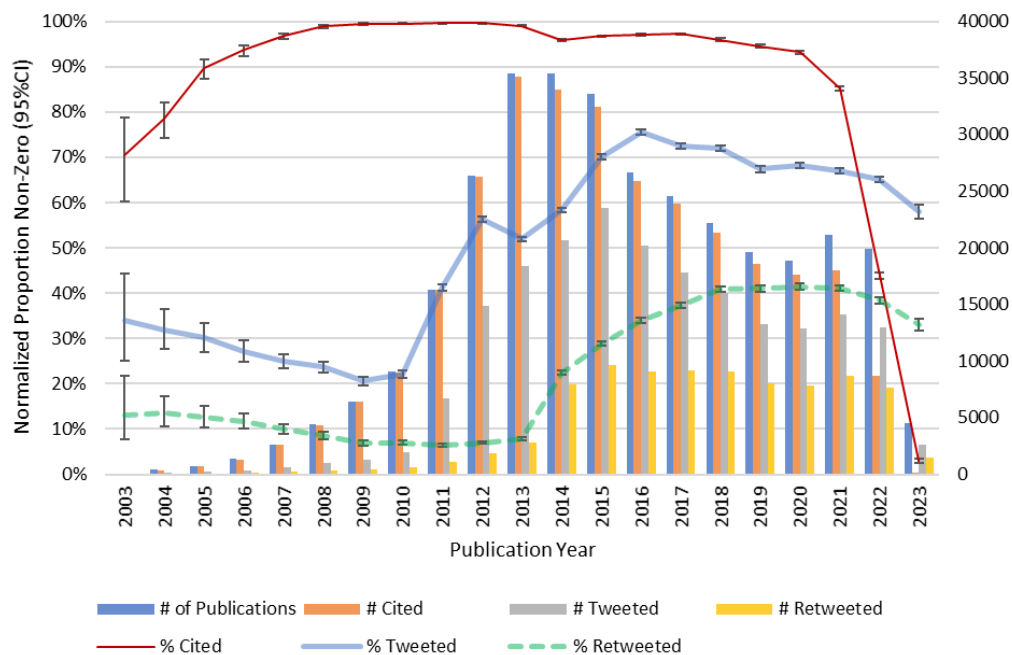
The calculations for world normalization are detailed in Thelwall (2017).

4. Findings

4.1. Normalized Proportion Cited

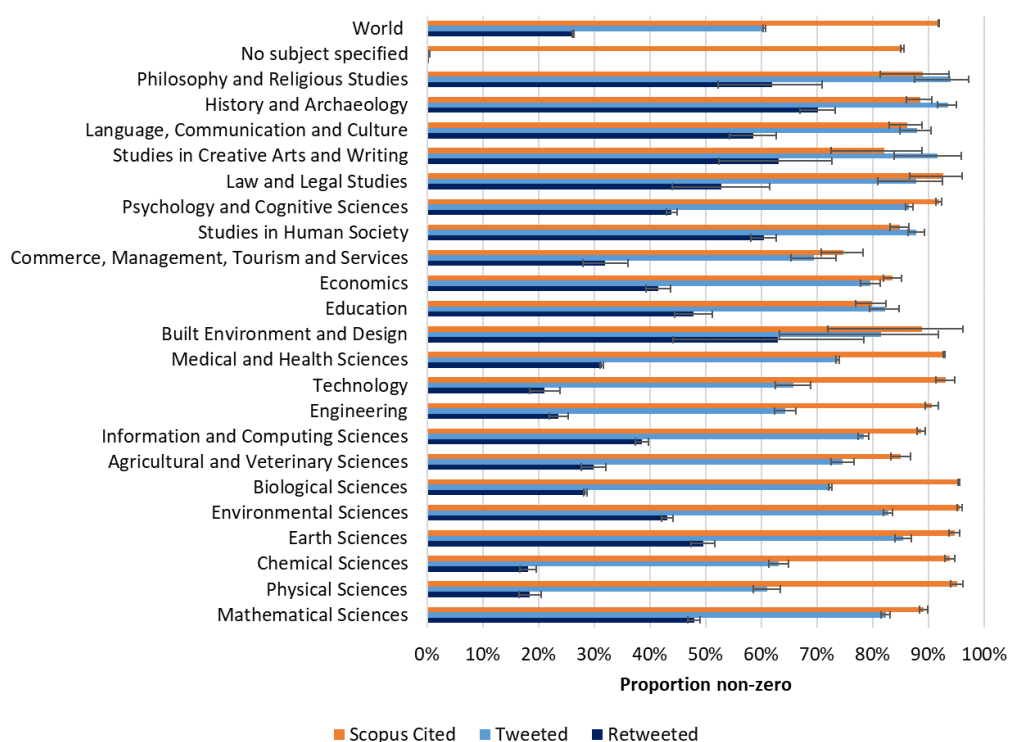
Figure 1 shows that the total publication frequency of PLoS had significantly increased from 87 in 2003 to just below 35,000 in 2013, after which the level drops and remains at around 20,000 annually. The proportion non-zero citations show a cumulative increase over time, the number of publications mentioned in tweets rose from about 20% in 2010 (about the time when altmetric.com started to collect tweets) to 76% in 2016 and then a fall to about 65% in 2022. The proportion non-zero retweets shows a delayed rise since 2013, rising to 40% by 2018, levelling off after that, while proportion tweeted has slightly dropped in the same period.

Figure 1: Frequency of total publications, publication cited, tweeted and retweeted and normalized proportion non-zero in the metrics



Presenting the results from the normalized proportion non-zero of metrics, Figure 2 shows that on average 92% of publications in STEM fields had been cited, while only 82% in SSH fields had received citations. On average, 75% of articles in STEM had been tweeted, compared to 85% in SSH, while only 35% of STEM articles and 50% of SSH articles had been retweeted.

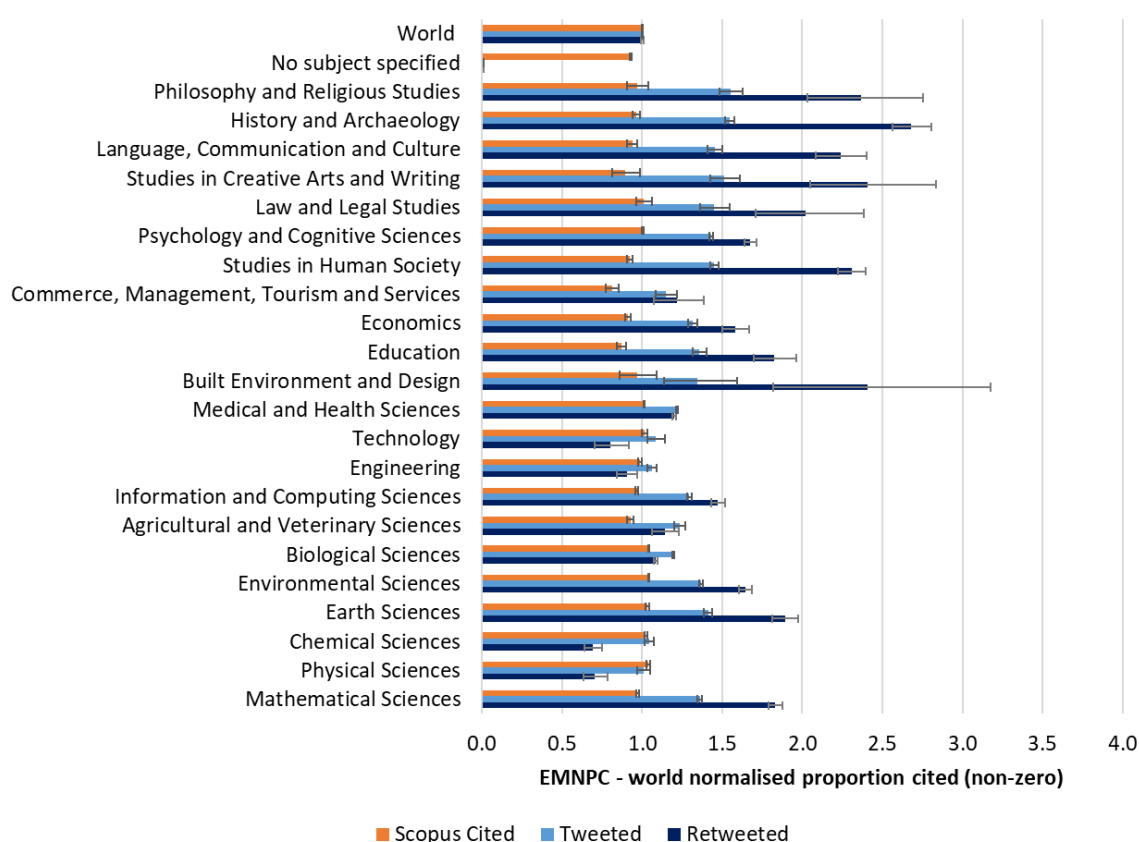
Figure 2: Normalized proportion cited, tweeted and retweeted across fields.



4.2. World normalised proportion non-zero for metrics or EMNPC

Figure 3 shows that after world normalization of proportions non-zero, both tweets and retweets appear significantly above world average in SSH fields for STEM the results are mixed both below and above the world average. Mathematical Science, Earth Science, Environmental Science and Information and Computing Sciences all show EMNCP >1 for tweets and > 1.5 for retweets, while all the other STEM fields remain below the world average. The results also showed that the diversion from the world average for retweets is at higher magnitude than for original tweets across all fields; for above world average counts, the proportion non-zero retweets was significantly higher than for tweets, and for below world average counts, the proportion non-zero retweets was significantly lower than for tweets. This may suggest a greater discrepancy across fields in terms of retweeting behaviour.

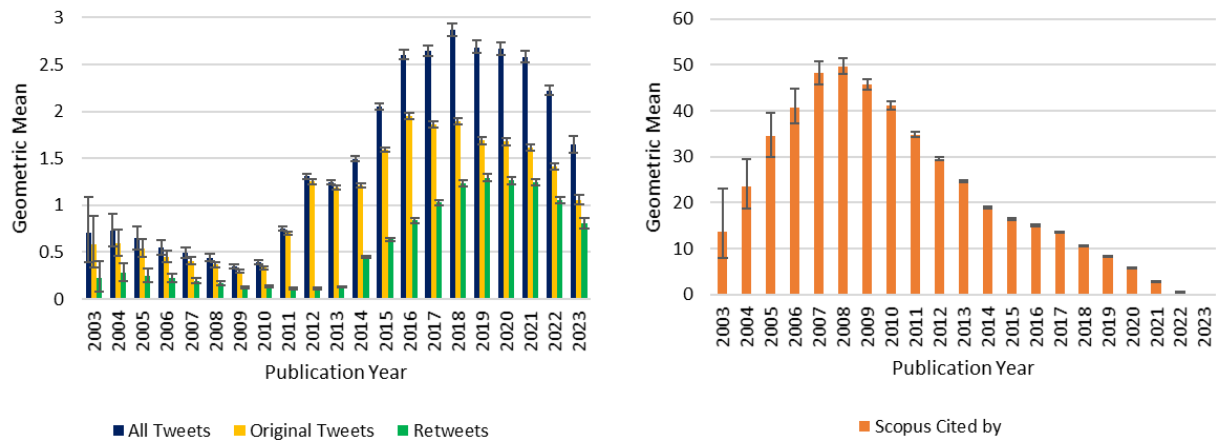
Figure 3: World normalized proportion cited, tweeted and retweeted across fields.



4.3. Geometric mean Citations vs. Original tweets and Retweets

Figure 4 illustrates the changes in geometric mean metrics over time, showing that the geometric mean for citations peaked at about 49 in 2008 before gradually dropping over years. The trend is, however, almost reversed for the metrics from Twitter, showing a slow drop between 2003 and 2009 (<1) before rising to about 3 for total tweets in 2018 (about 2 for original tweets and 1.25 for retweets), soon after which they too start to fall. The average geometric mean citations across STEM fields is 14, while about 9 across SS&H fields. In contrast, the average geometric mean all tweets, original tweets and retweets across STEM fields (3, 2 and 1, respectively) is approximately half the SS&H fields (6, 4, and 2).

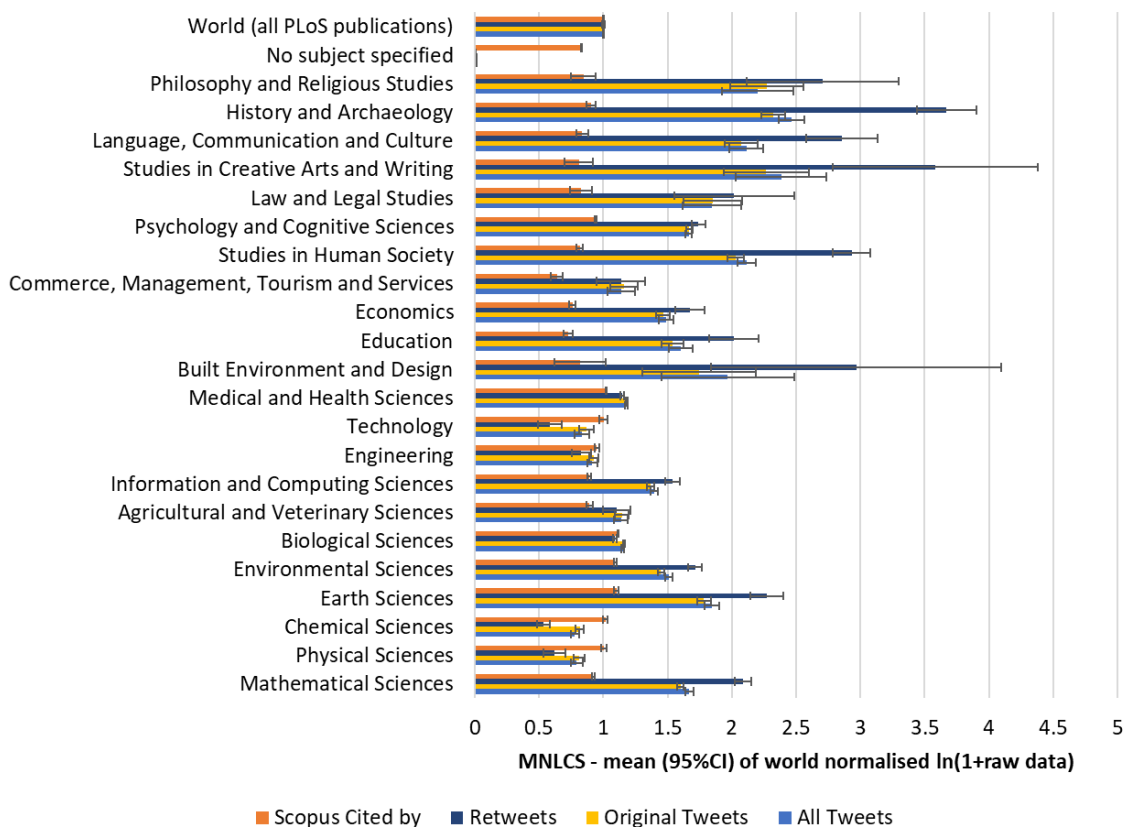
Figure 4: Geometric mean Scopus citations, tweets, original tweets and retweets over years.



4.4. World normalised mean metrics or MNLCS

The mean of world normalized $\ln(1 + \text{raw metric values})$ metrics from Twitter mentions indicate subject bias (Figure 6). In STEM fields, such as Chemical Science, the results are below the world average for tweets and retweets, while slightly above it for citations, but the case is very different for the SS&H fields. A majority of SS&H fields perform below world average in citations, but significantly above the world average in tweets and original tweets (up to 1.5 times the world average) and 3.5 times the world average in retweets (e.g., History and archaeology, and Creative arts and writing).

Figure 6: Mean of world normalized $\ln(1 + \text{raw citation, tweet, or retweet count})$ across fields.



4.5. Spearman's Correlation between Citations and different types of tweets

Table 2 gives the number of total publications, and publications with at least one citation, original tweet and retweet over the period of 2010-2023. This table helps to figure out the count of papers in the Spearman's correlation analysis including zeros and only non-zeros in the Figure 7. The correlation coefficients between citations and all tweet metrics showed stronger correlations when the zeros, i.e., articles with no citations or tweets, were included in the calculation (Figure 7). The correlations were weak but significant across the line. The strength of the relationship between citations and tweets has, however, first increased over time and then from 2019 started to fall, suggesting that citation takes time to be accrued and hence the relationships with citations lack strength. Furthermore, as of STEM fields when zero metric counts are included, the correlation coefficients were slightly stronger for *all tweets* than *original tweets* from 2011 ($r = .157 > .151$, respectively) through 2018 ($r = .299 > .296$), however the trend is reversed since 2019 ($r = .299 < .303$) when the relationship appears to be slightly stronger between citations and original tweets than for all tweets in both zero-included and non-zero datasets.

Table 2: Count of all publication, and publication with at least one Scopus citations, a tweet, or a retweet over time.

Publication year	STEM				SS&H			
	publications	cited	tweeted	retweeted	publications	cited	tweeted	retweeted
2010	6,506	6,492	1,873	585	223	223	124	47
2011	11,994	11,958	6,298	943	539	538	419	113
2012	20,849	20,794	13,842	1,657	1,050	1,046	944	179
2013	26,624	26,496	17,100	2,447	1,416	1,406	1,225	317
2014	26,094	25,762	19,186	7,244	1,426	1,407	1,248	658
2015	27,204	26,780	21,687	8,661	1,676	1,658	1,511	925
2016	22,343	21,823	18,293	8,202	1,477	1,428	1,358	811
2017	20,246	19,813	16,260	8,345	1,357	1,320	1,252	737
2018	16,921	16,519	14,318	8,142	1,497	1,448	1,331	841
2019	14,145	13,690	11,846	7,204	1,286	1,235	1,056	751
2020	13,506	12,917	11,319	6,880	1,328	1,242	1,066	741
2021	14,368	12,674	11,353	7,124	1,650	1,404	1,213	780
2022	14,672	6,852	5,785	3,741	1,667	705	552	354
2023	2,980	104	90	63	427	14	9	7

Figure 8 illustrates a heatmap of the correlation coefficients between Scopus citations and the three metrics of all tweets, original tweets, and retweets across subject fields for zero and non-zero datasets. The findings suggest that the median correlation coefficient of Scopus citations across fields is highest with original tweets (median $r = .310$), while weak but significant with retweets (median $r = .087$). However, for the SS&H subject fields the median correlation coefficients between citations and original tweets were at medium level (median $r = .409$), in contrast to the weak correlation in STEM subject fields (median $r = .162$).

Including zero metric counts in the datasets resulted in *stronger* correlation coefficients between citation and all the other metrics in SS&H fields (median r with original tweets = 0.409 in zero-included dataset, 0.329 in non-zero dataset), but *weaker* in STEM subject fields (median $r = 0.175$ in non-zero dataset, $r = 0.149$ zero-included dataset). It would appear that tweets are

moderately likely to align with traditional research impact in SS&H, but they indicate only a weak relationship and a limited usage in STEM subject fields.

Figure 7: Spearman's correlation coefficients between Scopus citations and all tweets, original tweets and retweets over time.

	STEM						SS&H					
	Including zeros			Only non-zeros			Including zeros			Only non-zeros		
	All	Original	Retweet	All	Original	Retweet	All	Original	Retweet	All	Original	Retweet
2010	0.205	0.206	0.165	0.202	0.213	0.135	0.404	0.415	0.234	0.339	0.375	
2011	0.157	0.151	0.156	0.201	0.183	0.11	0.27	0.259	0.257	0.264	0.247	
2012	0.2	0.195	0.179	0.217	0.206	0.153	0.325	0.319	0.293	0.312	0.305	0.303
2013	0.218	0.215	0.181	0.236	0.228	0.17	0.373	0.366	0.337	0.344	0.335	0.311
2014	0.221	0.218	0.2	0.245	0.243	0.209	0.337	0.343	0.287	0.336	0.344	0.286
2015	0.241	0.236	0.222	0.239	0.231	0.216	0.39	0.387	0.359	0.367	0.363	0.336
2016	0.284	0.275	0.277	0.291	0.283	0.252	0.395	0.376	0.389	0.372	0.354	0.33
2017	0.29	0.284	0.282	0.289	0.282	0.261	0.384	0.376	0.352	0.363	0.347	0.337
2018	0.299	0.296	0.279	0.282	0.278	0.273	0.34	0.356	0.295	0.311	0.332	0.262
2019	0.299	0.303	0.278	0.282	0.288	0.28	0.346	0.351	0.31	0.292	0.301	0.284
2020	0.301	0.311	0.27	0.278	0.293	0.25	0.277	0.295	0.256	0.231	0.25	0.193
2021	0.284	0.297	0.251	0.252	0.267	0.223	0.232	0.26	0.187	0.184	0.236	0.202
2022	0.216	0.217	0.199	0.172	0.183	0.156	0.124	0.138	0.098		0.114	0.113
2023	0.096	0.091	0.095									

Figure 8: Spearman's correlation coefficients between Scopus citations and all tweets, original tweets and retweets across fields. The empty cells indicate no statistical significance ($p > .05$).

	Citations & All Tweets		Citations & Original Tweets		Citations & Retweets	
	with zeros	non-zeros	with zeros	non-zeros	with zeros	non-zeros
Mathematical Sciences	0.027	0.063	0.092	0.149	-0.045	0.092
Physical Sciences					-0.068	
Chemical Sciences		0.087		0.139	-0.050	
Earth Sciences	0.164	0.170	0.235	0.261		
Environmental Sciences	0.071	0.115	0.136	0.207	-0.043	0.091
Biological Sciences	-0.079	0.053	-0.050	0.103	-0.096	0.053
Agricultural and Veterinary Sciences	0.210	0.232	0.238	0.290	0.139	0.184
Information and Computing Sciences	0.210	0.212	0.248	0.265	0.116	0.137
Engineering	0.143	0.115	0.162	0.151	0.057	
Technology					-0.099	
Medical and Health Sciences	0.031	0.121	0.063	0.175	-0.018	0.123
Built Environment and Design	0.546	0.447	0.637	0.605		
Education	0.346	0.257	0.412	0.329	0.178	0.198
Economics	0.362	0.266	0.388	0.297	0.234	0.150
Commerce, Management, Tourism and Services	0.373	0.335	0.409	0.369	0.215	0.363
Studies in Human Society	0.388	0.328	0.445	0.390	0.246	0.234
Psychology and Cognitive Sciences	0.233	0.222	0.310	0.307	0.043	0.131
Law and Legal Studies	0.315	0.215	0.401	0.319		
Studies in Creative Arts and Writing	0.241	0.279	0.431	0.308	0.300	
Language, Communication and Culture	0.347	0.309	0.409	0.376	0.212	0.318
History and Archaeology	0.206	0.131	0.291	0.217		
Philosophy and Religious Studies	0.469	0.449	0.484	0.481	0.360	0.394
All	0.075	0.096	0.099	0.153		0.095
Median of all fields	0.233	0.219	0.310	0.294	0.087	0.150
Median of 11 STEM fields	0.107	0.115	0.149	0.175	-0.044	0.108
Median of 11 SS&H fields	0.347	0.279	0.409	0.329	0.225	0.234

5. Discussion

Current study compared citations, original tweets, and retweets, as measures of impact assessment. The results were in line with some of the findings in earlier research (e.g., Costas et al., 2015; Haustein et al., 2015). The results showed clear disciplinary differences in how scientific articles had been mentioned and shared on Twitter, but it was also discovered that scientific articles in Social Science and Humanities receive up to 2 to 3 times as much retweets as the world average, compared to Natural Science and Engineering which were below the world average. The results also showed the distinct impact implication of Original tweets and retweets as the correlations between citations and original tweets were clearly stronger than between citations and retweets, and the correlations overall were stronger for SS&H subject fields, than STEM subject fields. The results clearly point at the differences between original tweets and retweets, confirming that the two do reflect different types of metric and therefore, should be treated separately, at least when it comes to altmetrics research. Although the differences between original tweets and all tweets is slight, the strength of correlation appear to be slightly more in favour of original tweets at field level and when analysing more recent (past five years) publications. Thus, the recognition of significant disparities between all tweets, original tweets and retweets serves as a foundation for discussing the reconsiderations needed in employing composite metrics such as RG score and Altmetric Attention Score. This observation naturally leads to a need for more research to understand the detailed dynamics of distinct forms of social media interactions and their roles in scholarly communication.

Funding information

This research was funded by the Academy of Finland (funding decision: 332961).

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